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# Interaction Design Applied to the Design of Sensory Integration Experiences

MASTER DISSERTATION

**Tiago Leonardo Aguiar Teixeira**

INTERNATIONAL MASTER OF INTERACTIVE MEDIA DESIGN



UNIVERSIDADE da MADEIRA

*A Nossa Universidade*

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SUPERVISION

Mary Alejandra Luiz Barreto

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# Abstract

Therapies and treatments for autistic children have always been a challenging to set up due to the difficulty of diagnosing properly their difficulties and correctly addressing these. In fact, the spectrum comprehension changed over the years to a more accurate diagnosis. Thus, nowadays, treatments are more successful. Autism Spectrum Disorder (ASD) is a complex neurological disorder that information processing, social interaction, and communication. Attending to multiple cues present in the environment is demanding and might lead to a child not responding to a stimulus which, according to some researchers, might be a central aspect of ASD.

Play-based therapies (gamification) have been one of the most fortunate approaches in achieving better results in developing cognitive and motor skills. Autistic children are increasingly exposed to technology in their daily lives, and digital games have been yielding more impact in this area since the last decade.

In fact, studies demonstrate that autistic children engage more easily with technology than with people because of their impairments. Designing games for autistic children can be challenging, since as users, they may process information differently compared to a typically developing child. Therefore, many factors must be considered and conceptualized with their difficulties in mind (e.g., colors, sounds, mechanics, interface, levels) to keep the user engaged in the task.

Since autistic children are interested in technology, video games might be a promising way of multiple cue treatment and developing their cognitive skills.

**Keywords:** Autism Spectrum Disorder · Game Design · Interaction Design · Pivotal Response Treatment · Conditional Discrimination · User Experience Design

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# Resumo

Terapias e tratamentos para crianças autistas têm sido sempre um desafio devido à natureza do problema. A compreensão do espectro mudou ao longo dos anos para um diagnóstico mais preciso. Portanto, nos dias de hoje, os tratamentos são mais bem-sucedidos. O Transtorno do Espectro Autista (TEA) é uma desordem neurológica complexa que afeta o processamento de informações, interação social e comunicação. Atender a múltiplos estímulos presentes no ambiente é exigente e pode levar a uma criança não responder a um estímulo, o que, segundo alguns investigadores, pode ser um aspecto central do TEA.

Terapias baseadas em jogos (gamificação) têm sido uma das abordagens mais bem-sucedidas para desenvolver habilidades cognitivas e motoras. Crianças autistas estão cada vez mais expostas à tecnologia em suas vidas diárias, e jogos digitais têm tido mais impacto nessa área desde a última década.

De fato, estudos demonstram que crianças autistas se envolvem mais facilmente com a tecnologia do que com pessoas, devido às suas limitações. O design de jogos para crianças autistas possa ser desafiador, pois são utilizadores que podem processar informação de maneira diferente comparado com outra criança com um desenvolvimento normal, por isso muitos fatores devem ser considerados e conceptualizados pensando nas suas dificuldades (por exemplo, cores, sons, mecânicas, interface, níveis) para manter o usuário envolvido na tarefa.

Visto que as crianças autistas têm interesse na tecnologia, os videojogos podem ser uma forma promissora de tratamento com múltiplos estímulos e desenvolvimento de suas habilidades cognitivas.

**Keywords:** Transtorno do Espectro Autista · Design de Jogos · Design de Interação · Tratamento de Resposta Pivotal · Discriminação Condicional · Design de Experiência do Utilizador

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## Lista de Acrónimos

**AAC** Augmented and Alternative Communication

**ABA** Applied behavioural analysis

**ADHD** Attention deficit hyperactivity disorder

**APPDA** Associação Portuguesa para as Perturbações do Desenvolvimento e Autismo

**ASD** Autism Spectrum Disorder

**DSM** Diagnostic and Statistical Manual of Mental Disorders

**NDBI** Naturalistic Development Behavioral Interventions

**PDD** Pervasive Developmental Disorder

**PDD-NOS** Pervasive Developmental Disorder Not Otherwise Specified

**PRT** Pivotal Response Treatment

**SI/SP-T** sensory integration/sensory processing treatment

**UI** User Interface

**UX** User Experience

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## 1 Introduction

Autism Spectrum Disorder (ASD) is a complex neurological condition that affects the way a person communicates, interacts, and processes information. Children with autism are characterized by social and communication deficits, attention problems, repetitive or restrictive behaviors, and poor performance in motor coordination skills. Those impairments vary in different levels from one individual to another, they do not develop at the same rate, and their needs can differ a lot, that is why autism is an intricate subject, also is unlikely to find one one-size-fits-all solution that may help these people.

Autism can manifest in different ways and at different stages of life, but usually, the symptoms start to show by 12 to 18 months of age. The sensory system (sight, hearing, touch, smell, taste, vestibular and proprioception) might be affected and expressed in different ways, some individuals may be hypersensitive, typically they try avoiding those stimuli which can be overwhelming, or they may be hyposensitive, in that case, they may seek those kinds of stimuli [1]. Not only the senses are impaired, but communication and social interaction can also be a challenge, low functioning autistic people may be nonverbal which requires external help for them to communicate, normally apps with AAC (Augmented and Alternative Communication).

Autism has been increasing over the years, according to the World Health Organization and a study [2], evidenced that 100 in 10000 children had autism in 2022 and the prevalence of this condition, in 2012, was 62 in 10000. There is no evident scientific explanation of what causes autism, but many scientists believe that genetic and environmental factors may be some of the causes. Usually, undeveloped countries have a higher rate of children with autism [3]. The growth of children with autism requires more therapy solutions because what works for one individual may not work for another, so designing experiences for these groups of people is a challenging and intricate process.

## 2 Literature Review

This section presents the understanding of Autism Spectrum Disorder and the criteria associated with that condition and the concept of therapies that were developed over the years. The research and analysis of the studies were important to understand autism, the complexity of this condition, the concept associated with the therapies, what were their objectives, the skills they aimed to develop, and their advantages and disadvantages.

In the early days autism had a different characterization and was much less accurate than nowadays. The studies conducted by scientists, psychologists and therapists were essential to differentiate autism from other similar conditions, such as Attention deficit hyperactivity disorder (ADHD) and Asperger's syndrome, and because of that the initial therapies had less impact.

### 2.1 Autism Spectrum Disorder definition evolution

The term "autism" evolved over the year in its definition and disabilities that an individual might have to be diagnosed as an autistic person. The word is from the Greek *autos* (self) and *ismos* (a suffix of state or action) and it was first introduced by Bleuler (1911) to describe the egocentric thinking and withdrawal from the social interaction of a child with schizophrenia, which is a mental disorder where people interpret reality abnormally [4]. In 1943, Kanner differentiated autism from schizophrenia and defined autism as an inability to relate to people and situations along with characteristics such as solitude, the inefficiency of using language to communicate, repetitive and restrictive behavior/routines, but good cognitive potential [5].

Kanner was the first to conduct a study about these people, resulting in a more accurate definition. Communication failure or delay was not always considered an autistic characteristic, in 1956, Kanner and Leon Eisenberg, judged that language impairment was a result of lack of interaction with other people, so they did not consider it an indicator of autism. The same indicator was discussed by Michael Rutter (1978), who argued that language impairments are essential deficits of autism and should be included in diagnostic criteria.

The specific cause of autism is, still to this day, unknown, Kanner (1943), primarily, assumed that non-emotional parenting, emotional isolation, and the home environment could be related to developing autism. Later, recognized that was insufficient to produce the disorder, then suggested autism was the result of biological, psychological, and social factors, which is close to what scientists believe today. Studies have shown that genetics and environmental factors play a role in ASD. Researchers have found differences in the development of several regions of the brain.

Autism is more common to develop in premature children and disruptions of brain growth may be the result of defects in genes that control brain development. In 2013, the Diagnostic and Statistical Manual of Mental Disorders-5th edition (DSM-5) updated the concept of "spectrum"(see fig 1.), from the previous edition to be more accurate in diagnosing ASD at an earlier age, combining pervasive developmental disorder (PDD) diagnoses: autistic disorder, Asperger's disorder, childhood disintegrative disorder, and pervasive developmental disorder not otherwise specified (PDD-NOS), into one. Therefore, Autism Spectrum Disorder is characterized by deficits in social communication, restricted interests, and repetitive behaviors [4] [5].

Changes	DSM-IV	DSM-5
Location in manual	Disorders usually first diagnosed in infancy, childhood, or adolescence	Neurodevelopmental disorder
Sub-criteria	3 sub-criteria Qualitative impairment in social interaction  Qualitative impairments in communication Restricted repetitive and stereotyped patterns of behavior, interests, and activities	2 sub-criteria Persistent deficits in social communication and social interaction across multiple contexts  Restricted, repetitive patterns of behavior, interests, or activities
Needed to diagnose	Triad: 3/3 diagnostic criteria must be met	Dyad: 2/2 diagnostic criteria must be met
Diagnostic criteria	Qualitative impairment in social interaction, manifested by at least 2 of the following:  Marked impairment in the use of multiple nonverbal behaviors such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction  Failure to develop peer relationships appropriate to developmental level  A lack of spontaneous seeking to share enjoyment, interests, or achievements with other people  Lack of social or emotional reciprocity  Qualitative impairments in communication as manifested by at least one of the following: Delay in or total lack of, the development of spoken language  In individuals with adequate speech, marked impairment in the ability to initiate or sustain a conversation with others Stereotyped and repetitive use of language or idiosyncratic language Lack of varied, spontaneous make-believe play or social imitative play appropriate to developmental level  Restricted repetitive and stereotyped patterns of behavior, interests, and activities, manifested by at least one of the following: Encompassing preoccupation with one or more stereotyped patterns of interest that is abnormal either in intensity or focus Apparently inflexible adherence to specific, nonfunctional routines or rituals Stereotyped and repetitive motor mannerisms Persistent preoccupation with parts of object	Persistent deficits in social communication and social interaction across multiple contexts, as manifested by the following:  Deficits in social-emotional reciprocity, (including abnormal social approach and failure of reciprocal conversation, reduced sharing of interests, emotions, or affect, failure to initiate or respond to social interactions)  Deficits in nonverbal communicative behaviors used for social interaction (poorly integrated verbal and nonverbal communication, eye contact and gesture/body language abnormalities)  Deficits in developing, maintaining, and understand relationships (including adjusting behavior in various social contexts, difficulties in sharing imaginative play or in making friends, or lack of interest in peers)  Restricted, repetitive patterns of behavior, interests, or activities, manifested by at least two of the following: Stereotyped or repetitive motor movements, use of objects, or speech Insistence on sameness, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior Highly restricted, fixated interests that are abnormal in intensity or focus Hyper- or hyporeactivity to sensory input or unusual interest in sensory aspects of the environment
Age of development	Onset prior to age 3 years	Symptoms must be present in early developmental period but may not manifest until social demands exceed limited capacities or may be masked by learned strategies
Not better explained by	Rett's disorder or childhood disintegrative disorder	SPCD
Sensory symptoms	Not addressed	Sensory symptoms are a new criterion introduced in DSM-5 under the sub-criteria of restricted, repetitive patterns of behavior, interests, or activities

Fig. 1: DSM-V - changes of autism spectrum disorder criteria [5]

## 2.2 Therapies and Interventions

While the notion of ASD has changed, the therapies and, and brain growth disruptions may result from early intervention approaches were not appropriate because autism was not understood as it is nowadays. Initial approaches involved teaching the child that relationships could result in love and acceptance by removing them from home, but this approach barely had success [6]. When autism began to be recognized as a behavioural disorder, behavioural interventions started to be frequent in the treatment of autistic children. Applied behavioural analysis (ABA) is one of the most used behavioural interventions, which consists of increasing or decreasing behaviours frequency. One of the goals of this procedure was to reduce the temper tantrum behaviour and when that behaviour occurred the child was isolated. Initially, this procedure reduced the frequency of tantrums but over time the same behaviours occurred with the same frequency.

Another highly used intervention is sensory integration/sensory processing treatment (SI/SP-T) [7] [8]. The goal of this treatment is to remediate deficits in neurological processing and integration of sensory information to allow the child to interact properly with the environment. During the procedure is utilized equipment and specific devices, such as weighted vests, and performing activities that, hypothetically, enhance sensory integration and sensory processing. There is no consensus about the effectiveness of SI/SP-T among scientists and therapists because the fair evidence base, and unbiased clinical studies are limited, but does not mean that this type of intervention is not effective.

Naturalistic Development Behavioral Interventions (NDBI) is a procedure that has extensive evidence based on improvements in ASD symptoms [7]. NDBIs use a constructivism approach, where experiences are designed to engage children's attention, help them to connect with new experiences with existing knowledge, increase the complexity of learning experiences, and enable autistic people to discover the regularities in the world around them.

NDBIs are implemented in natural settings, utilize natural contingencies, and use behavioural strategies to teach them appropriate skills [9] [10]. Early application of this intervention found that generalization improved, and teaching in the context of natural environments, in which cues were continually changing, decreasing the need to teach each skill in multiple situations. For example, an activity where a kid needs to label a toy, and if he receives the same toy, as a reward, that he correctly answered it helps to develop cognitive skills. The relationship between response and reward should be natural rather than arbitrary.

NDBIs research contributed to the development of other type of intervention, which is Pivotal Response Treatment (PRT).

## 2.3 Pivotal Response Treatment

Pivotal Response Treatment emerged from previous studies that demonstrated autistic people having severe limitations in responding to environmental stimuli, which may be related to the number of components contained in the stimuli resulting in a lack of normal responsiveness to environmental stimuli [11]. Some scientists suggest that unresponsiveness may be a central or pivotal aspect of ASD condition, and the more complex the situation is, more difficulties are shown (e.g., identifying a black square is easier than a big black square with a white border, there is more information to be processed).

