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Animal-Assisted Therapy for Alzheimer Patients Using Virtual Reality

MASTER DISSERTATION

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MASTER IN COMPUTER ENGINEERING

UNIVERSIDADE da MADEIRA
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Animal-Assisted Therapy for Alzheimer Patients using Virtual Reality

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Dedicated to someone special…

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Resumo

A doença de Alzheimer é a principal causa de demência. Trata-se de uma doença neurodegenerativa incurável que conduz a falhas cognitivas e problemas comportamentais. A demência constitui um enorme fardo social e económico para os doentes e para os cuidadores. A medicação ajuda a prevenir alguns sintomas da doença, mas não cura podendo revelar efeitos secundários indesejáveis. Algumas terapias alternativas têm vindo a ser exploradas, por exemplo a terapia animal (AAT). Para evitar as desvantagens da terapia animal, como a necessidade de treino, foi desenvolvida uma solução com realidade virtual. Realizamos um estudo com 12 pacientes diagnosticados com demência para perceber que tecnologias e modos de interação são mais adequados para esta população. Os resultados indicam que tecnologias com interação direta são mais adequadas (por exemplo Tablet ou AR). Foi desenvolvido um jogo de interação com animal para tablets. Realizou-se um estudo com 10 pacientes diagnosticados com demência num centro de dia. Este estudo tinha o objetivo de examinar a aplicabilidade desta ferramenta nesta população e perceber se uma sessão de terapia animal virtual poderia ter efeitos na disposição do participante, através da avaliação das suas respostas emocionais. Os participantes responderam a questionários pré- e pós-intervenção para obtenção de informação relativa ao seu estado emocional e à sua perceção da sessão de jogo. Foi utilizado um questionário destinado ao terapeuta que registou a sua opinião relativa aos efeitos no participante. Os resultados indicam melhorias na disposição dos participantes, uma boa aceitação e usabilidade desta abordagem e respostas emocionais positivas.

Palavras-Chave: Doença de Alzheimer, Demência, Terapia Animal, Realidade Virtual

Abstract

The Alzheimer's Disease is the main cause of dementia. It is incurable and regarded as a neurodegenerative disease that leads to cognitive and behavioral impairment. Dementia brings along a heavy burden from both a social and economic perspective. Traditional medication helps in slowing down the disease but is not able to cure it, and it may also bring undesirable side-effects. Alternative therapies are being further explored, being one of them Animal-Assisted Therapy (AAT). To avoid the disadvantages of conventional AAT, such as the need for trained animals, or hygiene issues, a Virtual Reality approach was adopted. We conducted a pilot study with 12 dementia patients to understand which technologies and interaction modalities were preferred when developing for this population. Devices that promote direct interaction were preferred (Tablet and AR) so, combining the positive aspects of traditional AAT and the promising aid of VR, an animal interaction tablet game was developed for this population. This study, conducted with 10 dementia patients in a daily-care center, aimed to examine whether a session of virtual AAT was feasible and able to produce any changes in the mood of participants, evaluating the acceptance and emotional responses as well. Participants completed pre- and post-intervention questionnaires to assess their mood and perception of the game session and a therapist was also asked to provide insight on each participant. Therapist's reports and observations reveal positive mood changes, good acceptance by the patients and positive emotional responses.

Keywords: Dementia, Alzheimer's Disease, Animal-Assisted Therapy, Virtual Reality

Contents

I. List of Tables

II. List of Figures

III. List of Abreviations

AAT	Animal-Assisted Therapy
AD	Alzheimer's Disease
AI	Artificial Intelligence
FR	Functional Requirement
FSM	Finite State Machine
IRR	Inter-Rater Reliability
MCI	Mild-Cognitive Impairment
MMSE	Mini-Mental State Evaluation
NFR	Non-Functional Requirement
QoL	Quality of Life
RQ	Research Question
SAM	Self-Assessment Manikin
SG	Serious Game
UI	User Interface
UX	User Experience
VE	Virtual Environment
VR	Virtual Reality

Chapter 1

Introduction

1.1. Motivation and objectives

The Alzheimer's disease is incurable and regarded as a neurodegenerative disease that leads to cognitive and behavioral impairment. Alzheimer patients suffer from both harmful behaviors such as agitation and aggression, which represents a mental and physical burden for both professional and family caregivers [1]. Although pharmaceutical approaches have been developed to target certain dementia related symptoms, many undesirable side effects have been reported. In addition, Alzheimer's disease related treatments are costly; worldwide dementia related health costs reached 818$ billion in 2010. In the same year, Portugal's dementia related health costs ranged between $1652.8 million and $2120.4 [1]. Thus, non-pharmaceutical approaches have been taken into consideration.

The main goal of this project is to, by using technology and virtual reality, explore alternative non-pharmacological therapies in the treatment of Dementia. The main idea is the development of an interaction game, in which the player is able to perform the most common activities done during real animal therapy sessions. The objective is then to explore and validate to what extent it is possible to capture the most positive aspects of animal therapy with this application without having the downsides of real animal-assisted therapy.

1.2. Research Questions

Arising from the literature review made during this project's conception, which can be read in the next subsequent chapters, the focus of this work revolves around obtaining answers for the following research questions.

RQ1: Is virtual AAT feasible?
RQ2: To what extent can be the virtual animal-assisted therapy realistic?
RQ3: Can a virtual dog generate empathy?
RQ4: What is the effect of customization in this game?

1.3. Thesis Outline

The following text outlines all the individual chapters in this thesis document as they form its structure.

Chapter two of this thesis consists of a topic overview, consisting in an introductory analysis on dementia and one of its major causes, the Alzheimer's Disease. The reader is presented with a state of the art for both dementia alternative therapies, being one of them Animal-Assisted Therapy, and an overview of the existing technological approaches to support these therapies.

Chapter three explains a user study with 12 dementia patients to study the applicability of different technologies to this population. The results of this study contributed to reshaping this project it from its original conception, based on what was experienced about the disease and which design decisions taken to satisfy the needs of dementia patients.

The fourth chapter explains all the technical development of this project's application starting from the selected software development process, the functional and non-functional requirement listing to the final product. In this chapter the reader will also find an explanation of each screen in the game and how an Artificial Intelligence component for the game character was developed.

The fifth chapter and last chapter of the present document reveals the experimental process of validating the developed application with a sample of 10 dementia patients, by sorting its goals, methodology, procedure and the final results and conclusions.

Chapter 2

Topic Overview

2.1. Dementia and the Alzheimer's Disease

The Alzheimer's Disease is characterized for being a degenerative brain disease that happens when nerve cells, specifically neurons, are damaged to the point in which they no longer function in a regular way. Alzheimer's Disease is the most common cause of dementia [2], [3].

Dementia carries, as symptoms, a decline in memory, language, capacity for solving problems and some other cognitive skills which eventually lead to an incapacity of the patient to perform some basic functions that otherwise they would not experience [3]. Alzheimer's patients usually reveal symptoms such as difficulty remembering recent conversations, some apathy and depression as well as frequent mood swings [3]. In later stages the disease can bring some other symptoms such as an impairment in communication, disorientation and confusion giving patients a poor judgmental capacity, frequent behavior changes and ultimately difficulty speaking, swallowing and walking [3].

Currently the disease has no identified cure and the conducted research in this area mainly focuses on slowing or preventing the progression of the disease as it is believed that early detection is indistinguishably important in every Alzheimer instance.

The main risk factor associated with the disease is age. People aged 65 or older are more likely to develop the pathology, one of the primary consequences of increased life expectancy. Even though the majority of the diagnosed patients fit in this profile, there are also other potential risk factors to consider: family history, previous cardiovascular diseases, traumatic brain injuries and even lower levels of education as well as social and cognitive engagement of an individual [2], [3].

2.1.1. Impact of the disease

In 2015 the estimations revealed that there were 46.8 million people around the globe living with dementia and this number is expected to double every twenty years (as is graphically visible in Figure 1). Economically speaking, the worldwide costs of the dementia related disorder treatments have increased from 604 billion US$ in 2010 to a massive amount of 818$ billion in 2015 [2] and it is expected to reach 1 trillion US$ still in 2018 [3]. Socially, the impact of dementias can be considered at three different levels that are interconnected among them. First, the person living with the disease, who will progressively experience ill health, incapacities, impaired quality of life and therefore a reduction in their life expectancy. Then, the family and friends of the patient, who will play a major role in the health care and support of the ill person. Finally, it is necessary to consider the wider society that, directly or not, incurs the costs (discussed above) of providing the needed well-being and social care for these patients [3].

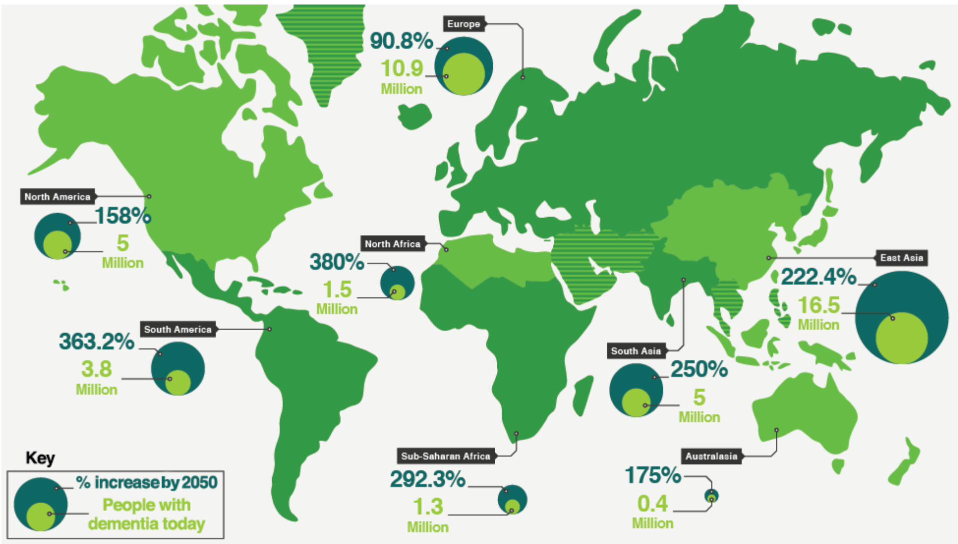


Figure 1 – The expected increase in the number of people living with dementia by 2050 (adapted from [4])

2.1.2. Pharmacological and non-pharmacological approaches

With great infortune, a cure for dementia has not been found yet. Pharmacological treatments are always a possibility to slow down the progression of the disease, but these mainly tackle some of the symptoms that come along and do not always have the desired effect in the patients [5]. Some of the most common pharmacological agents: acetylcholinesterase inhibitors and N-methyl-D-aspartate receptor antagonists can be effective in controlling the cognitive decline symptoms and temporarily improve the activities of daily living for the ones living with the disease but they are not able to restore what has been cognitively lost and may not work in patients in later stages of dementia.

It is a heavy burden that those who have relatives with the disease have to carry, and to experience emotional and behavioral changes in the loved ones is also a part of that burden. To diminish this burden, either economic or social, non-pharmacological approaches are being creatively developed and improved as it is thought that a care plan that revolves around non-pharmacological approaches is a best practice to manage the psychological symptoms as well as increase the quality of life (QoL) of the patients suffering from dementia [6].

Non-pharmacological therapies are those that do not rely on medication. These can be found in a wide diversity of forms such as music and reminiscence therapies, sports, arts or even animal-assisted therapies. Even with a big variety of therapies, none of them (both pharmacological and non-pharmacological) seem to prevent the progression of the disease. Nevertheless, they do help in slowing down and improving some problematic symptoms associated to the disease [3], [6], [7].

The three main areas in which treatments or therapies can work over are the cognitive ability, the ability to perform activities of daily living, and behavioral and psychological mood. There is a wide range of possibilities that can be applied to each patient in order to improve their well-being. Table 1 organizes the different therapies that have been studied in recent years in each of the three domains described above.

Many of them have already been tried in the past to alleviate some of the symptoms associated with the progression of dementia [7].

Symptoms	Interventions
Cognitive ability	• Cognitive stimulation therapy/cognitive training • Counseling • Light therapy • Music/Music therapy • Physical activity/exercise • Reality orientation • Reminiscence therapy
Ability to perform activities of daily living	• Validation therapy • Cognitive stimulation therapy/cognitive training • Physical activity/exercise • Reality orientation
Behavioral and psychological symptoms	• Animal-assisted therapy • Aromatherapy • Behavior management • Cognitive stimulation therapy/cognitive training • Environmental manipulation • Light therapy • Massage/touch • Music/Music therapy • Physical activity/exercise • Reality orientation • Reminiscence therapy • Validation therapy

Table 1 - Diversity in alternative therapies and their effects in the different symptom areas (adapted from [7])

Even with a large amount of non-pharmacological approaches many of these therapies fall into the “might work” category. There is no strong evidence that these consistently work and most of the studies conducted have inconclusive results [7]. Still, there is agreement when it comes to the fact that having the correct structured set of activities for patients can help ameliorating some of the experienced behavioral issues such as aggression, agitation and sleep problems [7].

2.2. Animal-assisted therapy

Animal-assisted therapy (AAT) consists of the deliberate inclusion of an animal in a treatment process. It has been practiced already for many years, gaining only recently a cumulative interest in representing its efficacy and potential [8]. It can be employed in a large diversity of health-care scenarios – both in the physical and mental domains [9]. AAT should not be considered a stand-alone treatment but can be a positive complement since it facilitates creating bounds between the patient and the therapy animal while providing, at the same time, a safe warm atmosphere which can be independently therapeutic or even aid patients to accept other treatments’ interventions. Using an animal as the central piece in a person’s treatment can also work as a social agent to improve well-being and reduce withdrawal, improving short-term memory, trigger long-term memory and improve the patients’ communication skills [10]. AAT has been employed in many different studies with different treatment scopes and individuals of different ages [8]. The animals most widely used for animal therapy are dogs and cats since not only are the most common animals that people own, but have personality traits such as need of attention and ability to bound with a human. However, many other types of animals have been used for therapy scenarios: rabbits, birds, horses and even reptiles [9], [11]. The most common activities performed in AAT can include close contact with the animal, touching its fur, cuddling, talking and petting it, searching for hidden objects or throwing balls. The most important aspect of it is that it should be adaptable to each visit depending on the patients' current health state and preferences regarding animals [11].

Regarding the appointments, AAT is organized in previously scheduled and agreed visits from dog handlers with their corresponding therapy dog – usually referred to as the therapy dog team. Each session should be prescribed by a registered nurse and an occupational therapist. Also, the therapy teams are formed of both the animal and an animal handler, as they undergo training from one to five years, providing assistance to the patients over extended periods of time and approaching them in a calm and gentle way. The animal handler should be able to understand the animal's behavior as well as be prepared for the patients reactions to the animal stimuli while interacting with a person, in our case, living with dementia [9], [11], [12].

2.2.1. Evidence from animal-assisted therapy interventions

A study with animal-assisted therapy [10], conducted in a nursery home, endorsed interactions between patients and animals, in this case dogs. The interactions consisted in actions such as touching, petting, brushing, holding, talking to and playing with the animal. This study results showed improvement in social interaction, lower levels of agitation and a decrease in verbal aggression accompanied by an increase in pleasure observed during the visits of the dogs when compared to a secondary condition that involved human interaction. These results, however, were not very substantial post-therapy as they decayed to relatively low values after the therapy ended.

Another study, parallels the effects of a visit made by a person (human-interaction), a person accompanied by a robotic pet and a person accompanied by a living dog [13]. All three visits stimulated positive social interactions with no significant differences between them. The study confirmed that a plush dog can be used in this type of interventions resulting in an increase in positive emotions such as pleasure, alertness and a reduction in sadness and anxiety for people with dementia [13]. Also, the same study states that different dog-related conditions (either a real dog, a plush, puppy video, robotic dog or dog painting) have no influence in the interest revealed by the participants. Nevertheless, another study found out that embodiment, in animal interaction, can be very important for having therapeutic effects (in stress related problems) [14]. A comparison of the use of a pet robot and virtual pet both showed therapeutic effects. However, the physical embodiment of the pet robot had a relatively greater effect than the virtual animal. An interesting aspect to retain is that the results also showed that the virtual pet appeared more dynamic and it was reported by the participants that the virtual pet was able to produce better behavioral responses to the stimuli from the users compared to the pet robot [14].

The appearance, specially the size of the animals, revealed to be important in terms of gathering the interest of therapy participants as bigger dogs got more attention from dementia patients. At the same time, for the participants who revealed no interest in animals at the start, the size of the animal was not significant at all [13]. Furthermore, another study discovered that dogs that are familiar to the patients proved to be more beneficial in terms of relaxation and decrease of blood pressure during intervention rather than a strange or unfamiliar dogs [15].

Past interventions with animals were also helpful in reducing the pressure in social interaction as the animals served as mediator for conversation and interaction in groups [16].

2.2.2. Downsides of Animal-assisted therapy

It can be difficult to have a proper AAT ready-to-go setup do to the lack of trained and skilled therapy teams. Linked with this issues there is the problem that animals are not very well accepted in most health-care or nursing facilities due to potential parasites, vaccination or hygiene issues. There is also the possibility of scratches and bites together with the possibility of some of the patients having some sort of animal phobia [12].

Sometimes, even if animals are accepted and regarded as positive for patients in health-care facilities, theirs needs may not be satisfied by the available space conditions (which also limit the spaces for activities). Due to these problems, there is a tendency to substitute real animals for robotic pets, for example in robot-assisted therapy [17].

2.3. Robot-assisted therapy

Robot therapy uses a robot to promote social interaction and other diverse activities with the patient aiming to enhance mental aspects such as pleasure or relaxation. Different kinds of robots have been used according to the demands of the specific treatment scope and to the patient's health condition. There are therapy specific robots such as Paro [17]–[19], a seal-type mental commitment robot designed for therapeutic purposes. Other kind of robots have also been used. For example, human interactive robots, which are those that are ready to interact with a human within the physical world either using verbal or non-verbal communication. The most known example of a robot of this kind is the Sony's AIBO [10], [15], [20].

The use of robots in therapeutic scenarios is well suited in a context where it is difficult to attend to the biological needs of living animals.

2.3.1. Evidence from robot-assisted therapy interventions

Past studies using robot therapy have proven that a real animal can be substituted by a robotic pet when it comes to reducing loneliness in long-term health care facilities [15]. Another past experiment using the Sony's AIBO proved that robot-therapy was efficient in decreasing stress and loneliness after one hour of intervention [17]. Using PARO in therapy also proved to be useful in reducing depressive symptoms and negative behaviors in dementia patients [17].

A previously conducted study addressed the capability of a patient becoming emotionally attached to a therapeutic robot by measuring the level of attachment (using the Lexington Attachment to Pet Scale - LAPS) [15]. Results showed that in this specific context it is possible for a robotic dog to substitute a living dog.

As downsides of robot therapy, multiple studies reported that a robot pet encourages less active interaction from the patient and require more intervention from the occupational therapist when compared to a living animal [12], [17], [18], [21].

