Media Engineering and Technology Faculty
German University in Cairo

Serious Game For Detecting Social Processing Deficits

Bachelor Thesis

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Supervisors: Prof. Dr. Slim Abdennadher
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Submission Date: 01 August, 2021

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This is to certify that:

(i) the thesis comprises only my original work toward the Bachelor Degree

(ii) due acknowledgement has been made in the text to all other material used

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Raneem Wael Sayed
01 August, 2021

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Abstract

Participation in social aspects of everyday life is crucial to developing a person's character and mental health. Many individuals who possess social processing deficits are unbeknownst that such deficits can be hard to detect on oneself. Although there are numerous verbal and written techniques to detect the scarcities in question, such as questionnaires and experimental tests, little has been done to gamify those methods. This study explores the possibility of detecting social processing deficits in individuals through their participation in a game. The game consists of a storyline-like environment where the participant would react to certain situations that are essentially gamified tasks previously tested or survey questions to summarise what possible social processing deficits they might have. A questionnaire was also requested from everyone involved to identify any deficiencies being tested for in this study. The survey results were then compared to the findings obtained through gameplay. Although the similarities were promising, more participants and testing need to occur to further generalize those results.

Contents

Chapter 1

Introduction

Processing deficits are problems with the process of sensual recognition and interpretation of information. Visual and auditory perception are the two most common aspects of processing problems associated with social disabilities. These areas are further split into two categories; social and cognitive. This research focuses on how visual, auditory, and situational perceptions affect an individual's social interaction and participation.

Various techniques have been applied throughout the years to detect such deficits. These methods ranged from experiments to monitored tasks and interviews. Scale questionnaires have also played a big part in having people rate themselves based on situations and specific reactions as a means of social processing deficit detection. Although many procedures exist to detect these scarcities mentioned, none of these techniques has been gamified.

This research aims to find the most convenient methods to help discover a player's social processing deficits through their participation in playing a game. These methods help address the question of this research being: ***Can serious games be used to detect social processing deficits?***

The most common deficits have been collected and narrowed down to only those that can be gamified. The game consists of one level in the form of a storyline, where the player is to come across particular situations with other fake "bot" players and is asked to take certain decisions. The collection of these decisions and their correlation to each other aided us in providing them with a scale on the possibility of them possessing specific social processing deficits. In addition to that, sample questions were used from four questionnaires to compare the inferred game results to the trusted ones resulting from the surveys. Previous studies suggested that future research should include independent trials and direct comparisons of game-based and non-game-based options for varied user groups [1] which this study hopes to achieve by using the previously mentioned data along with answers from the trusted questionnaires to compare the results.

This thesis is divided into six chapters. **Chapter 1** is the introduction. **Chapter 2** is the background; it mentions different applications and systems designed to detect social

processing deficits in individuals. **Chapter 3** describes the game implementation while **Chapter 4** includes a detailed description of the game design. **Chapter 5** discusses the last phase of this project which is the evaluation phase, and its results. Finally, in **Chapter 6**, we discuss our conclusion and suggestions and include information about future work.

Chapter 2

Background

2.1 Related Work

Throughout the years, no studies have been conducted to try and identify social processing deficits through games. Even though various methods supported by research papers are available and have been tested to detect such deficits, it has not been attempted to gamify those techniques.

This study aims to collect the tested techniques from previous research and combine them in a game environment to present a new way of detecting these deficits.

2.2 Social Processing Deficits

Social processing deficits refer to the difficulties individuals face when interpreting information through visual and auditory perception affecting their social interactions and participation. Research has suggested that a social processing deficit can be categorized under one of three classes; affiliation and attachment, perception and understanding others, and social communication [2]. The following is a summarized idea of how the implementation of the chosen tasks were designed.

2.2.1 Affiliation and Attachment

Affiliation is a commitment to positive social interactions with other people. Annexation, also referred to as attachment, is selective affiliation due to social bond development. Some of the social processing deficits under this category that this research attempted to gamify are mentioned below.

Social Anhedonia

Social anhedonia is characterized by a lack of interest in social contact and a lack of pleasure in social situations. It is linked to lower social functioning and lower reward from social interactions. [3]. This social trait influences how much people change their behaviour in response to socially rewarding cues, and it establishes a tool for dimensionally measuring social reward responsiveness.

Social withdrawal, a lack of relationships, or withdrawal from previous relationships are all symptoms of anhedonia. Social anhedonia is measured in a variety of ways.

For instance, people with high social anhedonia show minor changes in response bias in the social reward task compared to individuals with low social anhedonia [4]. Social rewards form a silent, full-colour video clip of a celebrity providing approval by simultaneously smiling, nodding, and showing a thumbs-up gesture when the player completes a task.

Research has shown that there exists an inverse relationship between anhedonia and willingness to expend effort for rewards **Effort-Expenditure for Rewards Task (EEFRT)** [5]. This relationship is modelled by making the player choose between two mini-games; one easy with less reward, the second slightly more complex with higher reward. People's decisions are often about what to do and how much effort to make; they decide whether the extra effort is worth it.

Furthermore, by using the **The Self-Assessment Anhodenia Scale [6] (SAAS)**, the results were easily comparable, and it helped in determining the success of the gamified tasks in detecting social processing deficits.

Increased Altruistic Punishment

An act is altruistic if it is costly for the person performing it but beneficial to someone else. Punishment is thus altruistic if it is costly for the punisher and results in a change in the punished person's behaviour. This kind of punishment is usually done to influence better actions from the punished individual in the future.

Several different paradigms have been employed in altruism research, including the ultimatum game and the public goods game [7].

The game of ultimatum is an economic experiment in which two parties have anonymous and unique interaction, so reciprocation is not problematic. It evaluates players' reactions to the fairness of offers of a share of money [8]. The first player suggests how to split a cash sum with a second party. If the second player rejects this division, nothing will be given to either. The ultimatum game is a simple, take-it-or-leave-it bargaining environment [9]. Logically, every offer ought to be accepted because no individual profits are made without an acceptance. However, if the division is considered unfair, Person B may punish his partner by denying the wrong offer [7].

The **Public Goods Game (PGG)** is an experimental economics standard. The subjects secretly choose how many tokens to put in the public pot in the game. The tokens are multiplied by a factor then this "public good" is divided evenly among players. If either of the subjects does not contribute with their token, they retain them. Public good games serve as a metaphor for modelling cooperative conduct in groups in the presence of free ride incentives. When a person does not contribute to the pot, they are known as a "free rider," When they contribute, they can be said to be acting altruistically. These "free riders" often incur altruistic punishment from others in attempts to force cooperation in the future [7].

These two paradigms were similarly implemented but more simply to integrate them into the game's storyline without providing a complicated explanation of their dynamics beforehand.

There is no need to support these tasks with questionnaires further as both were tested before and are used globally to measure altruistic punishment. Furthermore, these two paradigms were compared to several surveys such as **The Altruistic Personality Scale** and **The Big Five Models of Personality Scale** and were proven to accurately identify altruistic punishment in individuals [7].

2.2.2 Social Communication

Social communication disorders are widely misinterpreted as relating only to speech problems; however, it covers more aspects including the actions an individual chooses to perform during communication of any sort. These actions include diminished cooperativeness when it comes to helping or collaborating with others to achieve shared success.

The cooperative-related questions of the **Cooperativeness and Competitiveness Personality Scale [10] (CCPS)** were used in hand with the tasks to be explained to solidify our findings further.

Diminished Cooperativeness

Highly cooperative individuals are more likely to cooperate with others, consider others' perspectives and enjoy working with others. Hence, a person with diminished cooperativeness is less likely to exhibit any of the previously mentioned traits.

Reduced cooperation can be estimated in various ways.

In the Prisoner's Dilemma, individuals' self-interest conflicts with that of the partnership, so it measures cooperation [11]. Two players will receive the same amount of money while deciding whether to cooperate (share) or defect (keep the money). If both defect, pay is the lowest and vice versa. However, a participant can make the most if they defect and their partner cooperates. A simplified, more understandable version of this can be observed in "The Game of Trust," where only if a person puts a coin in a machine, the other player gets three coins – and vice versa, and both can either cooperate or cheat [8].

The dictators game stems from the ultimatum game, where one player (the proponent) offers the other a one-time offer (the responder). The dictator's space for action starts by giving nothing to the recipient or giving them all the funds. As the recipient plays a passive role, the dictator fully decides the final division of the money[8].

2.2.3 Perception and Understanding Others

The term "perception of the individual" refers to the different mental processes that people use in social psychology to form impressions [12]. This perception encompasses how people make these impressions and and how they draw conclusions from these impressions about other people.

Individuals experiencing a deficit in this area tend to misunderstand people and their intentions, leading to a negative perception of the observed people around them.

Reduced Empathy

Empathy is the ability to understand or feel what another person experiences, that is, the capacity to position themself within the other person's frame of reference.

This deficit is measured using two methods, the first one being basic empathy tasks such as making the player choose between helping other people or not [13]. Another symptom of reduced empathy is the inability to identify videos or audios depicting painful stimuli [2]. Measuring this inability acts as the second method and is carried out through inserting soundtracks with cries and pleas for help, then asking the player to rate how disturbing the audio was.

In addition to the previously mentioned cases, the players answered questions from the **Basic Empathy Scale [14] (BES)** to identify the effectiveness of the tasks in identifying the deficits they measure.

Mentalizing Deficits

Theory of mind (ToM) is the ability to attribute mental states to ourselves and others, serving as one of the fundamental elements for social interaction. Having a theory of mind is vital as it can predict and interpret other people's behaviour. It is an essential social-cognitive skill that involves thinking about mental states, both a person's own and others. Simply put, it is a study of how human learners put two "imperfect" heads together to make utility-maximizing decisions [15].

Deficiencies in this area were detected using situations that test for an individual's ability to correctly assess who of the other players to trust depending on how they have treated them before [16]. Testing for this ability is done by recording a player's repeated choices based on other characters' hints and their repeated reaction to them.