An investigation by Lovaas et al [12] compared how different it is the success of responding when the number of components increases. In the first test, it was used three-component complex stimuli and found that 100% of autistic children had problems in responding. In the second test, the number of components was reduced to 2 and 77,8% of children demonstrated problems in responding, which suggests that responsiveness may be influenced by the number of components contained in a stimulus.

To work around this problem, investigators have begun to develop interventions that might help. It created a technique called multiple-cue conditional discrimination. Multiple-cue training programs consist of structured stimuli, which involve children to respond a conditional discrimination task containing at least two or more components of the stimulus.

## 2.4 Multiple-cue investigation

John Burke and Laurie Cerniglia [11] conducted a study utilizing multiple-cue conditional discrimination method, which is a pivotal response treatment approach. Four children, ages 8 to 15, participated in the experiment. The children had a identical diagnosis that was required to meet the following criteria: (a) inconsistent responses to verbal instructions, ignoring others in social situations, and commonly failing to respond to conversation; (b) children were free from any peripheral visual or auditory sensory impairment; (c) the children were diagnosed autistic by not associated agencies.

All of them showed moderate to high levels of self-stimulatory behaviours, reduced amounts of appropriate play, and moderate to severe delays in appropriate speech and language.

The sessions were conducted in small rooms with the least possible visual and auditory distractions, containing only one table and three chairs, a set of tasks, and a box with toys and other objects to be used as reinforcement.

The tasks were imposed by verbal instructions requiring visual discrimination and motor responses from the participants. It employed a cross-modal task involving four components and two values for each component (size- big/small; color – red/blue; object – pencil/crayon; location – cup/box). All objects with those characteristics were displayed on the table and the kid had to perform the appropriate discrimination according to the therapist’s verbal instructions, which could range from single component stimuli (e.g., pencil) to multicomponent stimuli (e.g., big red crayon in the cup). In each session, the therapist changed the position of the containers to eliminate the possibility of learning discrimination based on position cues. The complexity of the tasks did not follow any specific sequence and the same level of complexity was not consecutively given more than three times. The session results were tabulated according to the percentage of correct responses for each component instruction (single component and multi-component – two to four). Three measures of generalization were subsequently employed to evaluate if the experiment affected other situations.

The results have determined that conditional discrimination may facilitate generalized responses of complex stimulus across different settings, including social responsiveness

## 2.5 Games therapy approach

Games are playing a fundamental role in the therapy of children with autism. Therapies such as speech and communication, occupational therapy, and psychomotricity have higher success when it

has play-based component. Autistic kids spend most of their free time playing games if they have access to them [13] [14]. Therapies based on video games or technology tend to be designed for high-functioning children and tested to see how they can help improve the skills they already have, as the characteristics of these games or technologies require higher cognitive and/or motor skills, which for a low-functioning child can be an obstacle [9], but if the concept of the game is developed for low-functioning children, if the objectives and functionalities are adequate, these children can also develop cognitive and behavioral skills depending on their degree of difficulty.

1) *Benefits*: Digital games offer an alternative approach to fostering and assessing desired cognitive and motor skills in a more naturalistic setting which might improve the quality of life and independence of autistic individuals [14].

Learning social cues and communicating is essential because social isolation is a general issue in autism. Digital games allow communication with their peers without facing each other, which for an autistic person can be difficult, thus encouraging them to communicate. In more delicate settings, where kids cannot communicate properly, games might help them to engage and stay engaged with therapy exercises because, depending on the game, they do not need to make eye contact with the therapist [15] [16].

Stress is also problematic, daily life can be harsh, and their impairments affect the way of processing all information present in the environment which can be stressful, so games might help distract them from their worries and concerns with everyday life [17].

Autistic children have cognitive deficits such as attention, memory, perception, and logic. Digital games may promote the cognitive skills mentioned above, but to achieve the best results a controlled environment and a well-thought design (visual, interaction, experience, etc) are essential to keep them engaged as much as possible.

2) *Design Considerations* - Creating experiences, objects, spaces, or games for autistic children is crucial to understanding how to design them specifically for this audience. In digital games, there are general design guidelines that may help design a better experience [18] [19] [20].

- **Goals** - The game goal should be unique, one goal associated with one single task, in this way, it is easier to promote the cognitive process. If different tasks are displayed at the same time, it may be overwhelming due to the complexity of the information to be processed.
- **Level** - it should support increasing levels of complexity. Progression may keep the user engaged with the game.
- **Rewards** - rewards may increase child motivation. Visual or audio effects can be implemented as positive reinforcement, but in case of bad performance, those elements should be reduced to avoid frustration issues.
- **Repeatability** - It is important to allow to repeat any level or learning skill, therefore mastering the desired skill
- **Graphics** - the game should have minimalist graphics, visual elements that are not relevant must be removed otherwise they might get distracted, still visual elements should be pleasant and aesthetic.

- **Audio** - audio is a double-edge feature, it can be used as a motivating factor but if it is not applied properly, it can create extra stress considering that certain audio stimuli might be overwhelming.
- **Dynamic Stimuli** - During the game session, animations and sounds should be provided, if visual elements remain static too long, the child may lose interest and move attention to something else.

### 3 Related Work

Conducting a thorough search of related work in a research project is essential for several reasons. It allows researchers to identify gaps in existing knowledge, build a solid theoretical foundation, and avoid redundancy by learning from previous studies. Understanding methodologies employed in prior research helps in selecting appropriate methods while placing one’s work in the context of existing literature provides a rationale for the study’s significance. Familiarity with related work enhances the credibility of the research, inspires new ideas, and facilitates the formulation of focused research questions and hypotheses. Additionally, it helps researchers stay updated on the latest developments in their field, identify key researchers and reputable journals, and contribute to the ongoing process of academic inquiry.

#### 3.1 Go Go Games

Go Go Games (see fig. 2) is a video game that uses a pivotal response treatment method, more specifically multiple cue responding. In its investigation, it is mentioned that children with autism do not receive enough occupational therapy and since autistic people are “attracted” to technology and games, video games could be a medium to reduce that gap.

Our environment has a lot of complex visual information, and stimuli can have a lot of components (cues) that might be difficult for an autistic kid to process. An example in real life is traffic lights, a normal traffic light is easy to understand, but if there is a traffic light indicating that you cannot go forward but can turn left, that information could be more difficult to handle, because it has shape, color and direction. Thus, the purpose of the game is to teach multiple cues responding skills which might help to interact better with the environment [21].

Over four months, the research team worked with 30 children with autism to test prototypes, that allowed them to iterate and improve the game. Initially, paper prototypes were used, which were ineffective. The researchers found out that timers, moving items and complex gestures were features that made user testers lose interest.

##### 3.1.1 Mechanics and Design

The core mechanic of each mini-game is to select the correct choice from a pool of options. For example, in the “build-a-Train” mini-game, the user must build the same train that is shown above (fig.2), by dragging the same carriage through the trail connecting with the train. This game has six levels with different difficulties, the first level only has two options to discriminate, and the differences are more noticeable in terms of color, shape, and content of the carriage.

Level six presents three options and the carriage cues are more similar. When the carriage is chosen correctly audio and visual effects are triggered, if the user fails, a new set of options is generated. No sound or visual effects are triggered by failure, which could cause stress or discouragement. When a level is completed, an animated scene is presented as a transition to another level and might boost confidence and willingness to continue to play [22].

The feedback for correct and incorrect selections resulted from several tests and iterations that allowed them to comprehend what was best for the audience. Throughout mini-games and levels, the number of cues varies from 1 to 3 cues and the number of choices ranges from 3 to 5.

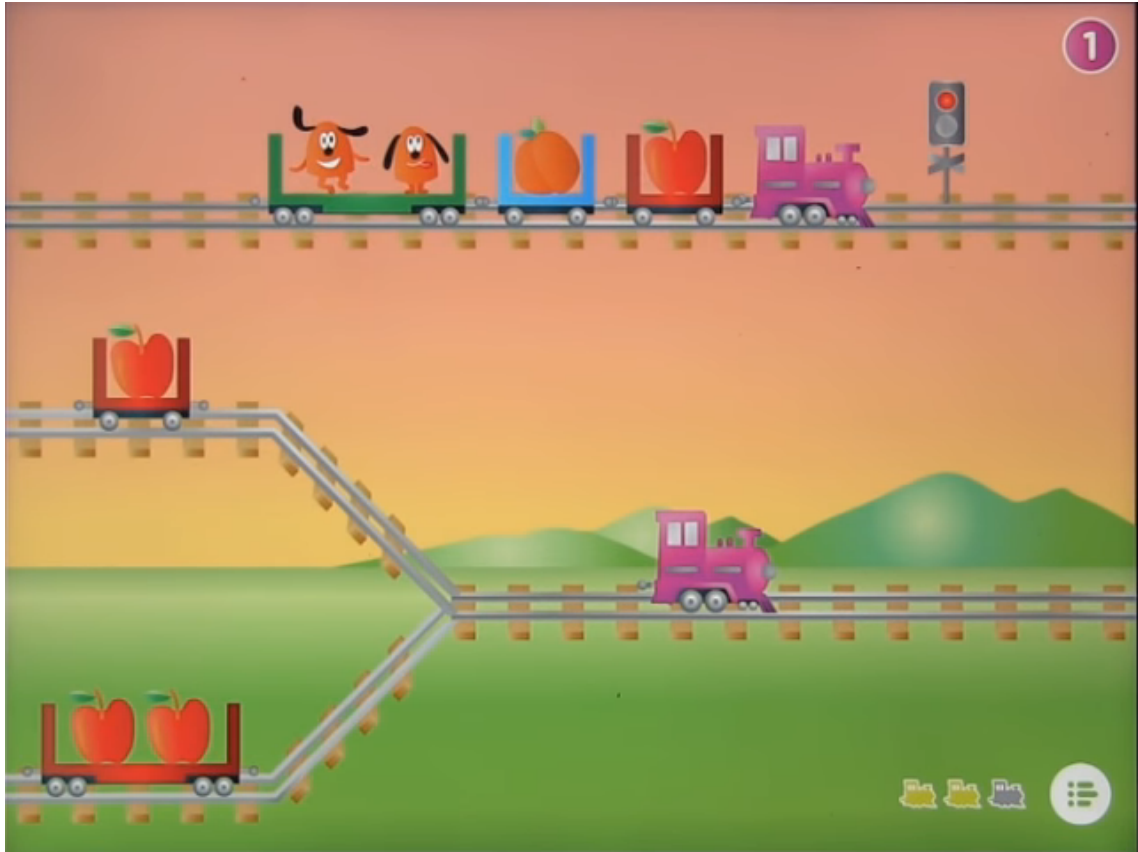


Fig. 2: Build-a-Train - Go Go Games

### 3.1.2 Algorithmic Design

To keep the game enjoyable as the user is learning, the level of difficulty needs to be balanced between increasing and stress relief. So, they designed an algorithm to modulate game difficulty over time based on correct and incorrect selections.

The items were measured by the number of differences between them, for example, if the user selected the wrong item and the only difference between the correct item and the one he selected was the color, the failure has a measure of 1. In the easiest levels, the differences between choices are more noticeable and while the user progresses successfully, the difficulty increases by displaying similar items. The algorithm could create 560 possible combinations of 20 different categories of features, which the game generates depending on the success of the player.

### 3.1.3 Results

In test sessions, the users could play independently, but few required initial support and they played for at least 10 minutes without telling them to keep playing. Later, the game was released on the App Store, and users from 80 different countries downloaded it. The overall average time of the game session was approximately 12 minutes. A non-positive statistic was the number of returning players; only 47% of the users returned.

At the time this paper was released, it did not provide many details about game sessions, how it was evaluated, the results, and the impact/benefits in the daily lives of the testers.

## 3.2 Play Guided Blocks

Prior to creating the game, a technology was devised to utilize games and toys as a foundation for comprehending children’s play patterns and supporting behavioral intervention while they play. The development of guide play technology drew inspiration from Applied Behavior Analysis (ABA), a successful approach for mitigating restrictive and repetitive behaviors (RRBs). Because of the constrained interests and repetitive behaviors exhibited by autistic children, their play may be impacted, leading to inappropriate play, limited object engagement, restricted play styles, and diminished functional and symbolic play behavior.

Object play is a foundational skill in a child’s developmental journey, progressing through various stages. Exploratory play involves manipulating objects to gain insights about the physical world. Functional play entails using objects in socially and functionally intended ways, while Symbolic play revolves around treating an object or situation as something else, often through pretend scenarios.

Symbolic play unfolds in several stages. In the early stages, children might use one object to represent another, and as they advance, they engage in more complex pretend play. This includes using multiple objects, assigning roles, crafting plots, and planning scenarios. Autism has the potential to impact the development of these crucial play skills, which play a pivotal role in fostering cognitive, motor, and behavioral abilities and enhancing environmental understanding [23].

### 3.2.1 Design Principles

The goal of Guided Play is to create a platform that can understand children’s play behavior and improve play skills. Guided Play embodies the following design principles. Ubiquitous – One of the challenges of understanding behavior is to capture its context (antecedent and consequence), it is necessary to collect behavioral data about a child’s life continuously and ubiquitously, so the platform may integrate data from multiple sources and use multiple interaction models. Extensible – open platform, third third-party components can connect to the service, upload data, and receive synthesized results. Intervention – guided play does not depend on specific intervention technology. It embodies several ABA principles that have been proven to be effective in reducing RBB.

