

Enjoyable sustainability video games for neurodiverse people

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Due to their potential in educational/medical settings, video games have been developed for neurodiverse people frequently in the form of serious games that intend to reduce what are considered “flaws” of the individuals. Although serious games can provide entertainment, the lack of focus on “fun” often results in a predominantly medical-oriented database of games with little to no entertainment value. Furthermore, games directed towards neurodiverse people often base themselves on neurotypical norms and ideas, causing misappropriated games, constituting a problem as this minority ends up being deprived of a much-needed human right (Article 27, UDHR¹). As such, our objective with this work is to create an entertaining video game, focused on the theme of sustainability and specifically designed with and for neurodiverse people. In this work, we applied a co-design approach methodology based on previous studies [4, 5, 7, 15] engaging with 4 institutions across Europe and 60 PID to design and implement a video game considered fun for the population. We used a procedure of 5 CDS each one focused on a design topic: sustainability, video game preferences, narrative, gameplay, and accessibility. We obtained results that highlight features of games considered “boring” or “fun” for the population and identified accessibility struggles/strengths that should be considered when designing a video game for PID. Furthermore, we created a game design, implemented a prototype that incorporates the results, and tested it with the population to assess its success regarding entertainment value.

Additional Key Words and Phrases: Video game, Neurodiverse people, Sustainability, Co-design, Player Experience

1 INTRODUCTION

In the past two decades, social movements such as the “Autistic Rights Movement”, influenced and reshaped psychiatry, generating new studies and concepts concerning individuals with learning disabilities. The emergence of new concepts, such as neurodiversity, has indicated a shift in how these disabilities are perceived and the approach to treating them.

Neurodiversity doesn’t define any singular “correct” way of thinking but rather regards learning disabilities as a distinct variation of the neurotypical brain. Neurodiverse people can sometimes struggle when interacting with others or the world due to their distinctive approaches to thinking and decision-making. While the concept of neurodiversity has existed for some time, its societal adoption is relatively recent. Given that these individuals represent a minority, it can be challenging to find and provide means for sustaining their quality of life (entertainment or otherwise) due to their scarcity and occasional oversight.

Simultaneously, there has been a surge in the video game industry, with a growing number of individuals, including children, teenagers, and adults, dedicating their time to this form of entertainment. Although the industry is relatively new it has delved into the concept that games can serve to entertain, educate, and develop skills across multiple areas. Video games often place the player in

specific scenarios, effectively simulating and controlling situations as though they were real.

1.1 Problem and Objective

Video games have been frequently employed by researchers to assist various groups, such as PID (part of the neurodiverse community), in the past [19, 28, 31]. However, studies that primarily focus on creating entertaining games, rather than just helpful, and especially those co-designed with the population are scarce[28]. Serious games are games in which the main purpose is not that of entertainment and constitute the core of video games designed for this target audience.

Consequently, the objective of this thesis was to study and develop a video game centered around entertainment with social and environmental sustainability in mind. This project worked in parallel with the “*ALL SUSTAINABLE*” project and in partnership with *CerciOeiras*², which provided the co-design subjects and aided in the methodology’s construction/execution of the CDS.

2 RELATED WORK

In this section, multiple researched works are described in order to understand previous studies on the subjects surrounding the aforementioned problems, themes, and methodology.

2.1 Neurodiversity

The concept of neurodiversity has been highly discussed in the past, but there is still much controversy surrounding it. Neurodiversity is a term that aims to change the social model of disability by suggesting that the defects attributed to the group of people commonly identified with intellectual disabilities are mere differences in the brain of individuals [4, 13, 15, 20, 28] and that the common grounds for accessibility often exclude this minority due to the misunderstanding of this concept. It uses as a basis the premise that the deemed faults of the individuals come from a place of general assumption of means for supporting basic needs [28] and that being neurodivergent “[...] *simply means being ‘wired’ in a different way rather than ‘wrongly’*” [2].

2.2 Neurodiversity and Video Games

Looking into the current research works on video games for this target audience, a constant pattern can be found in regard to the creation of serious games with the medical purpose of diagnosing and decreasing what are seen as flaws for this group of people [1, 6, 8–11, 14, 24]. Serious games are often the chosen platform to engage with neurodiverse people as they tend to prioritize extrinsic values over entertainment.

The work from Zheng et al. [31] makes a review of works designated for the neurodiverse community, in this case, specifically ADHD. This work aims to identify, analyze, and review research conducted to support and correct problems associated with this

¹ *Universal Declaration of Human Rights*, <https://www.un.org/en/about-us/universal-declaration-of-human-rights>

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² *CerciOeiras*, <https://www.cercioeiras.pt/pt>, December 26, 2022

neurodivergence through the use of serious games. Previous works like that of Spiel et al. [28] have studied this problem by discussing the lack of entertainment-focused HCI games in the neurodiverse community and what steps developers should take to prevent it.

2.3 Video Game Design Principles

Due to the video games market success, their increase in popularity has also generated a need for designing and evaluating video games inducing the creation of multiple works aiming to study and provide the best tools for achieving the entertainment value needed to make a successful game [17, 18, 23, 25, 26, 29].