To ensure the success of the gamified tasks in measuring an imbalance in the theory of minds, **The Multidimensional Mentalizing Questionnaire [17] (MMQ)** was used to compare the inferred results to the actual ones from the survey.

Empathy is often associated with the capacity to accurately gather the thoughts, intentions, and emotional states of others [13]. This relationship suggests overlapping two deficits, mentalizing deficits and reduced empathy, which is crucial in measuring some shortages together by integrating them in one situation.

2.3 Serious Games

A serious game, also known as an applied game, is one that is designed for a purpose other than pure entertainment [18]. The "serious" adjective refers to video games used in defense, education, scientific exploration, health, urban planning, engineering and politics.

We aim to design, in this study, a serious game that will help us in the scientific exploration of whether or not the detection of social processing deficits through them will be possible.

2.3.1 Serious Games and the Detection of Deficits

Serious games are rapidly growing as a gaming industry, as well as a field of academic research [18]. Serious games have been adapted in various researches to treat or prevent specific medical and psychological problems [19] [1]. However, the gamification of the detection of psychological deficits is a field yet to be explored. A similar project, a game with the name of "The Happiness Project", was developed in hopes of helping scientists try and figure out what brings us happiness. It was created to try to measure someone's happiness through a series of tasks and rewards. This study hopes to achieve something similar with, however, more concrete results regarding social processing deficits.

Chapter 3

Game Implementation

3.1 Game Engines

Game engines provide a foundation for developing video games that operate on mobile devices and personal PCs. A gaming engine is separated into numerous components, each of which is responsible for a different set of features. The components of a typical gaming engine are as follows:[20]:

1. **Resource Manager:** which loads graphics from a storage media into memory and prepares them for usage It is in charge of discriminating between all resources available in the game, loading and unloading resources to and from memory, and ensuring that no duplicate resources are present in memory at the same time.

2. **Rendering Manager:** this engine loads graphics into memory and draws them to the screen. The engine determines how to draw an image's pixels to the screen. It is also in charge of determining the game's resolution.

3. **Physics Manager:** it is in charge of ensuring that the physics rules are applied to the game's objects realistically inside the application

4. **Audio Manager:** this engine manages the connection between the game and the audio hardware, as well as the application of sound effects and the setting of the game volume level.

Multiple powerful engines give the developers the ability to create games. *Unity*, a popular game engine, specifically, possesses a high development speed and the ability to build projects on multiple platforms and hence is most commonly used by developers. [21]

3.1.1 Unity Engine

Unity is a multi-platform powerful game engine. The *Unity* editor allows developers to build a game visually where one can manage assets and move objects without writing any or using minimal code. The ability of *Unity* to target games on several platforms is noteworthy. [22]

In addition, it supports many platforms, including Windows, Linux, Android and iOS. Therefore, the *Unity* game engine was the most suitable engine for developing the game.

Features

1. **Mecanim Animation Engine:** *Unity* has a rich and sophisticated animation system ***(Mecanim)*** which provides an easy workflow and setup of animations for all elements of *Unity*, including objects, characters, and properties. It also provides animating different body parts with a different set of logic and layering features.

2. **Scripting:** *Unity* supports three different programming languages, C Sharp, JavaScript and Boo, to use for scripting.

3. **Physics:** *Unity* physics engine supports rigid and soft body dynamics, simple cloth simulation and character controllers.

Unity Editor

Creating unity game assets can be done by dragging the needed asset from the asset manager into the game environment as game objects. Game objects can have multiple components. A set of components define how the engine treats the game objects. There are also physics-based components that handle applying the physics rules on the game object to which they are attached, such as gravity. Each component can have a set of properties that define how the object behaves.

Logic is added, through scripting, to move game objects and dictate what should happen to them under certain conditions. It is written in C Sharp, JavaScript or Boo. The use of scripts as components makes Unity entirely modular and makes the scripts highly reusable.

The game is a personal computer desktop game developed using the Unity game engine. Unity supports three different languages: C Sharp, JavaScript, and Boo. Since C Sharp is more advanced, optimized, and has more features than the other two languages, it was used as a programming language for scripting, and Unity was used to develop the game as a WebGL build. [21, 21]

Unity Build

A unity build (also known as unified build or jumbo build) is used in C and C++ software development to speed up project compilation. This speedup is obtained by combining numerous translation units into a single one, which is often accomplished through the use of directives that bundle multiple source files into a single larger file. Unity offers a wide selection of builds to choose from, including the "Universal Windows Platform", "Android", "iOS", and "WebGL" builds.

The WebGL build is targeted to publish applications to a web browser. It can be used to publish content as JavaScript programs which use HTML5, JavaScript, WebAssembly, the WebGL rendering **Internet of Things (IoT)**, and other web standards. [23]

We decided to go with the WebGL build for this project as we intended to publish the game online to maximize its reach and the number of participants.

3.2 Deployment

All of the activities that result in the availability of a software system are referred to as software deployment [24].

Deployment of this project was done through uploading the WebGL build, along with the game files to *Itch.io*, a high traffic internet gaming forum. An open invite to participate in this research was posted on *Itch.io*, as well as on the following social media sites: *www.reddit.com*, *www.facebook.com*, *www.twitter.com*, and *www.instagram.com*.

The purpose of deploying the game online rather than using in-person testing was to facilitate the speed of the testing phase and make players feel more at ease so as not to get the sense of being scrutinized by watchers.

3.3 Databases

An organized database is a collection, typically stored electronically in a computer system, of structured information or data. It provides easy access, management, modification, update, control, and organization of the data [25].

3.3.1 MongoDB

MongoDB is a source-available cross-platform document-oriented database program. Classified as a NoSQL database program, *MongoDB* uses JSON-like documents with optional schemas [25].

NoSQL databases are useful for storing massive amounts of scattered data. They are effective for addressing large data performance concerns that relational databases were not designed to address. They are best when an organization needs to scan large quantities of unstructured data or data stored in the cloud on several virtual servers [26].

MongoDB Atlas

MongoDB Atlas is a fully-managed cloud database developed by *MongoDB* creators. *MongoDB Atlas* handles all the complexity of deploying, managing, and healing deployments on one of the following cloud service providers: **Amazon Web Services (AWS)**, Azure, and **Google Cloud Platform (GCP)** [27, 26].

We chose to link the collection of data from the unity game to *MongoDB Atlas* using the **AWS** cloud server.

The file responsible for this (**playerData.cs**) transaction is activated within the last scenes of the game and uses the POST **IoT** to send the data to the database on *MongoDB Atlas*.

MongoDB Compass

MongoDB Compass is a graphical user interface for accessing, aggregating, and analyzing *MongoDB* data. Compass is available for free and can be executed on macOS, Windows and Linux [26].

After deploying all game data and saving it to *MongoDB Atlas*, we used *MongoDB Compass* to be able to export the data in a **Comma Separated Values (CSV)** format and start our analysis.

MongoDB Realm

MongoDB Realm is an open-source database management system object and was first available for mobile operating systems (Android/iOS), but is currently also licenced under the Apache licence and is available for platforms like Xamarin, React Native and others, including Desktop apps (Windows). It is a platform for developing modern, data-driven applicationss. *MongoDB Realm* can be used to build mobile, web, desktop, and **Hypertext Transfer Protocol (HTTP)**. *MongoDB Realm* features an inbuilt object-oriented database that allows for the development of real-time, offline-first apps [26].

A web callback (also called a webhook or **HTTP** push **IoT**) is a way to provide real-time information to other applications [28]. A webhook sends data to other applications as it happens, which means it is delivered promptly. Webhooks in *MongoDB Realm* webhook are a method of augmenting or altering the behavior of the database with custom callbacks. Third-party users and developers can maintain, modify, and manage these callbacks.

We created a new webhook to post the data sent it to the required player data database.

3.4 Models and Sounds

Most of the models were downloaded from the unity asset store. The sound effects used throughout the game were downloaded from accessible sources online and edited using *Audacity*, a free, open-source, cross-platform audio software used for recording and editing sounds.

3.5 Game Architecture

The main scripts responsible for game flow and data collection are:

1. ***TypeWriterEffect.cs:*** the typewriter script is included to display the text in a progressive way to furtherly encourage player to read them with the recursivley appearing text.

2. ***setPlayerInfo.cs:*** this script is invoked after the scene where we collect user data to be able to load the appropriate avatar (male or female) accordingly.

3. ***PlayerMove.cs*** and ***CameraMove.cs:*** these scripts control the movement of the player and camera along with them.

4. ***Controller.cs:*** this script is responsible for the constant collection of player and game data throughout the different scenes and scenarios the player experiences. It is persistent throughout the exchanging of scenes through the *DontDestroyOnLoad()* method. This file contains a variable for all the needed data collected and sent to *MongoDB Atlas*. These variables include a counter for each social processing deficit to keep track of the scores of each individual. Moreover, the script contains important methods that set the different music required at each stage, activates and deactivates player movements when needed, and finally, loads the required scenes after each other.

5. ***SlideAmount.cs:*** this script's aim is to translate a slider's value to points based on certain scale systems to add them to the required social processing deficit variable in ***Controller.cs***. It contains a different method for each slider it gets invoked on.

6. ***playerData.cs:*** the purpose of this script is to send the collected player data to *MongoDB Atlas*. S new object with fields containing the recorded data is created in C sharp and is then parsed to a JSON string to achieve that purpose. This JSON string is passed to the database through a webhook link, created through *MongoDB Realm* that uses a database's "POST" method to add the data to it.

7. ***endTime.cs:*** this script is responsible for ending the game after thirty minutes to uphold an online gaming feel, where due to prolonged time of inactivity, a player is forced to refresh the web page.

Chapter 4

Game Design

This game aims to detect social processing deficits in the individuals playing it. It helps them get an easy at-home rating of their social processing deficits on certified scales. The game consists of a storyline theme. The player is to walk through a forest and encounter situations with decisions to make. There are many simple mini-games that the player played for two reasons; the first is to try and put the player at relaxed ease and not feel as if they are being tested, and the second reason is to incorporate some of the tested tasks into the game simulation.