### 3.2.2 Behavior Modeling and Analysis

The game uses a graph-based formalism to model dynamic building operations and static block structures. Each block movement will generate an operation graph representing the operation and a structure graph as a snapshot of the block structure updated by the operation.

The system maintains a history of all the operations and structure snapshots and based on the graph model, the system can independently compute the following metrics.

Variability –Consists of operational variability and structural variability. The first measures the variability of block operations, it is measured as the average difference between the operation graphs, and the Structural variability is the variability of completed block constructions and it is calculated as the average difference between the structure graphs. Complexity – measures the complicatedness of the blocks and their relationships. The block complexity metrics are based on dimensions (height and width), size (number of blocks and connections), dimensionality (0D, 1D, 2D, and 3D) and symmetry (reflectional and rotational).

Compliance with guidance – Calculation of the structural similarity between the instructed construction and the construction the child made.

### 3.2.3 Behavior Shaping

The game has two modes, the free-play mode allows the player to build anything using the block without intervention from the system, only provides a sound and visual feedback to block movements. If the percentage of symbolic play falls below a certain threshold the system switches to guided play mode.

In the Guided play mode the system uses the following methods to influence player behavior: Building repertoire - Guided Play aims to enhance a player’s range of constructions by simulating alternative yet related responses (new objects to build). Based on the current repertoire of construction, the system finds in the library and suggests a similar construction to build next.

Prompting – The system can prompt the player to build a new structure using background and shape outlines, so the children need to “fill the blanks”. If the player does not follow the prompt the system may generate the next move for the player by adding a missing block.

Reinforcing – it refers to reinforcing a (rewarding) desired behavior. The system attributes rewards at different levels according to users’ compliance with the guidance, using sound and visual effects.

### 3.2.4 Evaluation

Guided Play Block was tested on 6 children with autism, from 5 to 6 years old, 5 male and 1 female. All participants have a high-functioning profile and meet the defined criteria: ages between 2 to 5, having autism diagnosis, being verbal, being able to use Ipad, and having RRBs in playing physical blocks or similar toys. The sessions were held at the association site. It was conducted one session per week for each participant over consecutive weeks, four participants had 6 sessions and two had 5 sessions. Each session lasted for up to 1 hour with breaks.

The evaluation session had 2 phases, first, the user played the baseline phase (free play mode) and treatment phase (guided play mode), that method is based on similar studies of RRB intervention that used a multiple baseline [24].

Baseline – The researcher ran the app in free play mode and demonstrated first how to play by moving some blocks randomly into the canvas and prompting the participant to build something. When construction was completed (when the user expressed verbally or physically or when they were not engaged with the app) or the canvas became full, the researcher cleared the canvas and asked the participant to make another construction. The player was allowed to take breaks and during the breaks, they could play their favorite activities.

Treatment phase – the game runs in the guided play mode. As in the previous phase, the researcher demonstrated how to play, selecting first the category (toy, animal, transportation, etc), then selecting 1 of the 6 objects available in each category and finally constructing the object by filling out the outline. After the demonstration, the experimenter asks the user to follow the same procedure. Unlike the baseline phase, in the treatment phase the system reinforced behaviors by triggering sound when connecting blocks, sound and visual effects for placing blocks into the outline and animation related to the object constructed (see fig.3).

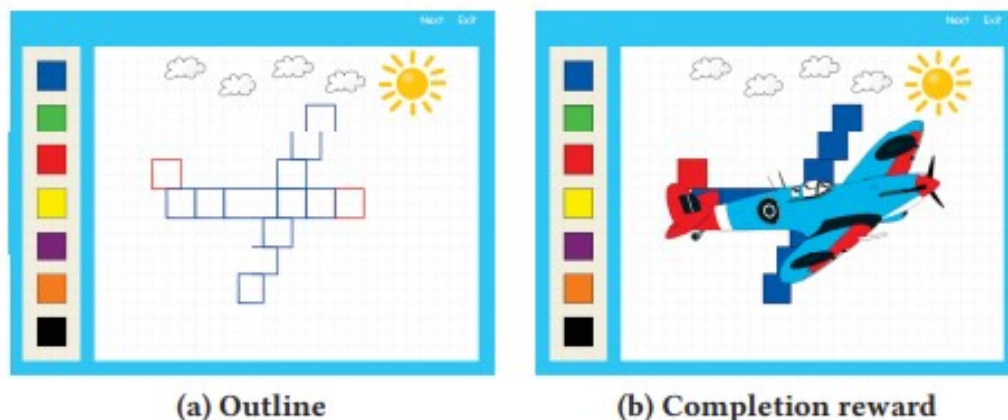


Fig. 3: Guide Play Blocks - guided play mode

The researchers defined some research questions to understand if there are the same patterns playing in the physical world as in digital play; if the digital activities change the children's behavior in the app and how those effects impact the physical world.

### 3.2.5 Materials

The sessions were conducted in a room with minimal distractions. The device used was Apple iPad Air 2 (9.7-inch screen and 2048x1536 resolution).

### 3.2.6 Results

In the baseline phase, the symbolic meanings of the constructions in the baseline (free play mode) were analyzed using the following criteria:

- Representational - the constructions resemble in shape a real-life object.
- Functional - the blocks are used to form patterns not resembling real-life objects.
- Sensory-Motor- the construction does not form a recognizable pattern or object, the behaviors are motivated by sensory simulations offered by the system.

Based on these categories, the researchers were able to identify 3 behaviors profiles, three users were able to make many recognizable and meaningful objects, two users placed the blocks randomly and one user enjoyed filling up the entire canvas. The play behavior in this phase contains more sensory-motor play than functional and symbolic play behaviors and the diversity of the constructions in terms of symbolic meaning and structural category is low. So, the participants showed behavior patterns consistent with their real-life behaviors which conclude that their first research question is true.

In the treatment phase, the representational constructions increased from 28% to 87%, the functional was 1% and 13% were sensory-motor. All participants started to make more symbolic constructions in the treatment phase, which indicates that changes were caused by guided play. It was noticed a drop of symbolic construction after the second treatment(see fig.4). Most of them were able to understand the intention of the guidance and follow the instructions well.

The second research question is also true, the findings indicated that Guided Play not only elevated the occurrence of representational play but also enhanced the extent and variety of the response repertoire.

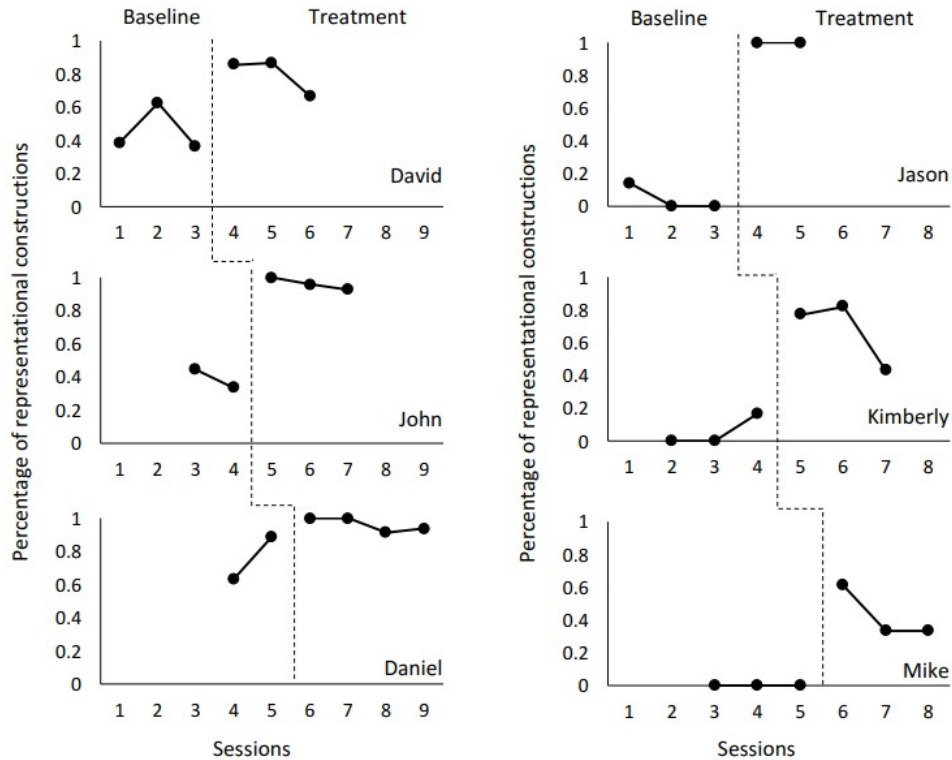


Fig. 4: Percentage of symbolic constructions across two conditions

### 3.3 Emotional Adventure

Emotion Adventure is a game that aims to educate children about the distinction between their own emotions and the emotions of others, even in the same situation, and it is based on the Theory of Mind which refers to the understanding that feelings can be different from one person to another in the same situation. The primary objective is to evaluate the applicability of practicing social cognitive abilities of children with ASD [25].

The game arose due to the lack of support for high-functioning autistic children with difficulties in socializing. It was noticed that existing games are imbalanced in terms of entertainment and therapy, blurring the line between both concepts.

#### 3.3.1 Game Concept

The Emotion Adventure is based on a role-play therapy model of therapeutic intervention. The game helps in facilitating better social engagement within peer groups. The game diverges from multiple-choice quizzes into digital formats, instead, it employs a Trivia-style game design where children are presented with predetermined answer choices (see Fig.5).



Fig. 5: Emotion Adventure prototype

Emotion Adventure is designed for children to be curious about the situation of others, to understand their emotions and feelings, which is one of the difficulties of autistic children.

The game has two primary mechanics, inquiry, and reflection. The NPCs share three-sentence stories that encapsulate the essence of their situation, then the player chooses one of the four dialogue options, and there is a more suitable option for each situation which will help the NPCs engage and open up about their feelings. If there is an effective communication choice the NPCs will reflect their emotions through facial expressions, which gives the player a card that visually represents the social cues. After collecting all the cards, the player presents to an NPC (Gami) to explain to Gami how these social cue cards relate to other people's emotions.

These mechanics aim to encourage players to analyze the situations and respond properly based on the emotions of the NPC.

### 3.3.2 Evaluation

A study was conducted with 13 participants children between the ages of 7 to 10, 2 females and 11 males, with the capacity to understand the rules and mechanics of the Emotion Adventure prototype. The sessions were held at the Department of Psychiatry, Seoul National University Bundang Hospital.

Some of these participants were diagnosed with various conditions other than autism, such as ADHD, Tic Disorder and Mood disorder. Before testing the game, it was collected data about autism diagnostic tests (see fig.6) ADOS-2 (Autism Diagnostic Observations Schedule) and CARS (Childhood Autism Rating Scale) are two methods to diagnose autism. In ADOS-2 scale a number greater than 4 indicates the child has autism and in CARS value greater than 28 indicates the same diagnosis. The IQ score presented in the table suggests that the participants could understand the rules and mechanics of the game.

Participants Information				ASD Diagnostic Test		Intelligence Test	
				ADOS-2	CARS	K-WISC	K-WPSSI
ID	Gender	Age	Final Diagnosis	Comparative Score	Total	FSIQ	FSIQ
01	M	8	ADHD	2	24.5	.	124
02	M	9	ASD, ADHD	.	36	.	84
03	M	8	ADHD, Mood Disorder	.	20.5	102	.
05	F	9	ASD, ADHD	.	27	104	.
06	M	6	ASD	6	30.5	.	106
07	M	9	ASD	9	.	.	.
08	F	8	ASD, ADHD	6	26	64	.
09	M	7	ASD, ADHD	.	27	89	.
10	M	7	ASD	8	35	.	58
11	M	8	ADHD	.	.	117	.
13	M	10	ADHD, Tic	.	.	121	.
14	M	10	ASD, ADHD	8	.	91	.
15	M	8	ASD, ADHD	.	26.5	.	81

Fig. 6: Participants clinical information

The usability test had a maximum duration of 60 minutes per participant and each one of them had a smartphone with the game. To ensure that the children engaged properly with the prototype, the researcher first explained the game controls, the navigation and interaction with the characters.

After that, the users had a 20-minute play-test session to observe the interactions and usability patterns of the users. Then, the children had to fill out a survey, providing their feedback on their experience. To have a deeper understanding of user's perspectives it was conducted an interview where they could express their thoughts and opinions about the game experience.

### 3.3.3 Results

#### *Acquired and Used Cards*

The player could receive and use a maximum of three cards with Gami, to teach the Theory of Mind. It was observed four cases, the first case, the player obtained and used the same number of cards, indicating effective communication with NPCs. The case number 2, the player acquired

three cards but only used one or two, possibly due to interest in other NPCs. In the third case, the player didn't use any cards, suggesting a focus on searching for social cues rather than connecting emotions. Lastly, the fourth case where it was used more cards than obtained, indicating premature access to unlocked cards.

From 52 cases collected from the 13 participants, case 1 occurred 28 times, Case 2 occurred 9 times, case 3 occurred 6 times, case 4 occurred only twice and 7 instances were invalid. The prototype demonstrated a decent level of usability and difficulty for autistic children, with a correct rate of 79.16

#### *ASD Typical Choice*

The participant had four different options for the dialogue: polite verbal option, friendly verbal option, polite non-verbal option, and friendly non-verbal option. Of all the choices, the first one is considered the best option for obtaining social cue cards and unlocking additional story content that showcases NPCs' emotions.

Throughout the interaction with the NPCs, the game had different dialogue variations, empathetic verbal, joking verbal and ASD-typical responses. From 78 responses, 58 opted for empathetic responses, 19 ASD-typical and 1 joking choice. It was analyzed that the children tended to deviate from their typical pattern of selecting the first answer choice, which may indicate that the participants perceived the game characters as their representation and were inclined to choose ASD-typical responses.