One concept of game entertainment evaluation is that of heuristics [17, 18, 26] which intend to evaluate games by using a framework that details which aspects a game must have to be considered fun. This method consists of a grid with several criteria that a game evaluator uses to analyze which game features consist of a theoretically wrong approach. Other discussed methods are that of costs vs benefits [?] that discuss the means of evaluation of a game by comparing what negative and positive points a game brings to the user. This method is based on evaluation directly from the players and is useful for a more late evaluation when a prototype is already created. Furthermore, regarding the topic of concretely designing a video game for the neurodiverse population, the work from Tomé et al. [29] studies possible design principles to create a game for this target audience. The main concepts of this study consider the following categories as staples for the design: Interface, User Control, Identification with the game, Feedback, Transmission of Concepts, and Accessibility.

2.4 Sustainability and Video Games

The concept of sustainability has been highly discussed in the past due to its naturally diverging definition that is deeply associated with each individual's perception of the environment surrounding them [3, 7, 12, 21, 27, 30]. Biggemann et al. [7] work reinforces this by stating that to properly assess what sustainability means, co-design procedures must be conducted with the target population, as it allows to better determine what the population needs to become sustainable. Other works studied refer to the education of sustainability through the use of video games [16, 21, 22] and their potential to test, teach, and showcase what sustainability means for the world currently. These works study how allowing players to control the infrastructure of a city over a period of several in-game years can help people understand what problems and concepts the current society is facing, inspiring them to think about how to solve these problems and what they can do to reduce them.

2.5 Co-design

One topic that is discussed during the work of Spiel et al. [28] is that of co-design. The authors mention how most research works developed towards neurodiverse individuals often exclude the population from the design process, leading to a wrong interpretation of their preferences and needs. When correctly structured, co-design increases the success of a project by providing more positive and meaningful experiences to its population.

One work that supports that correct structured co-design is the D4D Framework created by Benton et al. [5]. Using the TEACCH program as a basis, the study provides a framework that can help researchers design PD methodologies when working with neurodiverse children, focusing on the neurological condition's strengths instead of struggles. The addition to the framework of Bayor et al. [4] also adds to this tool with their Competency-based design. Similarly, the work from Piedade [15] studies how inclusive robots can promote inclusion between neurodiverse and neurotypical children, co-designing with the population. Both these works contain valuable guidelines for structuring a co-design methodology that reinforces the target audience to formulate their wants and needs, offering more accurate results regarding what they deem important.

3 METHODOLOGY

For the methodology of this work, we took the suggestions regarding the neurodiverse community from the previously discussed authors and planned 5 co-design sessions (CDS) that allowed us to fully understand what an enjoyable game means to this population. For each of these CDS, we established an important topic on which the session would take basis in order to explore all the concepts described in the previous chapter. Due to our partnership with the "All Sustainable" project, we were aided by the project's partners in the process of design and implementation of the sessions. For this work, we consider that CDS 2 and 4 were the most important, and as such will focus the detailing of the methodology on these two.

The topics of each CDS were as follows:

- CDS1: Characteristics of the sustainability and independent living challenges. This session focused on defining what sustainability is for our target audience, using a set of themes and allowing the participants to vote or suggest those that they preferred to discuss, or felt were more relevant to them.
- CDS2: Collaborative vs. competitive games. In this session, participants were able to play up to 10 games of different genres and evaluate which they liked more, which they liked less, and why.
- CDS3: Narrative, scenario, and characters in digital games. This CDS focused on allowing participants to write a story with a set of characters and scenarios, allowing them to express what they felt was an engaging story.
- CDS4: Rules, dynamics, game progression, and gamification element in digital games. In this session, participants were able to take on the role of a game developer and create their own game. They were aided by a game developing kit created by us and were asked to build a simple game design using the created story from the previous session.
- CDS5: Accessibility: What's good for me in a game? This last session asked players to evaluate a set of elements for their accessibility and what preferences they had regarding what they would see in the game.

3.1 CDS2

This session was focused on the participants playtesting multiple games from different genres, player modes, and devices to understand their preferences and skills in regard to the various games.

It was important that this session was focused on practical activities to better analyze the enjoyment of the participants across all games in a direct manner. As such, facilitators were tasked with observing the reactions or lack thereof from the participants when playing the presented video games. As mentioned, our team participated in person in the session's implementation at CerciOeiras.

To prepare for the session, the facilitators divided the participants into 5 groups and assigned one facilitator per group. Each facilitator was assigned 2 games and tasked with learning their instructions/playing them to help the participants with their games during the session. This helped the facilitators solve questions the participants might have had during the game or even explain controls and objectives when they were not clear during play.

To allow each group to play the prepared games, different digital stations were prepared. Each station had one game and the necessary hardware and software to properly run it. During the session, each group would play a game for a certain amount of time and then move to the next station to continue the activity.

To properly test the different game genres, 10 games were chosen in total. These games were chosen by their genre, player category, accessibility, and availability in the partner countries. The chosen games were *Plants vs. Zombies 2* (Strategy, Single-Player, Touch device), *The Curse of Monkey Island* (Point and Click, Single-Player, Computer Mouse), *World Craft* (Casual, Single-Player, Keyboard and Mouse), *With You* (Puzzle, Cooperative, Keyboard), *Hammer Dingers* (Party, 4-Player, Controller), *The Sims Mobile* (Simulation, Single-Player, Touch device), *The Legend of Zelda: A Link to the Past* (Adventure, Single-Player, Keyboard), *Temple Run* (Action, Single-Player, Touch device), *Super Mario Bros.* (Platform, Single-Player), and *Rocket League* (Sports, 4-Player, Controller).