2.4. Virtual Reality

Virtual environments (VE) can be defined as interactive virtual image displays that can be enhanced by special processing and by non-visual display modalities and they serve the purpose of immersing users in a synthetic space [22]. Virtual Reality (VR) can be defined as any technology or system that immerses the user in a VE having the capacity of allowing them to explore and engage with a VE experiencing a sense of presence [23].

VR has been adopted as a strategy not only for ludic purposes but also in health-care with many successful attempts (see the review in [24]). In the dementia area, most applications nowadays face the challenge of diagnosing and cognitive training of mild cognitive impairment (MCI) and dementia patients (see the review in [24]). The introduction of VR in the treatment of the Alzheimer's Disease patients focuses around providing memory aids and educational support as VR is often used to implement tasks that train some very basic activities such as navigation, orientation, facial recognition, cognitive functionality and instrumental activities of daily living (see the review in [24]).

Serious Games (SG) had their way paved by the evolution of the available technologies and represent one of the many possible scenarios in which VR can be employed with great success. This type of games specializes in purposes other than just entertaining. They can be related to education, leading to societal impact on specific subjects, enhancing the user's aptitudes and even in cognitive training for the Alzheimer's Disease [25].

Health purpose SG can be classified in different categories according to their therapeutic utility. Physical or exergames are games that encourage physical fitness can affect in a positive style some very specific skills of the players with mild AD and Mild Cognitive Impairment (MCI) such as their balance and posture [26]. Cognitive games are those that aim cognitive improvement and can be used to recover and train cognitive functions, for example memory and attention [27], [28]. Finally, there are simultaneous physical and cognitive games that can have a positive impact on the social and emotional functions of people living with dementia, by improving their mood and increasing sociability at the same time reducing depressive symptoms [28].

Related to AAT, there are numerous SG that simulate animal behavior and taking care of pet companions. It all started with the Tamagotchi™ and now, for example, Nintendogs [29] is one of the most famous pet interaction games. Even with so many different options, most of these games are not prepared for being used by people with dementia [28], either for not having a suited interface, non-fitting interaction modalities or just by adding unnecessary complexity to the game logic.

2.4.2. Evidence from Virtual Reality interventions

As previously mentioned, VR has been used not only for entertainment purposes, simulation or for data visualization but also for health-care purposes and in many different areas such as neuropsychology (in the treatment of phobias, stress and anxiety [24], [30], [31]), surgical training, post-stroke interventions, musculoskeletal recovery and pain mitigation, among many others [24], [32], [33].

Past studies show that VR interventions were more effective in ameliorating psychological disorders or behaviors than some active interventions [23], suggesting that VR solutions can be efficacious forms of psychological treatment and a promising addition to existing treatment options.

Regarding the usage of SG, research shows that, for players of any age, a given task if performed with some gamification in a digital form becomes more fun and induces a heightened sense of flow [34]. However, performing the same tasks in pen and paper can be more efficient [34].

Role-playing games have also been shown as a powerful tool in dealing with behavioral change problems [35].

Previous research made use of the Nintendo Wii Sports game with AD patients with the objective of understanding if the usability of the system was appropriate for dementia participants and the results showed positive results complemented by good performances [36]. Other study reports that dementia patients thought that the same set of games were enjoyable [37].

The Nintendo Wii has been one of the most used systems for therapy purposes, even with a music therapy study [38]. This pilot study used the MINWii game and it its results show that this game promotes meaningful interaction between the patient and their caregiver. The results of this study report positive improvement in balance and gait when compared to a control group that participated in a walking program.

Another study using a kitchen and cooking activity related SG with AD and MCI patients revealed some promising results in sparking interest and motivation in more apathetic patients that showed a reduction in self-initiated behaviors [39].

When developing SG for dementia, research shows that, it is important to introduce some fundamental aspects to the games or activities such as, an engaging, attractive and colorful interface, an obvious "what to do next", an element of challenge or progression and finally feedback based on the user's performance [40].

2.4.3. Previous attempts of virtual AAT

Although AAT is a well-known and commonly used alternative therapy, the lack of research in virtual AAT reveals that virtualizing a pet animal for therapy purposes, and especially for dementia, was not very explored until this day.

A past study reveals that the usage of a virtual pet, in the form of a game, can be beneficial to improve asthmatic children's self-management abilities [41]. It consists in a virtual companion who instructs children to blow air into a microphone as part of a game while it collects and stores data relative to their performance. Based on that it can provide emergency instructions and allows parents to remotely monitor their children's condition.

Another past intervention describes the usage of a virtual pet dog game with the purpose of reducing childhood obesity [42]. In this study made use of a pet game developed with Unity together with technology such as the Microsoft Kinect. The player would have some joints tracked with the Kinect and would perform certain actions such as throwing a ball and making the dog jump. Results reveal that this system had a practical potential to increase exercise behaviors in children within the camp in which it was used [42]. This was not the only attempt to reduce obesity levels as another study explains that, throughout the use of a virtual pet care game, it was possible to generate healthier habits regarding food [43].

To sum up, since traditional medication does not stop the progression of the disease and sometimes brings undesirable side effects the alternative therapies, such as AAT have gained interest during the past few years. In dementia there were multiple attempts with different therapies. Although AAT has been used in dementia treatment, due to its limitations, past studies found inconclusive results. VR approaches have also been used in different treatment scenarios, including dementia. To avoid some of the disadvantages of the conventional AAT approaches, for example the need of a highly trained animal, which takes time and a financial effort robotic pets have also been used in therapy instead of living animals. In this work we aim to explore the possibility of developing a pet therapy solution using VR to minimize the negative aspects of conventional AAT. Although VR has been previously explored, there is a lack of studies regarding the more appropriate technologies and interaction modalities for developing Serious Games for dementia.

Chapter 3

Explorative comparative study of technology in Dementia

From the initial idea and after gathering insight obtained through the literature review provided in the previous chapter, it was possible to define what would be the scope of this work: creating a serious game tailored for people living with dementia based on animal-assisted therapy common interactions. The main goal is to capture the beneficial aspects of AAT mitigating the disadvantages that it can have. With this aside, and since SG has a wide range of possibilities, there was the need of having to decide which technology and which interaction modalities would be the best-fitting choice to develop a virtual AAT product that would be helpful to people living with dementia.

Although during literature analysis, there were some good recommendations for developing serious games for people living with dementia [28], no prior study tried to understand which the best technological choice for this sort of game would be. Especially when considering this very specific population, mostly comprised of aged adults with cognitive impairment due to the disease.

Given a large number of possibilities regarding technology and lacking conclusive past reports on interaction with people living with dementia, a qualitative interaction study was conducted at the Alzheimer's Association in Madeira.

3.1. Objectives of the study

The goal of this study was, given several viable technologies available in the lab (Leap Motion, HTC VIVE, Tablet, Computer and Augmented Reality with projections), to understand which technology would be the best-fitting for implementing a SG for people living with dementia. Adding to the mentioned technologies, different combinations of interaction modalities were considered resulting in ten different levels for the participants to experiment. Another objective related with the one previously mentioned was, after locking the technology choice, understand which the most adequate interaction modalities were and which problems could arise from that selection to minimize them during the development process. This study would produce theoretical guidelines for developing the serious game for dementia patients.

3.2. Methodology

3.2.1. Technology

The experiment consisted in observing the participants while they tried a variety of technologies available in the market. From the equipment available in the lab the technology options were the HTC VIVE, PC (with the mouse), Tablet, AR (using projections) and the Leap Motion Controller. Table 2 the specifications for the different technology setup used during this experiment.

With these five technologies, it was possible to generate a variety of combinations based on the different interaction modalities that each of them allowed. For example, it is possible to use the HTC VIVE with the controllers or exclusively using the headset for watching a 360º movie. With this, different activities were prepared to understand the advantages and disadvantages of each technology were, combined with each different interaction style.

Technology	Model specifications and system requirements	Image
Laptop Computer (PC)	**Toshiba Satellite L850-1HZ** • Windows 10 – 64 bits • 4GB RAM (DDR3) • AMD Radeon HD 7670M (1GB) • Intel Core i7-3630QM CPU	
Desktop Computer	**Custom Built Desktop Computer** • Windows 10 – 64 bits • 16GB RAM • Radeon RX580 Series • Intel Core i7-6700 CPU	
Leap Motion	**Leap Motion Controller** • Motion sensor • Wired (USB) • OS Required: Windows 7, 8, 10 or MacOS X10.7 Lion	
HTC Vive	**HTC Vive VR Headset** • Dual AMOLED 3.6" screen • 1080 x 1200 per eye • 110º Field of view • Steam VR Tracking, G-sensor, gyroscope and proximity sensor • HDMI, USB2.0, Stereo 3.5mm headphone jack, power, and Bluetooth • Integrated microphone **Minimum required specs:** • NVIDIA GeForce GTX1060 or AMD Radeon RX480 • Intel Core i5-4590 or AMD FX8350 • 4GB RAM • HDMI 1.4, DisplayPort 1.2 • 1 USB 2.0 port • OS: Windows 7 SP1, Windows 8.1 or later, Windows 10	
Tablet	**Samsung Galaxy Tab E** • OS: Android 4.4 (KitKat) • QuadCore 1.3 GHz • 8GB up to 256GB with MicroSD • 800 x 1280, 16:10 ratio Display	

	• 9.6 inches	

Table 2 - Study technology specification

For classifying each technology according to their inherent interaction type the following definitions were adopted:

- **Direct Interaction devices:** there is no need for having an extra intermediary device to interact with the VE and "the movement of the body equals the input of the machine." Direct interaction devices require less cognitive resources as there is no need for "conscious mental translation" as opposed to indirect interaction devices [44].
- **Indirect Interaction devices:** they require an intermediate device to interact with the VE, translating human action into data. Moreover, using indirect interaction devices demands more cognitive resources as it involves conscious spatial and mental translations to convert real-world movements into virtual actions [44].

According to these two definitions, it was possible to categorize every technology used (see Table 3).

Indirect Technology Devices	Direct Technology Devices
Mouse HMD w/Controllers	HMD w/ Leap Motion HMD Tablet AR Leap Motion

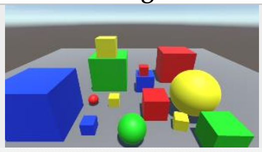
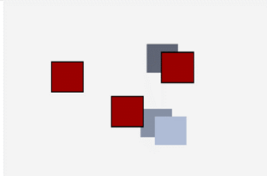
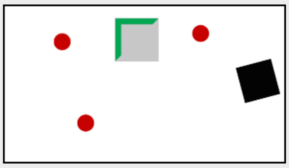
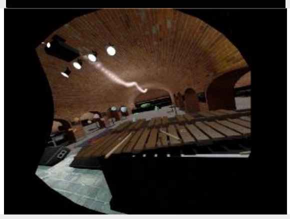
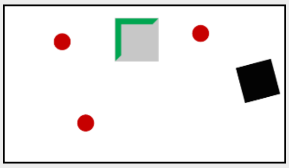
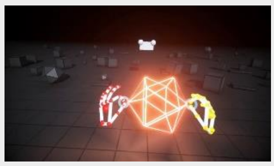
Table 3 - Categorization of Direct and Indirect Devices

3.2.2. Activities

As previously reported in this chapter, different activities were considered for this study and to simplify the analysis each activity was put under a certain category according to the type of tasks that they promoted:

- **Move objects from A to B:** the participants would be asked to perform tasks that consisted in moving an object from a starting to a finishing location.
- **Observation:** the participant would be asked to report what they were seeing or to answer about some of the details of the virtual environment.
- **Manipulating Virtual Objects:** consisting of tasks that would involve grabbing virtual objects, lifting, rotating and throwing them.
- **Play music instruments:** the participant would be asked to play a virtual music instrument, for example, a virtual piano or xylophone.

Table 4 shows the different activities adopted for this study and some of the details regarding which technology was used in each of them as well as the main objectives for that activity.

Activity	Category	Technology	Activity objectives	Image
Playground	Manipulating virtual objects	Leap Motion	The player had to grab and move around virtual objects (spheres, cubes and cylinders).	
Teleport	Moving objects from A to B	PC (Mouse)	The player had to click in one object and then move the mouse to click in another matching object, completing a sequence, to complete the game.	
Drag and catch balls	Moving objects from A to B	Tablet	The player had to drag a square around the playing area towards some red balls. Then after capturing each ball, return to an end-point to drop the balls and complete the level.	
Virtual Forest	Observation	HTC VIVE (Headset only)	The player had to explore the virtual environment of a Forest and describe what they were seeing (flowers, trees, grass, the sky, etc.)	
Virtual Piano	Playing music instruments	Leap Motion	The player had to freely interact with a virtual piano, playing some keys, using their own hands with the Leap Motion controllers.	
Xylophone	Playing music instruments	HTC VIVE (with controllers)	The player had to use the VIVE controllers, moving them around, to play a virtual xylophone in a virtual environment.	
Catching balls (AR)	Moving objects from A to B	AR with projections	Using an AR marker, the player had to move a square around the playable area to catch red balls and then move them to a specific destination marked in the play area with a dark square.	
Ghost Ship 360º Movie	Observation	HTC VIVE (Headset only)	The player had to watch a 360º video of a ship navigating in the sea and describe the elements that would show up in the video. The environment was in movement as well as the camera.	
Blocks	Manipulating virtual objects	HTC VIVE + Leap Motion	Using the HTC VIVE headset together with the Leap Motion controller, the player had to grab cubes that would be around them. Then they would be asked either to stack cubes, to throw others around or to push these virtual objects.	

Virtual Objects	Manipulating virtual objects	HTC VIVE (with controllers)	Using the VIVE controllers the player would be placed in front of a virtual table with different objects (teacups, book, phone, and others) over it. The player would be then asked to grab objects, place them in another position, rotate them, drop them or even lift objects in the ground.	

Table 4 - Technology and interaction study: extended activity list and description

For each of the activities performed with a given technology, six dependent variables were collected:

- **Assistance Provided:** we measured the number of times assistances required to aid participants (i.e., researchers and therapists).
- **Comprehension Issues:** we gathered data regarding participant's general understanding of the tasks and interaction with technology.
- **Perception Issues:** we counted the number of times participants had visual, audible and tactile related issues during task performance.
- **Interaction Issues:** we calculated the number of software and hardware related issues that participants had encountered.
- **Discomfort:** we counted the number of times participants felt distressed during task performance (i.e., fatigue, cybersickness).
- **Equipment at risk:** we calculated the number of times that the equipment was exposed to external hazards.

3.2.3. Participants

According to the inclusion criteria stated in the Inform Consent (see Appendix A), an experimental subject would be eligible to participate in this study if:

- The experimental subject can independently use their upper limbs;
- The experimental subject has functional hearing ability;
- The experimental subject has functional comprehension ability;
- Optional – The subject can read.

In total, the study was conducted with 12 participants (8 were female and 4 were male), but some of the participants were not able to conclude every activity available, and some participants quit the study before completing it. Table 4 includes detailed information regarding all the participants of this study.

Participant ID	Gender	Education	Age	MMSE	Dementia Type
1	F	4th grade	70	25	Alzheimer
2	F	4th grade	85	19	Alzheimer
3	F	3rd grade	78	18	Vascular
4	M	-	81	17	Alzheimer
5	M	5th grade	67	24	Frontotemporal
6	F	3rd grade	74	12	Alzheimer

7	F	4th grade	71	14	Alzheimer
8	M	4th grade	82	21	Lewy Body
9	F	6th grade	65	11	Alzheimer
10	F	12th grade	88	10	Alzheimer & Parkinson
11	F	4th grade	77	26	Alzheimer
12	F	12th grade	63	11	Frontotemporal

Table 5 - Study participant's demographics

Before starting their first activity, the participants would be presented with an inform consent regarding this experiment, which they would have to sign if participating. In this document, they would be able to find information about the objective of the study, proceedings, inclusion criteria, risks and benefits, information regarding the confidentiality of the study and their personal data as well as an optional authorization for video recording of their experimental sessions (see Appendix A for the full document).

3.2.4. Protocol

The experiment was conducted during multiple sessions, organized in daily visits to the Alzheimer's Association, according to the availability of each participant, during nearly three months. In each session, of about 15 minutes, the participant would interact with different technologies. All participants (or legal guardian) were required to sign an informed consent form to participate in this study. The experiment was also video-recorded according to the participant's consent (with an additional signature). This video recording was made from an angle behind the participant, with the use of a tripod, in order to hide their identity as this was also one of the premises for the recording consent.

The experiment was conducted with two researchers present in the designated room. While one was assisting the patient during the period of the activity, the other was responsible for preparing and adjusting recording equipment when needed. This second researcher was also constantly taking notes on possible interaction problems or other significant events that might occur during the experimental session to later compare with the video recordings (if available). The presence of a health care professional was needed during some sessions to supervise the participant and assist the researchers in the case of participants who were at later stages of dementia. At the end of every activity, the participant would answer a couple of questions regarding the interaction tasks they had just concluded. Any personal information regarding the participants would not be published, and any face that appeared in the video recordings would later be hidden.

A protocol (see Appendix B) was designed to help the researchers during the experimental sessions and to maintain the same coherence throughout the study with all participants for each of the different activities. Some of its measures included:

- **Duration of the Study**: the experiments that will be conducted in this study will have a maximum duration of 15 minutes for each of the interactions; the patient is allowed to repeat a task if desired.

- **Before initiating the task**: researchers explained to participants how to use specific technology in order to complete a task.
- **During the task**: the participants can ask researchers for help to repeat instructions or aid them regarding technology or task-related issues at any time during the experience. Also, the researcher could intervene in the task at any moment during the experiment. Moreover, participants were encouraged to think aloud during task performance. During the tasks, one researcher was conducting the experiment with the participant while another is taking notes.
- **Withdrawals**: the participants could abandon any of the tasks, or even the overall experimental trial, at any given moment.

3.2.5. Instruments

For the data collection, audio and video recordings were used. The video was recorded during the experimental session and the interview while the voice recording was exclusively used during the post-interaction interview. For the interview session, a semi-structured questionnaire was used. This semi-structured interview had questions concerning the perception of the participant of the current activity objective and execution (see Appendix C for the full questionnaire). It also had questions to assess if the activity had any negative impact on the participant or if they became tired of performing certain activities. The researcher was constantly taking notes on possible interaction problems or other significant events that might occur during the experimental session to later compare with the video recordings (if available).

3.2.6. Data Analysis

All the collected data was written down to different Excell sheets to be subsequently analyzed. First, the interview answers of the 12 participants and each of their activities was transcribed. The notes taken by the researcher during each activity were also stored in a file for each participant.

Regarding the video recordings, as they were one of the most valuable sources of data in this study, using Adobe Premiere, each of the researchers involved would watch, one by one, the videos of the interventions (for each activity from all participants). Then, each researcher would mark significant events with tags and the description of the event that occurred in that timestamp (see Figure 2).