## 4 Methodology

Multiple Cue responding is an intervention that might help autistic children interact more properly with the environment and with their peers. It is one of the areas of Pivotal Response Treatment (PRT), a well-evidence-based behavioral therapy with promising results in improving behavioral and cognitive skills [10]. However, there is a lack of digital games that implement PRT and consider motivation a central area of PRT, which can be a hard barrier to break. Developing a game using motivation as a core area might be unfeasible because the experience must be designed based on a child's interests to keep him motivated to learn a skill.

### 4.1 Investigation Approach

This study aims to understand how digital games might be designed to help autistic children improve cognitive and behavior skills while learning conditional discrimination.

The game was designed and developed to teach conditional discrimination, but instead of using the child's personal preferences as the core graphic element to retain his motivation, it will be implemented using rewards, that might keep the child engaged with the task. The game's graphics were designed in such a way that they didn't create an emotional impact on the children, using shapes that didn't have a direct meaning, for example, geometric shapes, squares, rectangles, circles, trapezoids, are geometric shapes that we can identify in our day-to-day lives in various objects and don't have just one meaning, it depends on the context that is inserted in the environment. But if a graphic is used that has a direct meaning associated with it, for example, dogs, a drawing of a dog will always be perceived as being a dog regardless of the style of drawing and the environment in which it is inserted, which for some children can be a motivational element, because they actually like dogs, but for others can provide a bad experience because they have a negative emotional relationship. So to create an experience that would benefit the greatest number of children, "meaningless shapes" were used as objects to discriminate.

### 4.2 Design Approach

The game targets high-functioning autistic children, from ages 7 to 13 years old. High-functioning autistic children can speak, read, write, and handle basic life skills, like eating and dressing.

This project uses a Human-Centered Design methodology linked with game design methods. This methodology focuses on the user, and to design a game for this audience it is important to know what the problem is and what are their needs, empathize with the user is essential, hence initial stages are focused on Human-Centered Design is divided into 7 stages (see fig.7), from stages 3 to 6 it is important to repeat those tasks as much as it needs to end up with the best result possible. A work plan was created to prepare future work to control the time of each stage of the process and deliver the project on time.

- **Research** - In the first stage it is important to have a strong knowledge of the topic that you are going to work on, so this stage is crucial to build a strong base that will influence the direction of subsequent stages.

In this stage, the objective was to collect the maximum information possible by analysing studies, which therapies were used and their results. Also, an interview was conducted with

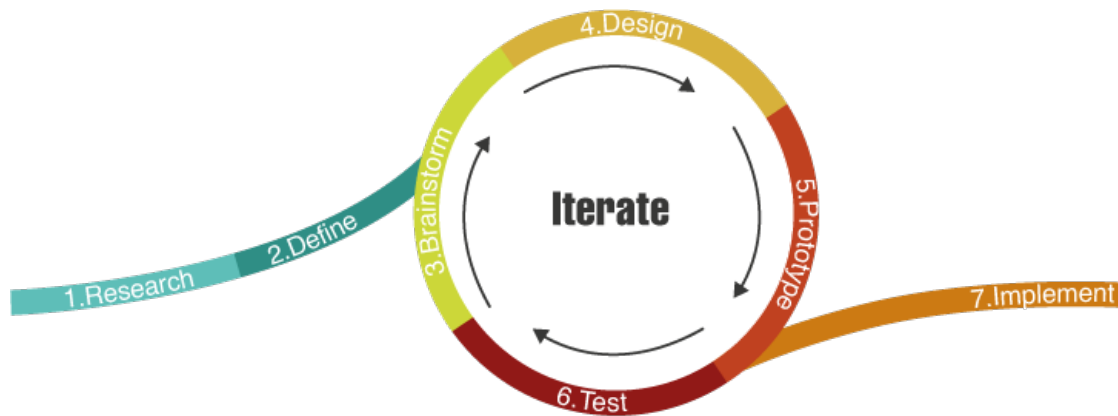


Fig. 7: Methodology proposal

a speech therapist, Dra Joana C novas, who works in Associa o Portuguesa para as Perturba es do Desenvolvimento e Autismo da Madeira (APPDA-Madeira), to deepen to knowledge about this topic and learn how autism is worked around in Madeira island. (See appendix A)

- **Define** - After research it is time to converge and filter all information collected in the research and define what the problem is, to whom you will design and how you will try to solve the problem. After extensive research work and analysis, the information collected was converged and selected what is relevant for the project. After framing the problem is important to answer the subsequent questions:
  - 1) What is the goal?
  - 2) Why is important?
  - 3) How is it going to be done?
- **Brainstorm** - In this stage of the process, all information diverges to generate many ideas. This project aims to create a digital game that teaches conditional discrimination, and like in every game there are things to have in consideration, for example: which devices the game will be designed for and game characteristics such as mechanics, visual style, levels, animation, sounds, rewards, UX & UI. This is a back and forward process, the initial ideas do not have to be fixed, going back on the process to adapt and improve is a natural procedure in creating games.
- **Design** - here is probably the most time-consuming stage, where all the things that were thought and defined in the previous stage come to life. Every component of the game must be designed with the same visual language, for example, if the characters of the game have a cartoon style the other components must follow the same style, this improves the overall experience and the game becomes more cohesive.
 

This project will have a participatory design, which means that user tests and feedback will be important to develop and improve the game, since this game has a specific target audience is important to design it considering user needs.
- **Prototype** - Subsequently, the objective of this stage is to materialize and connect all visuals with mechanics, in prototyping, every component of the game that was designed before is

grouped up to create a playable game. At this there is no need to be too precise down to the smallest detail, it is better to do a quick prototype and test it, it is almost certain that will be needed to rethink or redesign the assets or change mechanics.

- **Test** - Before implementing the project is important to run user tests with your target audience. After testing the game, the outcomes must be analyzed what worked and what it didn't and what must be improved, those outcomes are taken into a new brainstorming session. Going through several iterations is important to improve and deliver the best result.

The next tests will be with children on the spectrum who attend therapy sessions at APPDA-Madeira. It will be requested at least 4 users, with ages from 7 to 13 years old, ideally with high-functioning profiles. The goal of this first test with these users is to observe how they react to the graphics and audio components and interact with the game.

- **Implement** - Finally, after iterating and polishing, it ends up implementing the game to its final version.

## 5 Game Concept and narrative

Designing and implementing a game is a complex and hard-working process due to the variety of components there are in a game and all of them must be thought and designed in a proper way to end up with a functional and ready-to-test prototype. The most common thing to do when designing a game is to define a narrative and the concept, before designing any visuals, mechanics, levels etc., because is a component that should not change later otherwise, all progress might be compromised. Other components, like levels, visuals, and animations can be changed and adapted, and the need to adapt and evolve will arise over the iterations.

When designing for a specific audience, it is necessary to consider the needs of that audience, thus ensuring a better experience which will consequently bring better results. Therefore, the process of this project changed a bit due to what was defined in the investigation approach, design a game with meaningless objects or visuals that are unlikely to trigger emotions, to not influence the game performance, then that variable won't be needed to take in consideration on data analyses. That is why it started by brainstorming about the core visuals of the game and then how a game concept and narrative could be developed around it.

To learn conditional discrimination is necessary to have at least two options to compare and select and several cues that might differentiate one option from. So, the first thing to brainstorm is what are those options and how would they look, could be geometric shapes, organic shapes, or abstract shapes. Then, a narrative can be built based on those visuals, which must be simple considering the target audience.

### 5.1 Concept

In this project, the game concept is simple, a digital game that teaches autistic children to respond to multiple cues (Conditional Discrimination), which is one of the areas of Pivotal Response Treatment. The game was designed to be played on a tablet, because it only requires the user's fingers to interact with it, which makes motor coordination much easier than having an extra device, like a computer mouse, to control the inputs.

Art style is important to define as well, respecting user's needs, should be balanced between simplicity and realism, so they can understand the visuals and not get distracted by the details, so it should avoid complex shapes or distractive elements, such as very filled scenarios, incorrect use of User interface elements like uncommonly shaped buttons, buttons not looking like buttons, or having elements that are not clickable but feels like it is. The art style is important to catch the attention of the user even before the It is important to select well the game mechanics, improper mechanics might trigger emotions or behaviors that prevent children from playing the game properly, for example, a timer is not a suitable mechanic for those children, because can constrain their performance making them more stressed. The game mechanics that were implemented in the game were tiles/grids, levels, rewards, and feedback. The choice of these mechanics will be explained in detail later in the mechanics section.

A quick overview of the concept:

- The player has to play different levels to complete the game;
- Each level has different tasks that teach conditional discrimination;

- The number of cues increases throughout the game;
- Completing one task will unlock the next task.
- Completing the tasks with as many wrong answers as possible will trigger positive feedback and consequently, rewards.
- Wrong answer triggers negative audio feedback and responding correctly triggers positive feedback.

## 5.2 Narrative

The game developed in this project needs a narrative, likewise every other game. During the brainstorming sessions was defined that the concept and narrative should be simple and straightforward because the target audience, who are children with impairments at different levels, could conflict with the understanding of the game if the narrative is overly complex.

After brainstorming sessions, the two ideas that sustained the overall concept were build-type games or puzzles. Puzzle games usually are more complex, because involve strategy which is more demanding in cognitive skills. So, a building type of game is more suitable, even though when we think about build-type games, strategy is a mechanic that is present mostly in those types of games.

Then the question that came up at the table was, "Build what?". Considering the importance of having uncomplicated shapes, the most reasonable theme was house building, because of is something everyone is familiar with, and it does not require complex shapes to build a house. Thus, the narrative was built around that theme.

## 5.3 Mechanics

Mechanics play an important role in gaming, they shape the core gameplay and contribute to the overall enjoyment and success of a game. Choosing mechanics is also choosing the user's learning skills, for example, if the game has a strategy mechanic the user will learn how to plan, if it has feedback user will learn to analyze, status might learn how to be responsible, learn to discuss/reflect by adding action points, rewards/penalties mechanics.

One of the mechanics that compose the game is levels. Levels are important in the progression of the game, they tell the user, unconsciously, that the next level/task will be more difficult than the previous one, and it is important as well to give breaks to the user, considering the type of user of this game, if you don't provide moments where they can relax or rest, the levels of concentration might break down and levels of stress might rise. The transition between levels can not be too long otherwise they will lose their attention as well.

Tile/grid mechanic is a mechanic that creates a sense of building, and this game uses a variation of puzzle-style placement, in which certain objects must be selected correctly to meet certain objectives. It can introduce elements of spatial reasoning and puzzle-solving, creating, or modifying the environment. Since the concept of the game is to build houses, this mechanic is a must.

Reward is an essential mechanic because in pivotal response treatment (PRT) motivation is the core area of this type of treatment and rewards might be a way to motivate the user to play and willingness to do better and facilitate behavioral learning outcomes. So, a well-motivated

child might benefit from his learning process and, consequently, achieve better results in therapy. Rewards are not only for autistic children, but every gamer also likes the feeling of getting rewarded when achieving certain objectives and sometimes that feeling is what keeps the player playing the game even when is not enjoying it anymore [26] which is why rewards are one of the most used mechanics in games.

The last mechanic is feedback, which is important to increase the experience of the user. Feedback is what tells player their performance while playing, that could be by audio feedback, for example, a buzz sound effect when something is wrong, a sparkling sound effect when something goes right. Can also be used visual feedback, for example, points or stars, which permit the user to know if he reached the objective or how far he is from doing it. Basically, feedback adds valuable information to understanding the user's actions.

## 6 Game Design Process

### 6.1 User Experience

the psychology of the end-user, in this case, of the player. At this stage, you must enter the player's mind, understand how players think and behave, what the best features are to add, how long the game should be, the flow of the game, where the buttons should be placed, how many interactions, how it ends, etc., and it is not done randomly, it is important to analyze data, research about previous games that were done. Also, studying the user's target it is possible to anticipate their behavior, struggles and the way they might interact and engage with the game.

Designing the experience, was not only about the gaming aspect but also the test sessions, the place of the sessions, how many sessions, and the environment. In this case, because the target audience is very specific, it is needed to take into account small details, like objects in their field of view, external sounds, day and time of each session.

### 6.2 Level Design

When designing levels there are some important aspects to create an engaging experience, so the player can feel the progression throughout the game, feeling that is getting more difficult and more fulfilling experience. Is important to understand the constraints, for example, how long the level should be? How difficult should be? How the player will be rewarded? How does the player progress through the levels? etc., those contains does not have to be precise at this point it is just a guide to help design game levels to give the user the best gaming experience.

This game is divided into three levels of difficulty, "easy", "medium" and "hard" and each level has six tasks, which difficulty increases over the levels. As mentioned in the document previously, in teaching Multiple-Cue Responding or Conditional Discrimination, the patient, in this case, the child must observe and analyze the cues, of an image or object, to respond correctly. The more cues, or "characteristics", to compare the harder it is to respond correctly, for example, if the child has to compare a big red pencil with a small blue pen, the differences are obvious, and it will be easier to respond if it is asked to pick one or another. But if both objects are the same and the only difference is how they are spatially positioned it might be more difficult to answer properly because of the similarity of the cues. Cues, such as color, size, shape, and spatial orientation, were used to design the game levels and their difficulty.

#### 6.2.1 Easy level

The first group of tasks, the Easy group, they have not equal cues in the options to discriminate, so shape, color, size, and spatial orientation are all different, and because of that it is easier to discriminate correctly.