Each of these games was supported with two documents aiding the facilitators in playing them and a custom questionnaire regarding the objectives previously mentioned.

To start the session, the participants were separated into the previously planned 5 groups and assigned a starting station. Each group played for a determined amount of time, switching between members of the group controlling the game.

During the gameplay of each group, the corresponding facilitator for that session observed and reported the observed reactions, comments, and problems while playing the game on the game's corresponding questionnaire.

When all groups finished playing the first 5 games, the participants were asked to fill out a preference questionnaire.

After the first session of video games finished, the stations were changed and altered to have the new list of games ready for the go. Again, the same process was used for this second section of the activity where the groups would play a game for an amount of time and then rotate to the next session until they played all the games.

At the end of this second session, the facilitators wrapped CDS2 by collecting the opinions from the participants and briefing the plan for the next CDS.

3.2 CDS4

This session was focused on developing a prototype design for a game using a 'Game Design Kit' describing elements such as the

mechanics of the game, the rules of the world, and the characters in it.

To help the participants create their own game, we created a 'Game Design Kit' that simplifies the design key points into more approachable activities. This kit includes a set of cards, guidelines, and questions that aid the participants in each of the design key points. This kit will be detailed in the following paragraphs.

Using the video game 'Super Mario Bros.' as a reference, the kit consists of a set of 9 printable cards and 4 panels that belong to multiple categories of key points (identifiable by their colors) with a picture detailing the chosen key point and a subtitle with its name. It also contains guidelines for the facilitators to help the participants navigate through the activity and a set of questions that deepen the creation of the key points.

The cards and panels created for the kit are the Player Card (main character/player), Action Card (available actions/mechanics in the game), Effects Card (effect of an action), Victory Card (how to win the game or progress through a level/phase), Rewards Card (rewards received when exploring, completing a certain task, or finishing the game), Defeat Card (how to lose the game or fail in a level), Penalty Card (punishments received when fail occurs), Character Card (characters present in the game), Object Card (interactable/important objects), Level Panels (examples of easy and difficult levels), and Storyboard Panels (sequence of actions and effects).

Because the designing activity relied heavily on creativity, each partner could either divide the participants into small groups (3-4 people) or let them work alone depending on their skills. After explaining the details of the activities the participants started working on the design for the game using the cards and guidelines.

The first part of the activity consisted of creating the player/main character based on what the participants had chosen in the previous session. Participants also had the choice of drawing their characters on paper or describing them through words. After finishing the character, the participants were asked to paint their cards in the same color as the player category - light blue.

After finishing the first part, the participants were then asked to move on to the next cards - the action and effect cards. Similarly, participants were asked to think about actions their main character could have and what effect they would have on the world. The action and effects card parts of the activity were executed simultaneously to simplify these 2 mechanics since they are correlated in nature. This decision was made to aid with the process of action-creating avoiding the production of meaningless actions in the design.

When finished with the action-effect part of the activity, the participants moved on to the other parts. The process was repeated similarly for every section combining the following cards in the same activity: Victory - Reward; Defeat - Penalty; Character - Object.

Whenever necessary, participants could ask for the aiding questions to help in their designing process.

The level section of the activity was executed differently from the previous ones. To create a level, participants were asked to use the previously created cards and design a scenario where some of them would be needed simultaneously. To create an easy level, it was suggested that participants use fewer cards and reuse the same card multiple times in different ways. To create a difficult level the

opposite was suggested: participants should use more of their cards simultaneously.

Lastly, participants were asked to draw storyboards. The objective of this part of the activity was for the participants to more closely specify how the player would solve the challenges presented to them in the created levels.

The next section consisted of the participants sharing their cards and what mechanics and rules they created for the world.

Finally, the last activity for this session required that participants be divided into large groups (5-6 people). Participants were asked to use their cards and create a new game with everyone's ideas. Participants could opt to use all of their cards or discard some of them to create a game that worked for the whole group. This activity had the objective of collecting their preferred actions, effects, victories, etc..., while creating a game that had different views and outputs from everyone. The facilitators were tasked to observe their reactions and arguments as to what features should be in their game and how they made the final decision.

When finished with the activity, participants were asked to fill out a questionnaire regarding their satisfaction with the session. Facilitators were also tasked with filling out a report regarding what game each group had come up with and what common features, patterns, or comments the participants described in them.

To evaluate the kit being used, professionals were tasked with filling out a questionnaire detailing the clarity of the kit, efficacy in explaining the tasks to the participants, and methodology of the procedure during the session.

4 ANALYSIS

Due to each partner having a different results document, the sessions' results were all summarized into one final document with the combined conclusions of all partners. Our team contributed in writing and analyzing the results obtained from CDS 2 and 4.

To analyze all the collected results, we used both quantitative and qualitative research methods such as questionnaires, surveys, observation, and focus groups. Because there was a high volume of results from the CDS, we divided each topic into categories and sub-categories that could help determine what similarities and differences each result had from the others. The following sections detail the summarized results obtained from CDS 2 and 4, alongside the respective analyzed conclusions.