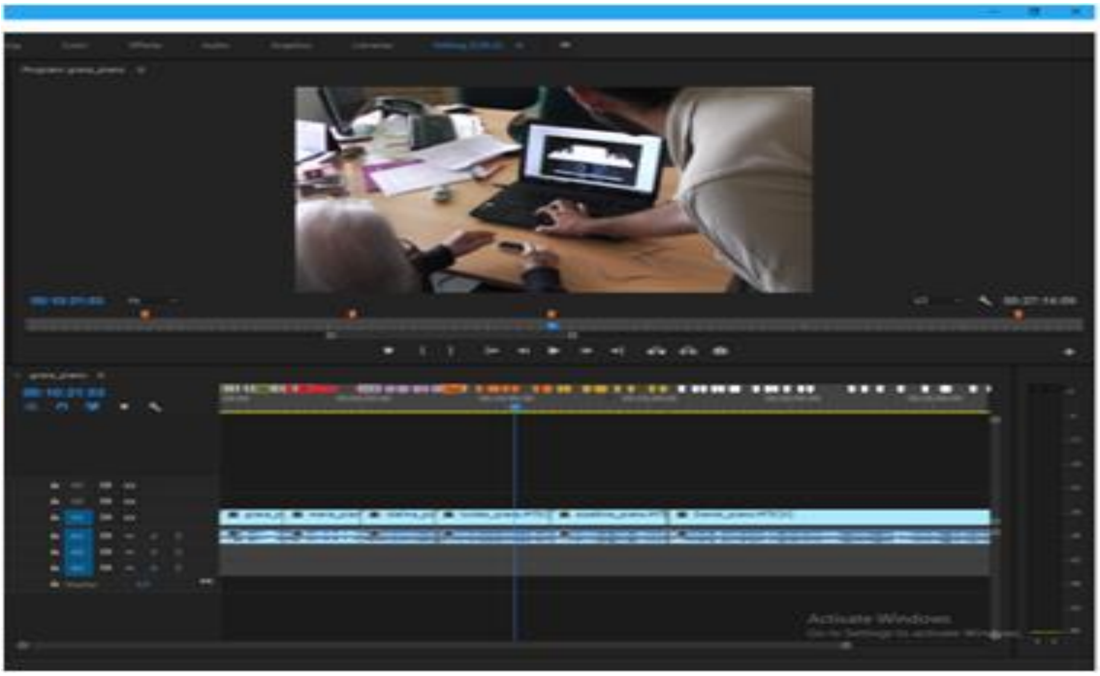


Figure 2 - Video Analysis with Markers in Adobe Premiere

These markers would be exported in CSV format (see Figure 3) to be compared by both researchers individually. The Inter-Rater Reliability (IRR) technique for observational data was used when comparing both researchers' markers and whenever there was a case of disagreement a third rater would rate the same event and classify it accordingly. The IRR, in statistics, can be defined as the level of agreement between two ratings given by independent raters [45]. It was used so that after comparing the evaluations of both researchers to each event in a video, it was possible to identify conflicts of opinion and solve them by having a third neutral element evaluating the same marker.

After this extensive analysis, the resulting data was computed using SPSS to find significance in the results and possible causalities.

	A	B	C	D	E	F
1	Marker Name	Description	In	Out	Duration	Marker Type
2			00:00:00:00	00:00:00:00	00:00:00:00	Comment
3		Explicação da ta	00:00:08:03	00:00:08:03	00:00:00:00	Comment
4		Como é que vou	00:00:12:10	00:00:16:11	00:00:04:01	Comment
5		A participante te	00:00:41:10	00:00:54:14	00:00:13:04	Comment
6		Levou QC para (	00:01:06:19	00:01:07:15	00:00:00:21	Comment
7		Vamos ver! - Ser	00:01:10:16	00:01:12:03	00:00:01:12	Comment
8		Apanhou BV	00:01:16:12	00:01:20:12	00:00:04:00	Comment
9		Levou QC para (	00:01:23:16	00:01:27:05	00:00:03:14	Comment
10		Apanhou BV. Fal	00:01:30:11	00:01:39:07	00:00:08:21	Comment
11		Levou QC para (	00:01:42:15	00:02:04:13	00:00:21:23	Comment
12		Falhou uma cont	00:02:10:24	00:02:15:15	00:00:04:16	Comment

Figure 3 - Exported video markers in CSV format

3.3. Results

In total each participant was asked to complete 10 different tasks and Table 6 presents which activities each participant completed (represented in green) and which activities that person did not participate at all (represented in red).

Participant	LM - Playground	LM – Piano	PC	Tablet	AR	HTC Vive - Still	HTC Vive - Movement	HTC Vive - Music	HTC Vive - Objects	HTC Vive + LM - Blocks
1	green	green	green	green	green	green	green	green	green	green
2	green	green	green	green	green	green	green	green	green	green
3	green	green	green	green	green	green	green	green	green	green
4	red	green	red	green	red	green	red	red	red	red
5	green	green	red	red	green	green	red	green	green	green
6	green	green	green	green	green	green	green	red	red	red
7	green	green	green	green	green	green	green	green	green	green
8	red	red	green	green	green	green	red	red	red	red
9	red	red	green	red	green	green	red	red	red	red
10	green	green	green	green	green	green	red	red	red	red
11	green	green	green	green	green	green	green	green	green	green
12	green	green	green	green	green	green	green	green	green	green

Table 6 – Participant's activity completion list. In green are represented the completed activities and in red the activities that the participants did not complete.

Direct and Indirect interaction

Regarding the different direct and indirect interaction devices (see Table 3 in Technology section), we tried to understand whether there was any difference in the participants' task performance according to the type of device they were using. Participants required significantly more assistance when using indirect interaction devices than when using the direct interaction ones (see Table 7).

Moreover, participants had significantly more difficulties understanding indirect related technologies than direct related technologies. However, there were no statistically significant differences regarding, interaction related issues, perception related issues and discomfort (see Table 7). The columns marked with * indicate the variables in which a significant difference between conditions can be found ($p < 0.05$).

	Assistance *	Perception-related issues	Comprehension related issues *	Interaction related issues	Discomfort
Direct Interaction	1.700 ± 7.000	4.250 ± 6.050	2.000 ± 2.775	7.125 ± 2.775	.775 ± 1.088
Indirect Interaction	3.000 ± 12.000	1.000 ± 6.500	4.000 ± 5.500	8.500 ± 13.000	.000 ± 1.500

Table 7 – Participants' performance in direct and indirect interaction devices

Cost-effectiveness of technology

Regarding the cost-effectiveness of technology used in this study, a relationship between performance issues, across the use of the different technologies, and technology cost can be seen in Figure 4. The prices in Table 8 are based on the time when such equipment was purchased (in Euros).

Technology	Price (€)
HMD w/ LM	1049€
HMD	899€
HMD w/Controllers	899€
AR	531.51€
Tablet	89.99€
LM	89.99€
Mouse	34.08€

Table 8 - Cost of the equipment at the time of purchase in Euros.

The three most expensive technologies were HMD w/LM (1049€), and both the HMD and HMD w/ controllers (899€) while the cheapest three were the mouse (34.08€), LM (89.99€) and Tablet (89.99€). The AR technology equipment presents the intermediate cost of 531.51€ as the technology in the middle of the scatter plot.

Regarding performance issues, HMD (63) and HMD w/LM (120) were the technologies with less performance related issues while Tablet was the one that presented the largest amount (467). Technologies such as Mouse (213), HMD w/Controllers (234), LM (261) and AR (262) presented moderate performance issues.

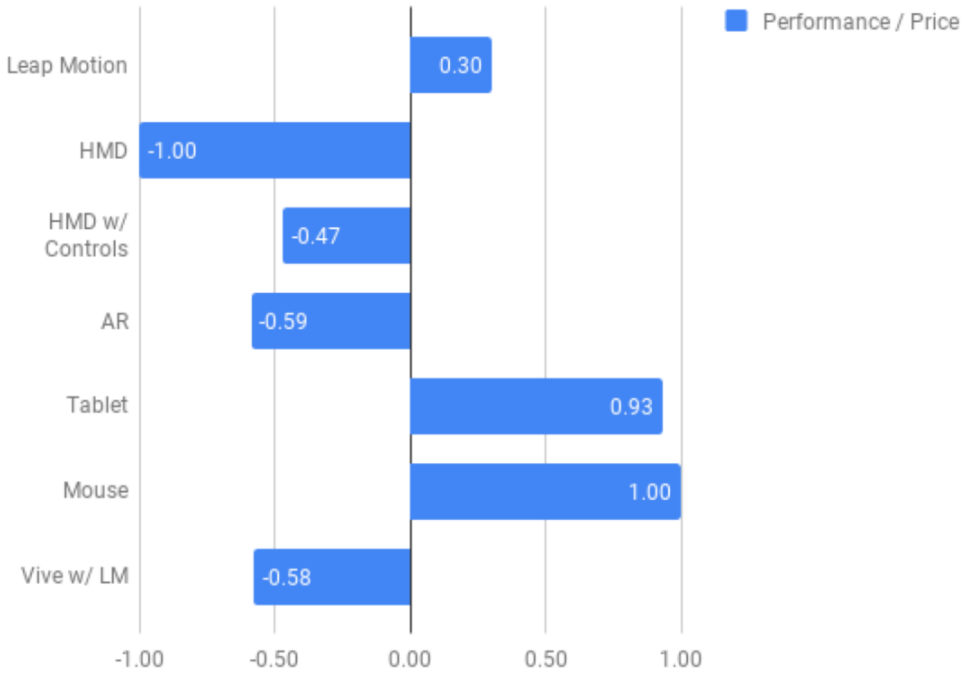


Figure 4- Cost-Performance analysis of performance issues identified and technology costs.

Table 9 complements with the cost efficiency calculus to determine which technology is the more appropriate for people living with dementia regarding performance and for the best price.

Rank	Technology (performance / costs)
1st	Mouse (1.00)
2nd	Tablet (0.93)
3rd	Leap Motion (0.30)
4th	HMD w/Controllers (-0.47)
5th	HMD w/LM (-0.58)
6th	AR (-0.59)
7th	HMD (-1.00)

Table 9 - Ranking of the technology used in the study regarding cost-effectiveness for people living with dementia

The costs and technological issues were normalized to [-1, 1] using the formula:

The more negative the results are, the less cost-effective is the technology. According to the analysis, the best four cost-effective technologies are Mouse, Tablet, Leap Motion and HMD w/Controllers as oppose to HMD w/LM, AR, and HMD.

3.4. Discussion and conclusions

It is important to mention that in every interaction activity there were people who performed well and people who did not perform so well. After analyzing the notes taken during the interventions together with the video recordings of each session, there was a clear idea that some of the chosen technologies for the study were not adequate for the use of people with dementia. For example, the HTC VIVE (especially when using the controllers) and the computer with a mouse, since interacting with a third element such as the controllers revealed to be complex and confusing for the participants. Most of the times they were not able to understand the buttons in the controller nor to understand which buttons they had to press when they were instructed to do it. Another factor that weighed against the HTC product was the fact that some of the participants reported cybersickness related problems. Regarding the computer with mouse interaction tasks, the participants felt great difficulty understanding where to click in a regular two-button mouse with scroll and some of them did not even understand or felt confused on how they should move the mouse pointer even after the researchers explained multiple times.

The technologies that, from the collected data, stood out regarding usability for dementia patients were the ones that provided a direct interaction modality such as the Tablet or the AR with projections and marker. When looking at the cost-effectiveness relationship in these technologies, even with quite positive results, there were also clear indications on problems that would eventually arise while this population interacted with the Tablet, which had the most performance issues across all technologies. One of these problems was the multi-touch issues that occurred when the participants rested their whole hand over the touch screen and tried to use their finger to perform the tasks. They would sometimes also press unnecessary buttons such as the volume or home buttons.

From this, it was possible to narrow down the list of possibilities regarding technologies for the development of the project. Even so, the problems that were described in the last paragraph should be considered when developing the game for people with dementia, either by avoiding them in the final implementation or at least trying to minimize the impact that they can have once they occur.

Chapter 4

Game development process

4.1. Development

4.1.1. Methodology – Project SCRUM solo

The SCRUM methodology is a software development method that simplifies the Waterfall Development model allowing the project to have a backlog (list of functionalities to implement) and daily iterations (backlog sprints) in the development of those functionalities [46]. It works well in small development teams as the team members can communicate with each other during the SCRUM meetings and discuss bottlenecks and progress that they might have in their current sprint. During this project's development, a variant of SCRUM for solo developers (SCRUM solo [47]) was used. Even with only one developer, during each day a 5 to 10 minutes period was taken just to analyze what the priorities and bottlenecks of the current state of the game were.

To manage the backlog list, GitHub's project tab was used, allowing the addition of multiple columns and to pin some cards describing an individual issue (see Figure 5), which were generated automatically from an issue list. The used columns were based on the different stages of the development process for each functionality (or each card): Backlog, In Analysis, In Development, Pending Tests and Finished (see Figure 6). Every backlog item would start, obviously, in the Backlog column. As soon as the analysis of how to implement started it would then transition to the In-Analysis column. While the code for a specific requirement was being developed, its card would be moved to the In-Development column, and when ready it would first be moved to Pending Tests and later, if correctly validated, to Finished.

The biggest advantage of this approach is that it allows the developer a clear vision of the project progress devoting a little amount of time every day.

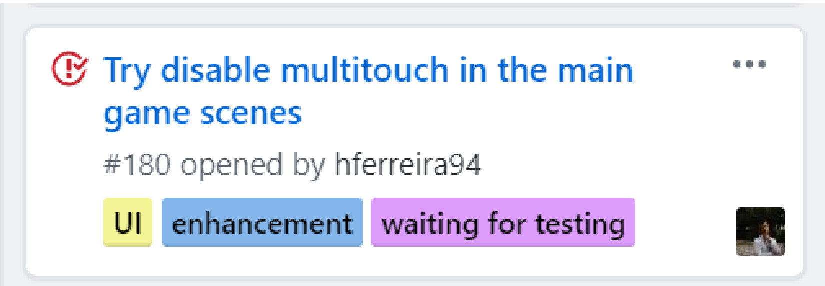


Figure 5 - Issue card generated automatically by GitHub. Describes the issue to be solved by displaying its assigned labels.

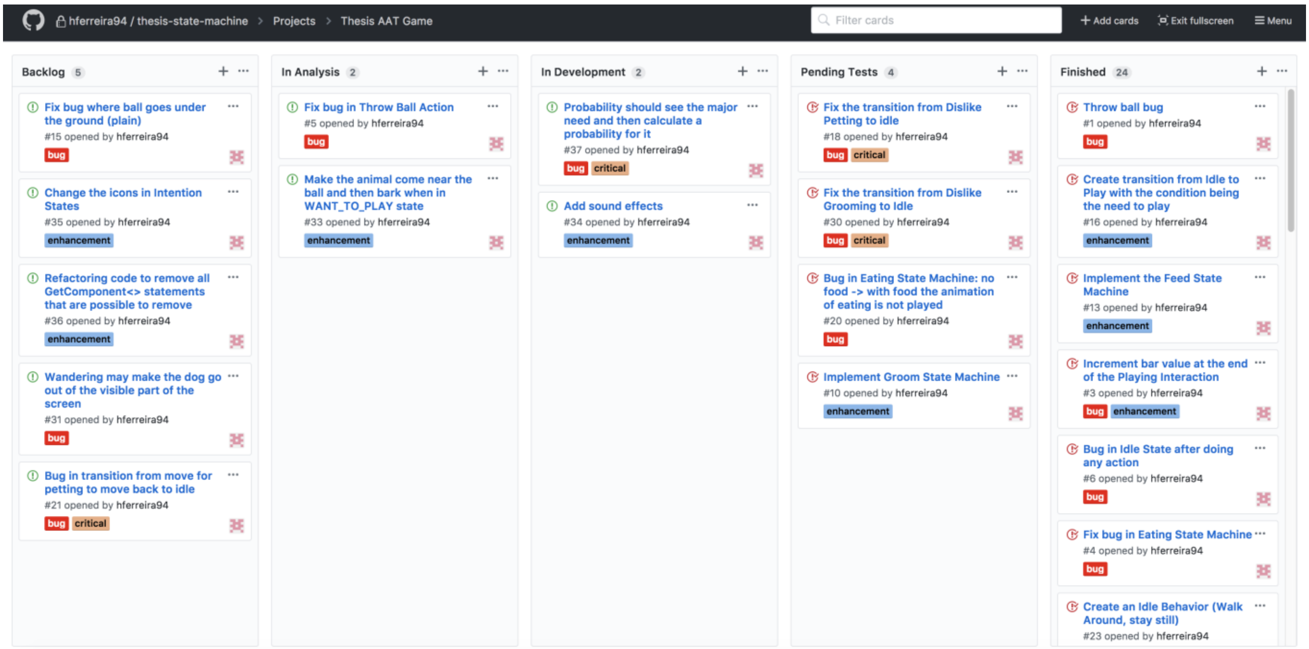


Figure 6 - GitHub's project page with all issues organized during project development

4.1.2. Version control – GitHub

It is known that one of the biggest problems when working with code is handling its changes. For example, adding, modifying or deleting certain lines of code is something that a developer may want to undo. At a simple level, there are commands such as undo or redo, for reverting or repeating a certain action, but that will only work for recent changes. In this particular case, there are no multiple developers but, since the development has been done in multiple machines, using Git allowed to have a repository where all the project code was stored and organized. Whenever there was the need to have a specific version of the code in another machine a single clone or pull changes command would be used. The code repository was created in private in GitHub so that only the project owner was able to see its contents. The repository was not only used for version control of each project version and respective scripts but also as a method to keep track of the issues detected along the development.

4.1.2.1. Git Flow

A Git Flow is a branching model created for Git that is widely used in large project development teams as a way to standardize the process of handling code versions and mostly the inclusion of new features or changes to previously tested and validated code. During the project, a specific Git Flow was used. This Git Flow consisted of having a develop branch and a master branch. The master branch would only host the most recent and well-validated functional versions of the project (releases). The develop branch would include the frequent commits and the working version of the project that was previously tested. Each time a new feature (project requirement, or item from the backlog) was implemented or a bug had to be fixed a new branch would be created in develop to host that specific change and later on be merged with its parent branch after being tested and validated. Because there was a single developer throughout this project's implementation, there were fewer chances of having code conflicts, and the major releases would not happen until the later stages of the development process. Therefore, it was decided that it was advantageous to work in the develop branch and later on merge it to master when a new implementation was successfully tested and validated.

4.1.2.2. Issue tracking

As mentioned before, each backlog item or functional requirement of this project would turn into an Issue. These issues would also be labeled as an Enhancement, being a development that would increment something to the project or if it corresponds to a functional requirement, or as a Bug if it described an undesired behavior of the application that needed to be fixed. Some other useful labels were created such as UI, if it described a UI/UX change requirement or Critical if it represented a crucial fix that would be troublesome for the application, between some others.