4.1 Understanding User's Needs

Before and during implementation, we had meetings with experts from departments related to human psychology to discuss the game and the gamification of tasks. We needed expert help and professional opinions on how effective the studies we gamified can measure social processing deficits in individuals.

We took some measures to reach the most suitable techniques and strategies to serve our purpose; they are discussed below:

1. A calming theme was used to avoid overwhelming players with possible social processing deficits such as anxiety.

2. The choices presented in each situation were distinguishable to avoid overthinking the decision-making process.

3. We mentioned to the participants that all their results would be confidential and anonymous to protect their privacy regarding sensitive matters.

4.2 Theme

The gameplay is set in a jungle where a human avatar is trying to reach their treehouse.

The player's conversational or instructional interactions appear in a boxed area at the bottom of the game screen to keep the interface simple and unchanged.

Background music played throughout the entire gameplay. We have chosen bird sounds to develop a soothing and quiet environment so, again, to not overwhelm the player and make them feel relaxed.

4.3 Characters and Avatars

All the characters in the game are human avatars. According to the player's gender, they are given a female or male avatar respectively, each of which is illustrated in **Figure 4.1**.

(a) Avatars: male.

(b) Avatars: female.

Figure 4.1: Avatar of the player.

The player is told, at the start of the game, that they will be playing with three real players; however, that is not the case. The other players are **Non-Player Character (NPC)** with all reactions and interactions hardcoded to have the study be controlled. The participant believes that the other players are actual people to relate the game to real-life situations and act how they would with real people. The player was told to wait while finding the partners to make the idea of online gameplay as believable as possible. To further comfort the players of their anonymity, we informed them that they and the other "real" players are displayed as a human avatar with a random name and look from a pre-specified set. The abundance of persons is to provide different approaches to the same task we want to test as some of the tests need repetition with a fixed helper individual.

The different players are:

1. **"Adam":** this **NPC** is used in several tasks throughout the game as a helpful person.

2. **"Omar":** this **NPC** is also used in several scenarios and acts as a selfish and untrustworthy individual.

3. **"Heidi":** this **NPC** is only used during a single scenario and acts generously.

We do not explicitly inform the player of the characteristics of each of the characters. Instead, their characters are portrayed through their interactions.

A couple of other **NPC**s are used throughout the gameplay; however, they are of no significance to the decision making nor do they affect the collected data. They are simply used as helper characters.

4.4 Game Aspects

Along with the measures taken to respect a user's need, we also attempted to keep the results as bias-free as possible by deploying the following game aspects:

1. Measures to try and ensure the players reading of instructions were deployed. This strategy is modelled in displaying the instructions/storyline text in a typewriter effect, where each letter is typed quickly after the other but with a relatively slow speed to mimic the reading time. This effect encourages users to read the instructions with the self typing text.

2. We ensured that the player would re-enact any of the scenarios they come across to maintain the online feel. Moreover, scenarios are loaded in and out of the screen each time to illustrate a randomized online environment.

3. Any decision-making scenarios that included sliders with a percentage was designed with a +-5, of a hundred percent, as an error margin of not placing the marker accurately.

4.5 Measuring Deficits

The scales and methods of adding up values to conclude whether an individual exhibits a social processing deficit were all developed with the help of psychologists and inferred from the papers that have previously tested them in a non-gamified environment.

4.5.1 Affiliation and Attachment

This category of social processing deficits is mainly affected by the reward and evaluative systems of the brain [2]. Therefore the coming explained tasks are intended to tackle each of these systems in their testing.

Social Anhedonia

1. **Response Bias:**

   After extensive research, we decided to gamify an experiment that was designed in one particular study [4] as follows:

   - The player is prompted to play a particular mini-game for some number of rounds consecutively. The game consists of showing along then a short stick and then showing either of them one after the other, at each time asking whether it is long or short. A social reward in the form of a silent, full-color video clip of an actor offering approbation by simultaneously smiling, nodding, and showing a thumbs-up motion was shown after each successful answer.
   - An asymmetrical reinforcement ratio is introduced, with one type of line (i.e. short or long) being rewarded more frequently; the line type that was rewarded most frequently is referred to as the "rich stimulus," and the line type that was rewarded least frequently is referred to as the "lean stimulus." A significant response bias indicates that an individual is more responsive to rewards [4].
   - Response bias was to be computed as:

     log(b) = $\frac{1}{2}$ * log [(Rich correct * Lean incorrect) / (Rich incorrect * Lean correct)]
   - This experiment suggests that players with low social anhedonia are more inclined to chose the rich line when they are not sure in opposition to the lean stimulus to [4].

   The research that carried this experiment suggested certain modifications to comply with the idea of "Corrections for Extreme Proportions" [4]. This idea implies that the previous question might present a 0 or 1 always if all the answers were respectively all correct or never correct. An extra question, along with a yes or no question, was added, and a new scale of measuring this deficit was used [29].

   Figure 4.2 shows the question which asks the player to mark a checkbox if they are not sure of their answer. The number of times this box was ticked with a "long" answer (lean stimulus) is recorded along with the corresponding number of times it was ticked with a "short" answer (rich stimulus). The lean stimulus was then subtracted from the rich stimulus and only added as a possibility of the individual having social anhedonia if it is greater than zero.

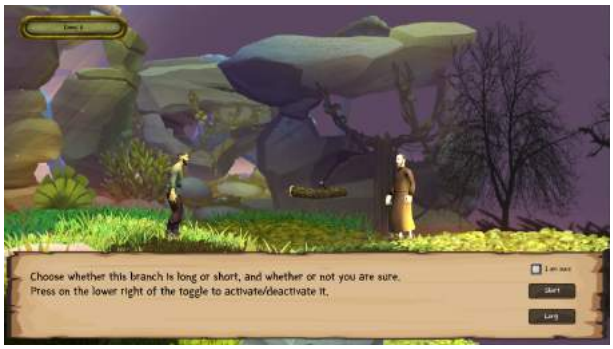


Figure 4.2: Reward bias: *are you sure* question.

We have also slightly modified the test, with the support of a psychologist, to show the socially rewarding video with only the rich stimuli to reach a better scale to measure social anhedonia. **Figure 4.3** illustrates where the social reward video is to appear.

Figure 4.3: Reward bias: social reward.

Moreover, the difference in lengths of both branches was relatively unnoticeable to continuously test what the player is inclined to choose at times of uncertainty. Lastly, we designed the game such that the continue button displayed after the participant chooses a correct rich stimulus is only made clickable after a delay of three seconds to ensure them noticing and watching the short video. The mini-game has been repeated a total of ten times.

2. **Effort-Expenditure for Rewards Task:** the **EEFRT** is a multi-trial game in which participants are asked on each trial to choose between two different task difficulty levels in order to obtain monetary rewards [5]. The player is offered a complex, highly rewarding task and an easy, less rewarding task. His choices are evaluated along with the gameplay. We reflected on this task in two different game scenarios, which will be explained later.

Social anhedonia scales [6] were used to confirm our findings.

Increased Altruistic Punishment

1. **Ultimatum Game [7, 8, 9]:** the player is to come across a treasure then have text display in the designated area; saying that "Somebody else has found this treasure first! However, he is willing to share it with a 80-20 ratio in his favor! If you reject this offer, neither of you will get anything. Do you decide to accept or reject this offer?". If the player chooses to decline the offer, further text appears opting for a more equitable divide. This is carried out once more if they reject the second offer as well. If the person rejects all splits, they are more likely to exhibit increased altruistic punishment.

2. **PGG [7, 8, 9]:** the player and another **NPC** come across a magic well. It is explained that whatever sum each put into the well from their savings will be summed, tripled, then evenly distributed among them. The user is told that the other **NPC** will not invest any of their money. We then record whether the other player invests with any of their money and if so, we also record the percentage they put into the well [7].

As mentioned earlier in **Chapter 2**, there is no need further to solidify our findings regarding the measuring of altruistic punishment as previous studies give precise scales to use to detect this deficit.

4.5.2 Social Communication

Similar to affiliation and attachment, this class of social processing deficits also tackles the reward and evaluative brain systems [2]. This means that it can be concluded that, thus far, all tasks have been integrated, and what we are gathering is a pattern of behaviour. The following deficit is measured and compared with the results of the **CCPS** to confirm our findings.

Diminished Cooperativeness

1. **Hints [16]:**
   - They come across an **NPC** that has given them a hint before. This character will be needing a hint (that our participant has). We then record whether or not the player is willing to give them a hint as an act of cooperativeness.
   - Along the way, the player was repeatedly asked if they would like to leave hints for other players to help them collect coins as well.

2. **Prisoner's Dilemma [7, 8, 9]:** the player and an **NPC** come across a magic well. It is explained to them that if either of them puts a coin from their savings, the other gets three. We inform our players that the other "person" has decided to cooperate regardless of their investment or lack thereof. They are then given a choice to make a decision based on that knowledge.

3. **Dictator Game [7, 8, 9]:** the player is to come across a treasure then have text display in the designated area saying that "Somebody else has found this treasure too! However, since you found it first, it's up to you to split it however you want!" The participant is then asked to dictate how they would like to split the treasure.

To ensure the success of the gamified tasks in measuring this deficit, **CCPS** is used to compare the inferred results to the actual ones from the survey.

4.5.3 Perception and Understanding Others

This particular branch of social processing deficits is slightly different from the other two as it depends on the brain's empathetic system [2].

Reduced Empathy

The **BES** should be used along with the following method to confirm our results further.

1. **Basic Empathy Accuracy Tasks:** the player comes across other characters in need of help and gets the choice to help them or not [13].

2. **Evaluating Audios Depicting Painful Stimuli:** the player crosses a cursed part of the jungle. During the crossing, the soundtrack switches to sad pleas and cries for help. Upon exit, the participant is then asked to rate the audio's disturbance, and their answers are recorded [2].