4.1 CDS2 Findings

Due to the unavailability of some games in the partner countries, each partner chose a set of games that were most suitable for their situation but maintained the critical aspects to be tested by the participants. As such, the charts and graphs showcased represent the most played/voted games of all institutions according to genre.

For all played games, some highlights and negative points were noted by the facilitators and our team whenever possible. These points offer a more detailed overview of each game's positive and negative aspects in regard to PID. Due to the high volume of comments and annotations, we will only discuss the ones we feel are more relevant to this work.

From all the collected opinions and forms, there are specifically 3 games that stand out: "Plants vs Zombies 2", "Super Mario Bros" and "Fall Guys". The first 2 games were the highest-voted games as well as the ones where most comments were given, while the 3rd one stands out due to its high rate of dis-likeability.

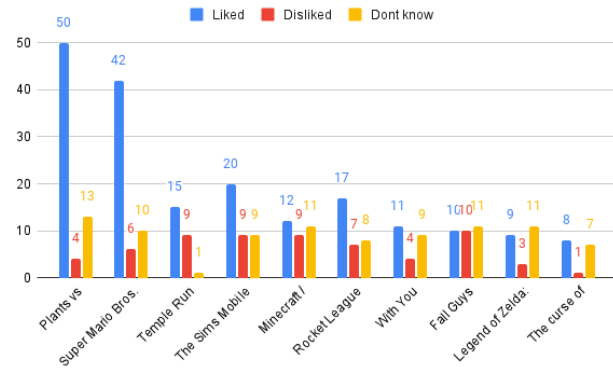


Fig. 1. Games likes and dislikes collected from questionnaires

Regarding the most liked genres, these are somewhat consistent with the highest-voted games with the most preferred genres being 'Platform', 'Puzzle', and 'Strategy' and the most disliked genres 'Casual' and 'Party'. The devices chosen were spread across the 3 types of used inputs which suggests that there is no device in particular that this target audience prefers. Finally, the most voted player mode was the cooperative mode, which suggests that our study's population enjoys playing together with other people over playing alone or against.

4.2 Plants vs Zombies 2

Regarding "Plants vs Zombies 2", it was clear that the simplicity of its tutorials and mechanics was a positive component of the participants' playthrough. They were easily guided through the game's instructions due to their icon-based nature (instructions were given by showcasing a hand clicking/dragging/pointing to the intended mechanic and showcasing the effect afterward) and emphasis on those icons bringing attention to them. Whenever the tutorials relied on written instructions rather than the use of icons, players would lose themselves in the tutorial and have a short moment of confusion.

It was also notable that the players appreciated the simplicity of the game, but some had some difficulty in strategizing their playthrough. More often than not these players ended up simply choosing random locations for the plants and completing the first levels due to their beginner-friendly nature. When advancing through the game, participants registered more frustration due to the added complexity of the levels, not understanding what they were doing wrong. Plants that had more visual mechanics such as the peashooter (shoots projectiles) and potato mine (explodes) were more easily comprehended than those who had not such as the wall-nut (blocks the zombies' path).

Although this is true, players showed high amusement and motivation in playing the game. One of the speculated reasons for this entertainment value is the constant presence of available tasks and things they could do/observe/interact with. If players were not placing plants, they were collecting items floating around on the screen or observing the constant game feedback in the background such as projectiles, explosions, and combat between zombies and plants.

At the same time, the screen's user interface was reduced, so players tended to focus more on the game and less on the interface when playing. Accidental clicks in the user interface seldom occurred and players were able to more easily interact with the gameplay elements.

4.3 Super Mario Bros.

Due to the game being played on a web browser by most of the partners, players who experienced the game in this way had to play with the keyboard, which made the game more difficult for the participants as they had to handle smaller and less accessible inputs. However, the comments of participants and answers to the questionnaires seem to reinforce that this game (regardless of the controls) is still appealing to this population.

Similarly to "Plants vs Zombies 2" this game needed almost no explanation from the facilitators. The rules were clear and the game's feedback was very helpful in letting the players know what they were doing wrong and what they were doing right. Although players had difficulty in reaching the end of the first levels, the players clearly showcased their enthusiasm whenever a goal was achieved. This happened as well with regard to frustration when they died, failed a jump, or lost a superpower. This is a positive point because it tells us that players were able to perceive their goals and mistakes whenever playing the game.

4.4 Fall Guys

In regards to "Fall Guys", the players report having difficulty in moving the character which led to frustration and boredom with the game. They felt like the controls were easy to understand but they did not have enough skill and/or coordination to move forward through the level. Facilitators also report that players often died but did not understand that, and kept trying to play the game (upon death, Fall Guys allows the player to become a spectator so they can continue watching the other players). This was deemed confusing for the participants since they would get frustrated when the character they thought they were controlling, was not reacting appropriately to their inputs.

Two positive points to note are those of the enjoyment of competition and the colorful graphics of the game. Facilitators noted that players became excited when hearing about the prospect of competing against each other and the players reported enjoying competing against their colleagues. The graphics of the game were considered attractive due to their vibrant and 'happy' colors, but, although enjoyed, were considered too abstract, and sometimes players could not interpret where they would have to go or what they could interact with.

4.5 CDS4 Findings

This session brought a multiplicity of games with different features that reflect all the effort put in by the participants. Below is presented a summary of the results collected during this CDS for each of the previously mentioned sections.