Labels would then be combined in issues trying to categorize them in the best way possible to visually be able to see the priorities of the development efforts quickly. Each time a code commit was made having the solution (fix) to one of the issues it would automatically be closed. This issue tracking method was not only used for being considered a good practice in software development, but it allowed to have a constant awareness of what was pending.

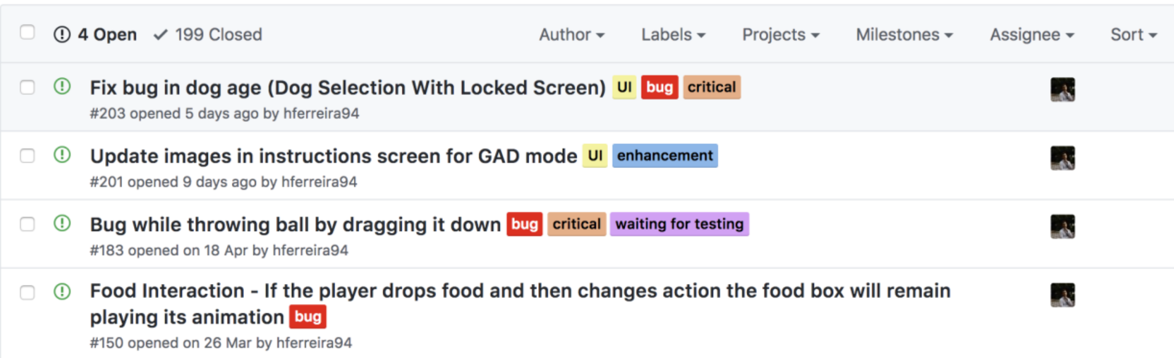


Figure 7 - GitHub's issue page with some issue examples

4.1.3. Game development

4.1.3.1. The concept

From the analysis made in Chapter 2, the developed game can be described as an interaction game for portable touch devices, such as tablets or smartphones, in which the player can interact with a dog. The available activities that the player can perform are those usually performed in AAT but in a virtual environment (playing, petting, grooming and feeding the animal). During the development process, there were specific design decisions taken, considering the ease or difficulty of the dementia patients in interacting with portable touch devices. These translated to some of the most important Non-Functional Requirements (NFR) of the application (see Table 10).

One of the key aspects of the customization layer for this game is to allow the player to change the species of the dog they will play with. The 3D models used for the development of this game provide the option of selecting one of twelve different species: Beagle, Border Collie, Bulldog, Bull Terrier, Chihuahua, Doberman, German Shepherd, Labrador, Poodle, Pug, Rhodesian Ridgeback and Saint Bernard.

Customization is also present in one of the features unveiled through the progression in this game, which is the existence of different scenarios for the player to raise a dog in (a garden, house interior, beach, and city). Each of these scenes has different characteristic elements associated with them and also a different background sound. For example, in the garden scene some birds can be heard in the background, and in the beach scene, the player will be able to listen to the sound of waves. The reasoning behind having different scenes is to introduce a customization aspect to allow people living with dementia to select a different stage in which the game will be played according to their personal preference.

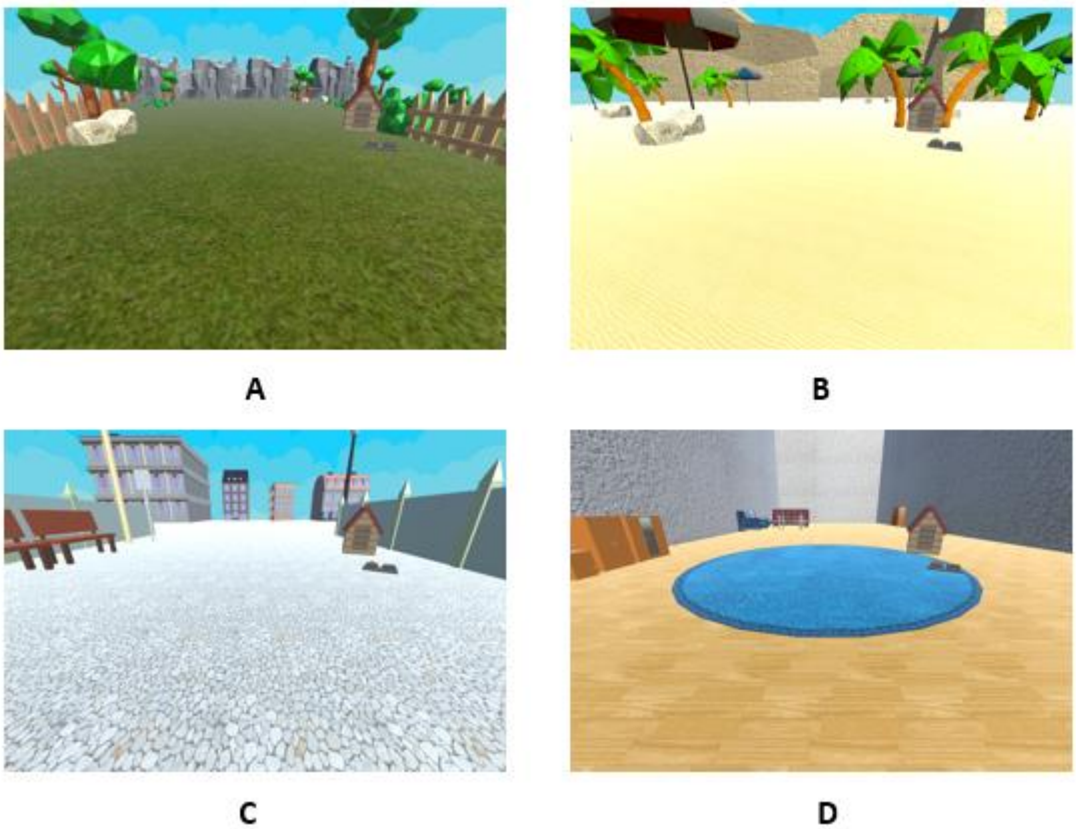


Figure 8 - Game scenarios: A - garden scenario, B - beach scenario, C - city scenario and D - house interior scenario.

Regarding its objective, the game has two different game modes. First, there is a free mode in which the player is able to fully customize its experience by selecting an animal from all the different species available. After selecting the dog species, the player can also customize its size from three different options: small, medium and large. Besides this, one of the four scenarios described before can be selected. The main goal of the free mode is to collect points (in the form of stars) by continuously satisfying the animal needs. The second game mode is the Grow-A-Dog mode. In this mode, the player starts with three different dog species available and that animal will always start as a puppy (small dog). The objective of this game mode is to maintain the animal happy, satisfying its needs, which will allow it to grow until it becomes adult (large dog). As soon as the dog becomes an adult, the player unlocks a new animal.

Table 10 translates the core concept and activities in the game regarding functional (FR) and non-functional requirements (NFR).

AAT Activities	Requirement (FR/NFR)
Playing with the dog	**FR1**: Create a throw ball method (in the Ball) **FR2**: Create catch ball method (for the Dog)
Grooming the dog	**FR3**: Create a grab groom method (in the Groom) **FR4**: Create a grooming method (in the Dog).
Feeding the dog	**FR5**: Create method for pouring dog food (in the Bowl) **FR6**: Create method to go eat (in the Dog)
Petting the dog	**FR7**: Create a method for petting (in the Dog)
Customization	**Requirement (FR/NFR)**
Dog and Scene customization	**FR8:** Create method to select animal species **FR9:** Create method to customize animal size (Small, Medium and Large) **FR10**: Create method to select game scenario (Garden, Beach, City and House)
Game modes	**Requirement (FR/NFR)**
Free mode	**FR11:** Create method to obtain points according to the satisfaction of the animal needs.
Grow-A-Dog mode	**FR12:** Create method to make the dog grow continuously according to the satisfaction of its needs. **FR13:** Create method to unlock new animal.
Other	**Requirement (FR/NFR)**
Game language	**FR14:** Create methods and classes for English and Portuguese languages in-game.
Game difficulty	**FR15**: Create method to adjust the frequency of changing the animal needs and satisfaction increase amount with three difficulty levels: Easy, Medium and Hard.
Interaction	**FR16:** The game activities should be done by clicking or drag and drop. **NFR1:** Multitouch functionality must be disabled to minimize interaction problems. **NFR2:** Game orientation in the tablet must consider the problems that occur form involuntarily pressing the volume and lock buttons.

Table 10 - List of functional and non-functional requirements in the game

4.1.3.2. 3D models

The chosen animal for the game was a dog. It was the first choice since dogs are one of the most common kinds of pet animals that people usually have at home and have special characteristics of being highly dependent on their owners because of their friendly nature. Also, dogs are commonly used in AAT scenarios, and since the game pretends to mimic an AAT session, this kind of animal fits the general concept.

The 3D models used for this game were available both online or in the Unity Asset Store. The Simple Dogs – Cartoon Animals package is available in the Asset Store and contains models ready for mobile game development (graphically optimized, low-poly) with some basic animations that fitted the needs of this game. Another important aspect to mention is that this package already brings prefabs for the animal perks as well, such as food bowls, dog house and some toys that also helped to maintain the visual consistency of the game (see Figure 9).

Figure 9 - 3D models of the pet animals and some dog perks

The links to all of Unity Asset Store pages of each of the 3D models used in the development of this project can be found in Table 11.

3D Models	Download link
Simple Dogs – Cartoon Animals	https://assetstore.unity.com/packages/3d/characters/animals/simple-dogs-cartoon-animals-82665
Low Poly Styled Rocks	https://assetstore.unity.com/packages/3d/props/exterior/low-poly-styled-rocks-43486
Low Poly Models	https://assetstore.unity.com/packages/3d/environments/low-poly-free-pack-58821
Cartoon Palmtree and Umbrellas	https://assetstore.unity.com/packages/3d/vegetation/cartoon-palmtree-and-umbrellas-58457
Desert Sandbox LITE	https://assetstore.unity.com/packages/3d/environments/fantasy/desert-sandbox-lite-25935

Table 11 - Links to the 3D models used for the development of the game scenarios (Unity Asset Store)

4.1.3.3. Game modes

Two different game modes were developed, providing two different objectives in the game according to which game mode the player decides to play. First, there is a mode where the player picks up a baby dog (puppy) and raises it until it reaches adulthood. This growth happens by performing the available actions in the game as soon as the animal shows any sort of needs. As soon as the player is able to completely raise the dog, a new dog species is unlocked. Also, in this game mode, every dog has a different background scenario in which the player will have to raise them. The second mode is a free game mode where the player has the ability to fully customize the game experience by selecting both the species and size of its dog. Also, the scenario here can be handpicked according to the preferences of the player. The objective in this free game mode is to collect points, in the form of stars, by maximizing the animal's happiness and quickly satisfying any need that the pet might have during this experience.

A tutorial level was also created for the player to be able to become familiar with the game mechanics before jumping into one of the remaining and previously described game modes.

4.1.3.4. The animal's AI

An important aspect in any interactive application are the responses or the consequences that might happen after every interaction, as well as the ability of an agent to induce starting an interaction.

State machines can be regarded as a technique often used for decision making in games. The basic theory behind a state machine is that, in a state machine each character can be in one state at the time. There are actions or behaviors associated to each state. With this said, a character in a given state will keep carrying on the same actions while there is no state change. States are connected together by transitions and each transition leads from a state to another state (target state). Each transition also has a set of associated conditions. The game is responsible, through events or any other influence, to determine if a condition is met (triggered) making it so that the state machine will transition from the current state it is in to the target state.

In this case, to develop the pet's AI we created a Finite State Machine (FSM) that has a finite number of states, which would also define what actions the animal would perform in a state and the possible transitions to other states. FSM fits the needs of the problem to solve here, since the main character of this game (the pet) will act in a limited set of ways. It will carry doing the same action or group of actions until some sort of event or exterior influence makes it change state.

The FSM used to implement the pet's AI in this game is shown and described below (see Figure 10).

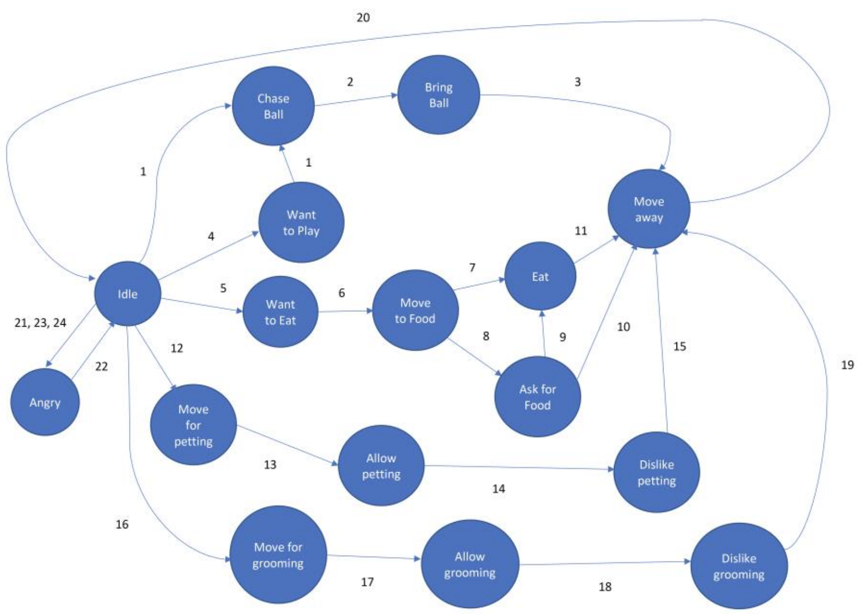


Figure 10 - FSM for the pet animal diagram (see text below for details).

In Figure 10, the circles denote the states in which the agent can be and the arrows, each represented by a number, denote the possible transitions that may occur during the game (see Table 13 for the Transition names).

4.1.3.4.1. States and behaviors

In the developed FSM (see Figure 10), there are 16 states (represented by the circles) which can be seen in detail in Table 12 and all of them represent a group of actions that the animal will conduct while it is on that state. In Figure 10, it is also possible to see all the transitions (represented by directional arrows) that occur between states as they will be explored in more detail in the following paragraphs.

State name	Description of the behavior
Idle	The animal will be in a state in which it will simply wander around the playable area, walking around and observing the environment.
Chase_ball	The animal, while in this state, will chase a ball thrown by the player, running after it until it is caught.
Bring_ball_back	After the animal picks up the ball it will be transitioned to the state in which its main action will be bringing the ball back to the player.
Wants_to_play	This state indicates that the animal has the need of playing as it wants the user to play with it. In this state the associated behavior of the animal will be the barks until a ball is thrown.
Move_back_to_idle	This state's associated behavior is simply making the animal walk from the position it currently is (for example after completing an action) to the initial central position of the playing area.
Go_eat	In the GO_EAT state, the behavior of the animal should be indicating that it wants to eat as its hunger has reached a certain amount.
Move_to_food	This state's associated actions are basically the movement of the animal from the place it currently is to the place where the food bowl is positioned.
Eating	The EATING state, as the name indicates, represents the eating action (displaying an animation while the animal eats its food).
Ask_for_food	This state happens when the animal needs to eat and the user did not drop any food to the food bowl. The expected behavior in this case is for the animal to come near the food bowl, see that it has no food in it and start barking until the player decides to pour some food.
Move_for_petting	The MOVE_FOR_PETTING state's actions are basically moving the animal from the place it currently is to a space near the player where the animal would appreciate some petting.
Allow_petting	In the ALLOW_PETTING state the animal will simply sit and wait for the player to pet it.
Dislike_petting	When the animal feels tired of getting pet it will simply stand up, bark and walk away.
Move_for_grooming	This state is very similar to the MOVE_FOR_PETTING state as the animal will simply move near to the player so it can be groomed.
Allow_grooming	In the ALLOW_GROOMING state the animal will sit down (similar to ALLOW_PETTING) and wait for the player to groom it.
Dislike_grooming	If the animal feels tired of getting groomed it will stand up, bark and then go far away from the player.
Angry	If the player keeps performing the same action and the dog already has that need satisfied it may become angry and start barking.

Table 12 - Description of each state and respective actions

4.1.3.4.2. Transitions

In the developed state machine, it is possible to distinguish two main types of transitions: game-triggered transitions and event-triggered transitions. The game-triggered transitions occur when a game internal variable is changed and, with that change, a condition for a certain transition is met. For example, consider the transition from the state IDLE to the state GO_EAT. In this transition, the defined condition is dependent on the need of the animal for food. In this case, the animal need is compared with an internal variable that indicates the animal hunger.

On the other hand, there are the event-triggered transitions that include the transitions that should only occur if the player interacts with a given object that will be responsible for triggering an event, making it so that the condition for an event transition is met. For this scenario, consider the transition from the IDLE state to the CHASE_BALL state. The condition for this transition to happen depends on the user throwing the ball. If the ball is thrown the animal will run, changing to CHASE_BALL state, and try to catch it. Table 13 describes all transitions in the game and which conditions should be met for them to happen.

Id	Transition Name	Transition	Condition	Result State
1	**transIdleChaseBall**	Idle -> Chase Ball	Ball was thrown	Chase Ball State
2	**transChaseBallBringBallBack**	Chase Ball -> Bring Ball Back	Ball was grabbed	Bring Ball Back State
3	**transBringBallGoBack**	Bring Ball Back -> Move Back	Animal arrived at ball drop position	Go Back State
4	**transIdleWantsToPlay**	Idle -> Want To Play	Animal needs to play	Want To Play State
5	**transIdleGoEat**	Idle -> Go Eat	Animal is hungry	Go Eat State
6	**transGoEatMoveToFood**	Go Eat -> Move To Food	Animal arrived at the food bowl	Move to Food State
7	**transMoveToFoodEating**	Move To Food -> Eating	The food bowl has food	Eating State
8	**transMoveToFoodNoFood**	Move To Food -> Ask for Food	The food bowl has no food	Ask for Food State
9	**transNoFoodEat**	Ask For Food -> Eating	The player puts food in the bowl	Eating State
10	**transNoFoodIdle**	Ask For Food -> Idle	The animal stops asking for food (probability)	Idle State
11	**transEatMoveBack**	Eating -> Move Back	The food bowl has no food	Go Back State
12	**transIdleMoveForPetting**	Idle -> Move For Petting	Animal wants petting (need too low)	Move For Petting State
13	**transMoveForPettingAllowPetting**	Move for petting -> Allow Petting	Animal arrives at petting position	Allow petting State
14	**transAllowPettingDislikePetting**	Allow Petting -> Dislike Petting	Animal gets tired of being pet	Dislike petting state
15	**transDislikePettingMoveBackToIdle**	Dislike Petting -> Move Back	Animal finishes barking and starts moving back	Go Back State
16	**transIdleMoveForGrooming**	Idle -> Move For Grooming	Animal needs grooming (need too low)	Move For Grooming state
17	**transMoveForGroomingAllowGrooming**	Move For Grooming -> Allow Grooming	Animal arrives at grooming position	Allow grooming state
18	**transDislikeGroomingMoveBackToIdle**	Dislike Grooming -> Idle	Animal finishes barking at the player	Idle State
19	**transAllowGroomingMoveBackToIdle**	Allow Grooming -> Move Back	Animal gets tired of grooming	Go Back State

20	**transMoveBackIdle**	Move Back -> Idle	Animal arrives at its idle position	Idle State
21	**transIdleAngryPlay**	Idle -> Angry	The animal is tired of playing	Angry State
22	**transAngryIdle**	Angry -> Idle	The animal finishes barking	Idle State
23	**transIdleAngryGroom**	Idle -> Angry	The animal is tired of grooming	Angry State
24	**transIdleAngryPet**	Idle -> Angry	The animal is tired of being pet	Angry State

Table 13 - Transition and condition list

4.1.3.4.3. Character animations

The animations for both the dog and other visual elements in the game are mainly the ones available with the models used for the development. Since the game is an interaction game, animations play a major role in providing feedback from the animal to the player according to the actions they perform.