Mentalizing Deficits

The technique used to detect the theory of minds deficit was the second-order false belief test. Which, in short, is a trust test. The player comes across a couple of two-choice mini-games in their path, and they are to choose whichever after they are told by another **NPC** which is easier [16, 15]. We then asked them to rate how much they trust their "partner" and record whether they act on their belief. Using this method, we measure a person's trust processing and reflexivity together. The players are supposed to decide on whether or not they trust each character based on the pattern of behaviour the characters have depicted throughout the gameplay [16]. We then developed a pattern from our findings based on them having different partners, one that treated them fairly and did not lie, then another that did.

Along with the previously mentioned cases, the player was asked questions from the **MMQ** to identify the effectiveness of the tasks in identifying the deficits they measure.

4.6 Scenes

The game developed consists of ten scenes as shown in **Figure 4.4**. The first four contain details about the project, then comes the actual gameplay scene, the final four scenes make up the questionnaire and credits, and finally, the tenth scene is for a timeout of the gameplay.

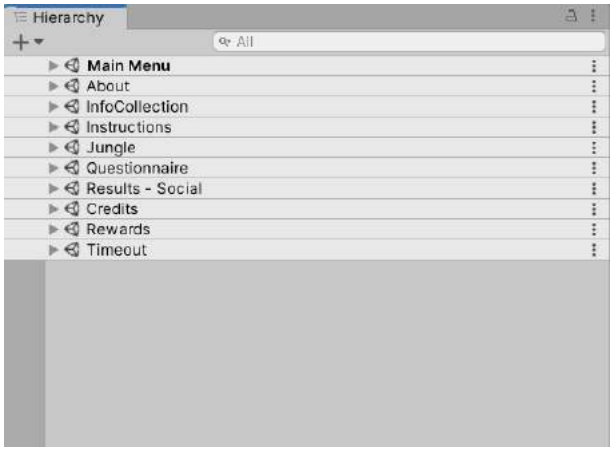


Figure 4.4: Scenes hierarchy.

4.6.1 Main Menu

Upon startup, the *Main Menu* screen is loaded. The *Menu* screen includes the title along with a start button.s

4.6.2 About

The *About* scene explains the purpose of the project to the player. It also reassured players of the anonymity of their results.

Moreover, participants were kindly asked to play the game only once to protect the collected data from repeated or biased responses.

4.6.3 User Data

We included a scene where the user data is collected to specify our results to the correct age and gender groups. As **Figure 4.5** illustrates, the player is asked to enter their age, gender, and education level. All the choices are made through a drop-down list for ease of use. The choice of gender reflects in the player's avatar to give a realistic feel to the gameplay. The age groups available to choose from starting from age 15 to age 56, and the education level offered three choices: none, school, university.

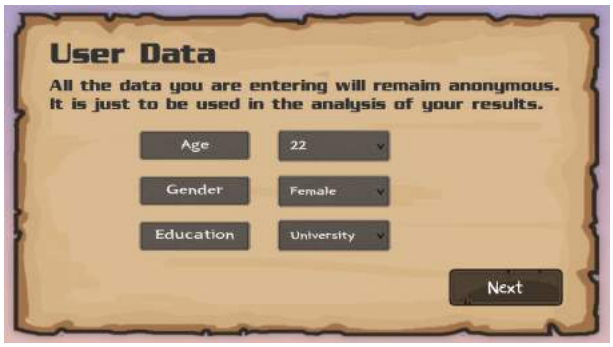


Figure 4.5: Collected user data.

4.6.4 Instructions

The *Instructions* view dictates the instructions of the gameplay to the users.

Regarding the decision-making, we included a disclaimer in the *Instructions* scene to encourage participants to choose what they would most likely tend to do if the situations were to happen to them in real life. It states the following: *You will come across situations where you need to make decisions, some of which will have obvious answers that are generally accepted by society; however, please imagine them being real-life events and choose what you would most likely do if put in such a setting for your results to be as accurate as possible.*

Players are asked to play in fullscreen mode to immerse themselves in the game and for a better gaming experience.

The player is also informed that they can not go back to a situation they previously answered with a choice and need to think well before answering each question. This measure is taken to prevent people from changing their decisions to preserve the idea of monitoring their first instincts.

Furthermore, it is stated to participants their inability to pause the game, as it is quite a rare feature for online games. Players are required to free their time for at least twenty minutes beforehand and are notified of such.

The two most important points mentioned in the instructions are that the game is online and is played with three other players and that the player is to collect coins that might sum up to a tangible reward at the end.

4.6.5 Jungle - Gameplay

The *Jungle* scene contains the actual gameplay. It is made up of eight different scenarios. Each scenario tests for the possibility of an individual having a specific deficit or a combination of deficits.

Once the player experiences all eight of the events, they reach the treehouse and complete the game.

For unification throughout the description of each scenario, all figures used will feature the male avatar as the player.

Whenever the player approaches an object at the start of a scenario, an exclamation mark bubble appears on top of it, **Figure 4.6** illustrates this aspect, which upon pressing starts a dialogue in the designated boxed area at the bottom of the screen.

Figure 4.6: Alert exclamation bubble.

Each scenario is mainly based on measuring one particular social processing deficit and may test for other secondary deficits; therefore, they will reference their respective deficits from **Section 4.5**.

Scenario One - Buried Coins

In this scenario, we use **NPC** *"Adam"*, the helpful one.

Upon approaching *"Adam"*, the appearing text is displayed as if it is *"Adam"* speaking and gives a hint to the player to dig in this area as he has found some buried coins before as **Figure 4.7** illustrates. The action of digging is achieved through pressing a button labelled dig. The button is only activated after the player has pressed the "Thank you!" button to ensure they have read the dialogue.

Figure 4.7: "Adam" gives hint.

After digging, the player is told, again through the fixed, boxed area, that they can earn more coins by digging some more from a third-person point of view. This telling is repeated three times after each dig. Here we use the idea of the **EEFRT** as mentioned under **Section 4.5.1**. This task is a way of measuring the level of social anhedonia of an individual. If the player chooses not to dig anymore at any given time, we hypothesized that it increases their possibility of exhibiting social anhedonia. Therefore, if they decided not to dig the first time, we add three to their possibility of exhibiting social anhedonia, then two then one each time respectively.

Before the end of the scenario, the player is asked whether they would like to leave a hint for the next player as *"Adam"* has done as a form of documenting their desire for cooperativeness as mentioned under **Section 4.5.2**. If the player chooses not to leave a hint, then a point is added to their diminished cooperation variable.

Scenario Two - Magic Well (PGG)

In this scenario, we use **NPC** *"Omar"*, which we depict as selfish and unhelpful throughout the game flow.

The player is made to believe that *"Omar"* has been waiting a while for a partner to engage them in an online game feel with real people and situations.

To play this game, the player needs to repeatedly click the button below the magic bucket multiplier in order to raise the bucket as **Figure 4.8** entails. It decreases by a small amount each second. This mini-game is added for the fun of the participant.

Figure 4.8: Magic well (PGG).

In this interaction, the player and their partner (*"Omar"*) come across a magic well. The **PGG** phenomenon is explained to them as is under **Section 4.5.1**. The amount the player might choose to invest is selected using a slider as shown in **Figure 4.9** and is a percentage of their current coin count.

Figure 4.9: PGG invest amount.

The point system affecting the increased altruistic punishment variable is divided as follows:

- If the player chooses not to invest at all, five points are added.
- If the player chooses to invest with less than ten percent, four points are added.
- If the player chooses to invest with less than forty percent, three points are added.
- If the player chooses to invest with less than seventy percent, two points are added.
- If the player chooses to invest with less than one hundred percent, one point is added.

The use of a scale system facilitates the categorizing of the severity of the deficit.

Since *"Omar"* "chose" not to invest, it acts as a clue for the player to view *"Omar"* as a selfish character and be wary of other interactions with him.

Scenario Three - Empathy (Collect Apples)

In this interaction, the participant comes across an old lady asking for help collecting the falling apples from the tree.

If the player chooses to help her, they engage in a fast-paced mini-game where they move the basket below the tree to catch the falling apples as is illustrated in **Figure 4.10**. The old lady proceeds to explain that her village has been raided, and they have not had food in a few days.

Figure 4.10: Catch falling apples.

If the player chooses to skip helping her, they are asked once more if they are sure as a means of awakening their empathetic emotions. At each answer of not helping her, a point is added to the reduced empathy variable.

Scenario Four - Cursed Forest

The cursed forest theme of the game merges two tests.

1. **Reward Bias - Forest Guard:** in this part, the player comes across a guard that dictates that to pass into the cursed forest, the participant's attentiveness needs to be tested first. This test is carried out as described under **Section 4.5.1** and measure an individual's social anhedonia.

2. **Screams of Pain:** after the player finishes the cursed forest guard's test and approaches the cursed forest, they are asked to turn up their volume for the following stage. This part of the jungle was designed to be dark and full of shadows, as **Figure 4.11** illustrates, to complement the disturbing audios accompanied with it.

Figure 4.11: Cursed forest.

Upon their exit of the cursed forest, the player is asked to rate the disturbance of the audios they heard.

The point system created by the psychologists we collaborated with and along with the results of the research this task was made to be as follows; two points were added to reduced empathy if the participant rated the audio disturbance to be less than ten percent, and one point was added if they rated them less than fifty percent.

Scenario Five - Dictator Game

The player is alerted by another **NPC** (*"Heidi"*) that there is a treasure up ahead.

The **NPC** *"Heidi"* was purposely designed to walk at a slower pace and stop the player stops to allow the participant to reach the treasure first. To open the chest, the player is given a choice to play an immersive game of a sliding puzzle of three different difficulty levels. The participant is told that the higher the difficulty, the higher the reward of opening the chest. If the player chooses the easy game, two points are added to social anhedonia; if they choose medium, only one point is added. If when playing the puzzle is deemed too hard, they can choose to skip it as **Figure 4.12** demonstrates; however, this adds a point to their social anhedonia variable.

Figure 4.12: Dictator game: sliding puzzle mini-game.

The rules of the dictator game are then relayed to the player as described under **Section 4.5.2**. The player dictates the percentage of the treasure to give *"Heidi"* using a slider, and it is evaluated as follows:

- If the player gives her less than ten percent, three points are added to diminished cooperativeness.
- If the player gives her less than thirty percent, two points are added to diminished cooperativeness.
- If the player gives her less than fifty percent, one point is added to diminished cooperativeness.