This group is composed of six tasks and each task has between 4 and 5 house features to discriminate. The first task is the easiest one with only four features. This level works almost as a tutorial, so the user understands the mechanics, the sounds, and the feedback of the interactions. To avoid having very simple and boring tasks, some of the options were made with similarities, for example, having two options with identical shapes or colors in some features. (add image example)

There is a logical order of the features that appear, first, the user has to identify the overall shape of the house or the base, then will trigger the next features, which are the roof, then the doors

and lastly the windows. The order remains the same, depending on the house's characteristics. The purpose of ordering the features is to facilitate the identification of the object that corresponds to the image.

### 6.2.2 Normal level

As the player advances, the difficulty must increase as well, and in this group, the tasks are more difficult. The difficulty of the tasks was designed by adding more similar cues, in that instance, the options have the same shape and size, which means that the user has to notice the color and spatial orientation to discriminate one option from another.

Like the previous group, this one, also, has six tasks, but on the other hand, the number of features varies from five to seven. Thus, to increase the difficulty of the tasks on this group it was designed more complex houses, were added more features per task and the similarity in cues was increased.

### 6.2.3 Hard level

The last stage of the game is more cognitively challenging for the players, additional features and cues were added to increase the difficulty of the tasks. This level was designed to users take longer to observe and think before choosing the correct option.

In comparison with the previous levels, this one has more cues to discriminate, four cues instead of three, in this one spatial orientation is introduced to the test, so the options are more identical and complex, in shape, color, and size and the user has to be more aware to the position of the object. Another feature added was the number of options, easy and medium tasks have only two options to compare, and hard tasks have three options, making it more challenging for the kids to analyze. This extra option was added, also, to understand how randomly the user picks their answers, which is an extra variable to consider in user results.

This stage has six tasks, and each task has between six to seven house parts to build. In the first four tasks, two of the three options are identical only differentiated by the spatial orientation and the other option is less identical. For the last two tasks, all three options are similar and only change the spatial orientation of the options, which makes it harder than the preceding tasks.

## 6.3 User Interface

Before prototyping is necessary to design all the visuals, interface and assets, is important to define an art style that makes sense to the concept of the game and respects the target audience, as this game was designed for autistic children is important to design a proper layout, buttons, choose appropriate colors and sounds, so the player enjoys the game at its best.

On a user interface is important to create affordances (visual clues), which give hints on how the user may interact with an object or something on the interface, it facilitates the experience, and the interactions are more intuitive. So, affordances are essential in every interface, but when designing for autistic children it is even more important because of the impairments they might have, which may difficult the experience if the UI is lacking visual cues [27]

Designing an interface has different stages; in this project, those stages were important creative and logical. The first stage of the process was to design everything by hand (see Fig.8), it is the

easiest and fastest way to visualize and adapt the user interface and its assets. Subsequently, the assets were designed using a specific design tool, Adobe Illustrator, because of the experience and knowledge of using this tool and due to the game being conceptualized for two dimensions, this tool provides the best features to design all graphics.

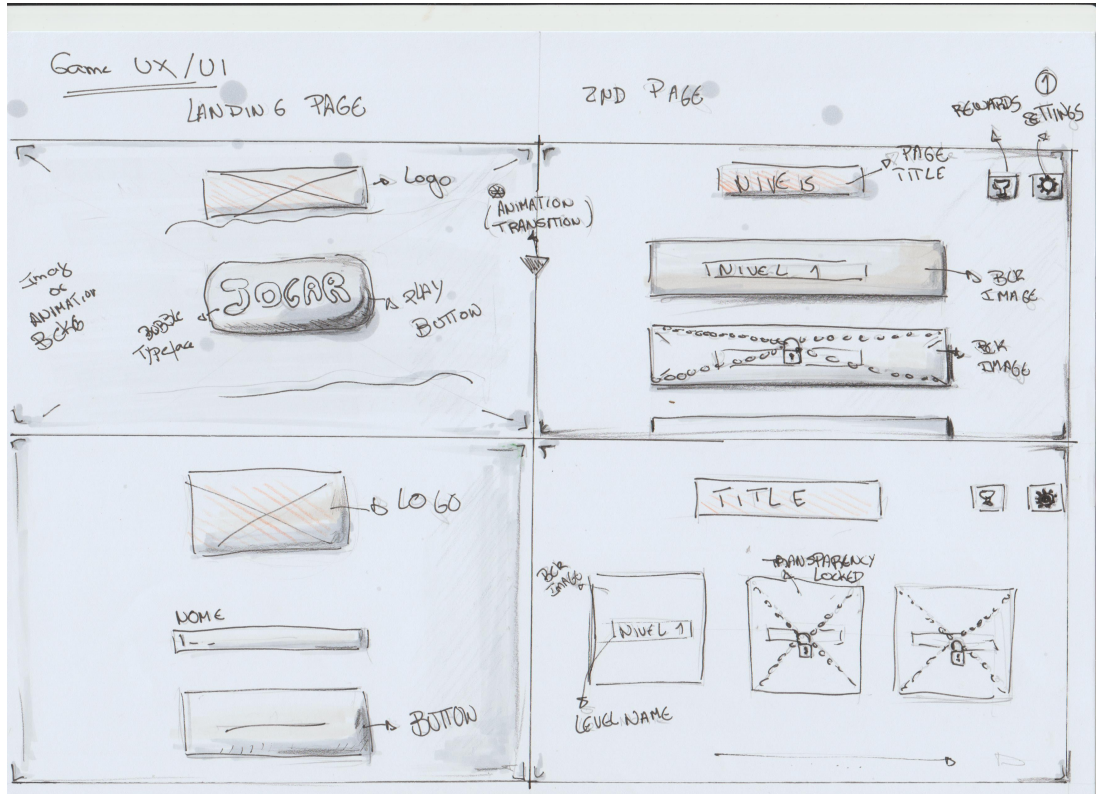


Fig. 8: Sketch of initial user interface pages

Finally, after designing the graphics individually, like buttons, backgrounds, menus, and houses, it was time to bring them together to create a prototype, to understand if everything together was practical and meaningful. To create this initial prototype, where it is possible to visualize the overall UI and its actions, was used Adobe XD (see Fig.9).



Fig. 9: Comparison of the first design of the user interface page and the final design of the same page

### 6.3.1 Layout

As mentioned before, the first stage of designing the layout was doing it by hand, designing the elements of each page, their shape and position. Due to the target audience, it was important to have a “clean” UI, since the children on the spectrum may have attention deficits, adding unnecessary details and buttons, and giving too much freedom to navigate through might deviate their attention to the main goal.

The landing page is composed of only one big centered button, so the player understands what he has to do to advance, it is important to restrict their actions. Next, the second page has a container with different stage levels, easy, medium, and hard, lined up horizontally from the left to the right, in the respective order, which scrolls horizontally as well. Two more buttons were added to this page, the reward and options buttons that lead to their pages, these buttons are placed in the right top corner and smaller because they are secondary buttons and do not have the same importance as the stage’s button.

When the player clicks on one of the stage levels, it triggers the task selector pages, which have the same layout in all three stages. On this page, the tasks are ordered from 1 to 6, the buttons are circular and below the buttons are the stars which correspond to the performance of each task. The tasks are also lined up horizontally, divided into two rows, one from 1 to 3 and the other from 4 to 6.

The layout of the gameplay page is the same for every task (see Fig.10). One-third of the screen is for the options button’s container, which is the area of action of the player, and the other two-thirds of the screen is dedicated to displaying the user actions when the player selects the correct option, the object will appear in that part of the screen as visual feedback action. On the right top corner is a button that exits the current task, the purpose of that button is to provide an option to go back if, for example, the user selected, by mistake, a level that already played, so he does not have to do it again. At the end of the task, it triggers a screen that displays the performance of the user, depending on the error rate, it will activate one, two or three stars.

### 6.3.2 Menus, Buttons and Colors

After designing the interface, it is time to design the filling graphics, such as frames, and buttons and define the predominant color palette, those that appear most throughout the game, and the secondary color palette. The process of designing is the same as the layout, first design everything by hand, make fast sketches to generate several designs, then select up to three designs and recreate them on Adobe Illustrator.

The primary color palette has to take into account the user impairments, like deficits in attention, and radical change of humor, they stress up easily, so to avoid that it is important to select a color palette that does the opposite, triggers stability, makes them calm and relaxed, and the best color that triggers these emotions is blue, however depending of the shade and hue of the color blue, it can trigger other emotions [28], which means that not all blues triggers calmness, relaxation and stability.

The background was made with a gradient of blues(see Fig.11.), even though it does not belong to the first plane, it is an element that occupies most of the screen, and like a painting, it is important to have a background that supports and matches the other elements.



Fig. 10: Early interface of in-game task

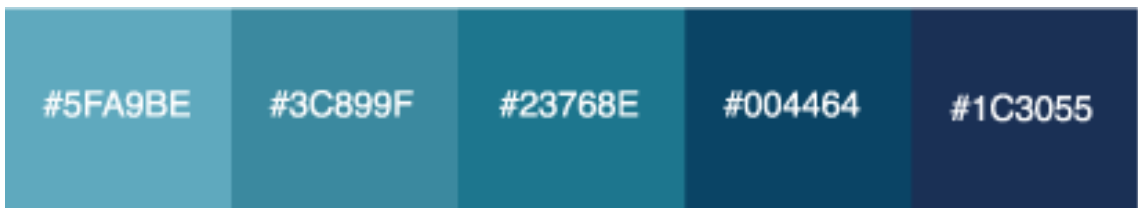


Fig. 11: Blue palette

Buttons are an important UI component in every game, it is by clicking buttons that the user can interact with the game, navigate from one page to another, and trigger interactions. Buttons must be designed to look and feel like buttons, which will provide a better gaming experience, if the user takes too long to identify what is clickable and what is not, something is wrong with the design of the button. Visual signifiers, like shape, color, size, and shadow, are important to reduce the effort that the user needs to identify it [29]. Autistic children, depending on the individual, may have reduced cognitive and motor skills, which might be even more difficult, compared with a more developed peer, to identify UI elements, that's why it's important to give greater importance and attention to designing buttons. For example, if a button is not proportional to the user's needs, it may take longer to perform the clicking action because of his low motor skills.

The buttons in this game were designed focusing on three visual cues, size, color and shape.

- **Size** - Due to the possibility of having users with low motor skills, it is important to have a finger friendly button to avoid the user having to be very precise on clicking to trigger the

action. The first button is 800px width and 245px height (21.2 x 6.5 cm) and the average of an adult index fingertip touch is about 57 pixels [30] on a mobile device, so this button is 60 times bigger than the average index touch, thus facilitating the user experience and making them feel comfortable at first. This button only has this proportion because it is the only UI element on that page, which has the purpose of making it less empty.

The buttons corresponding to level selection (easy, medium, hard) are squared 350px in width and height, smaller than the first button but still 12 times bigger than the average touch area of an index fingertip (See Fig.16.). Task selector buttons are smaller, only 160px in width and height, almost 6 times bigger than the average touch area of an index fingertip. The main reason for size variation throughout the pages is to train eye-hand coordination, the buttons appear by order in size from the biggest to the smallest, increasing the difficulty of the task throughout the game.



Fig. 12: button 1



Fig. 13: button 2



Fig. 14:  
button 3

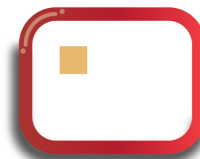


Fig. 15: button 4

Fig. 16: Buttons compared with an average index fingertip width (orange rectangle)

- **Shape** - All buttons have rounded corners because there are significant advantages on having rounded buttons than sharp edge buttons. The shape has aesthetic and functional importance, the round edges buttons may direct the user attention into the button, so the user will focus on the information inside, while sharp edges may draw attention to the outside since the corners are pointing away from the content. Another advantage is the attention of the user, when designing in two dimensions, whether a website or a game, most of the user interface layouts have a square grid design and having rounded buttons creates visual contrast. Rounded edges are easier to process visually.

There are studies that show that more neurons are involved in processing a rectangle than processing a circle [31], so rounded is easier on the eye. There is a link between psychology and the shape of the buttons, rounded rectangles, and circles, in general, are more positive than sharp rectangles, so having the right shape may increase feelings of relaxation and positivity.

The landing page button has a long rectangular rounded button, which immediately draws the user’s attention to that button and its content. Having fully rounded buttons is great in interfaces with adequate space because it is the only UI element on that page, it makes sense to have a button with those characteristics.

Then the subsequent buttons have a squared shaped button with rounded edges, which conveys a more user friendly and playful impression than buttons with sharp edges, this distinction between the serious feeling of sharp corners and the playful feeling of round corners comes from our real-world interactions with physical objects(See Fig.17.). Since children, we learn that sharp and pointy objects may be dangerous and round objects may be perceived as safe objects. The shape of these buttons was not designed just considering the psychological factors, it also, has a structural and visual reason. It is easier to fit all information (labels and icons) also to organize in a square button than a rectangular button and takes less horizontal space which avoids the need to scroll horizontally to make the button appear on the canvas.

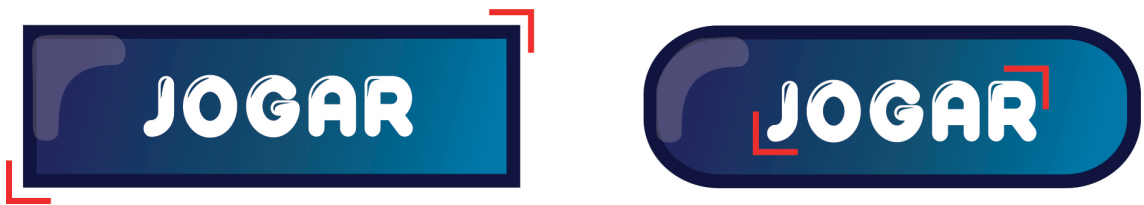


Fig. 17: Same button with different shape

At last, the buttons, that trigger the task levels, are circular for the same reasons that were described above, but this one has a stronger structural reason, because every button has “attached” a set of stars (feedback on user performance on that task), and circular shape was the best to fit the stars and sort both elements inside a rectangular frame.