For a correct usage of the animations, an Animation Controller (see Figure 11) was created using the animal's internal variables to determine either if the Running animation or the Eating animation would be played, for example.

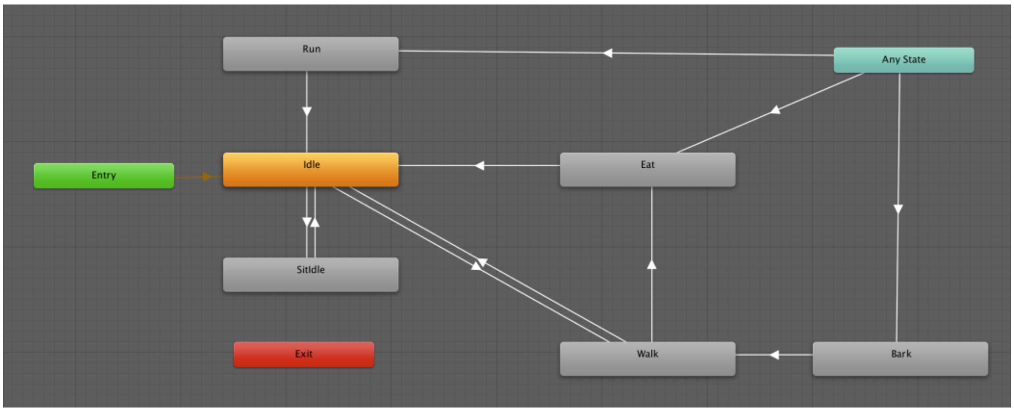


Figure 11 - Animation Controller scheme for the pet animal

In Unity, an Animation Controller is an Asset that allows to maintain a set of animations for a character or object. In most situations when developing a game, it is normal to have many different animations and there is the need of switching between them according to certain game events or player actions that might influence the character or game object by changing its animation (for example stop walking and start running). The Animation Controller is able to manage the different animation states (each one associated to one animation) and the transitions between them using a State Machine represented visually in the form of a flow-chart (boxes and arrows – see Figure 11).

4.1.3.5. Graphic User Interface (GUI)

4.1.3.5.1. Title Screen

The Title Screen (see Figure 12) is the first contact the player will have with the game as soon as it opens. Here there are several buttons that will allow the player to start a game session, read the instructions, see their collected animals and highest scores, adjust the game settings or exit the application.

There is also the option of changing the game language in the bottom right corner of the screen. The currently implemented languages are English and Portuguese.

Figure 12 - Game title screen

4.1.3.5.2. Game settings

In the game settings screen (see Figure 13) the player is able to adjust the difficulty level for the game by selecting one of the three available levels (EASY, MEDIUM and HARD). For the easiest difficulty level, the dog will earn points faster as the actions made by the player will have a higher impact on the increasing happiness of the animal that will also show needs in a slower pace. For the HARD difficulty level, the player will have to keep performing actions fairly quickly in order to maintain the dog happy and therefore completing each level.

In addition, in this screen there is also a button for erasing all progress made in the game (DELETE DATA button). This will soft-reset all achievements (collected animals and highest score data).

Figure 13 - Game configurations/settings screen

4.1.3.5.3. Instructions screen

The instructions screen provides the player (ideally a person with dementia) a small introduction to the game explaining most of the game screens. For example, how to select an animal kind or what are the objectives of each game mode, as well as the basic interactions available. This instructions screen is organized according to which game mode the player wants to learn about.

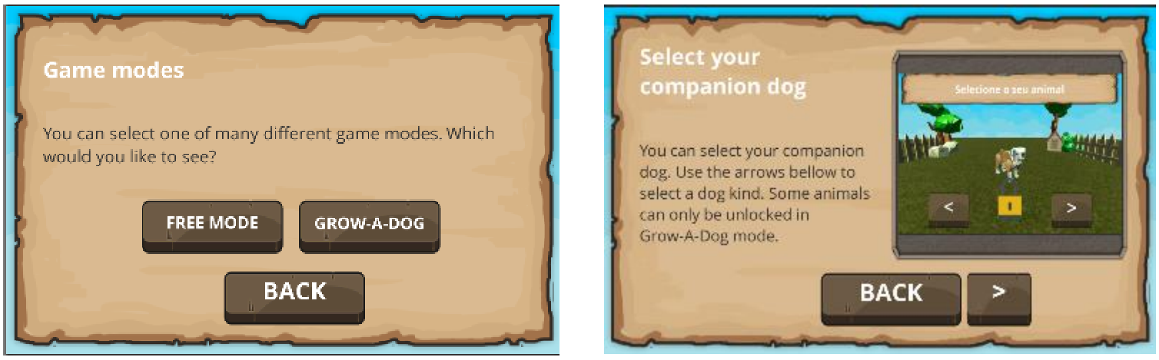


Figure 14 - Parts of the instructions screen

4.1.3.5.4. Achievements screen (My Dogs)

This screen (see Figure 15) displays all the achievements made by the player throughout the game. It shows how many stars the player has collected, and which dogs were unlocked. The already unlocked dogs have their pictures displayed in colors and the yet to unlock are shown greyed-out.

Figure 15 - Achievements screen

4.1.3.5.5. Species selection

The selection of the dog species can be made by using the Previous and Next buttons as the dogs are previewed in the screen and after that, by pressing the central button (finishing the species selection).

Figure 16 - Free mode animal selection screen (see text for details).

Here the player can use the directional arrows to change between animal species and finish the selection by pressing the paw icon button.

Figure 17 - Grow-a-Dog mode (see text for details).

In Figure 17 is represented the screen in which the player is able to select their animal species by utilizing the same directional arrows (left and right). Here the displayed dog is yet to unlock (represented by the Lock Icon instead of the finish selection button.

In Figure 16 it is possible to see the dog selection screen for the Free Mode while in Figure 17 the same screen appears with different particularities since it is for the remaining game mode. In the Grow-A-Dog mode, during the animal selection process there will be information about the current age of the animal (below the instruction panel on the top – Figure 17), corresponding to the progress made so far playing with that specific dog and whether it is possible to play with the animal or if it still needs to be unlocked.

4.1.3.5.6. Size selection

In this screen, the player is prompted to select the size of its animal. Here there are three available sizes: small, medium and large. Again, the selection can be made by using the Previous and Next buttons and the Central button as the mechanism to finalize this customization option. The button in the upper right of the screen allows the player to return to the Home Title Screen.

Figure 18 - Size selection screen (Free mode only) (see text for details).

By using the directional arrows (Figure 18), the player is able to change the size of the animal presented. The paw icon button can be used to finish the selection.

4.1.3.5.7. Scenario selection

In the Free Mode, the player has the ability to fully customize their experience. After selecting both the kind of the dog they want and their size, the player is able to select where they want to play: either a garden, a beach, a city open space or inside a house. This selection can be made by simply clicking over one of the displayed scenes (see Figure 19).

Figure 19 - Scene selection screen (Free mode only)

4.1.3.5.8. In game UI

Besides having a different background scenario, according to which scene the player has previously chosen, the specific mode panels (which will be detailed in the following paragraphs), it is possible to identify some common elements in the game screen.

Playable Area

The playable area comprises the background scene in which the dog is able to freely navigate and walk around. There are specific elements relative to each action that the player might perform together with the animal: playing – ball, feeding – food bowl, grooming – comb and petting – hand.

Some of the actions can be performed by interacting with the elements displayed in the scene. For example, by clicking in the food bowl it is possible to drop food to it if it is currently empty. Also, clicking the ball might throw it to a farther position so the dog can go fetch it.

Action menu

The action menu (see Figure 20) provides the player with the objects needed to perform every action possible in the game: throw the ball, drop some food in the food bowl, groom the animal or pet it. The interaction between the player and the animal is, therefore, performed using every element displayed in this menu, either by clicking or dragging and dropping an item to a specific game area. For example, throwing the ball can be either done by clicking the Ball icon in the action menu or by dragging it to the game area and then releasing it.


Figure 20 - Game action menu

Timer and status panel

The timer and status panel (see Figure 21) shows how much time has passed since the game session has started and the status bars (one for each animal need – Play. Eat, Groom and Pet) reveals the necessities of the animal should be fulfilled.

Figure 21 - Timer and status panel

Settings button

The settings button, which can be found in the upper right corner of the game screen (see Figure 22), if clicked, pauses the game and allows the user to go back to the main menu by exiting the current game session. Any progress made during that specific level will be lost.

Figure 22 - Settings button

4.1.3.5.9. Free mode game screen

Besides the previously mentioned different background scenario, there are small elements added to this scene. Some stars (that will fill overtime) and their respective numbers were added in order to represent the player's score. Since the objective consists on maintaining the animal happy, by satisfying each of its needs, the star representative of that specific need will keep filling and adding points to the final score (see Figure 23).

Figure 23 - Free mode game screen (see text for details).

In Figure 23, the user is presented with the selected animal and the GUI for the Free Mode presents a status panel (upper left of the screen) displaying information about the animal needs and the amount of points (in the form of stars) collected during the game. In the same panel there is also a timer. The panel at the bottom of the screen displays the possible actions for the user to interact with the animal. The options button (upper right of the screen) allows the player to pause or quit the game.

4.1.3.5.10. Grow-A-Dog mode game screen

For this game mode, the interface changes to a major extent with the inclusion of a vertical progress bar in the right side of the screen (see Figure 24). This bar represents the growth of the animal during the progress of the game session. The dog starts as a puppy (baby dog), with an assigned starting weight and it increases over time as the animal needs are satisfied by the player. There are three references marks in this growth bar. They are used to determine the current age of the animal while the bar keeps increasing over time. The weight of the dog is also displayed in the top of the bar.

Figure 24 - Grow-A-Dog mode game screen (see text for details).

In Figure 24, the user is presented with the selected animal and the GUI for the Grow-A-Dog Mode presents a status panel (upper left of the screen) displaying information about the animal needs. In the same panel there is also a timer. The panel at the bottom of the screen displays the possible actions for the user to interact with the animal. The panel with a bar on the right of the screen represents the growth of the animal as it increases during the progression of the game. The options button (upper right of the screen) allows the player to pause or quit the game.

4.2. Pilot usability Tests

4.2.1. Objective

To validate the developed game, a usability study with dementia patients was conducted in the Alzheimer's Association. The objective of this study was to merely observe and take notes on how the participants interacted with this game (trying out most of the game in an early development stage) with the goal of identifying usability problems or any development bugs that could occur and later on improve the developed application.

4.2.2. Methodology and participants

This experiment was conducted during between 5 to 10 minutes total, and the participants were asked to, by starting in the Tutorial Level, perform each action available in the game (play, feed, groom and pet the dog). After this, they would either try the Free mode (and perform animal species and size selection – navigating in the game menus) or the Grow-A-Dog mode. Then the participants would try the remaining game mode if there was still time available. While the participants played the game, the researcher was taking notes of the usability problems that happened. There was no structured interview at the end of the session, but the participants were always asked if they felt it was too complicated and if they enjoyed the overall experience.

The experiment was conducted with a total of four participants who were frequent users of the Alzheimer's Association in Madeira, Portugal, on two different days. The participants, or any of their family members, were asked to sign a written inform consent about this study. This consent described the whole intervention and its objectives.

4.2.3. Findings

All four participants could try every game mode. Overall, the results were positive in the sense that every participant was able to perform the core interactions necessary to play the game (dragging or tapping in the screen). The version of the game taken to this study had already been developed considering the results of the technology interaction study mentioned previously in this document (see Chapter 3), so every interaction was previously designed to be as easier as possible for dementia patients to complete.

There were some usability problems detected during both sessions, and most of them were common to every participant. For example, the participants had some troubles completing each level since the progress was too slow (both the bars and the stars filling in too slowly) and the difficulty was too high for them since the dog kept changing needs too quickly for them to be able to satisfy. Other important aspect noticed was that sometimes the participants would click navigation buttons twice while the game was loading. It happened because this version of the game had no feedback when a screen was loading.

Some other bugs occurred, for example, the lack of sound at certain levels. There were positive comments about the needs panel, as some participants mentioned that it was easy to understand when they had to do since they could always see it in that panel by looking at the bars.

On a side note, every participant felt happy and pleased after playing the game, and some even felt some empathy with the virtual animal by remembering pets they previously had during their lives. There was also one participant that asked for the game to be installed in their device.

4.2.4. Improvements made

This experiment was useful to get some feedback on the developed game directly from its potential end-user. To solve the usability problems found during the experimental sessions, different difficulty levels were created (see Figure 25), to tackle the difficulty of this population to progress in the game and, also a loading feedback was added while the game loads screens or changes scenes (see Figure 26). Another decision made was to disable the multitouch interaction since some participants rested their hands on the touchscreen causing some minor interaction problems.

Figure 25 - Game difficulty settings

Figure 26 - Loading feedback in the game

Chapter 5

Evaluation Experiments

5.1. Objective

The objective of this study is to evaluate the impact of the developed AAT game application on people living with dementia. One of the key aspects to address is to understand if a virtual animal could replace a living animal in AAT. This was done by comparing the verisimilitude of the character used in the game (both regarding appearance and behavior) and by assessing which positive aspects of animal therapy would be maintained in a virtual solution.

The research questions to address in this experiment are described as it follows:

RQ1: Is virtual AAT feasible?
RQ2: To what extent can be the virtual animal-assisted therapy realistic?
RQ3: Can a virtual dog generate empathy?
RQ4: What is the effect of customization in this game?

5.2. Methodology

5.2.1. Data collection instruments

To gather the data necessary to achieve the objectives of the study two questionnaires were developed. One of them was to be answered by the therapist and the other by the participant.

To measure the mood of the participant a Self-Assessment Manikin (SAM) scale (see Figure 27) was used in both questionnaires as it is a widely used instrument and provides a pictorial aid. This instrument was selected as Likert scales and open questions revealed not to be appropriate for a dementia population.

The therapist questionnaire was divided into two parts being the first one to assess pre-intervention mood, with the use of the previously mentioned SAM scale and the second part was used to assess the impact and the possible benefits of this game on that specific person and also its post-intervention mood from the perspective of the therapist. This second part of the questionnaire had yes or no and why questions (see Appendix D).

The participant questionnaire (see Appendix E), was equally divided into two parts. A first part that evaluates the pre-intervention mood, this time from the participant him/herself and then a second part that was largely focused around the game experience and post-intervention mood.

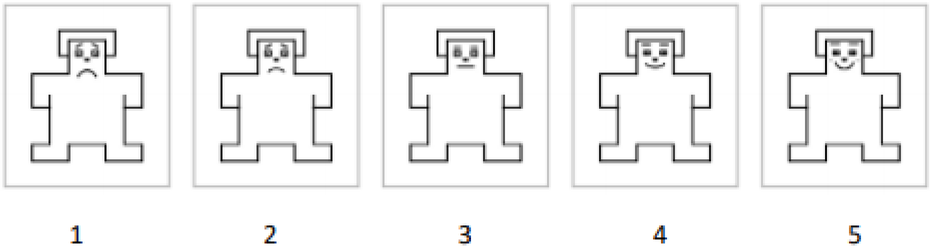


Figure 27 - Self-Assessment Manikin used for measuring the mood of the participant

For measuring the prototype usability, a set of questions (see Apendix E) was adapted considering each one of the Nielsen's Attributes of Usability [48] since this instrument uses Likert scales, which are not appropriate to this population.

For the questions related to the similarity between real and virtual dogs, we made use of a figure containing multiple dogs, from different species, that could also be found in the game (see Figure 28).

Figure 28 - Support image used for dog similarity question

5.2.2. Protocol

The experimental protocol used for this study, which can be seen in Figure 29, involved insights from both the therapist and from the participant in different occasions. The session would start with the arrival of the participant that would immediately have the attention of the therapist. The role of the therapist was to evaluate the mood of the participant before the virtual AAT session. After the therapist evaluation was completed, the participant would move in to another room with the researcher. Before the start of the playtest they would be asked about their mood at that moment. They would then be presented with the game application and would be asked to play it for a maximum period of 10 minutes. They had freedom to select the species and the size of the animal, as well as the playing scenario. The researcher provided assistance when necessary and noted it down in the experiment log.

As soon as the playtest ended, the participant would be asked to answer some questions, from a questionnaire, about the game. This interview was recorded using a voice recorder for later data analysis. Finished this questionnaire, the participant would return to the therapist that would re-evaluate their mood after the game session.

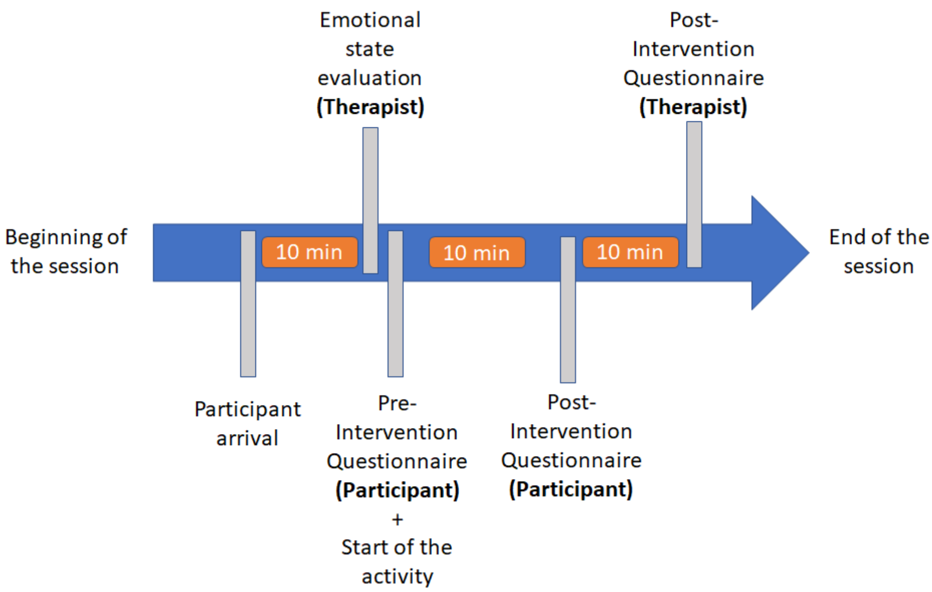


Figure 29 - Experimental protocol used for the evaluation experiment

Data on the cognitive capacity of the participants would be collected by a therapist using the MMSE (Mini-mental state evaluation). The MMSE data obtained for using in this study was measured two weeks before the intervention.