Regarding the player, because the player/main character characteristics were discussed in the previous session, some partners asked the participants to add more features to these characters to expand them. All participants mentioned having a customizable character. This could be an added value in the game since many PID mentioned the appreciation for this possibility.

Regarding actions and effects, the created actions and effects varied depending on the type of protagonist selected by the participants. Regular characters usually have actions and effects related to the countryside, while sports characters have actions and effects related to their sport. The majority of the participants considered it important that the main character should be able to talk with other people/animals.

Regarding non-playable characters and objects, the other characters identified were considered to either be supportive of the protagonist or enemies. These characters are typically in the form of animals, such as dogs, horses, and sharks but also in the form of imaginary beings such as plastic and oil monsters. When "regular" characters were protagonists, participants typically chose objects that served as crucial tools to the main character. In more extraordinary environments, participants described various objects. They mentioned accessories, gadgets, weapons, and elements that could aid the player, such as high-tech smartwatches, oil-collecting backpacks, and weapons.

Regarding victories and rewards, the victory elements of the game varied greatly depending on the participants' gameplay and scenarios. Two tendencies were observed during this section: human characters typically would win a level/game when they could get to a specific location or complete a certain task and superhero characters would win a level/game whenever they saved a victim/planet from a catastrophe. The rewards identified were either symbolic reinforcements, such as quality points, stars, and more lives, or concrete objects that could be useful in real life, such as coins, instruction books, or maps.

Regarding defeat and penalties, many of the described defeat elements relate to the inability of the character to do something requested in the game, such as not being able to arrive at the destination, not finishing something on time, or not doing a good job at their workplace. The penalties described mostly referred to the main character losing access to something, such as their tools, collected rewards, or superpowers. Finally, in the case of some stories, a penalty would be something bad happening at their work/main activity, for example, disqualification from their team, damaging their harvest, or their business.

The beginning of the game was very specific for each of the stories. Typically, participants imagined the start of the game with the character at home, in their territory/environment, or doing the activities of their normal life. The characters get motivated to act when they see bad things happening to their environment and loved

ones (nature and animals damaged), acquiring powers later during the game.

The level creation part of the session was considered by participants and facilitators to be the most difficult section, so not all groups were able to complete it. For the groups that did, we can summarize the description of the levels as follows: easy levels typically had only one objective, easy obstacles to overcome, and fewer enemies and tasks while difficult levels had more obstacles, enemies, challenges, and bad events such as natural disasters or catastrophes.

Regarding the gameplay, similarly to the designed levels, this part of the session was one of the most difficult ones, so not all the groups completed it. The options proposed included gameplay sequences such as running over obstacles and getting rewards, finishing a task and leveling up, reaching agreements and gaining new resources, and helping someone and gaining a new ally.

5 GAME DESIGN

From the gathered results, we designed a game that matched the topics, themes, and aspects collected from the participants.

The following sub-chapters detail each component of the game and why they were chosen for this game design.

5.1 Themes

The chosen themes for the game are in line with the most talked about themes during the CDS1 and the discussed themes for this project. For the game, there were two main sustainability pillars discussed: environmental and social sustainability. These pillars were touched upon using the sub-themes of independent living and the sub-themes of active citizenship.

There is another pillar touched upon in this game, albeit less than the others due to its complexity and difficulty in reaching this specific population: economic sustainability. The main character is able to collect components during their challenges/tasks that may be used later to create/improve gadgets. These gadgets will be used by the player to complete challenges and each one will offer its unique features. The economic aspect of this gameplay component is that the players have to make decisions regarding their gadgets that involve negative or positive impacts on the other themes of the game.

5.2 Story

The story for the game results from the various common story components suggested by the participants during CDS 3 and 4.

The game starts with a big catastrophe that plunges planet Earth into a state of constant disruption, leading to its continual deterioration and the generation of subsequent catastrophes that exacerbate the issue. A team of scientists believes that they can find a solution in a certain amount of days, but unfortunately, analysis of the current planet state suggests that doomsday will arrive before that.

As inhabitants of planet Earth, our objective is to influence other people to take active measures in their day-to-day lives that help the planet extend its life by a few more days. These measures include being self-sustainable such as producing their own food, socially-sustainable such as being an active citizen in their community, and environmentally-sustainable such as saving energy and water.

Because our main character is meant to be a regular person with a limited reach, they influence people through social media, by posting about their practices and encouraging people around the world to do the same in order to save the world.

5.3 Gameplay

The objective of the game is to save the planet by extending its lifespan (days left until doomsday) in order to give enough time for a group of scientists to find a solution to the problem.

To reach this objective, the main character must complete challenges that positively impact the social and environmental status of the world and influence other people to do the same. The planet's status is correlated with the planet's "well-being", and completing these challenges allows it to survive for more days than initially predicted.

The difference made by these challenges is directly correlated to the number of followers that the player has. More followers means that more people will be acting a certain way and the impact of their actions will be more significant. The player will have to juggle between what is necessary for the world to survive and what is necessary for their own comfort while taking into account that their followers will be influenced by them.

The challenges are chosen by the player and each one has a set of attributes that affect the player's gameplay such as time to complete challenges, amount of environmental/social/economic sustainability points received and number of followers gained. All challenges are different in nature and correspond to one of the discussed sustainability sub-themes or to interesting topics that we wish to bring awareness to.