- **Color** - – The buttons have different color on different levels of the game, but all of them have a common characteristic, designed with gradients, which are color transitions from one color to another. Using gradients makes the design more realistic, it creates a sense of dimension and dynamic to the button, which does not happen when using a solid color. On mobile devices, there is no feature, apart from its appearance and the sensation it conveys, to show that it is a clickable element, like on computers there are hover effects, so when hovering the mouse over a button it can react by changing color and size, or trigger an animation. The other reason for using gradients is because they stand out easily, so it is a way to create hierarchies on the user interface. But it is also important to not have too many gradients which can result in cognitive overload [32].

The first button as a gradient of dark blues, which gives a contrast from the background, which has brighter blue. To make it stand out even more, it was added a darker border than the gradient of the inside button, which helps to “separate” the user interface components from the background, it makes them look like they are in different planes, even though in 2D everything is in the same plane. On the second button, the easy level, the button has the same color gradient and border as the first button, which indicates without providing any instructions which button the user must click after the first interaction. If in a design are specific colors only for buttons, it will be easier to identify a button even without a label. This second button

uses blue to indicate that it gives access to the easy level tasks, considering that blue conveys a feeling of calm and relaxation.

Inside the easy level container, there are buttons which that lead to each task, and those buttons have the same color (with some exceptions)\* (See Fig.18. & Fig.19.), for guidance and logical reason, as mentioned before, buttons should not have too many different colors, and having the task buttons with the same color as the button that led the player to that page, indicates the player that he is in the correct page (easy tasks container) without reading the page label it is possible to identify a correlation between the two buttons).



Fig. 18: Buttons design - Visual cues representing difficulty (color, label, icon)



Fig. 19: task buttons corresponding to level button and rewarding task button

Moving on to the next button, the "medium" level button has an orange gradient. The orange color is a stronger color, and is associated with adventure, warmth, and energy [33], but also with warning and danger, thus choosing this color is to warn the user of the difficulty increase, it already gives a hint before playing the tasks. Like the easy task button, the medium container has buttons with the same color "medium" button, and the same reason is to create a relation between both buttons, assuring the user that it is on the right path.

For the last button of the level selecting container, the "hard" button, it was adopted the red color, which a powerful color, it has positive and negative impacts in its perception, but it was chosen to enhance the idea of greater difficulty. Then, when the player press that button it triggers the page with the different task levels, which have the same structure as the previous one.

The button's colors have a hierarchy that is commonly used in games with different levels, thus, by gaming experience the user might guess what each color represents, but even without gaming experience the are other visual cues that support the meaning of each button(see Fig.20). In fact, autistic children, may have a different perception of color, maybe red does not have the

same effect or meaning to a “normal” peer, but choosing color that are commonly used in other games or interfaces are type of affordances that may help developing that common perception of the colors.



Fig. 20: container of task buttons

\*In the first iteration, all task buttons had the color that corresponds to that level, then in the second iteration, rewards were introduced, and for the user could identify which tasks could be rewarded, these buttons were changed adopting a gold color, which may have an inspiring and uplifting effect, gold conveys to something that is valuable or precious and that may be a way to motivate the player on achieving the rewards.

### 6.3.3 Houses

Design houses was a long process and one of the most fundamental assets of the entire game because the house is the core item of the game concept, so it was crucial to spend more time and attention on this part of the process. Before starting to draw, research of house images was made, it was important to take ideas from the structures of existing houses and their features, like doors and windows. It is relevant to keep the concept of the house realistic and design the house as they are, due to the target audience which may have perceptual and information processing impairments.

#### Level 1

After completing the research, was selected cues and shape complexity for each level category, the house in the easy category must have more simple shapes than the medium and hard category, so the first level houses must have simple shapes and few details that require more attention.

The next step was sketching houses, getting the overall shape of the house then filling it with doors and windows. Sketch by hand before drafting on the computer can save time, it allows you to test different layouts and details, and this process is way faster than doing it on a digital device, but after having everything planned and sketched, designing with proper tools will facilitate the process. Hand drawing can boost creativity and improve problem-solving skills, it forces us to externalize our thoughts, making abstract concepts more tangible [34].

Firstly, was only sketched the house shapes for the easy tasks, most of them had square, rectangle, or trapeze shapes(See Fig.21.). Next it was sketched a varied set of houses and windows, and lastly, assemble all the pieces to “build” houses, the key was to draw simple shapes and forms. These sketches were used as a guide in digital design, not every house was made as in the drawings. (See Fig.22.)

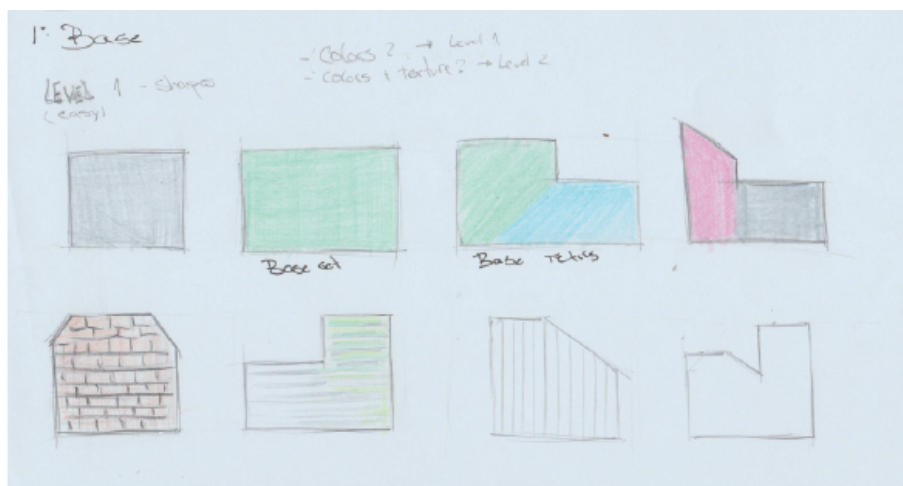


Fig. 21: sketches of house bases



Fig. 22: sketches of house sets

The next step was to draft digitally the sketches, and for that, it was used Adobe Illustrator tool. Here every component feature of the house (shape, roof, door, window) was designed separately because afterwards, these features would be used as options to build step-by-step the house. In this first level, similar colors were avoided to make it less stressful and to make the player get into the game without any significant emotional constrain.

After designing the first level houses, instead of starting immediately on the medium level, it was implemented before advancing, allowing to test if the design works, so designing and implementation were parallel processes, which allowed to test the assets if it had any compatibility issue with the rest of the interface in terms of size and color.

## Level 2

The process of designing the level 2 houses as the same as the level 1, firstly research was done to get visual references, in these levels the houses must be more complex in terms of shape and details (see Fig.23).

As stated earlier, in levels section, the medium level has more identical cues, in this case, the options to discriminate will have the same spatial orientation and the same shape, and the color is what the user must identify as the correct one. In the first three tasks, the colors of both objects to compare are less similar, but then from the fourth task the colors hue and shade are gradually becoming more identical, so the increasing difficulty is not only from one group of the task to another, but also increases inside of that group, for example, the task 1 of the medium tasks it was designed to be easier than the task 3 of the same group.



Fig. 23: Sketch and digital version of a house

Like the first level, sketches were made as guidance to design the houses digitally, but at this point that task was easier because a lot of the assets of the level 1 houses were used and adapted, so it was not necessary to design everything from the bottom ground. To create the wrong options was only needed to change the object color, which at this point, digital tools make a big difference

in saving time due to the features that it has, allowing to reuse and adapt the previously made designs in an efficient way.

Comparing level 1 houses with level 2, both share the same general shape, but on level 2 the houses are bigger, joining more than one geometric shape, forming a more complex shape. The houses are two stories high which allows adding more components, while on level 1 the house only has four to five features, on level 2, the houses are composed of up to six features, however, no house has a roof, which gives a modern look, beside that it was added more doors and windows which are components more difficult to distinguish.

### Level 3

In the last level, the complexity of the house should increase even more and to achieve that, it was crucial to repeat the same process as the previous ones, research, define features, sketch, and design digitally. For the last level, the research was done slightly differently, it was also done image research, but because the variety of images with desired characteristics was scarce, it was used an AI tool, Adobe Firefly, which generates images by text input, and was a great source of inspiration to design new houses. As designers, it is important to use every tool that might help improve the design process (see Fig.24).

Some of the text used to generate images: “3 story contemporary house with garage.”; “2 story contemporary house with roof and big front door.”; “a modern two-story house in vector style, front view perspective” “a modern two-story big house with a big door on the ground floor and windows”.



Fig. 24: House generated by AI and house design inspired by the AI tool

In the last group, the houses have more complex shapes, and the doors and windows have more details which requires more attention from the player, the houses were made up of seven house features, including, the base, some of them a roof, one or two doors and 2 or 3 windows.

In this last level, instead of two objects to compare, it was introduced an extra object, the user needs to analyze and compare three objects, and in these tasks, the objects must have the

same shape, size, and color, only spatial orientation was different at this stage(see Fig.25.), which demands more attention from the user the choose correctly.

When creating the houses on digital tools, firstly, were designed all features of the house (base, roof, doors and windows), to create the options with different spatial orientations, simply had to duplicate the same object and change its angle (easier to compare) or mirror it (more difficult to compare).



Fig. 25: Hard task gameplay layout and cues

#### 6.4 Rewards

Rewards are a great motivational game mechanic, that might boost user performance and the willingness to play the game or do a certain task within the game, so rewards have been used as a reinforcing strategy to facilitate behavioral learning outcomes. Motivation can be categorized as intrinsic, which is driven by the action itself, the user is motivated simply by doing an activity, and extrinsic motivation, which is driven by an external benefit [26].

There is a prevalent game reward classification devised by Hallford & Hallford [35], which proposes a taxonomy of four types of video games; rewards of access, rewards of sustenance, rewards of facility and rewards of glory. Each one of them has its purpose and applicability in video games or gamification interfaces, but in this game is important to understand the rewards of glory since is the type of reward that was applied. This type of reward does not impact every gameplay moment, so the reward is achieved by completing a challenge.

Designing rewards can be a complex task, especially for autistic children because motivating an autistic child can be more complicated as their understanding and perception of the information, they receive is very personal, unlike a child with normal development, who is easier to guess what kind of rewards they can motivate while playing. In PRT-type therapies they try to identify individual enjoys and use to motivate, something that in a video game is difficult to replicate, as the rewards have to be the same for everyone.

The process of designing the rewards was very similar to the process of designing houses. First, do research, analyze existing rewards that are commonly used for kid's games, then select the type of rewards, sketch and finally draft them into digital (see Fig.26).



Fig. 26: Sketch of rewards

After research, was defined that there would be three categories of reward design (rewards of glory), the first level had pins, the second level had medals and the third level had trophies, but due to time constraints, it was only possible to design the medals.

The medals go from tier one to tier five and the higher the tier the harder should be to get the reward, so each reward needs to have something that differentiates it from the previous one, something that makes it more eye-catching, more attractive, and more likely to make the user want to win it (see fig.27). As the same logic of the buttons, rounded shapes and forms were used, to give a sense of playfulness, and fun and attract their attention to the content.



Fig. 27: medals from one to five tiers (left to the right)

The first medal has a very simple shape and color, it is a brown color circle on the inside with a grey outline, because it has less bright and neutral colors is not very eye-catching, looks less valuable than the following medals. For an extra shine, it was placed on the center yellow and brighter star. The second medal is a variation of the first one, only adding a wing shape on both sides of the

circle and changing the color to full silver, the inner circle, outline, and wings, with different shades. The third is a more detailed version, the design has changed substantially, with the inner circle having a brighter yellow gradient, while the outside is a darker yellow. Complementing the circle on the outside, light blue triangular shapes have been added to give the feeling of something more valuable. Like the previous medals, a star has been placed in the center, but instead of yellow, it's the same color as the triangles.

The fourth changed the colors and some details, in this one instead of triangles on the outside it has a more elegant wings shape with purple color. The inner circle and star as purple as well but with different gradients and hues, to give contrast between the two elements. Finally, the fifth tier medal, the most ornate and eye-catching version, compared to the previous version a crown has been added on top and crystals on the inner circle. Instead of purple, this one has these details in red, which is a more attractive color.

## 6.5 Visual feedback and audio

Feedback is an excellent mechanic to improve the user experience, allowing the user to understand their actions and progress, when the player does something right or wrong it should trigger visual or audio feedback or both combined, which lets the player adjust the strategy and change behavior to achieve in-game goals.

Performance feedback in video games should be immediate, frequent, focused on outcomes and a mix of negative and positive feedback. When it comes to autistic children, this type of affordance is even more important because these children usually have more difficulty processing information, so it is necessary to reinforce information while they play.

Despite of feedback being an excellent gaming mechanic, it may also have a negative side of it if not used properly. Autistic children have attention deficits and excessive visual or audio feedback might be enough for them to lose focus or increase stress levels if negative feedback is triggered too often. The next paragraphs describe which visual and audio feedback was used, in what moments and why. When the UI buttons are clicked it triggers a pop sound, which increases the feeling that the user is clicking on a button.