5.2.3. Participants

For this study we recruited 10 participants (3 male and 7 female) from a daily-care institution (Centro de Dia - "Lugar de Memórias") in Funchal, Madeira, who were diagnosed with different types of dementias. All dementias were from the Alzheimer's Disease type except for 2 cases that had been diagnosed as Frontotemporal dementia. Regarding the participants level of schooling, all of them had the 4th grade. Their Mini-mental state evaluation (MMSE) score ranged from 14 to 25 (see Table 14).

Participant ID	Gender	Schooling	MMSE	Dementia Type
1	F	4th grade	18	Alzheimer
2	M	4th grade	22	Alzheimer
3	F	4th grade	24	Alzheimer
4	F	4th grade	14	Alzheimer
5	F	4th grade	17	Alzheimer
6	F	4th grade	23	Alzheimer
7	M	4th grade	18	Frontotemporal
8	M	4th grade	21	Frontotemporal
9	F	4th grade	16	Alzheimer
10	F	4th grade	25	Alzheimer

Table 14 - Participants' information

When asked whether they particularly liked dogs as a pet animal, 8 participants answered that they did, one did not know due to never being in contact with one and only 1 participant said that they did not like dogs.

5.2.4. Experimental setup

As previously mentioned, the experiment was conducted in a quiet room which was already used for several other activities performed in the daily-care center. In this room there was a big table in which the Tablet with the game would be placed and the participant would sit in front of it. The researcher would be siting alongside the participant so that it was possible to collect notes on possible interaction problems or assist the participant when needed. Figure 30 shows the setup used for the experimental session.

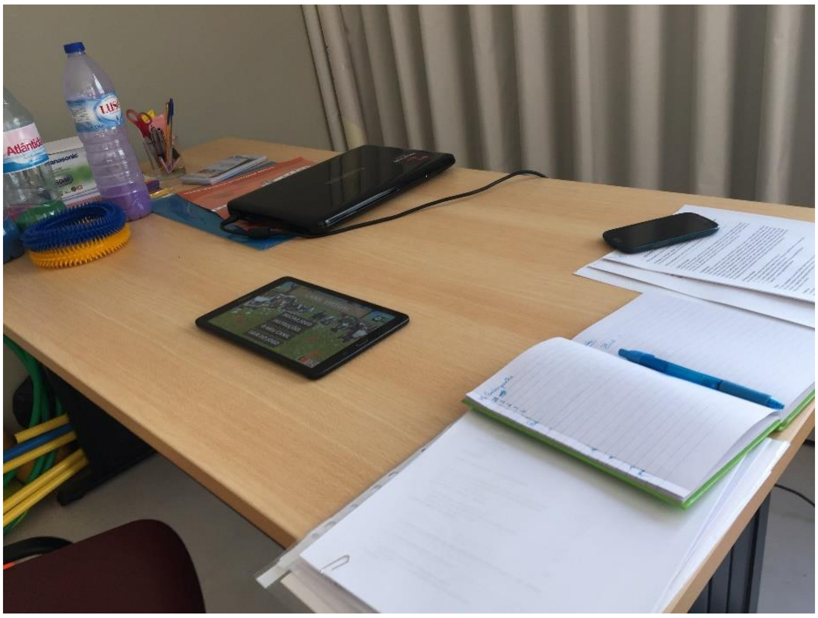


Figure 30 - Experiment Setup

The hardware used for this experiment consisted in a Samsung Galaxy Tab E device, the same that had already been used for the technology interaction study in Chapter 3. This device's operating system is Android 4.4 and has a 9.6" display and it is equipped with a quad-core 1.3 GHz processor. The software for the game application was also previously installed in the equipment and was already open as soon as the participant entered the room.

5.3. Results

5.3.1. Prototype Usability

Observations:

All participants could interact well with the application performing the simple interaction tasks (drag and drop and tap) when asked by the researcher. Not many errors were observed during the participants' interaction with the system. Due to the simplicity of the UI implemented, in general, all participants could find by themselves or with minimal help which objects they should drag or click to achieve the game objectives.

The improvements made after the preliminary usability tests revealed to be helpful since some of the problems detected at that moment were mitigated. For instance, during this experiment none of the participants clicked a button twice while waiting for a scene to load, understanding the loading feedback. Also, the difficulty used for the game sessions was the easy mode as otherwise not many participants would be able to reach any goal in a 10-minute game session. Another important improvement was disabling multitouch interaction that proved to be helpful, especially for participant 1, who frequently rested the palm of their hand on the touch surface.

There was still one bug that happened with the first two participants, which required the researcher's intervention or restarting the application.

Self Reports:

The system was rated according to Nielsen's Attributes of Usability, which were adapted from Likert scale to Yes or No questions and overall scored well. In the Learnability domain, all participants reported that the game was very easy to learn. For Efficiency, 9 participants answered that they were able to fully complete the tasks they were asked to complete while the remaining one did not remember or did not know how to answer. For the Errors attribute, 5 participants said that they did not make mistakes during the playtest. Regarding the lower Memorability score, half the participants reported that they would improve from learning if they had the opportunity to play once more. In the same domain 2 participants said that they felt that they would not be able to improve while the remaining ones did not know how they would perform and whether they would be able to use the learnings of the first session and improve in a following one. In terms of Overall Satisfaction every participant felt happy with their performance in the playtest session (see Figure 31).

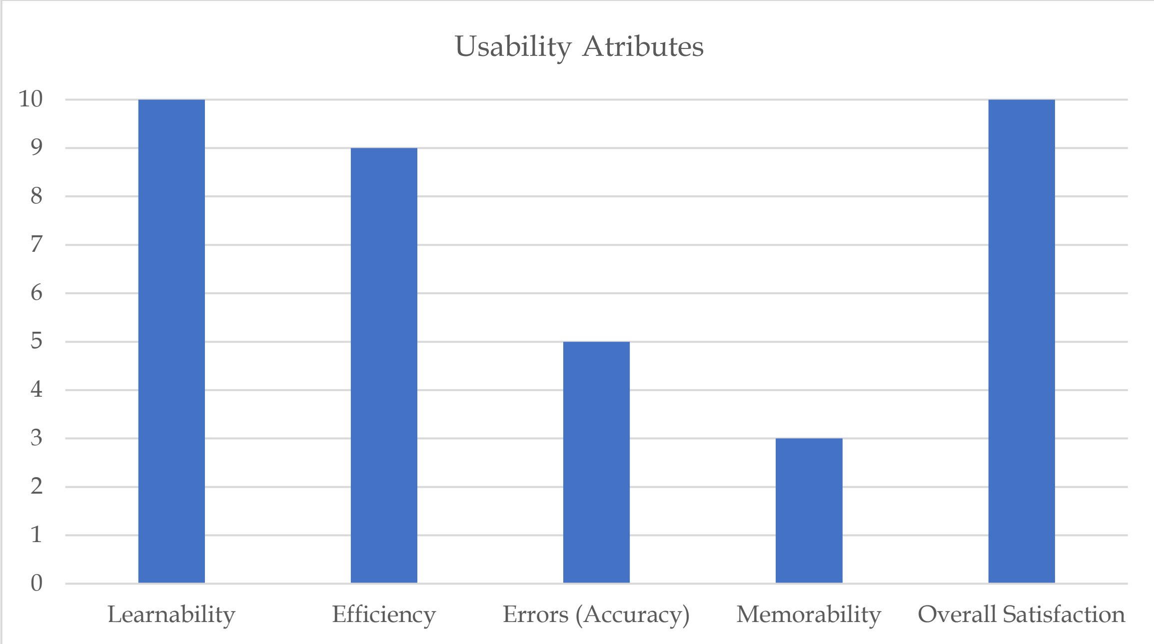


Figure 31 - Bar chart with the Nielsen's attributes of usability

RQ1: Is virtual AAT feasible?

During the interventions many participants appeared to be having fun while playing. Most of the times this would translate in laughs or smiles while the virtual animal was performing an action such as chasing the ball or barking for some food.

Participant 9 said that the activity was beneficial to her for allowing her to have a good time and be distracted from her daily problems. Also, some other participants, for example Participant 8 and Participant 10 mentioned after the experiment that having an animal such as that one would offer companionship and happiness to their lives.

The therapist added that this session was beneficial to some of the participants in terms of improving their mood. For example, Participant 8 would smile more often after concluding the experimental session, Participant 1 appeared to be slightly more aware and aroused and Participant 5 was collaborating more in activities. Another positive aspect mentioned by the therapist is that Participant 10 also showed an increased will to start activities by herself after completing the experimental session, even if it is normal happening with this person. The most interesting insight provided by the therapist was about Participant 7 that due to the disease's nature (Frontotemporal Dementia) reveals problems such as constant wandering and less aptitude to participate in activities. After the game session, the therapist reported that this participant had the initiative of moving to a chair and resting, and later moving to a bed to have some sleep and relax. This was considered a positive reaction by the therapist that is used to deal with this person every day. The opinion of the therapist and the remaining staff in the institution was also very positive and they were interested and very receptive in introducing this gaming activity in their regular activities list.

As mentioned before, a pictorial SAM scale was used to measure the pre- and post-intervention moods of the participants from their perspective as well as the therapist opinion on their mood. Each image had a number associated and the scale went from 1, meaning unhappy to 5, meaning very happy. The responses were organized in the following two tables (Table 15 for participant answers and Table 16 for therapist answers) and the difference between post- and pre-intervention scores was calculated, as well as the median for each table column. A positive difference in the Score Difference column would mean a positive improvement, while a null result will translate to no effect.

Participants pre- and post-intervention mood scores (classified by the Participant)			
Participant ID	**Pre-Intervention Score**	**Post-Intervention Score**	**Score Difference**
1	4	5	1
2	5	3	-2
3	4	5	1
4	5	4	-1
5	5	4	-1
6	5	5	0
7	5	5	0
8	3	3	0
9	5	4	-1
10	4	4	0
Median	5	4	0

Table 15 - Participants pre- and post-intervention mood scores (participant answers)

Participants pre- and post-intervention mood scores (classified by the Therapist)			
Participant ID	**Pre-Intervention Score**	**Post-Intervention Score**	**Score Difference**
1	3	4	1
2	4	4	0
3	4	4	0
4	4	4	0
5	5	5	0
6	4	4	0
7	2	3	1
8	4	4	0
9	3	3	0
10	3	4	1
Median	4	4	0

Table 16 - Participants pre- and post-intervention mood scores (therapist answers)

We found no significant differences between the two participants' mood scores.

RQ2: To what extent can be virtual animal-assisted therapy realistic?

The post-intervention questionnaire had a question to obtain information about the way the participant could think of the virtual animal as if it was a real living dog. This question made use of a picture with many distinct dog species as part of the support material.

Question	Positive Answers	Neutral Answers	Negative Answers	% Positive answers
Do you think that the in-game dogs were similar to the ones in the picture? (see Figure 28)	5	0	5	50%

Table 17 - Questionnaire results regarding the virtual dog realism

Only half of the participants reported that the virtual dogs were similar to the ones presented to them. The participants who replied negatively were asked about the reason that made them say the dogs were not similar and they mentioned aspects such as size or position of the animals as well as some differences in their ears.

Question	Positive Answers	Neutral Answers	Negative Answers	% Positive answers
The behavior of the dog in the game resembled the behavior of a real animal?	8	1	1	80%

Table 18 - Questionnaire results regarding the behavior of the virtual dog compared to a real dog

Regarding the virtual dog's behavior, 8 participants reported that the pet in the game had the same behavior that would be expected from a living dog. There was also one neutral answer obtained from a participant who had never interacted with a dog in their life and said that they did not know what would be the normal dog behavior. Also, one negative answer was found as that specific participant reported that there was something about the game dog that did not feel natural in its behavior, being unable to explain what.

To understand the perception of the virtual dog by the participants we address it from two perspectives: first in terms of the behavior of the dog and second, in terms of its appearance.

When it comes to the similarity of the game character models to living dogs in terms of its appearance, some participants mentioned that some of the models resembled real animals that they had met in their life. Nevertheless, there were two participants who did not perceive the character models as a dog having one of them reported that they were more similar to a cow than to a dog due to their pointy hears resembling horns.

Regarding the virtual dog behavior, most of the participants agreed that the game character was having the typical behavior of a living dog. There was still one person who reported that there was some sort of difference in behavior even if they were not able to tell what the difference was. Participant 3 also reported that while she was playing it made her feel like she was playing with her own pet dogs.

RQ3: Can a virtual dog generate empathy?

Participants were asked in the interview if they would take care of the animal they had just finished playing if they could take it home and the responses were mostly positive (see Table 19).

Question	Positive Answers	Neutral Answers	Negative Answers	% Positive answers
If you could take this dog home with you would you take care of it?	9	1	0	90%

Table 19 - Questionnaire results regarding the empathy with the virtual dog

9 participants responded positively complementing that they would appreciate taking the dog home as it would be a companion to them during their lonely moments.

An interesting aspect that was possible to perceive during the experiment was that participants had fun playing with the animal to the point that some of them, for example Participant 2, Participant 3 and Participant 6, would even give names to the virtual pet such as “Maxi”, “Bingo” or “Valente”. Complementing this, they would also confirm that those names were a reference to their own pets.

Participant 3 during the experiment time was constantly addressing the virtual pet with positive words such as “beautiful” and Participant 2 reported that he found the dog very lovely. Some participants also mentioned that the virtual pet would be able to provide companionship to them during the time they spend alone every day. One of these cases was Participant 10 that also added that the virtual pet could not only give her fellowship but also take care of her house. Participant 3 in another hand commented that she would appreciate having a fellow pet animal at home but it had to be virtual so that it would not play with her flowers.

RQ4: What is the effect of customization in the game?

Customization exists in multiple forms in this game. For answering this question, it is mandatory to consider two of them. In a first approach we consider the animal customization in terms of its species and then its size. The participant has twelve different species of dogs and may also select the size of their animal from three different possibilities: small, medium and large. There are also four scenarios available, in which the player can interact and play with their virtual pet dog.

Participants were asked if they would select the same dog again or any other if they had the opportunity to play the game once more. Table 20 shows that 8 participants said they would want to select another animal, and only 2 would keep playing with the same dog.

Question	Would select the same animal	Would select another dog
If playing again would you select the same dog or any other from the available ones?	8	2

Table 20 - Questionnaire results for animal selection preferences

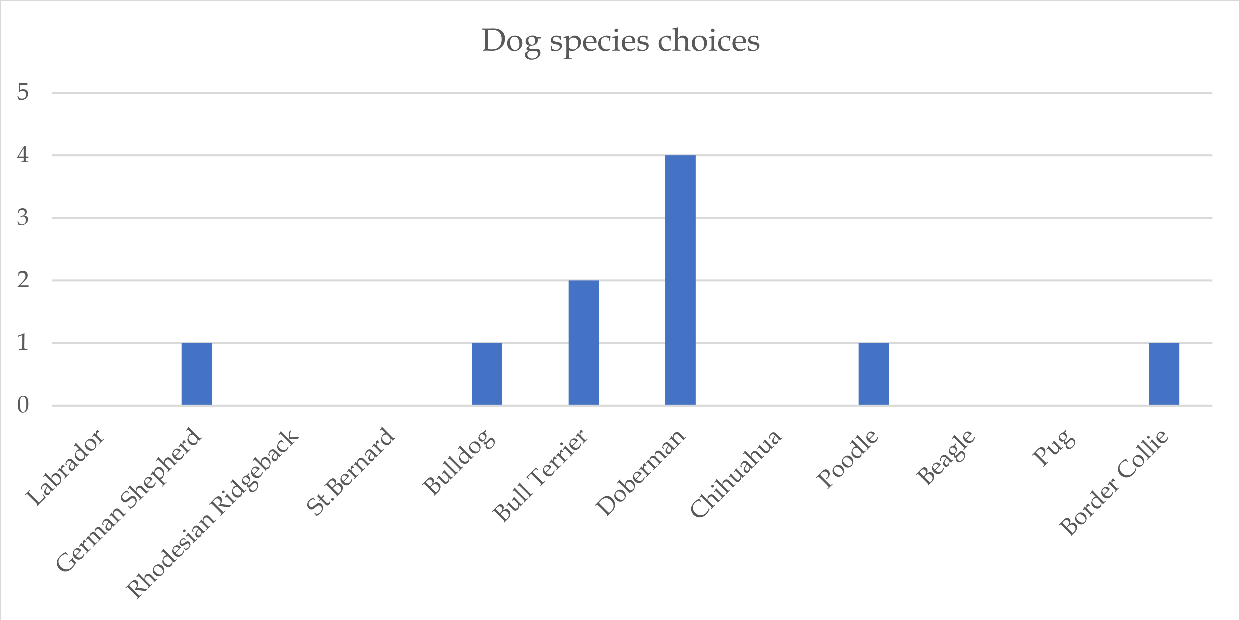


Figure 32 - Bar chart with in-game animal selections

They were also asked if they would prefer a dog with any other size from the available ones besides the current size.

Question	I only like dogs with the size I selected	Could be any other size
Would you prefer a bigger or smaller dog than the one selected?	8	2

Table 21 - Questionnaire results regarding the dog size preference

This results match and confirm the observations obtained from what the participants reported verbally during the experimental session. Figure 33 complements this information representing the frequency of each size selection during the experimental sessions done with all participants in this study. The x-axis represents the different size options available and the y-axis represents the frequency in which they were selected.