Scenario Six - Magic Well (Prisoner's Dilemma)

This interaction is similar to that of scenario two as the player comes across a magic well as well.

In this scenario, however, the player comes across a magic well alone and finds player *"Omar"* there. *"Omar"* explains that he has just played this game and tells the player that to unlock it, they need to choose one of two mini-games. He hints to the participant that the second mini-game is easier than the first. The player is then asked to rate the level of trust they have for *"Omar"* on a scale of 0 to 10 as is shown in **Figure 4.13**.

Figure 4.13: Rating trust towards "Omar".

The trust processing variable related to mentalizing deficits is altered as follows:

- If the player trusts him fully (moves the scale to a 10), three points are added.
- If the player sets the scale to greater than a 7, two points are added.
- If the player sets the scale to greater than a 5, one point is added.

The player is then required to choose one of the mini-games to play; they succumb to the same game to keep the experiment controlled. As **Figure 4.14** demonstrates, it is a simple flipped tile-matching game.

Figure 4.14: Prisoner's dilemma: tile matching minigame.

The reactivity variable related to measuring mentalizing deficits requires further calculations to alter. It is separated into two parts:

- The player chooses to play the first game.
  - If they rated their trust of *"Omar"* at less than 5, then one point is added.
  - If they rated their trust of *"Omar"* at less than 7, then two points are added.
- The player chooses to play the second game.
  - If they rated their trust of *"Omar"* at 10, then three points are added.
  - If they rated their trust of *"Omar"* at greater than 7, then two points are added.
  - If they rated their trust of *"Omar"* at greater than 5, then one point is added.

After finishing the mini-game, the player is told to wait while we fetch them a partner to partner up with for this magic well game. He is then paired up with the **NPC** *"Adam"* and is reminded of how he has given him a hint before and invested in the previous magic well.

The rules of the prisoner's dilemma game are then explained to the player as is described under **Section 4.5.2**. If the player does not put a coin, a point is added to the diminished cooperation variable.

Finally, the participant is told that **NPC** "player" *"Omar"* has not told the truth regarding which mini-game was easier and asked if that surprises them; if they answer yes, then a point is added to trust processing, indicating a deficiency there. The player is asked if they wish to leave the proper trip for the next player to, once more, measure their cooperativeness.

Scenario Seven - Empathy (Water Pipe)

This scenario is a repetition of scenario three involving the old lady and collecting apples.

In this interaction, the participant comes across a young boy asking for help fixing a water pipe to get water to his village from the river.

If the player chooses to help him, they engage in an easy mini-game where they click on the pipe tiles to rotate them and get the water flowing as is shown in **Figure 4.15**.

Figure 4.15: Water pipe mini game.

If the player chooses to skip helping him, they are asked once more if they are sure as a means of awakening their empathetic emotions. At each answer of not helping him, a point is added to the reduced empathy variable.

Scenario Eight - Ultimatum Game

In the ultimatum game scenario, the player re-enacts the dictator game but in reverse.

The participant again comes across the **NPC** *"Adam"* and is told to give him a hint of a treasure up ahead; otherwise, he might not see it. Considering *"Adam"* has helped them a countless number of times earlier, if they choose not to alert him, a point is added to diminished cooperation. However, if they decide to alert him, they are told to wait while he is being alerted to emphasize that the game is "online" and "multiplayer" based.

The **NPC** *"Adam"* was purposely designed to walk at a faster pace to reach the treasure first. To open the chest, the player is given a choice to play a light game where they need to match a grid puzzle to a picture by clicking on the tiles changing their color. **NPC** *"Adam"* advises the participant to play the first game as he reached the treasure first and knows it is easier than the second game. The player is then asked to rate the level of trust they have for *"Adam"* on a scale of) to 10.

The trust processing variable related to mentalizing deficits is altered as follows:

- If the player does not trust him at all (moves the scale to a 0), three points are added.
- If the player sets the scale to less than a 3, two points are added.
- If the player sets the scale to less than a 5, one point is added.

The player is then required to choose one of the mini-games to play; they succumb to the same game to keep the experiment controlled. **Figure 4.16** demonstrates the mini-game played.

Figure 4.16: Ultimatum game: grid matching minigame.

The reactivity variable related to measuring mentalizing deficits requires further calculations to alter. It is separated into two parts:

- The player chooses to play the first game.
  - If they rated their trust of *"Adam"* at 10, then three points are added.
  - If they rated their trust of *"Adam"* at greater than 7, then two points are added.
  - If they rated their trust of *"Adam"* at greater than 5, then one point is added.
- The player chooses to play the second game.
  - If they rated their trust of *"Adam"* at less than 5, then one point is added.
  - If they rated their trust of *"Adam"* at less than 7, then two points are added.

After finishing the mini-game, the rules of the ultimatum game are then explained to the player as is described under **Section 4.5.1**. **NPC** *"Adam"*'s first offer is an 80-20 in his favor, if the participant rejects it, one point is added to altruistic punishment. The second offer stands at 70-30, again in *"Adam"*'s favour with the same point mechanism. Lastly, the third offer of 60-40 is "presented" by **NPC** *"Adam"* and dealt with in the same manner. There is no need to further check for a 50-50 split as it is the most commonly agreed on fair split.

Finally, the participant is told that **NPC** *"Adam"* told the truth regarding which mini-game was easier and asked if that surprises them; if they answer yes, then a point is added to trust processing, indicating a deficiency there.

Tree House

Upon completing all eight scenarios, the player reaches their treehouse and is notified of their success.

4.6.6 Questionnaire

Several questionnaires were used to compare the gameplay results to actual results. This comparison helped us reach conclusive results to answer this thesis's research question.

The questionnaires used were answered at the end of the game. To encourage players to answer the questions, we integrated the questions within the game itself and stated that to display the participants' results, they are to answer a couple of questions first as shown in **Figure 4.17**. To choose an answer, the player moves the slider to the desired selection.

Figure 4.17: Questionnaire questions at the end of gameplay.

The questionnaires used are the following:

1. **The Self-Assessment Anhodenia Scale [6] (SAAS):** The SAAS exhibits adequate feasibility, reliability, construct, convergence and discriminant validity [6].

   From the twenty seven-item self-assessment scale, we chose the questions related to social anhedonia. The scale identifies these to be six of the total twenty-seven questions. However, by the advice of professional psychologists, two of them were eliminated:

   (a) ***"Do you enjoy playing with children?"*** This question was not used since some individuals may not favour children, which could contrast with the results of social anhedonia testing.

   (b) ***"Do you enjoy going to parties?"*** We also eliminated this question because some people may have never been to a party.

   Each item has three ten-point likert scales: **intensity** (from *a lot* to *not at all*), **frequency** (from *always* to *never*), and **change** (from *the same as before* to *less than before*). The higher the score, the higher the rating of social anhedonia. However, we only included two of these scale; the **intensity** and **frequency** ones as the **change** scale is redundant to our research.

2. **Cooperativeness and Competitiveness Personality Scale [10] (CCPS):** present research validated the construct and criterion validities of the **CCPS** in a social dilemma context [10].

   Our research uses the behavioural and affect competitiveness questions that best fit the fields it tests for through gameplay. These make up five of the total questions asked at the end of the gameplay. Furthermore, the wording of the statements was slightly changed to accommodate all age groups, such as changing the term "at work" to "projects."

   The items are classified on a scale of seven points ranging from 1 (*do not agree at all*) to 5 (*totally agree*). To simplify the analysis phase, we flipped the scale so that 1 corresponded to *totally agree* and 5 to *do not agree at all* and started the scale from 0 instead. Furthermore, to unify the wording of the scales with the rest of the used scales, the scale used ranged from 0 (*strongly agree*) to 6 (*strongly disagree*) hence becoming a six-point scale.

3. **Basic Empathy Scale [14] (BES):** this survey is a tool that has been used to assess empathy in young people and adolescents based on this dual-component conception [30].

   The questions in the **BES** questionnaire are divided into affective and cognitive. This study uses the ones listed under effective relative to our research, which sums up to five.

   The ratings use a four-point scale (0 - strongly disagree, 1 - disagree, 2 - neither agree nor disagree, 3 - agree, 4 - strongly agree). Similarly to the previous scale, we started the scale from 0 instead of 1 to help with the analysis process.

4. **The Multidimensional Mentalizing Questionnaire [17] (MMQ): MMQ** is a useful measure of mentalizing deficits as it shows satisfactory psychometric properties and a theoretically relevant factor structure [17].

   This questionnaire includes various questions to detect many of the subcategories that fall under the particular deficit. This study only tackles two categories; reflexivity and distrust. Hence the questions were chosen accordingly.

   The response format was on a four-point Likert scale which was modified to match that of the **BES** to unify the wording used in the whole survey.

Please refer to **Appendix A** to view the different questionnaire questions included in the game along with their scale point systems.

4.6.7 Results

The results that appear to participants are those of the questionnaire, not the gameplay. The questionnaire results were used not to give possibly false answers as the game is still in the experimental phase.

Each social processing deficit being tested for is stated, and a small paragraph explaining what each of them is. Then on a spectrum of low to a high possibility of an individual exhibiting a specific deficit, it is marked to players their score according to their answers to the questionnaire questions. **Figure 4.18** illustrates an example of the displaying of results.

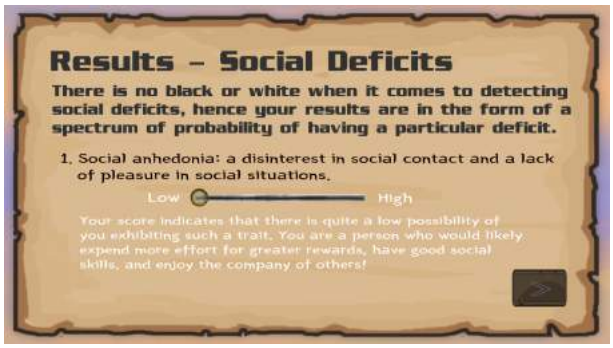


Figure 4.18: In game results.