While playing the tasks, a sound triggers when the player clicks on one of them, if the option clicked is the right one will trigger a sparkling sound (positive sound) and at the same time the option selected pops up on the right side of the screen (where the pieces of the house come up together). If the option is incorrect, it will trigger a buzz sound effect (negative sound). This audio feedback is important to the user to understand his actions and adjust his strategy.

A user interface triggers at the end of every task to provide information about the performance, and depending on the performance it may trigger one, two or three stars, this feedback shows how well the user performed. When the stars are triggered, it also plays a twinkle sound effect, enhancing the animation of the star appearing on the screen.

In tasks with rewards, if the player's performance is in line with what is required to earn the rewards, it will activate both visual and auditory feedback. Visually, the reward appears with an ascending, rotating animation for 2 seconds and then triggers another animation with a sparkling effect complemented with a sparkling sound effect (the sparkling effects used on other elements are different), showing the user that something special has happened in that task. Otherwise, if the user

cannot win the reward, it will trigger the interface with the silhouette of the reward complemented by a negative sound effect.

## 7 Game Implementation

Game implementation is an essential part and demanding process, everything designed needs to be transferred into a game engine to add functionality and structure. This is done by building user and system events, assigning actions to buttons, creating functions, defining variables, creating animations, implementing audio into the game, and assigning sounds to specific actions, in other words, is the process of translating instructions from our language into computer language.

The game was conceptualized and designed for mobile devices, so it is important to choose a game engine with the proper tools to develop this type of game.

### 7.1 Tools

The engine to build the game was Unity 2D, a free cross-platform engine that supports the mobile platform, which is the platform for which the game was designed. This engine is also appropriate for beginners' game developers because it has a variety of features that facilitate the development of 2D games. In addition, it used PlayMaker, which is a visual scripting tool that takes a higher-level approach, offering an intuitive structure with states, actions and events to quickly build behaviors. This empowers both non-programmers and programmers to create more quickly and efficiently.

### 7.2 Game Implementation

Every game has a beginning and an ending and for the player to be allowed to play these stages it needs a game structure that links all components and triggers the game components. This subsection is dedicated to explaining how the structure of the game and the logic of the actions were built.

#### 7.2.1 Levels & task buttons

The opening page, level selection page and task pages were built with UI game components because Unity has features that already had functionality for these components. For example, a button, the unity has a property panel that can define if the button is interactable or not by default, and if the button was created with a square shape, these functionalities needed to be added with code.

When the player gets to the level selection page, the medium and hard buttons are not interactable by default, so the player cannot skip the easy tasks. These buttons get unlocked after the last task of the previous level category is completed. To achieve that a system event was created, and an action was added that reads if the level was loaded and saves that variable. Then when the player gets back to the level selection page, another event loads that variable, and if it is "True" the medium level button unlocks and consequently an animation is triggered.

The task buttons have the same logic, when a task is loaded a variable, that checks if that scene was loaded, is stored then when that task is completed there is a state that loads that variable and if it is "True" the next task unlocks. By default, the tasks buttons from 2 to 6 are not interactable and have transparency and when it unlocks gets the same color as the first button.

#### 7.2.2 Stars

The implementation of stars events is divided into two parts, the feedback update at the end of each task and the stars updates at the task container. The number of stars that the player wins

per task depends on the number of wrong clicks, so it was created an integer variable with a value of 0 and an action was added to every wrong object, so when these objects are clicked it sums 1 value to the variable. If the number of wrong clicks is less than 2, the player gets 3 stars, if the number of wrong clicks is between 3 to 5 the player gets 2 stars and if it is greater than 5 the player gets 1 star.

At the end of each task, a UI is triggered to provide feedback relative to the user performance which shows the stars earned. It created an action that compares the “wrong clicks” variable with the values described previously, then added an action that plays a sound effect when the star is triggered. Lastly, another action that saves a variable with the number of stars earned (See Fig. 28).

Then to update the stars on the tasks container, it was created a FSM that loads the variable saved in the previous scene (stars earned) and compares its value with other values defined in that action. If the value is 1, it will update 1 star, if it is 2 then update 2 stars, and then 3 stars if the value of the variable is 3.

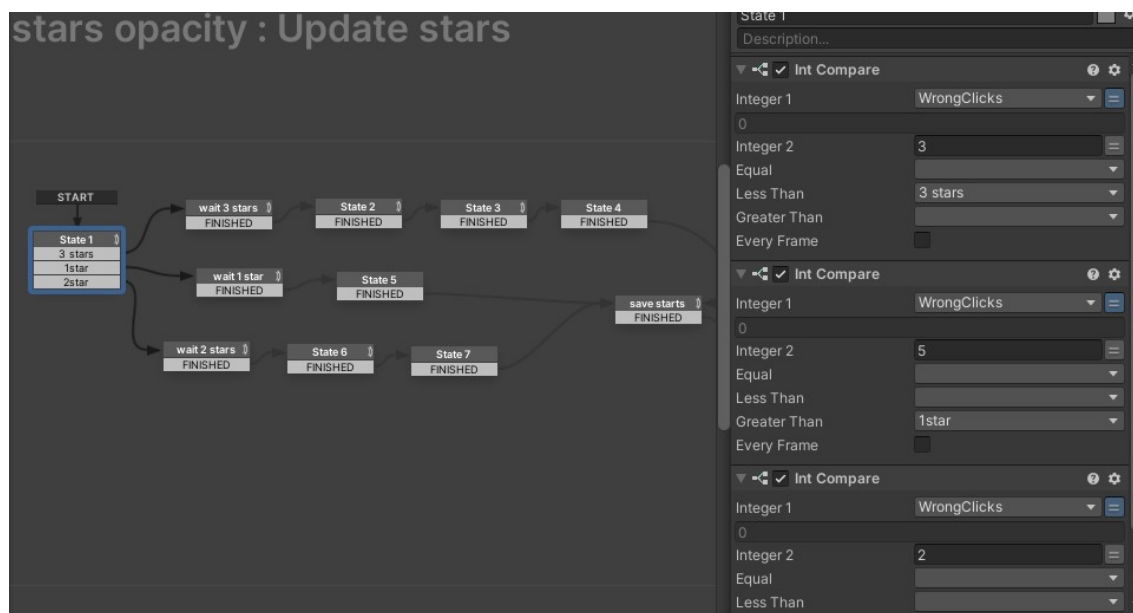


Fig. 28: FSM structure to trigger stars

### 7.2.3 House buttons

These buttons are divided in two categories, the wrong house buttons, and the correct house button, each one of these triggers' actions. The wrong house button is simpler and as mentioned before, when triggered by a user event (click), it triggers a sound effect (negative feedback) and adds a value to the variable assigned. The correct button triggers several actions when is triggered, it destroys the current options displayed, changes the transparency of the corresponding object, from transparent to opaque, and triggers a sound effect (positive feedback). Then the last correct option of each task is an extra action which is to activate the canvas with the performance feedback.

## 8 Game Evaluation

User testing is important to gain a deeper understanding of the target users, how they behave when interacting with the game, and whether the concept, the design, and the implementation provide an experience that allows them to achieve the goals previously defined.

Before testing it is important to define the structure of the test sessions, for example, how many sessions there are in total, how many users, the days of each session and in which location, which tools will be used to collect the session data.

A request was therefore placed to APPDA-Madeira to test the game with the children who attend this location, which made it easier to connect with this type of child and was without a doubt, essential for the game to be tested. The ideal profile for the test would be high-functioning autistic children between the ages of 7 and 13. Still, due to the lack of users with these characteristics, the association selected seven children within the age range but with different profiles, and only two users exactly matched the requested profile. The identity of the users has been kept anonymous, to prevent any identifying data (name or address) might influence the results.

Following the associations' therapist recommendations, the five sessions were held over a month, so that it would be possible to better analyze the evolution of each user. So, one session was carried out per week, this time gap between each session was to ensure that the user did not memorize the options, which could be an extra variable in the data analysis.

The sessions took place at APPDA's facility. A room was reserved exclusively for the tests, in which during the sessions only the user (one at a time), a therapist and the researcher of this study were inside the room. The room had good conditions for the sessions, with good natural light, tables and chairs, and few visual stimuli that could affect the user's attention. On the other hand, it could not isolate sound, as it is a room that contains several children with different disorders, and at times the outside noise affected the concentration of some users.

To ease later post-session data analysis, an observation checklist guide was used to annotate key elements of user behavior (see Fig.29.), like facial expressions, verbal feedback, errors on each level and their gravity, time of the session, difficulties processing verbal or visual information, which was a very supportive and excellent tool for the task at hand. Also, every user test session was recorded with parental permission, these sessions were recorded only for study purposes, the user anonymity was guaranteed, and every footage was deleted after completing the study. Parental permission was obtained previously for the sessions being conducted using an appropriate consent form for this type of data collection (See Appendix B).

<b>Lista de critérios</b>	
<b>Nível 1</b>	
Clareza dos efeitos das ações no jogo (1-10)	
Dificuldades na compreensão das ações do jogo	
<b>Nível 2</b>	
Número de erros	
Gravidade do erro	
Pediu ajuda?	
Número de respostas corretas	
Expressões faciais/emoções	Satisfeito /entusiasmado Frustrado / Motivado confuso / determinado aborrecido / animado desinteressado / interessado
Feedback verbal	
Tempo de cada tarefa	T1: T2: T3: T4: T5: T6:
Compreensão das regras (1-10)	
Clareza dos efeitos das ações no jogo (1-10)	
Dificuldades na compreensão das ações do jogo	
<b>Nível 3</b>	
Número de erros	
Gravidade do erro	
Pediu ajuda?	
Número de respostas corretas	
Expressões faciais/emoções	Satisfeito /entusiasmado Frustrado / Motivado confuso / determinado aborrecido / animado desinteressado / interessado

2

Fig. 29: Second page of the observation guide

The rewards were not implemented in the first two sessions so it would be possible to analyze whether the rewards worked as a motivational element and whether they had any impact on the

player's performance. In the third session, the rewards could be achievable in the game and the fourth and fifth sessions the user could achieve the same rewards in physical format.

The game sessions had the same gameplay structure over the sessions, the levels were always played the same way and there was no need to create a randomized trial because the game has over 100 combinations, which are unlikely to be memorised and additionally the sessions were a week apart.

During the sessions, quantitative data was collected on user performance, the number of errors per task and the time it took the user to complete the task. This data may not be entirely related to the user's evolution because the player can obtain good results by playing the game randomly, so a few errors do not mean cognitive or behavioral improvement, but it is a way of complementing the qualitative analysis, which was observing how the user interacted with the game, emotions, facial expressions and verbal feedback, for example, if a user made plenty mistakes in a task, analysing both quantitative and qualitative data it is possible to understand why that happened (emotions, mood, willingness to play, environment stimuli are factors that may impact the user performance). This table also helps compare the performance between high-functioning autistic children and low-functioning autistic children.

The first table (see Fig.30) corresponds to the performance of high-functioning autistic children and the second table (see Fig.31) corresponds to the performance of low-functioning autistic children. Overall, this data suggests that low-functioning children had more difficulties playing the game properly, but that does not mean there was not any improvement.

User	Age	Session Time		Session 1			Session 2			Session 3 (rewards)			Session 4			Session 5		
				E	M	H	E	M	H	E	M	H	E	M	H	E	M	H
User 1	13	~8	errors	2	2	4	7	1	7	3	7	5	2	2	4	0	0	2
			time	9s	10s	22s	8s	8s	16s	7s	11s	15s	6s	7s	15s	8s	10s	15s
User 2	8	~7	errors	1	7	4	-	-	-	-	-	-	1	2	4	0	0	3
			time	9s	12s	17s	-	-	-	-	-	-	9s	11s	18s	9s	12s	18s

Fig. 30: performance (time/errors) of high-functioning children per session

It was decided to describe each user session in detail due to the complexity of each user's spectrum, they have different profiles and difficulties, and the evolution factors of each user were also different, so it is not appropriate to only make a comparison between users and quantitative data, a qualitative analysis is also important. Through the sessions, a lot of information was obtained by observing how to user played, interacted and reacted to the game, which will be described in the coming sections.

## 8.1 User 1

High-functioning autistic male child of 13 years old. Despite not communicating verbally, has a high cognitive ability, can focus on a task from start to finish and can easily understand verbal instructions.

User	Age	Session Time		Session 1			Session 2			Session 3 (rewards)			Session 4			Session 5		
				E	M	H	E	M	H	E	M	H	E	M	H	E	M	H
User 3	8	~7	errors	18	23	35	18	13	37	23	16	37	13	12	43	17	14	+50
			time	8s	9s	12s	10s	10s	14s	8s	11s	13s	7s	10s	10s	6s	9s	13s
User 4	10	~10	errors	26	38	-	23	36	50+	15	-	-	15	23	-	13	21	Inc.
			time	21s	32s	-	20s	40s	30s	25s	-	-	15s	15s	-	15s	20s	Inc.
User 5	7	~6	errors	20	22	27	-	-	-	18	13	26	-	-	-	17	15	22
			time	15s	16s	13s	-	-	-	15s	20s	13s	-	-	-	14s	18s	24s

Fig. 31: performance (time/errors) of low-functioning children per session

### 8.1.1 Session 1

The first session lasted seven minutes, and throughout the session the user showed no signs of difficulty, he didn't need help at any point in the game. The user was able to identify the concept of the game, understood the mechanics and its objective. the player's first action was to turn down the sound of the game, either because it was too loud or because he didn't like the background music.

In the easy tasks, the player took on average, 9 seconds to complete each task, and only did two mistakes, these errors were made when the user tried to complete fast two tasks, which are not considering major errors. The user managed to get 3 stars without repeating any task.

In medium tasks, despite being theoretically more difficult, the performance was very similar to easy tasks, the user only had two wrong answers (1 on 1st task and 1 on 3rd task), thus earning all the stars, and it took on average 10,6 seconds per task.