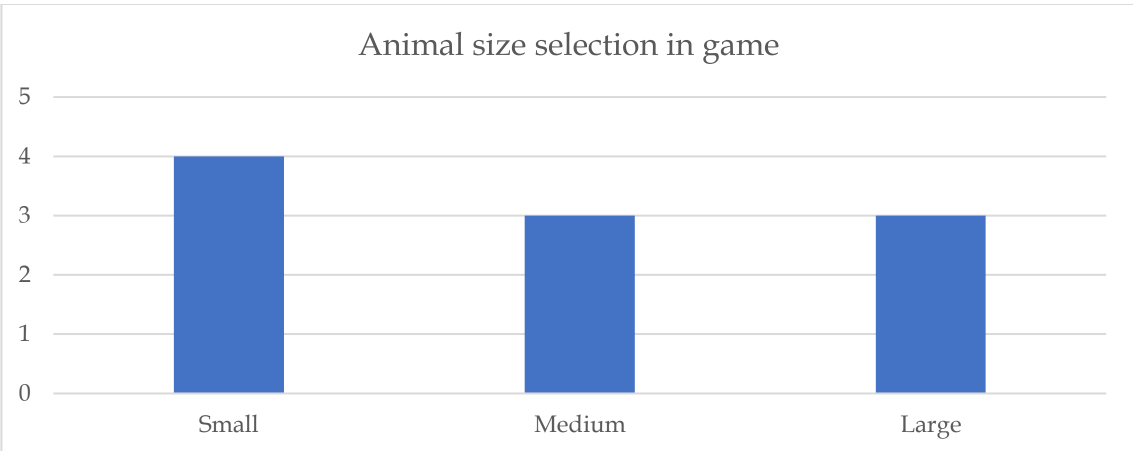


Figure 33 - In-game size selection options

From this experiment it is possible to understand that size customization has some importance in this type of games since from all participants eight mentioned that they had preference for a specific size for their pet dogs and they would not consider the possibility of having a larger or smaller one. Also, having different species available for selection gave participants the opportunity to select an animal they would feel comfortable with. Some participants, such as Participant 2 and Participant 6 said that specific dogs shown during animal selection were very similar to dogs they previously owned.

In terms of the scenario selection, participants preferred the Garden and the Home scenes as can be seen in Figure 34, even if every scenario was selected at least one time. The x-axis represents the different scenarios available in the game and the y-axis shows the selection count for each scenario.

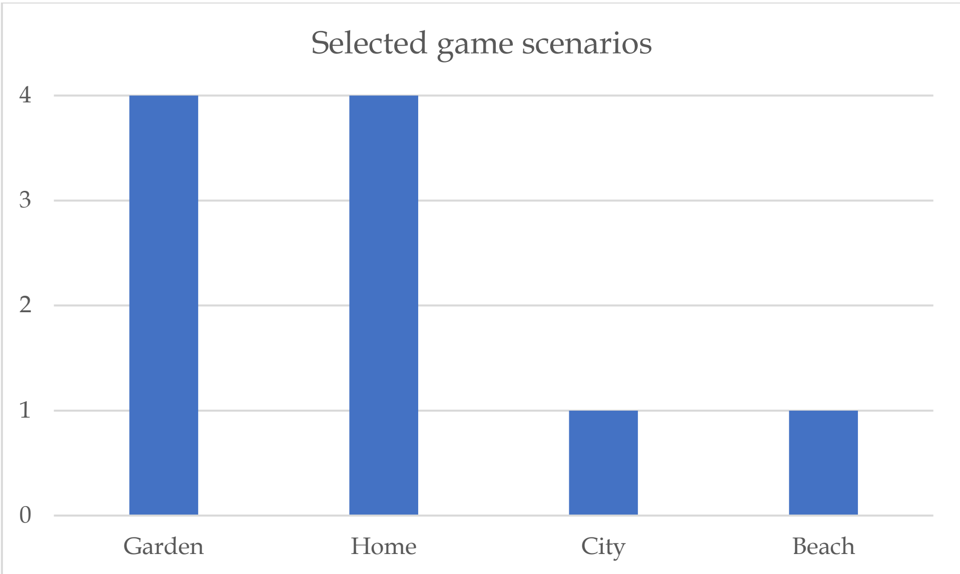


Figure 34 - Results of the game scenario selection

An interesting aspect to consider in this type of games is to have more types of animals instead of just having dogs. Participant 9 mentioned that would have preferred playing with cats because she does not like dogs.

5.3.2. Other relevant observations

Recall of previous companion pets

While playing, 4 participants mentioned their own pets. Some of them even talked about pets they previously had at home and how special they were in their lives. No negative reactions were observed while participants were talking about their late pets. Participants often compared the animal they had selected to their domestic animals whenever they performed an action. Participant 2 felt happy when he was told he would be interacting with a dog, and during animal selection he pointed at one specific dog (Rhodesian Ridgeback) and he said that it reminded him of

"Valente", a dog he once had at home. The same person also commented that in his opinion dogs are the best friends of men.

A new activity

Besides having the animal therapy component, it is important to understand that this game implies the use of a portable tablet device, which is something that this population is not very used to. The therapist highlighted this fact and stated that for some of these participants it was very beneficial to have the opportunity of interacting with new technologies. Participant 6 reported that the activity was good because it allowed them to do something different from what they usually do daily.

This experiment also sparked the curiosity of some participants. For example, Participant 8, who was very intrigued on how technology enables having an animal inside a game that acts just like a real one.

Animal phobias

Animal phobias are something to take into consideration. When developing a game focused around a specific animal, there might be potential end-users that will not be able to fully experience the game due to phobias. A similar situation happened to Participant 9 who did not feel very comfortable playing with a dog but accepted to play when she was told the dog was not real. Even exhibiting a positive mood during the session, she kept commenting that she would not want to have a dog at home because she was afraid. In the end, she laughed and said that if it went wrong, she would never try to play with a dog anymore. Participant 1 also reported during the interview that at the beginning of the activity she felt scared of the dog, but she soon realized that there was no harm.

5.3.3. Discussion

From the statistical point of view, it is not possible to say that this session had any significant impact on the participants' moods even if the feedback from both the participant and the therapist was positive. It is not possible to say that virtual AAT using this application will improve the mood of people living with dementia with this specific methodology since one of its weaknesses is that this scale may not be appropriate to measure what is pretended and, having a bigger sample might have helped to clarify the application effect on patients' mood. Even so, participants revealed positive reactions to the experience and good mood indicators such as laughs, and smiles were observed after the intervention.

Regarding the comparison of the virtual animal with real living animals in terms of appearance, the disparity illustrated by the answers may be justified by the fact that the participants had to answer this question based on comparing the in-game dogs with a couple of dogs in one specific support image. Also, the game 3D models consisted in low-poly models that abstracted the concept of a real dog by hiding some details and people with dementia may often reveal difficulties comparing them due to their condition and difficulty in this type of judgment.

The responses regarding the empathy between participant and virtual animal revealed that participants revealed interest in adopting this type of virtual pets taking them home although, from a statistical point of view it is not possible to say that there was in fact a sense of empathy.

Customization also revealed to be important for the participants of the study. Many options in the game were explored, as for example every game scene was used at least twice during the study. Regarding the animal customization, we can understand that for some participants the aspect of being able to select the size of the animal they would play with was important. This happened mainly because people had already established a preference over a certain size over the other two. Regarding the animal species there was not much difference in the results of the in-game selections. These results also reveal a tendency to select the animals whose species represent the middle of the selection array.

Chapter 6

Conclusions

Dementia, as a neurodegenerative disease, currently has no known cure and affects a large amount of people worldwide. By affecting such a large amount of the world population, it is a disease that requires a considerable economic effort. In this work, it was stated that since the medication available still produces negative side-effects, alternative therapies are one way to alleviate some of the symptoms commonly associated in the disease. As previously seen, animal-assisted therapy (AAT) was selected as a complementary therapy due to its reported social-psychological benefits for a person with dementia.

This work proposed the development of a Serious Game (SG) revolving around the concept of AAT and animal interaction. This system takes advantage of the positive aspects of conventional AAT, for example pet interaction, generating a sense of companionship and creating bonds, while at the same time it should be able to mitigate some of the less attractive aspects associated to having a real animal especially trained for therapy purposes.

Due to the difficulties inherent to this specific population, both advanced age and the disease, we first conducted a study with 12 participants to understand which technology and interaction modality would be the best. From this experiment we concluded that direct interaction modalities were prefered for this population, being some of them the Tablet and Augmented Reality, instead of the indirect interaction ones that added an extra layer of complexity by introducing controllers to the activity (for example, HTC VIVE w/Controllers or Mouse). Even so, there were specific problems associated to each technology that needed to be addressed when developing a game for this population.

A virtual pet game, focusing around the four basic interactions commonly performed in AAT (petting, feeding, grooming and playing with an animal) was developed for tablet. This development was made in Unity with an Android Build and always taking into consideration the findings of the previous experiment. The development process included multiple iterations and a usability study with our target population. This study involved 4 patients from the Alzheimer's Association in Madeira, Portugal. The results showed that the game had satisfactory usability for this specific population but there were still minor improvements to be made.

The findings of the usability tests were implemented into the final version of the game which was then deployed at the Centro de Dia – "Lugar de Memórias" in Funchal, Madeira in a study that included 10 dementia patients. With this study we aimed at addressing the following research questions:

RQ1: Is virtual AAT feasible?

The session of virtual AAT conducted was well accepted by the participants and therapists. The developed application revealed a relatively good usability for this population. Although statistically it was not possible to determine whether there were any mood changes in the participant after one session, therapists observed and reported positive reactions such as frequent laughs and smiles. Therapists also confirmed that they considered this application positive for this population.

RQ2: To what extent can be the virtual animal-assisted therapy realistic?

Even using virtual animals instead of a living dogs results reveal that virtual pets can be perceived as living animals. The participants reported that the behavior of the virtual pet was similar to the one of a living animal.

RQ3: Can a virtual dog generate empathy?

Participants were interested in the virtual pet since the beginning of the activity and some of them reported that they would be interested in taking the animal home to be able to play with it more often.

RQ4: What is the effect of customization in this game?

Regarding the customization aspect of the game the results reveal that participants were curious to see different animals and would select their virtual dog according to their preferences. For example, in terms of the size customization, some of the participants mentioned during interviews that they would not enjoy playing as much as they did if the animal was bigger or smaller than the ones they selected.

The aspects mentioned in the previous research questions were evaluated using instruments such as pre- and post-intervention questionnaires. For the mood assessment a pictorial SAM scale was used. The same study also assessed the usability of the application making use of an adapted version of the Nielsen Attributes of Usability.

This work presents some limitations, mostly due to the lack of available scales for assessing the emotional state and the mood of this population. In addition, the tests were conducted with the relatively small sample size of ten participants and only ten-minute game sessions in only one session. Assessing the impact of this system was a challenge, since this population cannot undergo standard interviews, questionnaires and evaluation scales. Hence, many of the questions done during the questionnaire had to be adapted, and even so, the answers might not reflect exactly what happened during the game session.

While the developed system shows promise as a complementary tool or activity during the treatment of dementia patients, there are also certain areas that this work has not been able to explore. It would be useful and interesting to understand if the social enhancing aspect of AAT can be replicated using a multiplayer game.

Further, the game was developed using only a dog character, but conventional AAT makes use of other therapy animals such as cats, rabbits. The application would benefit by considering some of those, allowing a better customization according to the patient preferences.

Bibliography

[1] A. Wimo, B. Winblad, and L. Jönsson, “The worldwide societal costs of dementia: Estimates for 2009,” *Alzheimer's Dement.*, vol. 6, no. 2, pp. 98–103, 2010.

[2] M. Prince, A. Comas-Herrera, M. Knapp, M. Guerchet, and M. Karagiannidou, “World Alzheimer Report 2016 Improving healthcare for people living with dementia. Coverage, Quality and costs now and in the future,” pp. 1–140, 2016.

[3] S. Report, “2015 Alzheimer ' s Disease Facts and Figures,” 2015.

[4] M. Prince, A. Wimo, M. Guerchet, A. Gemma-Claire, Y.-T. Wu, and M. Prina, “World Alzheimer Report 2015: The Global Impact of Dementia - An analysis of prevalence, incidence, cost and trends,” *Alzheimer's Dis. Int.*, p. 84, 2015.

[5] V. Gardette, N. Coley, and S. Andrieu, “Non-pharmacologic therapies: a different approach to AD,” *Can. Rev. Alzheimer's Dis. Other Dementias*, vol. 13, no. 3, pp. 13–22, 2010.

[6] G. D'Onofrio, D. Sancarlo, D. Seripa, F. Ricciardi, F. Giuliani, F. Panza, and A. Greco, “Non-Pharmacological Approaches in the Treatment of Dementia,” *Updat. Dement.*, no. September, 2016.

[7] C. Hulme, J. Wright, T. Crocker, Y. Oluboyede, and A. House, “Non-pharmacological approaches for dementia that informal carers might try or access: A systematic review,” *International Journal of Geriatric Psychiatry*, vol. 25, no. 7. pp. 756–763, 2010.

[8] J. Nimer, B. Lundahl, J. Nimer, and B. Lundahl, “Animal-Assisted Therapy : A Meta-Analysis A Meta-Analysis,” vol. 7936, no. September, 2016.

[9] C. Chandler, “Animal assisted therapy in counseling,” *Anim. Assist. Ther. Couns.*, pp. 1–154, 2012.

[10] W. S. Pope, C. Hunt, and K. Ellison, “Animal assisted therapy for elderly residents of a skilled nursing facility,” *J. Nurs. Educ. Pract.*, vol. 6, no. 9, 2016.

[11] A. H. Fine, *Handbook on Animal – Assisted Therapy Theoretical Foundations and Guidelines for Practice*. 2010.

[12] A. Swall, B. Ebbeskog, C. Lundh Hagelin, and I. Fagerberg, “'Bringing respite in the burden of illness' – dog handlers' experience of visiting older persons with dementia together with a therapy dog,” *J. Clin. Nurs.*, vol. 25, no. 15–16, pp. 2223–2231, 2016.

[13] M. S. Marx, J. Cohen-Mansfield, N. G. Regier, M. Dakheel-Ali, A. Srihari, and K. Thein, “The impact of different dog-related stimuli on engagement of persons with dementia.,” *Am. J. Alzheimers. Dis. Other Demen.*, vol. 25, no. 1, pp. 37–45, 2010.

[14] R. Hayashi and S. Kato, “Psychological effects of physical embodiment in artificial pet therapy,” *Artif. Life Robot.*, vol. 22, no. 1, pp. 58–63, 2017.

[15] M. R. Banks, L. M. Willoughby, and W. A. Banks, “Animal-Assisted Therapy and Loneliness in Nursing Homes: Use of Robotic versus Living Dogs,” *J. Am. Med. Dir. Assoc.*, vol. 9, no. 3, pp. 173–177, 2008.

[16] C. Olsen, I. Pedersen, A. Bergland, M. J. Enders-Slegers, G. Patil, and C.

Ihlebæk, “Effect of animal-assisted interventions on depression, agitation and quality of life in nursing home residents suffering from cognitive impairment or dementia: A cluster randomized controlled trial,” *Int. J. Geriatr. Psychiatry*, 2016.

[17] T. Shibata, “Therapeutic seal robot as biofeedback medical device: Qualitative and quantitative evaluations of robot therapy in dementia care,” *Proc. IEEE*, vol. 100, no. 8, pp. 2527–2538, 2012.

[18] S. Petersen, S. Houston, H. Qin, C. Tague, and J. Studley, “The Utilization of Robotic Pets in Dementia Care,” *J. Alzheimer's Dis.*, vol. 55, no. 2, pp. 569–574, 2015.

[19] K. Wada, T. Shibata, T. Asada, and T. Musha, “Robot therapy for prevention of dementia at home-results of preliminary experiment,” *J. Robot. Mechatronics*, vol. 19, p. 691, 2007.

[20] S. C. Kramer, E. Friedmann, and P. L. Bernstein, “Comparison of the effect of human interaction, animal-assisted therapy, and AIBO-assisted therapy on long-term care residents with dementia,” *Anthrozoos*, vol. 22, no. 1, pp. 43–57, 2009.

[21] V. Bernabei, D. De Ronchi, T. La Ferla, F. Moretti, L. Tonelli, B. Ferrari, M. Forlani, and A. R. Atti, “Animal-assisted interventions for elderly patients affected by dementia or psychiatric disorders: A review,” *J. Psychiatr. Res.*, vol. 47, no. 6, pp. 762–773, 2013.

[22] S. R. Ellis, “What are virtual environments?,” *Comput. Graph. Appl. IEEE*, vol. 14, no. 1, pp. 17–22, 1994.

[23] W. A. Turner and L. M. Casey, “Clinical Psychology Review Outcomes associated with virtual reality in psychological interventions : where are we now ?,” *Clin. Psychol. Rev.*, vol. 34, no. 8, pp. 634–644, 2014.

[24] R. I. García-Betances, M. T. Arredondo Waldmeyer, G. Fico, and M. F. Cabrera-Umpiérrez, “A succinct overview of virtual reality technology use in Alzheimer's disease,” *Front. Aging Neurosci.*, vol. 7, no. APR, 2015.

[25] B. Bouchard, F. Imbeault, A. Bouzouane, B. J. Menelas, and S. Qc, “Developing Serious Games Specifically Adapted to People Suffering from Alzheimer,” pp. 243–254, 2012.

[26] K. P. Padala, P. R. Padala, T. R. Malloy, J. A. Geske, P. M. Dubbert, R. A. Dennis, K. K. Garner, M. M. Bopp, W. J. Burke, and D. H. Sullivan, “Wii-fit for improving gait and balance in an assisted living facility: A pilot study,” *J. Aging Res.*, vol. 2012, 2012.

[27] P. A. Rego, P. M. Moreira, and L. P. Reis, “Natural user interfaces in serious games for rehabilitation,” *6th Iber. Conf. Inf. Syst. Technol. (CISTI 2011)*, pp. 1–4, 2011.

[28] P. H. Robert, A. König, H. Amieva, S. Andrieu, F. Bremond, R. Bullock, M. Ceccaldi, B. Dubois, S. Gauthier, P.-A. Kenigsberg, S. Nave, J. M. Orgogozo, J. Piano, M. Benoit, J. Touchon, B. Vellas, J. Yesavage, and V. Manera, “Recommendations for the use of Serious Games in people with Alzheimer's Disease, related disorders and frailty,” *Front. Aging Neurosci.*, vol. 6, no. MAR, pp. 1–13, 2014.