4.6.8 Credits

In the *Credits* scene, we give our thanks to the participants and include some details about the game developers, researchers and supervisors.

4.6.9 Rewards

The game depends on rewarding the player afterwards with a tangible prize, such as discounts in the *SWVL* transportation application, to encourage them to focus and invest in the gameplay entirely. The rewards are required because many of the tests used include money-making decisions, hence the need for reflection in real life. The use of this reward mechanism is done to get the results to be as accurate as possible. If no rewards are available at the moment, the player is told so, but again, in the end, not to discourage them.

4.6.10 Timeout

The game ends after a specific interval of time (thirty minutes) to support the idea of it being deployed online. The player is informed that all of the other players have finished the game and that they can play it again because their responses were not recorded.

4.7 Functionality

The game runs on personal computers only and is deployed on an online gaming site, **itch.io**, to facilitate the testing process. The player is supposed to use the keyboard keys to control and interact with the simulated environment generated.

The game controls are kept simple by using the keyboard arrows to move forward in the jungle. As for the decision-making, they are done by clicking over the answer.

Chapter 5

System Evaluation

5.1 Data Collection

We collected a wide range of data to aid in our analysis. This data includes user information, gameplay results, and survey results. Each of the previous categories includes a number of variables that were sent to *MongoDB Atlas* and saved in a database form then be exported using *MongoDB Compass* in a **CSV** form.

The variables that makeup user information are as follows:

- Age
- Gender
- Education level

The variables that make up gameplay results and survey results are as follows with the respective maximum scores for each:

- **Social anhedonia**
  - Gameplay: eleven points
  - Survey: eighty points
- **Diminished cooperativeness**
  - Gameplay: eight points
  - Survey: thirty points
- **Reduced empathy**
  - Gameplay: six points

  - Survey: twenty points

- **Trust processing (mentalizing deficits)**

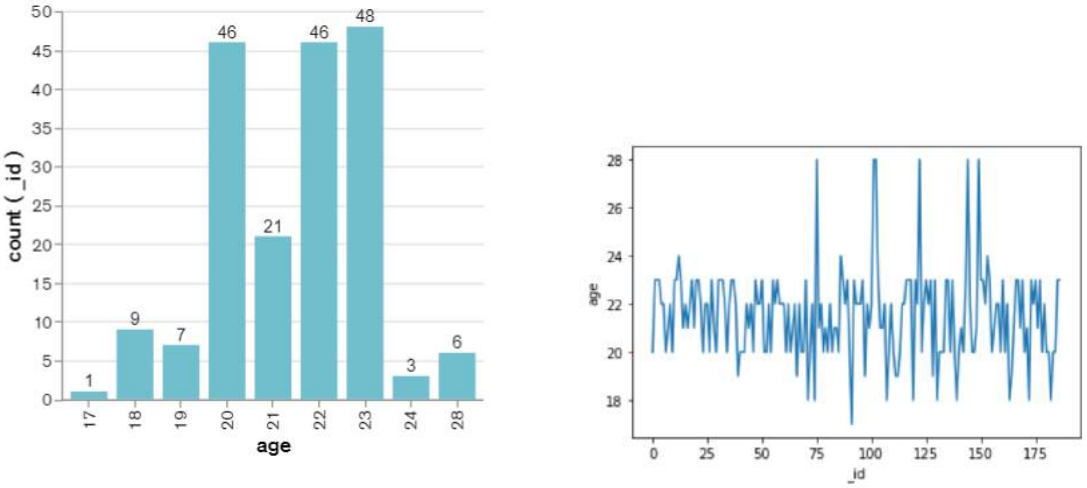
  - Gameplay: eight points
  - Survey: twelve points

- **Reaction processing (mentalizing deficits)**

  - Gameplay: six points
  - Survey: twelve points

5.1.1 Participants

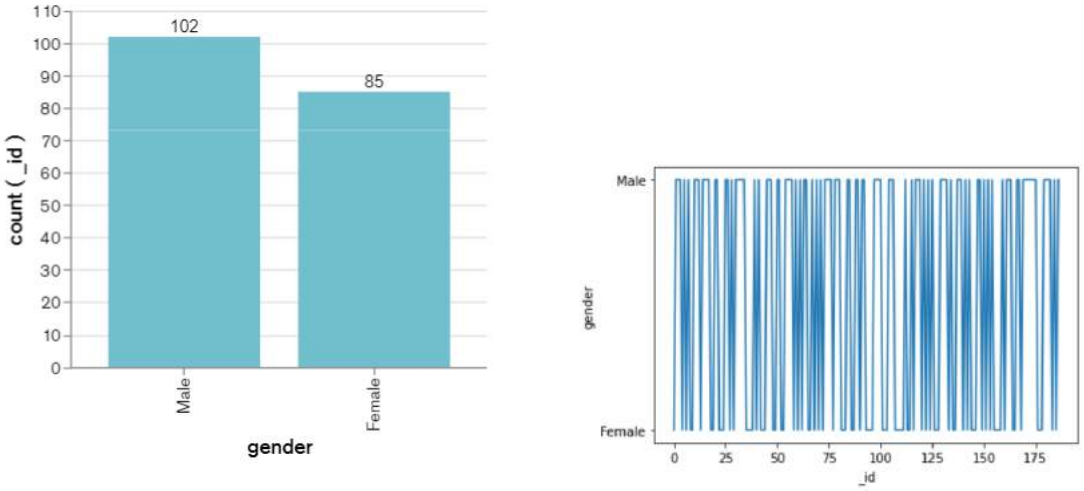
One hundred eighty-seven people played the game. The mean age was 21.5 years, and males of age 23 years mostly used the game. Most of the people were university students, which was expected considering the mean age. **Figures 5.1, 5.2 and 5.3** show the different grouping and distributions of each of the collected participants data.



(a) Age grouping.

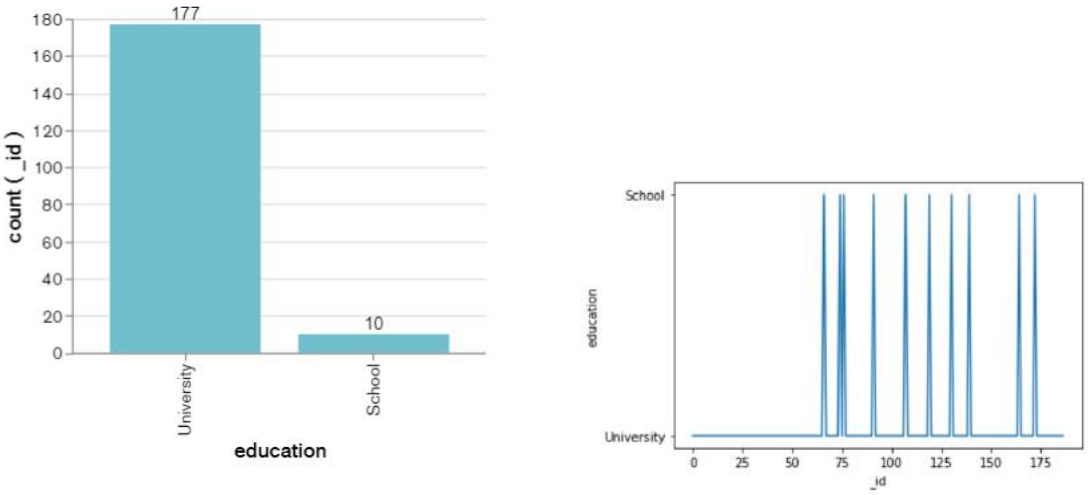
(b) Age distribution.

Figure 5.1: Participants' ages.



(a) Gender grouping. (b) Gender distribution.

Figure 5.2: Participants' genders.



(a) Education grouping. (b) Education distribution.

Figure 5.3: Participants' ages.

5.2 Data Analysis

5.2.1 Methods

- First and foremost, to compare the two different sets of data, a conversion was needed. Each of the scores a participant got through either gameplay or survey questions was converted to an equivalent of 100. We then statistically analyzed our

data and compared the inferred results to those resulting from the questionnaires' taking.

- We equalized, with the approval of psychologists, the game and survey results that were within a margin of difference of ten points. Since we wanted to deduce trends or infer results in an exploratory manner, a ten percent margin is acceptable.[31] This scale was chosen upon a basis of comparing the different values and deducing that this margin preserves the results shown to the player. To further elaborate, this ten-point scale still allowed the data to remain within the same range of the possibility of an individual exhibiting a particular social processing deficit.

- After considering the previously mentioned aspect and plotting the data, we realized that the survey results and gameplay results had converging highs and lows; however, the peaks were not at matching levels. This problem was observed in all deficits being tested for, except for the trust processing deficits. To overcome this, we multiplied the game results by a factor tailored to each deficit to even the peaks. This factor was derived using the standard deviation, a measure of the amount of variation or dispersion of a set of values [32], of each deficit's gameplay data set and survey values data set. The lower value was then divided by the higher, and the resulting decimal was used as the factor used to even out the fluctuations of both data sets. In case of future work and analysis, the factors for each deficit need to be re-calculated till we decide on a conclusion regarding this project. Using this technique to match the values further suggests that the point systems used need to have their values modified, according to the factor mentioned, for later use.

- For comparing the data sets, regression along with correlation coefficients and the coefficient of determination are used.

  - Regression analyses are a set of statistical processes used in statistical modelling to estimate the relations between one or more explanatory variables and a dependent variable. The dependent variable is the game data set results measured against the independent variable being the survey value data sets. A linear regression approach is a model for comparing scalar response and one or more dependent variables. For an explanatory variable, "simple linear regression" is the term used to refer to this linear approach. [33]
  - Correlation coefficients assess the relationship between two variables. The relationship can be linear, monotonic, or linear but in the opposite direction. The variables cannot change at the same rate in a monotonic relationship.