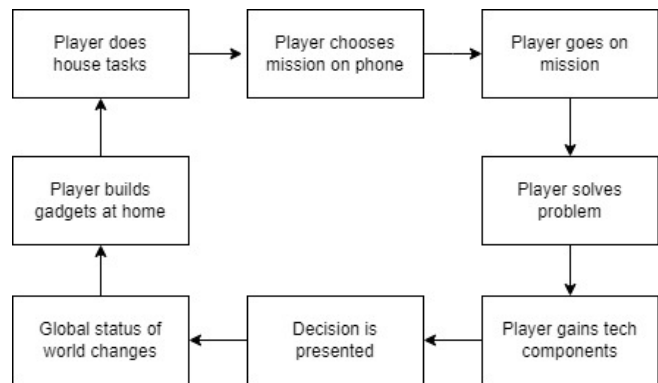


Fig. 2. Main game loop of the game

There are three types of challenges: house, community, and world challenges.

House challenges pertain to the independent-living theme and involve tasks in which the player must complete a to-do list within an amount of time in order to have a comfortable and healthy life. These challenges are the only ones that cannot be chosen by the players and have direct negative consequences in case of failure. To fail, the player must ignore the challenges during their respective deadline which results in the respective challenge consequence.

These challenges serve the main purpose of introducing the players to the concepts of self-sustainability and independence.

Community challenges involve the community and are available in a wide range of sustainability themes. These challenges often pertain to the active citizenship theme and can be started by striking up a conversation with the neighbors, or through their messaging app. The purpose of these challenges is to showcase how people can help their community grow by being active, social, and role models for others.

World challenges involve more abstract concepts of sustainability. These challenges represent the concepts and problems that are often depicted through the news and media, but that are less noticeable/present in most people's day-to-day lives. Concepts such as floods, fires, the global warming effect on the polar ice caps, and poverty are depicted in these challenges and offer the possibility for players who have never been in contact with these concepts to have some kind of experience with them. Their purpose is to raise awareness of problems that exist around the world and suggest actions that the player can do to help contribute to their improvement.

5.4 Interface and devices

Per the obtained results this game will be available on two main devices: mobile and computer. Due to the preference for touch/click inputs and the difficulty in dragging and pressing, the game design is constructed in a way that requires the player to execute short clicks/touches to do everything, avoiding the need for continuous presses and slides.

According to the story, the player has access to an in-game mobile phone that contains their home to-do list (house tasks), a messaging app between their neighbors (community challenges), a forum app where they can see online requests for help (world challenges) and their social media app where they can post their status/comments/photos and influence people around the world.

Similarly, the interface also contains the current day, the days left until doomsday, and the current sustainability state of the world.

To move the character the player clicks the screen and the character walks towards that point. To start tasks, the player must click their phone and navigate through their text messages/forums or directly speak with neighbors by clicking on characters with an exclamation point above them. To complete tasks the player must follow the on-screen instructions and challenge demands.

Besides this, the interface was designed based on the use of symbols and drawn elements instead of text whenever possible. Situations where text is necessary are accompanied by a text-to-voice option that allows the player to listen to what is written.

The graphics for the game are simple, realistic in a cartoonish way, and colorful as per the collected preferences of the study participants.

6 RESULTS

To test our game design we developed a game prototype with some of its main components such as the challenges, challenges game loop, gameplay graphics, and chosen input, and conducted a short experiment with 9 PID. The total of participants for this test was 3

participants from CerciOeiras and 6 from *Amica*³. This experiment was fully conducted by us both in CerciOeiras, with no interference from a facilitator, and in *Amica*, with small interference from a facilitator who translated the player comments.

For this experiment, we collected the results differently depending on the institution. In CerciOeiras we placed the participants in a room together and allowed the players to decide who would play the game. At the end of the experiment, the players filled out a quiz detailing what parts of the game they liked the most and what/how they would change the ones they disliked. At *Amica*, the participants were shown the game in groups of 2 and decided who would play the first half of the game and who would play the second. The players were given a short introduction of the game objective, instructions on how to begin playing, and aid whenever necessary. In this case, the data was collected only by observation and comment annotation.

For the 3 participants in CerciOeiras, it was noted that the players began the game with some confusion regarding what to do. All players managed to move the main character in the game, although with some lack of understanding of how the input worked. The mobile phone present in the interface of the game was also ignored and the players needed help with understanding how to move further in the game. After being given a hint about the importance of the mobile phone, the players were able to play the game mostly without aid (it was necessary to read out loud the text since there were no voice-overs implemented at this point).

The challenges and tasks that would appear throughout the game would be easily noticed and solved by the players. One challenge to note in particular was a challenge where the players would have to divide a set of 4 garbage pieces into their corresponding recycling containers. This challenge sparked a conversation between the players and was regarded as more difficult than the other ones since they would need previous knowledge to solve it. One thing to note is that challenges that presented choices were considered to be the most

The 3 players managed to beat the game on their first try and while one participant was answering the questionnaire, the other 2 continued playing in the background by their own choice. As can be observed in figure ?? two challenges were the most successful ones regarding entertainment value: 'walk the neighbor's dog' and 'vote'. The first challenge is simple but has much more visual interaction than the other challenges which may have captivated the players more. The second challenge required the players to think about the consequences of their vote, which sparked a conversation between them. On the opposite side, we can observe that the 'recycle' challenge had the most dispersed opinions. This challenge in particular was talked about between the players with the participants who enjoy more difficult gameplay liking it, and the ones who don't disliking it. This challenge required that the player had some previous knowledge about separating garbage and recycling it which may explain the diverse opinions.