[29] Nintendo, “nintendogs + cats.” [Online]. Available:

http://nintendogspluscats.nintendo.com/. [Accessed: 17-May-2018].
[30] R. M. E. M. Da Costa and L. A. V. De Carvalho, "The acceptance of virtual reality devices for cognitive rehabilitation: A report of positive results with schizophrenia," *Comput. Methods Programs Biomed.*, vol. 73, no. 3, pp. 173–182, 2004.
[31] R. A. McCann, C. M. Armstrong, N. A. Skopp, A. Edwards-Stewart, D. J. Smolenski, J. D. June, M. Metzger-Abamukong, and G. M. Reger, "Virtual reality exposure therapy for the treatment of anxiety disorders: An evaluation of research quality," *J. Anxiety Disord.*, vol. 28, no. 6, pp. 625–631, 2014.
[32] T. D. Parsons and Z. Trost, "Virtual reality graded exposure therapy as treatment for pain-related fear and disability in chronic pain," *Intell. Syst. Ref. Libr.*, vol. 68, pp. 523–546, 2014.
[33] D. Tsoupikova, N. S. Stoykov, M. Corrigan, K. Thielbar, R. Vick, Y. Li, K. Triandafilou, F. Preuss, and D. Kamper, "Virtual Immersion for Post-Stroke Hand Rehabilitation Therapy," *Ann. Biomed. Eng.*, vol. 43, no. 2, pp. 467–477, 2015.
[34] L. E. Nacke, A. Nacke, and C. a Lindley, "Brain training for silver gamers: effects of age and game form on effectiveness, efficiency, self-assessment, and gameplay experience.," *Cyberpsychol. Behav.*, vol. 12, no. 5, pp. 493–499, 2009.
[35] G. Rebolledo-Mendez, K. Avramides, S. D. E. Freitas, and K. Memarzia, "Societal impact of a serious game on raising public awareness: The case of FloodSim," *Proc. 2009 ACM SIGGRAPH Symp. Video Games, Sandbox '09*, pp. 15–22, 2009.
[36] G. Legouverneur, M. Pino, M. Boulay, and A.-S. Rigaud, "Wii sports, a usability study with MCI and Alzheimer's patients," *Alzheimer's Dement.*, vol. 7, no. 4, pp. S500–S501, 2011.
[37] H. Tobiasson, "Physical action gaming and fun as a tool within elderly care : Game over or play it again and again…," *Proc. IEA 2009 Conf.*, 2009.
[38] M. Boulay, S. Benveniste, S. Boespflug, P. Jouvelot, and A. S. Rigaud, "A pilot usability study of MINWii, a music therapy game for demented patients," *Technol. Heal. Care*, vol. 19, no. 4, pp. 233–246, 2011.
[39] V. Manera, P.-D. Petit, A. Derreumaux, I. Orvieto, M. Romagnoli, G. Lyttle, R. David, and P. H. Robert, "Kitchen and cooking, a serious game for mild cognitive impairment and Alzheimerâ€™s disease: a pilot study," *Front. Aging Neurosci.*, vol. 7, no. March, pp. 1–10, 2015.
[40] N. Alm, A. Astell, G. Gowans, R. Dye, M. Ellis, P. Vaughan, and P. Riley, "Engaging multimedia leisure for people with dementia," *Gerontechnology*, vol. 8, no. 4, pp. 236–246, 2009.
[41] H. R. Lee, W. R. Panont, B. Plattenburg, J.-P. de la Croix, D. Patharachalam, and G. Abowd, "Asthmon: Empowering Asthmatic Children's Self-Management with a Virtual Pet," *Proc. 28th Int. Conf. Ext. Abstr. Hum. factors Comput. Syst. - CHI EA '10*, p. 3583, 2010.
[42] K. Johnsen, S. J. Ahn, J. Moore, S. Brown, T. P. Robertson, A. Marable, and A. Basu, "Mixed reality virtual pets to reduce childhood obesity," *IEEE Trans. Vis. Comput. Graph.*, vol. 20, no. 4, pp. 523–530, 2014.
[43] J. Pollak, G. Gay, S. Byrne, E. Wagner, D. Retelny, L. Humphreys, P. J.P., G. G.,

B. S., W. E., R. D., H. L., J. Pollak, G. Gay, S. Byrne, E. Wagner, D. Retelny, and L. Humphreys, “It’s Time to Eat! Using Mobile Games to Promote Healthy Eating,” *IEEE Pervasive Comput.*, vol. 9, no. 3, pp. 21–27, 2010.

[44] A. C. McLaughlin, W. A. Rogers, and A. D. Fisk, “Using direct and indirect input devices,” *ACM Trans. Comput. Interact.*, vol. 16, no. 1, pp. 1–15, 2009.

[45] D. Armstrong, A. Gosling, J. Weinman, and T. Marteau, “The place of inter-rater reliability in qualitative research: An empirical study,” *Sociology*, vol. 31, no. 3, pp. 597–606, 1997.

[46] M. Mahalakshmi and M. Sundararajan, “Traditional SDLC Vs Scrum Methodology – A Comparative Study,” *Int. J. Emerg. Technol. Adv. Eng.*, vol. 3, no. 6, pp. 2–6, 2013.

[47] T. Pagotto, J. A. Fabri, A. Lerario, and J. A. Goncalves, “Scrum solo: Software process for individual development,” *2016 11th Iber. Conf. Inf. Syst. Technol.*, pp. 1–6, 2016.

[48] J. Nielsen, “Usability Engineering,” *Morgan Kaufmann Pietquin O Beaufort R*, vol. 44, no. 1/2002, p. 362, 1993.

Appendix A – Informed Consent for the Explorative Comparative study of technology in Dementia

Informação ao Participante de Investigação e Consentimento Informado

Título do Estudo: Estudo observacional sobre o uso de tecnologia em pessoas com demência.

Investigador(es) Principa(l/is): Nome: Luís Ferreira e Henrique Ferreira **Instituto:** Madeira Technologies Institute. **E-mail:** Luis Ferreira - ldaf1989@mail.com / Henrique Ferreira - henriquedantasferreira@gmail.com **Tel**: 969 329 669 / 965 642 784

Outros investigadores: Sofia Cavaco, Sergi I Bermúdez.

Objetivo do Estudo
O objetivo deste estudo é observar como jogadores usam vários tipos de tecnologias já existentes no mercado.

Procedimento
A experiência consiste em observar participantes a utilizar uma variedade tecnologias já existentes no mercado. A experiencia será efetuada durante várias sessões. Em cada sessão, os participantes vão interagir com dois ou três tecnologias diferentes. A experiência será filmada (caso consentido) para depois ser avaliado no laboratório. No fim do estudo experimental, os participantes irão responder um pequeno questionário. Todas as respostas serão gravadas.

Critérios de Inclusão
Será considerado elegível para participar neste estudo se:
O sujeito experimental consegue utilizar os membros superiores de forma independente.
O sujeito experimental tem audição funcional.
O sujeito experimental tem capacidades de compreensão funcionais.
Opcional - o sujeito experimental sabe ler.

Riscos
Os riscos associados ao presente estudo experimental não são maiores do que aqueles encontrados no dia-a-dia. A atividade experimental consiste em utilizar várias tecnologias que se encontram disponíveis no mercado. Contudo, a exposição demasiado prolongada dos participantes no Jogo poderá causar, eventualmente, fadiga ou dores de cabeça.

Benefícios
O conhecimento adquirido durante a experiencia poderá ter um impacto positivo no desenvolvimento de novas ferramentas que visam melhorar a qualidade de vida de pessoas portadores de demência.

Confidencialidade
A confidencialidade dos dados será mantida das seguintes formas:
Todos os **dados pessoais** fornecidos na experiencia serão guardados e não serão partilhados com terceiros. Contudo, os dados recolhidos durante a experiencia, incluindo alguns dados relevantes (ano escolar, valores do MMSE e idade) poderão ser usados/publicados para fins científicos ou educativos. O nome de **TODOS** os participantes serão **OCULTADOS**, incluindo nos artigos científicos publicados.

Autorização Opcional
Entendo que os investigadores podem querer usar fotografias, vídeo ou áudio por razões ilustrativas nas apresentações e publicações deste trabalho, para fins científicos ou educativos. Eu dou autorização para fazê-lo, **DESDE** que o nome e rosto **NÂO** apareçam.

Assine no lugar pretendido:
___________________________SIM ___________________________NÃO

Direitos
A sua participação é voluntária. Você é livre de interromper a sua participação em qualquer momento. A recusa em participar ou interrupção da participação não resultará em qualquer penalização, ou perda de eventuais benefícios ou direitos. O investigador principal poderá decidir, de forma fundamentada, interromper a sua participação neste estudo. Caso se verifique esta situação, esta não resultará em qualquer penalização, ou perda de eventuais benefícios ou direitos.

Esclarecimento de Dúvidas & Contatos
Se você tem dúvidas sobre este estudo, poderá fazer agora todas as perguntas. Se quiser fazer perguntas mais tarde, desejar obter mais informações, ou desejar interromper a sua participação no estudo, entre em contato com o Investigador Principal em pessoa, por telefone ou e-mail. A informação de contato está disponível no início da primeira página deste documento.

Consentimento Informado Voluntário
Ao assinar este documento, você confirma que leu a informação acima descrita sobre este estudo, e que todas as suas perguntas foram respondidas. Assim mesmo, você poderá fazer perguntas adicionais a qualquer momento durante o estudo, e mesmo após este ter terminado. Ao assinar este documento, você concorda em participar neste estudo de investigação. Irá receber uma cópia deste documento de consentimento informado assinada e datada.

___________________________________ ________________

ASSINATURA DO PARTICIPANTE DATA

___________________________________ ________________

ASSINATURA DO REPRESENTANTE LEGAL (se aplicável) DATA

Investigador que Obtém o Consentimento

Como membro da equipa de investigação, confirmo que expliquei ao participante acima referido a natureza e finalidade deste estudo de investigação, e que esclareci quais os potenciais benefícios e eventuais riscos da participação no estudo. Todas as perguntas foram respondidas e estou disponível para esclarecer quaisquer dúvidas que possam surgir ao longo do estudo.

___________________________________ ________________

ASSINATURA DO INVESTIGADOR 1 DATA

___________________________________ ________________

ASSINATURA DO INVESTIGADOR 2 DATA

Ao assinar este documento, você confirma que leu a informação acima descrita sobre este estudo, e que todas as suas perguntas foram respondidas. Assim mesmo, você poderá fazer perguntas adicionais a qualquer momento durante o estudo, e mesmo após este ter terminado. Ao assinar este documento, você concorda que o seu membro familiar participe neste estudo de investigação. Irá receber uma cópia deste documento de consentimento informado assinada e datada.

Appendix B – Protocol for the Explorative Comparative study of technology in Dementia

Protocolo para testes com pacientes de Alzheimer

- **Objetivo do estudo**

  O objetivo deste estudo consiste em perceber que tecnologia e que interações são as mais adequadas para criação e desenvolvimento de jogos sérios para apoiar na terapia dos pacientes de Alzheimer.

- **Duração do estudo**

  Os testes que serão conduzidos neste estudo terão uma duração máxima de 15 minutos para cada uma das interações.

  O paciente poderá repetir alguma tarefa se assim o desejar.

- **Antes da tarefa**

  Explicar a tarefa / objetivo

- **No decorrer da tarefa**

  O paciente pode pedir ajuda para perceber ou completar alguma tarefa a qualquer momento do decorrer da experiência.

  O investigador intervir na tarefa a qualquer momento do decorrer da experiência

  Think aloud - O paciente deve dizer em voz alta tudo o que vem na cabeça.

  Um investigador está a conduzir a experiencia enquanto outro está a tirar notas.

- **Entrevistas**

  Será realizada uma entrevista relacionada exclusivamente com a tarefa que o paciente acaba de realizar após cada um dos testes.

Caso o paciente realize mais que uma tarefa poderá ser questionado sobre que método de interação preferiu.

- **Recolha de material audiovisual**

  Poderemos gravar voz e/ou vídeo da interação do paciente com a tecnologia caso esta recolha de dados seja permitida pelos familiar e pelos cuidadores e prontamente registada no formulário de consentimento.

- **Desistências**

  O paciente tem o direito de abandonar qualquer um dos testes, ou mesmo a experiência, a qualquer momento.

  O paciente poderá ser incentivado a continuar a realização das tarefas restantes sem que esta progressão no estudo seja forçada.

Appendix C – Questionnaire for the Explorative Comparative study of technology in Dementia

Nome:____
Idade:____
Tipo
Demência:____
Estado:____
__

Questionário acerca da interação com (inserir tec.)______________

Interação

1) Percebeu o objetivo da tarefa que lhe foi pedida
    a. De modo geral, descreva o objetivo.

2) O que teve de fazer para completar a tarefa que lhe foi solicitada?
    a. Descreva os passos para completar a tarefa.

3) De que forma utilizou a tecnologia/aparelho?
    a. Que braços/mãos utilizou para completar a tarefa?
        i. Utilizou uma mão? Duas mãos? Dedos específicos? Explorou o ambiente virtual movendo a cabeça? Etc…
    b. As tarefas realizadas com esta tecnologia/aparelho fizeram sentido para si? O que achou mais difícil na utilização desta tecnologia/aparelho?
    c. O que achou mais fácil na utilização desta tecnologia/aparelho?
    d. O que achou mais confuso na utilização desta tecnologia/aparelho?
    e. O que achou mais desconfortável na utilização desta tecnologia/aparelho?

Dificuldade

1) Achou que as ações realizadas na tarefa eram intuitivas/naturais/fáceis de perceber?
    a. Foi fácil perceber se estava a fazer bem ou mal?
    b. Conseguiu fazer tudo o que queria fazer da maneira que queria fazer?

Mobilidade

1) Sentiu alguma limitação física durante a utilização desta tecnologia?
    a. Sentiu as mãos, braços, dedos, etc. cansados?

Imersividade

1) Sentiu-se envolvido na sua tarefa?
    a. Sentiu que estava a tocar um piano?
    b. Sentiu que estava a tocar nos brinquedos?
    c. Sentiu que estava a tocar numa figura geométrica?
    d. Sentiu que alguma vez se distraiu durante a realização da tarefa?

2) Algum comentário adicional?

Perguntas adicionais quando o utilizador usar mais do que UMA tecnologia no mesmo dia

1) Qual o aparelho/tecnologia que mais gostou?

2) Qual aparelho/tecnologia que achou mais confortável de usar?

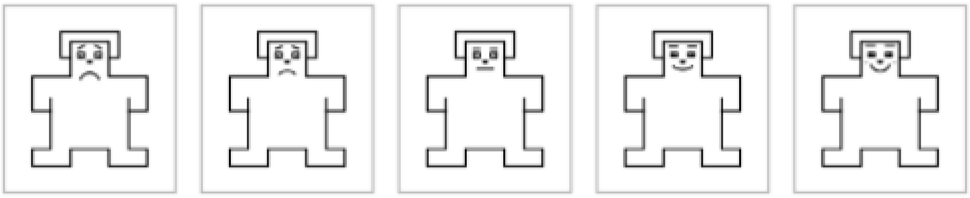
Appendix D – Therapist Questionnaire for the Evaluation Experiment

Id: ____

Questionário sobre a experiência com terapia animal virtual – TERAPEUTA

PRÉ-INTERVENÇÃO

1. Como classificaria o estado emocional do participante hoje?



1 2 3 4 5

PÓS-INTERVENÇÃO

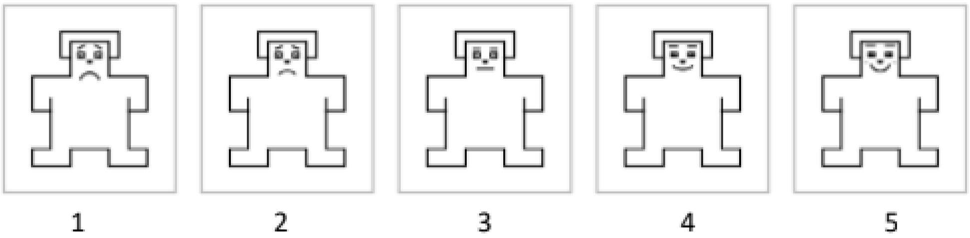
Efeito pós-sessão de jogo:

1) Sentiu que esta sessão de jogo foi positiva e/ou benéfica para o paciente? Se sim, em quê?

Estado emocional:

2) Houve alguma reação e/ou comportamento negativo ou atípico após o término da sessão?

Como classificaria o estado emocional do participante após a experiência?



Appendix E – Participant Questionnaire for the Evaluation Experiment

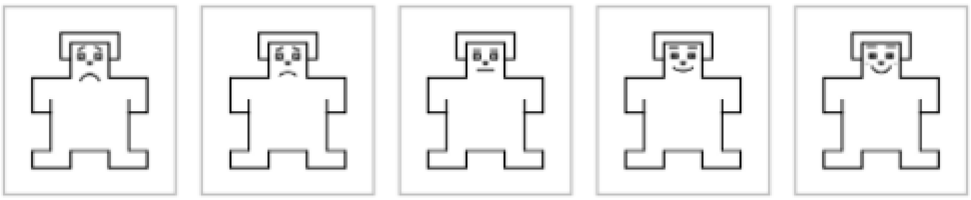
Nome: ____
Idade: ______________
Tipo de demência: ____
Estado: ______________________________ (MMSE) ______________________
Id: ____

Questionário sobre a experiência com terapia animal virtual – PARTICIPANTE

PRÉ-INTERVENÇÃO

Estado emocional:

1. Como se sente hoje? [Escolha a imagem que melhor descreve a forma como se sente.]



1 2 3 4 5

PÓS-INTERVENÇÃO

Usabilidade:

1. Sentiu que o jogo era muito difícil de aprender? [Foi difícil?, Achou difícil?]

2. Sentiu que conseguiu realizar as tarefas do jogo com sucesso? [Conseguiu completar o jogo?]

3. Sentiu que cometeu muitos erros durante a experiência? [Acha que se enganou muitas vezes a jogar?]

4. Se voltasse a jogar acha que conseguia melhorar os seus resultados? [Conseguia fazer melhor?]

5. Sentiu-se satisfeito/a em relação às tarefas que realizou neste jogo? [Gostou do jogo?, Acha que jogou bem?]

Semelhança com animal real:

1. Os cães do jogo são parecidos com estes?

NOTA: O investigador deve utilizar material de suporte, mostrando o cão com que a pessoa interagiu no jogo e uma fotografia de cães reais.

2. O comportamento do cão no jogo parecia o de um cão real?
    a. Porquê?

NOTA: O investigador deve utilizar material de suporte, mostrando o cão com que a pessoa interagiu no jogo e uma fotografia de cães reais.

Interação com o animal:

1. Sentiu-se divertido/a enquanto brincava com o cão? [Divertiu-se a brincar com o cão?]
    a. Porquê?

2. Que atividades gostou mais de realizar com o cão ao longo do jogo? [O que é que gostou mais de fazer com o cão?]
    a. Porquê?

Personalização do animal:

1. Não preferia um cão maior/mais pequeno?

NOTA: O investigador deve utilizar material de suporte, mostrando o cão com que a pessoa interagiu no jogo e o cão maior/mais pequeno.

2. Prefere ter a opção de escolher vários cães ou jogaria sempre com o mesmo? [Gostaria de jogar com vários cães diferentes ou apenas com aquele que jogou?]

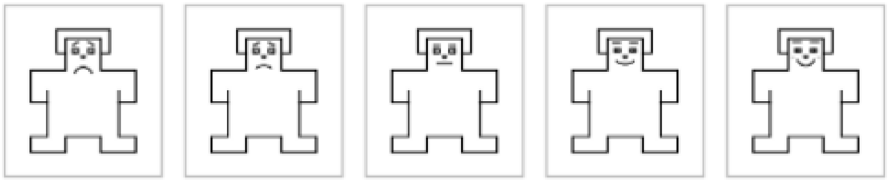
NOTA: O investigador deve utilizar material de suporte, mostrando o cão com que a pessoa interagiu no jogo e um outro cão do jogo.

Empatia com o animal:

1. Gostaria de poder cuidar deste cão mais vezes? [Se levasse o cão para casa cuidaria dele?]
    a. Porquê?

<u>Estado emocional:</u>

1. Como se sente após jogar?



1 2 3 4 5