    Three methods for calculating the correlation coefficient exist; Pearson correlation method, Kendall Tau correlation method and Spearman correlation method. In this investigation, the Pearson correlation coefficient is applied. The covariance of two variables is divided by the product of their standard deviations to produce this coefficient. This correlation evaluates the linear connection of two variables. The coefficient of the Pearson correlation ranges

from +1 to -1. The value 1 shows a linear correlation between x and y variables. The value 0 shows no link between the variables x and y. The value -1 indicates that the variables x and y are inversely proportional. The Pearson correlation coefficient is also called as Pearson product-moment correlation coefficient. [34]

– The coefficient of determination, R2, is used to analyze how a difference in a second variable can explain differences in one variable. R-squared expresses the percentage variance in y explained by x-variables. The determination coefficient, R2, is similar to the R-correlation (correlation coefficient). The correlation coefficient formula tells how strong a linear relationship there is between two variables. R-Squared is the correlation coefficient, R, squared (hence the term r squared). [35]

It is worthy to note that the tasks related to the deficit of altruistic punishment have not been included in the analysis since, as mentioned before in **Chapter 4**, previous researches support them, and studies [7] to be effective, and the scales used were taken from them as such.

5.2.2 Tools Used

The *Jupyter Notebook* is a free and open-source web tool for creating and sharing live code, equations, visualizations, and text documents [36]. It was used to analyze the data using machine learning through *Python*. Machine learning is a computer field that makes it possible to help computer programs learn from past experiences and to improve how specific tasks can be carried out using statistical techniques [37].

Python is a general-purpose programming language so that it can be used for many things. *Python* is used for web development, **Artificial Intelligence (AI)**, machine learning, operating systems, mobile application development, and video games [38].

Along with using *Python* as the programming language, we also used a few packages to help with the analysis:

1. **pandas:** *pandas* is a fast, powerful, flexible and easy-to-use, *Python* programming language based as a data analyzing and handling tool [39]. *pandas*' DataFrame class uses Corr(), a function that computes three different correlation coefficients between two variables using one of the approaches listed: Pearson, Spearman and Kendall Tau. These methods calculate the correlation coefficients between +1 and -1. [34]

2. **Matplotlib:** a large library for making static, animated, and interactive infographics in *Python* [40].

3. **Sikit-learn:** a free software machine learning library for the *Python* programming language [41]. It features various classification, regression and clustering algorithms. *Scikit-learn* is largely written in *Python*. Also know as *Sklearn*, it integrates well with many other *Python* libraries, such as *Matplotlib* for plotting and *pandas* data frames. *Sklearn* is used to plot the line of regression and to calculate the correlation coefficients and the coefficient of determination.

5.2.3 Results and Discussion

The likelihood of a person having a specific shortage is measured on a spectrum or scale [42]. This scale probability is what we intended to collect from the game data. Our goal was to find a positive, linear correlation between the gameplay data sets and survey values to help find an answer to whether or not serious games can be used to detect social processing deficits.

1. **Social Anhedonia:** the factor calculated for social anhedonia was 0.85 and helped the gameplay and survey data sets to match almost completely as **Figure 5.4** entails.

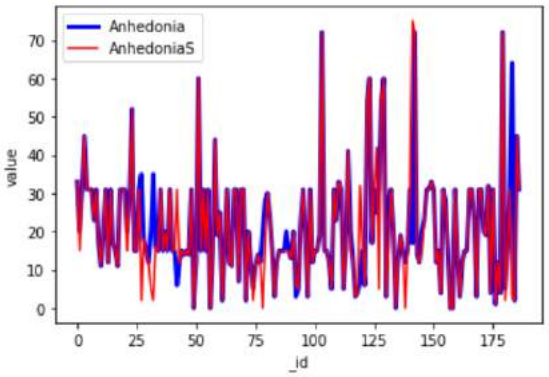


Figure 5.4: Plotting of social anhedonia values.

After plotting the line of regression, we found the value of the coefficient of determination to be at 0.7 as **Figure 5.5** entails. This number corresponds to a seventy percent match of the social anhedonia scores collected through gameplay and the survey results. For most cases, a value of 0.7 is considered a satisfactory result and resembles great significance [43]

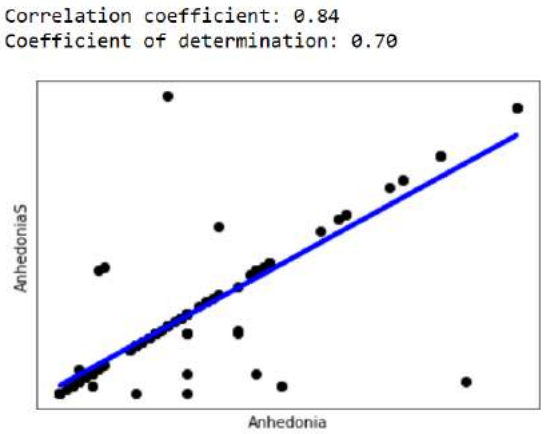
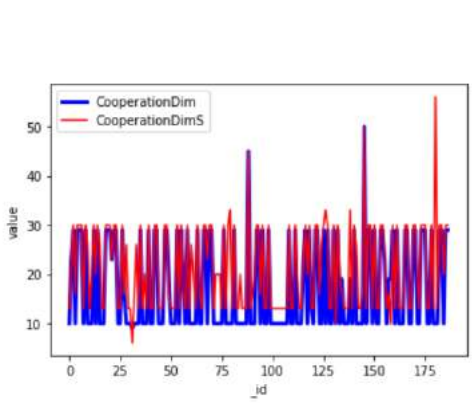


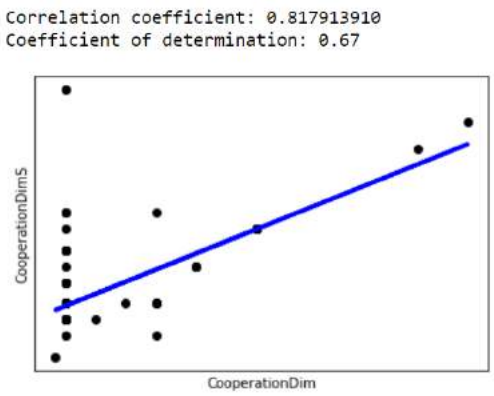
Figure 5.5: Plotting of social anhedonia regression.

2. **Diminished Cooperation:**

   As is shown in **Figure 5.6**, all the gameplay data related to diminished cooperativeness was multiplied by a factor of 0.79 to even out the extremities. The plotted regression model helped us calculate a matching percent rate of 0.67, similar to that of social anhedonia. This value entails that the gamified tasks of these two deficits were accurately (by an average of 70 percent) carried out to test for the mentioned deficits.



(a) Plotting of diminished cooperation values.



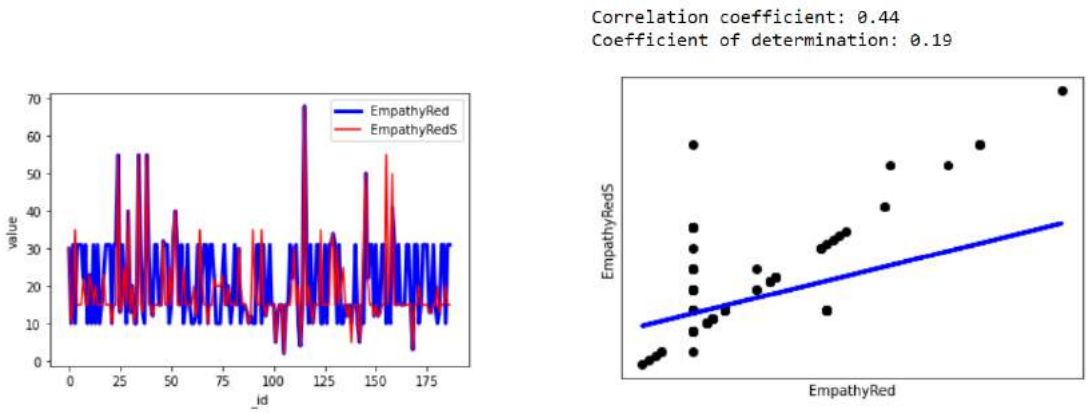
(b) Plotting of diminished cooperation values..

Figure 5.6: Analysis of diminished cooperation.

3. **Reduced Empathy:**

   The factor used here was of value 0.63 and was computed as previously explained in **Section 5.2.1**. The regression fit, shown in **Figure 5.7**, had a coefficient of determination of 0.19. An R-square as low as 10 percent is generally accepted for

humanities and social sciences studies because human behaviour cannot be accurately predicted. Therefore, a low R-square is often not a problem in studies of the previously mentioned fields. [44] We believe that the reason behind the failure of the tasks to detect reduced empathy with high conformity is the lack of actual players present in the scenarios.



(a) Plotting of reduced empathy values.

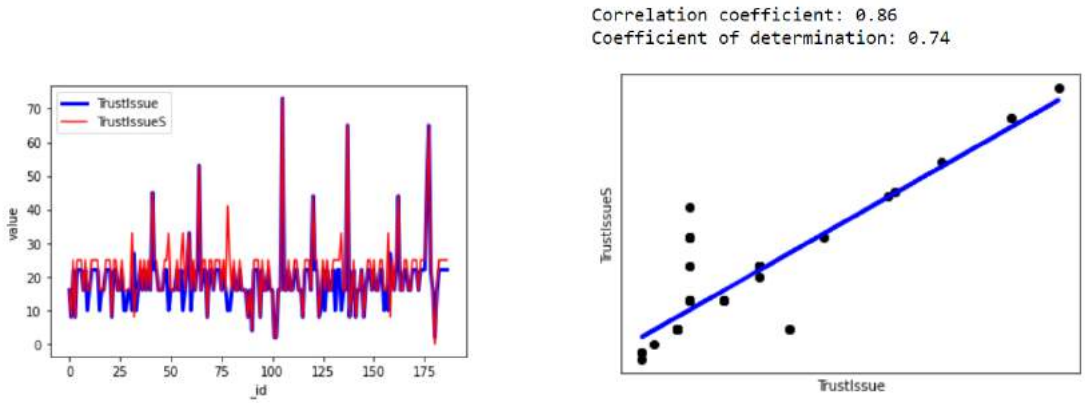
(b) Plotting of reduced empathy values..