In *Amica*, this didn't happen. Since players were given instructions at the beginning of the game, they managed to move through its start more easily and completed the game faster. They were given some aid at the beginning of each challenge to understand what

³ *Amica*, <https://amica.es/es/>, October 19, 2021

Prototype Test Results

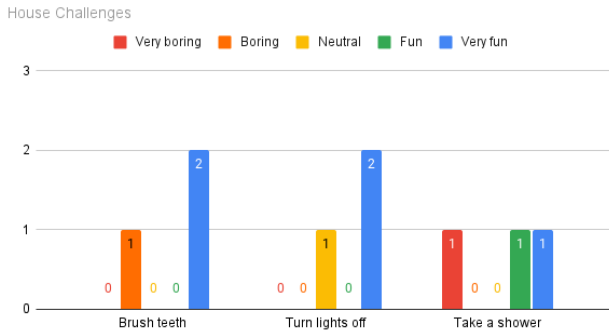


Fig. 3. Rank of house challenges

Prototype Test Results

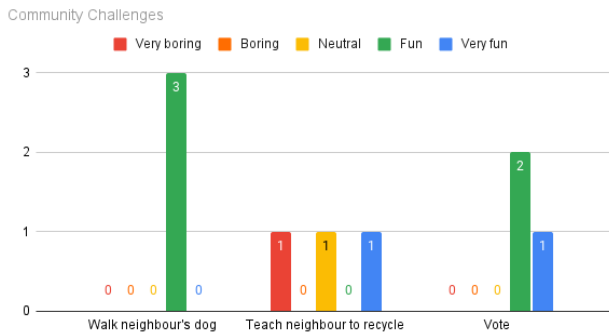


Fig. 4. Rank of community challenges

Prototype Test Results

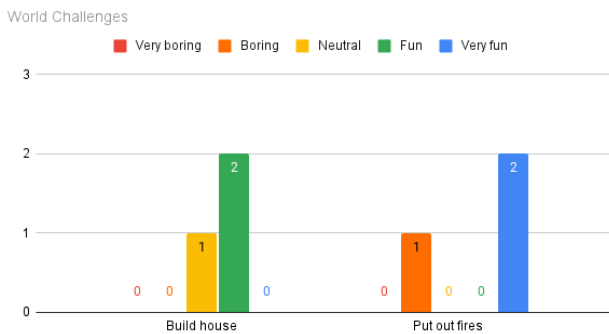


Fig. 5. Rank of world challenges

to do, and as such had no trouble understanding them. One thing to note is that the players in Amica had more trouble finding the challenges. Challenges that were placed outside of the house and required some exploration were difficult to find and the participants needed help in locating them. These participants only played the

game 1 time, since they would rotate between each group to play the game.

Some results that were congruent among all participants are the lack of understanding of the importance of time and state of the world in the game, how to use the phone applications, how to correctly move the character (players would try to drag the character instead of clicking the screen on where they wanted the character to go), and how to start the challenges (players would click the indicator arrow instead of the object). Although this is true, 2 of the players report finding the game accessible and appropriate for their skill level which may stem from the lower difficulty of the prototype regarding the challenges.

This prototype was also tested by a group of facilitators, educators, and therapists who considered the game to have an overall positive message and fun gameplay.

6.1 Results discussion

From the collected data we were able to identify some positive aspects of the game, and some negative points to take into consideration.

It is pertinent to say that when not given clear instructions on what to do, the players demonstrated confusion and even some boredom when they couldn't figure out where to start. This is congruent with our results from the CDS and is supported by the opposite reactions from the players who were given instructions.

One interesting thing to note, however, is that the lack of instructions in some participants might have caused them to have a different playstyle than those who did not. Players who were not given instructions explored the world more and were able to be more independent once they understood what to do, while players who were given instructions had trouble figuring out the next step once it was not obvious to them. The second type of player relied more heavily on the facilitator, needing constant advice and help from them.

This particular difference also seems to have affected the participants' enjoyment of the game. The first type of players started the game confused and somewhat bored but slowly became more excited and interested once they knew what to do. They became more chatty and started relying more on each other to solve the challenges and help the main character reach the end. It seemed to be also obvious to them that they would have to finish all challenges for the game to end.

For the second type of player, the enjoyment seemed to be constant throughout the game. By observation, the players seemed to be satisfied but were more focused on following the instructions given by the facilitator and not as much on enjoying the game and reaching the end. It was not obvious to them that they would have to solve everything to finish the prototype.

Some analysis that can be extracted from these results is that the players seem to benefit from a certain level of abstraction of the instructions. Feeling that they were able to figure out a problem by themselves prompted players to demonstrate more enjoyment, independence, and curiosity for what they could do in the game and consequently more playability. However, it is also important to note that the players only felt this kind of enjoyment after we

brought the interface to their attention. Before that, the players demonstrated boredom, confusion, and disinterest in the prototype.

Another important result to bring to attention is that of the game difficulty. While most participants found the game to be fun and entertaining, one described the game as 'too easy'. This player commented that the difficulty of the game decreased their enjoyment of the prototype. The other participants had almost opposite comments to make. Challenges that were considered more difficult were not as fun as the others and they preferred easier challenges. One solution we would offer to this is that of adjustable difficulty. Since not all players have the same cognitive capabilities, it might make it more accessible and fun if the game allows the player to choose how difficult they want their challenges to be.

Concerning the results regarding the lack of understanding of the importance of time and the state of the world (sustainability points) we may attribute this problem to the unclear interface and unfinished implementation of the time system. Since we were not able to include the final interface graphics in this prototype, we used placeholder graphics that displayed all the important elements necessary for the gameplay. The graphic elements were not in accordance with the co-design results and as such reduced the probability for the participants to be able to perceive their purpose. Regarding the lack of the time system, the same can be said. Since these mechanics were unfinished, it was more difficult to understand their importance and why the player should care about them. The time system is also very correlated to the story of the game, which was not explained or demonstrated to any participant.

Regarding the difficulty in understanding the input of movement in the main character, we suggest that the movement should have more input or be more visual. Having an indicator marking the spot where the character is moving or even adding onscreen controls such as visual joysticks might help mitigate this problem.

Finally, regarding the overall enjoyment of the game, all participants report having enjoyed their time with the prototype (figure 6), feeling like they learned something new, and considering that they contributed to the final design in some way (figure 7). Although the data we collected from observations reinforces this, it's important to hear the direct opinion of the players since the concept of enjoyment varies from person to person and can be hard to perceive for someone on the outside.

One other analysis is of the educational value of this game. The participants showcased an understanding of what the challenges meant regarding sustainability and reported having learned something from the game that they previously weren't aware of.

We can conclude from this analysis that although deemed fun by the players, to be more enjoyable the game should provide optional help, a more intuitive interface and controls, and a small level of abstraction regarding what, in what order, and where the player should go. If possible it should provide multiple difficulty levels that can be adjusted by the player.

It is important that players feel some independence over what they can do in the game and that they feel challenged in solving problems but not as much to not be able to move on.

Despite all of this, we considered that the study was successful in creating a game that was considered enjoyable for neurodiverse people and that the results obtained offer important and useful

Prototype Test Results

Was the game fun?

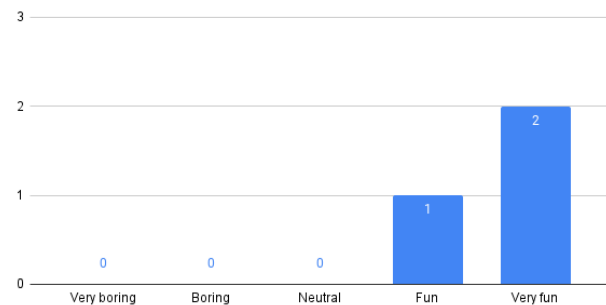


Fig. 6. Evaluation of the entertainment value of the game from 1(very boring) to 5(very fun)

Prototype Test Results

Do you feel that you contributed to the game design?

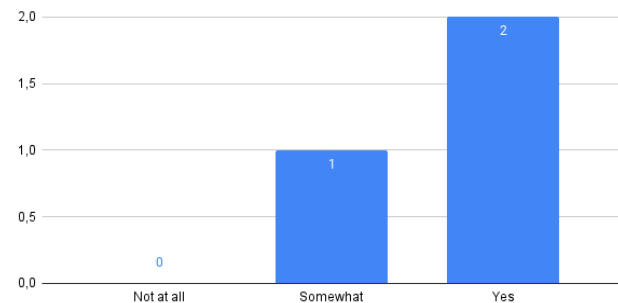


Fig. 7. Evaluation of the perceived contribution from the participants for the game design

guidelines for developers who want to develop a fun game for this target audience.

7 CONCLUSION

In this work, we have studied how to make enjoyable games for neurodiverse people and PID with the themes of sustainability and a co-design approach. We have developed a game design from the methodology described in this document and the results were considered positive in regard to the question proposed in this study: "How to make an enjoyable/fun game for neurodiverse people?", with a plethora of results supporting that this group of people have certain requirements/preferences that allow a game to become more enjoyable for them. We had successful results in regard to our prototype and players report having fun while playing it.

We believe that our main contributions are our guidelines on the CDS, mainly CDS 4 where we provide a starter kit that allowed our target audience to design a game and our results regarding what makes a game fun for this target audience. Besides this, we contributed to creating a neurodiverse-oriented game design considering the results of the conducted sessions, a first prototype of

this design, and the results of its test that showcase the efficacy of the design. Although this work had some limitations, the main one being the high volume of participants, we believe that with this study, we have created a set of tools that allow further research on making games that have entertainment value for this population, as well as other possible target audiences that could benefit from a co-design methodology.

For future research, we suggest that lengthy CDS be divided into two different days so that the participants are not tired and provide more accurate results. We also recommend that the prototype created from the results of the CDS be tested multiple times with the participants, reworking it to create a better game, and finally tested with an unbiased population to avoid conflict of interest. If there are facilitators aiding in the sessions, a previous workshop in preparing and collecting data for the study should be provided so the results are not tainted by third parties. Finally, we recommended that the data collection be better adapted to the population to allow them to give concrete and correct results.

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