Figure 5.7: Analysis of reduced empathy.

4. **Mentalizing Deficits:**

- **Trust Processing:**

  The data sets' peaks were already aligned enough for trust processing and did not need to be adjusted. **Figure 5.8** is used to illustrate our findings. The r-square value was 0.74. When the coefficient of coordination value is 0.12 or below, it indicates a low correlation of the data; if it is between 0.13 to 0.25, then data correlation is mildly accurate; 0.26 or and above values indicate high effect size [45]. Hence, the gamified tasks carried out to measure trust processing succeeded by 74 percent.

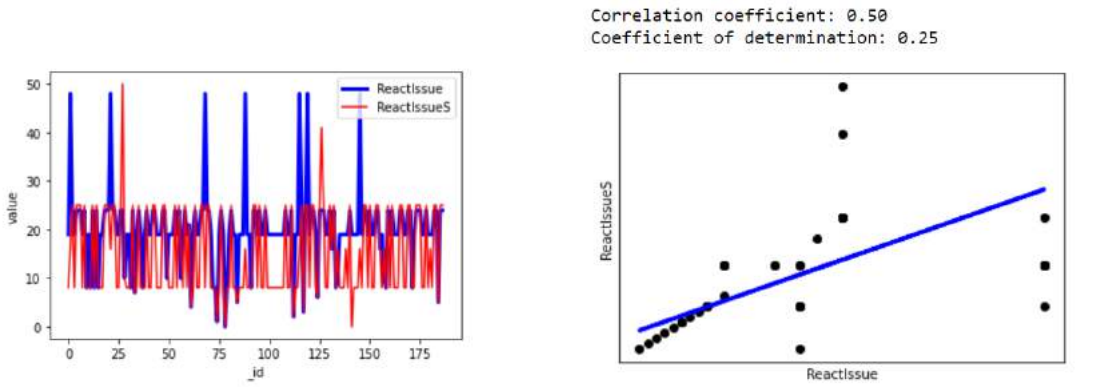


(a) Plotting of trust processing values.

(b) Plotting of trust processing values.

Figure 5.8: Analysis of trust processing (metalizing deficits).

- **Reaction Processing:**
  In **Figure 5.9**, the graph of values does not conform to both data sets on top of one another, even with the help of a 0.89-factor multiplier. Hence, it was no surprise that the coefficient of determination was relatively low, at 0.25. However, just because effect size is small does not necessarily it is unworthy of being interpreted [43]. We believe the low-value results from a scarcity in the tasks implemented to measure this deficit.



(a) Plotting of reaction processing values.

(b) Plotting of reaction processing values..

Figure 5.9: Analysis of reaction processing (metalizing deficits).

5.3 Limitations

While performing the system evaluation, we faced some challenges, which are represented in the following points:

- How individuals react to different genders should be studied and reflected in the game as it may influence their decisions differently.
- The basic empathy tasks had no feel of real players, and we believe it to be the reason behind why the values did not match. Therefore, these tasks may need to be emitted or reworked.
- **Access to organizations:** finding an organization where doctors and psychologists accept the idea of trying an experimental game on patients with recorded social deficits was hard to find. Hence, the game was not tested on anyone with a diagnosis.

Another possible limitation could have been that people can lie about how they will act in social situations; however, this is not necessarily related to the gamification process of such tasks as they would lie if asked in person too.

Another wide misconception is that people can lie in simulations related to altruistic behaviour as it is a positive characteristic, and people can show bias with measures for self-reporting; however, the behavioural paradigms used together have the added benefit of measuring actual behaviour within a social situation [7].

Chapter 6

Conclusion and Future Work

We have proposed a serious game to detect the presence of social processing deficits in individuals. A game with one storyline level was developed in order to reach that. Throughout the gameplay, the player is constantly tested based on reward, evaluative and empathetic systems. We then conducted a study made up of questionnaire questions and actual gameplay to test and collect and analyze the results.

This tool was tested out with 187 participants, and when we compared the inferred game results with that of the questionnaires they were asked to fill, they matched with an average percentage rate of 70.3 percent after emitting the results of reduced empathy and reaction processing due to their significant difference from the rest of deficits. This match rate is exemplary [46] considering that as the data set size grows, so does the percentage.

The game is believed to be an effective intervention tool. Although many pieces of research addressed social processing deficits, little has been carried out to develop a game that helps detect them. This factor was the biggest motivation to carry out this study. The game used as an alternative to traditional diagnosis allows individuals to understand what social processing deficits they might be suffering from and be encouraged to seek professional advice on what to do next.

There exists a vast amount of social processing deficits, and in this study, we only focus on a select few. We can confidently say that we believe this game to identify the presence of the previously discussed deficits in individuals. However, there is a lot to explore still, and we hope that the publishing of this study will encourage more researchers to look into this exciting field.

We plan to work on some improvements to the game. First, players should be notified that the displayed results are those of the questionnaire so as not to be disbelieving. Along with that, players need to be made aware of a couple of other things, including the inability to star mini-games without reading and acknowledging the instruction by pressing all the required buttons. Second, we will add more scenarios to the game to further help support our hypothesis. Third, we will gamify other tasks involving "real"

players and use them to measure reduced empathy since the lack of other "players" biased the data collected. Fourth, we plan to add more ways to detect reaction processing to try and reach more conclusive results regarding this deficit. Finally, we will continue carrying out the online testing and collection of data in order to reach an even more significant conclusion regarding our thesis.

Appendix

Appendix A

Questionnaire

SAAS

The items are rated on a two ten-point scale ranging from 0 ("a lot") to 10 ("not at all") and from 0 ("always") to 10 ("never").

The higher the score, the more of a possibility of the individual of exhibiting social anhedonia. The maximum score is 80 points.

1. **Do you enjoy going for a walk?**
   a lot □—□—□—□—□—□—□—□—□—□—□—□—□ not at all
   always □—□—□—□—□—□—□—□—□—□—□—□—□ never

2. **Do you enjoy being with your family and friends?**
   a lot □—□—□—□—□—□—□—□—□—□—□—□—□ not at all
   always □—□—□—□—□—□—□—□—□—□—□—□—□ never

3. **Do you enjoy meeting new people?**
   a lot □—□—□—□—□—□—□—□—□—□—□—□—□ not at all
   always □—□—□—□—□—□—□—□—□—□—□—□—□ never

4. **Do you enjoy people you love kissing or embracing you?**
   a lot □—□—□—□—□—□—□—□—□—□—□—□—□ not at all
   always □—□—□—□—□—□—□—□—□—□—□—□—□ never

CCPS

The items are rated on a six-point scale ranging from 0 ("strongly agree") to 6 ("strongly disagree").

The higher the score, the more of a possibility of the individual of exhibiting diminished cooperativeness. The maximum score is 30 points.

A. Behavioural

5. **I would usually consider the interests of both parties in two sided situations.**
   - ☐ Strongly agree.
   - ☐ Somewhat agree.
   - ☐ Agree.
   - ☐ Neutral.
   - ☐ Disagree.
   - ☐ Somewhat disagree.
   - ☐ Strongly disagree.

6. **I can stand in other peoples' shoes to consider their interests.**
   - ☐ Strongly agree.
   - ☐ Somewhat agree.
   - ☐ Agree.
   - ☐ Neutral.
   - ☐ Disagree.
   - ☐ Somewhat disagree.
   - ☐ Strongly disagree.

B. Affect

7. **Working with other people makes me happy.**
   - ☐ Strongly agree.
   - ☐ Somewhat agree.
   - ☐ Agree.
   - ☐ Neutral.
   - ☐ Disagree.
   - ☐ Somewhat disagree.
   - ☐ Strongly disagree.

8. **I like collaborating with team members in a project/at work.**
   - ☐ Strongly agree.

- ☐ Somewhat agree.
- ☐ Agree.
- ☐ Neutral.
- ☐ Disagree.
- ☐ Somewhat disagree.
- ☐ Strongly disagree.

9. I enjoy helping others so we can all achieve common success.

- ☐ Strongly agree.
- ☐ Somewhat agree.
- ☐ Agree.
- ☐ Neutral.
- ☐ Disagree.
- ☐ Somewhat disagree.
- ☐ Strongly disagree.

BES

The items are rated on a four-point scale ranging from 0 (”strongly disagree”) to 4 (”strongly agree”).

The higher the score, the more of a possibility of the individual of exhibiting mentallizing deficits. The maximum score is 20 points.

10. My friends’ emotions don’t affect me much.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

11. After being with a friend who is sad about something, I usually feel sad.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

12. I find it hard to know when my friends are frightened.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

13. Other people's feelings don't bother me at all.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

14. My friends' unhappiness doesn't make me feel anything.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

MMQ

The items are rated on a four-point scale ranging from 0 ("strongly disagree") to 4 ("strongly agree").

The higher the score, the more of a possibility of the individual of exhibiting reduced empathy. The maximum score is 24 points.

A. Distrust

15. I often think about why things happen.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

16. I find it beneficial to analyze other people's behaviour.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

17. I am a thoughtful person.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

B. Reflexivity

18. I am interested in understanding my mental processes.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

19. I find it beneficial to analyze my behaviour.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

20. I am able to reflect on my behaviours.

- ☐ Strongly disagree.
- ☐ Disagree.
- ☐ Neutral.
- ☐ Agree.
- ☐ Strongly agree.

Appendix B

Lists

SAAS	The Self-Assessment Anhodenia Scale [6]
CCPS	Cooperativeness and Competitiveness Personality Scale [10]
BES	Basic Empathy Scale [14]
MMQ	The Multidimensional Mentalizing Questionnaire [17]
PGG	Public Goods Game
EEFRT	Effort-Expenditure for Rewards Task
AWS	Amazon Web Services
CSV	Comma Separated Values
GCP	Google Cloud Platform
API	Application Programming Interface
IoT	Internet of Things
HTTP	Hypertext Transfer Protocol
NPC	Non-Player Character
AI	Artificial Intelligence

List of Figures

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