In hard tasks, the user struggled a bit more, making 4 mistakes in total (1 on 3<sup>rd</sup> task, 1 on 4<sup>th</sup> and 2 on 6<sup>th</sup>), which one is a major mistake, the player clicked on a wrong option and after hearing the negative feedback sound clicked on the same option again. It took on average 22 seconds per task to complete.

Throughout the session, there was no sign of boredom or dissatisfaction, on the contrary, at the end the user swiped on the level menu to see if there were any more levels to play. there was only a moment when the user diverted his attention from the game, he was distracted by an object he was carrying, but after the therapist drew his attention, he focused on on the game again.

### 8.1.2 Session 2

Before starting the session, the user was showing signs of impatience and little desire to play, showed few signs of confusing, did not understand the mechanics, tried to zoom in on the images, click on the house image instead of the options. In the very first task the user was clicking randomly on the options and did 7 mistakes which gave him only one star. Immediately starts again the same task level and completed flawless receiving three stars. The stars were an important feature to motivate the user to improve his performance. The other tasks of easy category were done without a single mistake and with a time of 8 seconds per task on average.

In medium category, the user was already calmer and more focused, completed all tasks, with only one mistake in the 6<sup>th</sup> task with a time of 8.3 seconds per task on average. On last stage, the user performed worse than the first session, which may have been due to emotional reasons that made him lose concentration. He made 7 mistakes in total (2 on 2<sup>nd</sup> task, 1 on 4<sup>th</sup>, 1 on 5<sup>th</sup>, and 3 on 6<sup>th</sup>), which two of them the user did not process the negative feedback at first and chose the same option. The user played the last task to earn the three stars.

In this session the user used some interjections while playing and it can be considered as verbal feedback, the sound “ahhhh” mean dissatisfaction when could not win the three stars, “hummm” when was hesitant and “uau” when the user enjoys something about the game.

### 8.1.3 Session 3

This session was when the rewards were introduced, and it was an eight-minute session. In the beginning, he was a bit agitated, in the first task he started by doing it without observing the options and the image of the house, so in the first task of the easy category he made 3 mistakes and consequently earned only 2 stars, so before moving on to the next level he repeated the same level to earn the 3 stars which were done in the second attempt. On easy tasks, the user made 3 mistakes in total with a time average of 7 seconds, slightly faster than the previous session.

On medium task, the user struggled more compared the second session, committing 7 errors in total (2 on 2<sup>nd</sup> task, 1 on 4<sup>th</sup>, 1 on 5<sup>th</sup>, and 2 on 6<sup>th</sup>) and with it took 10,3 seconds per task. He repeated the 6<sup>th</sup> task twice to obtain the reward, which he needed to do it without a single mistake. Interjections were used, but this time more frequently and intensified, indicating that the user was more stressed or was not enjoying playing the game.

In the end the user was more focused, made only 5 mistakes (2 on 2<sup>nd</sup> task, 2 on 4<sup>th</sup>, and 1 on 5<sup>th</sup>) in the hard tasks and averaged 15 seconds per task. He was happy with his performance and wanted to repeat some tasks.

The rewards increased slightly his motivation e attention, in the 6<sup>th</sup> task of medium category he failed to win the reward then repeated the game but this time more calmly, taking a closer look at the options

### 8.1.4 Session 4

By the fourth session physical rewards were introduced and before starting the session the rewards were already on the table and it said to the user that was a chance of winning the physical rewards if he managed to win them in the game as well.

This session was the one the user started more focused in the game, only making 2 mistakes in total (3<sup>rd</sup> task) averaging 6 seconds per task, a better result than the previous session. In contrast, the user did not express himself facially or verbally.

On medium tasks, the achieve a time average of 7 seconds per task and only did 2 mistakes (5<sup>th</sup> task). He was very interested in the rewards and identified correctly which physical reward matched the reward triggered in the game.

In last category, the user could not win the last reward in the first attempt for making two mistakes and expressed his displeasure, but on the second attempt he succeeded. In total, he made 4 mistakes (1 on 1<sup>st</sup> task, 1 on 5<sup>th</sup>, and 2 on 6<sup>th</sup>) and averaged 15 seconds per task.

When the sound of the stars triggered in the first time, the user turned down the volume, probably annoyed by the sound but then turned up the sound a bit when the background music was playing.

### 8.1.5 Session 5

There were no significant differences between this session and the previous one, the user understood the mechanics perfectly, and which tasks could earn the rewards. He had no difficulty identifying the buttons or understanding the game's progression route.

On easy tasks the user managed to play without making any mistakes, he did the tasks in a more cautious manner, achieving an average time of 8.4 seconds per task, even though this session had a superior time compared to the previous one, the user behavior and cognitive were better, so this increase in time was positive.

Therefore, on medium tasks the quality of the gameplay was slightly better, the user averaged 10 seconds per task and didn't make any mistake. Finally, the hard tasks, on the last two tasks of that category, the concentration decreased a bit, and some haste was noticed in the way the user clicked on the options. This may have been due to increased boredom, the game being too easy, not wanting to play anymore or the game being too monotonous in the way it is played. Despite this, the rewards are something that the user liked and interacted with, when he earned them he would place them on the table as he earned them.

### 8.1.6 Data discussion

This user has a high cognitive skill, he can maintain focus on the tasks from the beginning till the end, which means that he has strong skills in sustained attention. The user's performance did not depend only on his cognitive and behavior skills, his mood was also variable. The evolution might not be linear throughout the session and in this case, the user performed better in the first session than the second simply because in the second session the user was frustrated and didn't have the same desire to play.

With the introduction of rewards, the user became more motivated and focused, on the tasks in which he failed to earn the rewards, the user would take the initiative to repeat the same task, but this time he would do it more calmly and pay more attention to detail.

Initially, the user had more difficulties in discriminating the cues of hard tasks, especially the windows that only change the gradient color, for example, if a window is rotated 90<sup>o</sup> degrees the spatial orientation maintains the same, but its inside content (color gradient) changes. And these were the details that the user had the most difficulties in comparing and processing. Over the course of the sessions that struggle became less evident, it was still noticeable a hesitation on those objects but not as much as in the beginning.

In the fourth session, his sustained attention and visual processing were slightly better, in contrast with the previous session which the user had some moments less attentive, in this session he stayed engaged during the entire session and responded more accurately and faster. Having physical rewards impact positively this user, providing a more immersive experience, abstracted from external stimuli.

Despite this user having high cognitive levels, it was possible to detect slight improvements in his sustained attention and visual processing when playing this game.

## 8.2 User 2

The second user is a high-functioning autistic female child of 8 years old. No unusual behavior was noticed during the sessions

### 8.2.1 Session 1

In the first session, the user didn't need any instruction or have any doubts about the mechanics, neither the assets nor the game's progression route.

On easy tasks, he only made one mistake in the last task and had an average of 9 seconds per task. The user completed these tasks quite easily, did not hesitate in the way he chose his options, and analyzed the game assets quickly and accurately.

On medium tasks, the user struggled a bit and made 7 errors in total (1 on 2<sup>nd</sup> task, 1 on 3<sup>rd</sup>, 2 on 4<sup>th</sup>, 2 on 5<sup>th</sup>, and 1 on 6<sup>th</sup>), hesitated at more points in the game and showed some difficulty in discriminating some colors. Despite showing more difficulties, she didn't lose focus nor the willingness to play and went on to the next category.

In the last category, curiously the user performed better than in the medium tasks, only making 4 mistakes and averaging 17 seconds per task. The quality of this time was better than in the previous tasks, she didn't hesitate as much and sometimes made sure more than once that the option she was going to choose corresponded to the correct element of the house.

At no time did the user speak verbally, nor was there any facial expression to indicate displeasure or annoyance, always remained focused and didn't look away from the screen.

### 8.2.2 Session 2

In her second session, the rewards had already been introduced. The performance was very similar to the first one in terms of errors, time and attention level. On easy tasks, only 1 error was made on the 3rd task, and averaged 9 seconds per task, the same as the first session. The next tasks are where the user improved, only making 2 mistakes with an average of 11 seconds per task. And the last category, hard tasks, any differences were noted from one session to another, made the same error on the same tasks and performed with the same time average.

Like the previous session, no help or instructions were needed, the user played from the beginning to the end without providing any verbal feedback. But this time before starting to play the background music was already playing and she requested if she could turn the volume down a bit. In this case, the rewards did not make much difference in motivation, even though winning all rewards only wanted to keep one (Tier 4 – the purple one), and probably had a preference for the shape and colors.

### 8.2.3 Session 3

Last session, the user performed as well as the other sessions, her sustained and selective attention was on point, and even with auditory stimuli during the session, it wasn't enough to distract her and make her lose focus on the task.

On easy and medium tasks, the user did not make any mistakes and completed them with an average time of 9.2 seconds and 12.3 seconds respectively. The user has more difficulties when two colors are very similar, but she managed to choose them correctly.

In the hard tasks, the user made 3 mistakes (1 on 5<sup>th</sup> task and 2 on 6<sup>th</sup>) so she did not get the last reward, which made no difference, she did not want to repeat the level again. She had more difficulty discriminating the mirrored doors and windows options, which are the details of these objects that matter to understand the right option.

#### 8.2.4 Data discussion

This user was the most difficult to evaluate, as he only took part in three sessions which was not enough to gather concrete data and there were not many differences between sessions.

The user didn't have tendencies to choose randomly, despite being fast it was noticeable that she made his choices by observing and processing the cues. The number of wrong clicks decreases from one session to the next in some tasks, for example the first session, on medium tasks the user had a total of 7 errors meanwhile in the second session she only had 2 errors, that doesn't mean that she understood better the cues from one session to another, it may have been because she wasn't completely focused on the first session.

The main cognitive improvement that was noticeable was the processing speed, especially comparing the first session with the third, on hard tasks the user had fewer moments of hesitation, made her choices faster and the number of wrong clicks didn't increase.

### 8.3 User 3

Low-functioning male autistic child of eight years old. Despite being a verbal child, he cannot communicate properly, has difficulties interacting with others, has difficulties understanding instructions and initiating conversations, and tends to repeat words. Also has repetitive behaviors, like head shakes and walking around repeating the same route.

#### 8.3.1 Session 1

In the beginning, he immediately recognised the buttons and easily reached the first task. There the user thought he had to drag to option to the place that was displayed on the right side of the screen, but after two attempts he noticed that he had just clicked on the right option.

In the first task of easy level, the user was doing as supposed, but then he started to click randomly, starting to lose his interest and focus on the game. When this action was noticed the therapist intervened which had a positive effect, he tried to play properly but rapidly returned to the same behavior. In total, the user made 18 mistakes (1 on 1<sup>st</sup>, 5 on 2<sup>nd</sup>, 1 on 3<sup>rd</sup>, 2 on 4<sup>th</sup>, 6 on 5<sup>th</sup>, and 5 on 6<sup>th</sup>), and averaged 8 seconds per task. The user had repetitive verbal behavior, repeating the words that appeared in the game.

On medium tasks, the user already understood how to play the game but continued to play randomly. It was noticed that the user was getting bored and unfocused, he often looked away from the screen usually to the therapist and stopped playing a few times. In total, the user made 23 mistakes with a time of 9 seconds per task.

On hard tasks, his behaviors were the same, in some moments he tried to respond correctly, observing the options and the complete image of the house, and he did that in a few options but most of them were done randomly. The player averaged a time of 12 seconds per task and chose wrongly 35 times (some options the user insisted on clicking on the same, despite hearing the negative feedback).

### 8.3.2 Session 2

The second session was very similar to the first, the user could not focus or show interest in the tasks for long periods. In the first three tasks of the easy category, the user was able to concentrate without his attention being affected by sound or visual stimuli, but from then on his focus and attention gradually began to wane, resulting in total of 20 errors ( 2 on 1<sup>st</sup>, 2 on 2<sup>nd</sup>, 2 on 3<sup>rd</sup>, 4 on 4<sup>th</sup>, 5 on 5<sup>th</sup>, and 5 on 6<sup>th</sup>), which on the fifth and sixth task the insisted on clicking the same wrong option, which means the user was not attentive to the game feedback.

On medium task, the behavior was the same the user was engaged with the device but not with the game, he did the task hastily. A curious fact observed was the way he made his choices, in one task the correct options followed a pattern (first option, second option, first, second) and if he understood this order, then in the next task he applied the same pattern. He performed better than the previous session in terms of results, making only 13 mistakes, but because he was selecting in a random way, it is not possible to determine the quality of these results, there might have been some option that he chose by analyzing all canvas (options and house image) but most of them he was just looking at the options.

On hard tasks, the performance was the same as the medium tasks, made his choices randomly even though the therapist called his attention, he continued with the same behavior. Throughout the game, the user mimics some therapist words and words displayed at the user interface.

### 8.3.3 Session 3

In this session, the rewards were introduced, but there was not any positive effect on the user. While the user was playing, there was a lot of noise and this stimulus was overwhelming for him, who felt uncomfortable with the noise, which made him more distracted. When a louder noise occurred, he would look back with a frightened face.

In this session, he underperformed in every task category compared with the previous session, he was very distracted, sometimes he wasn't even looking at the screen when making his choices and at times he chose the wrong option repeatedly showing signs of frustration.

Because the environment conditions were not optimal, the performance was influenced by external factors which may prove that overwhelming stimulus can impact negatively the performance.

### 8.3.4 Session 4

Session 4 The fourth session was held in the morning while the previous one was after lunch, and this one had the best results in terms of levels of attention and behavior. At the beginning and with the instructions of the therapist, the user started doing the tasks more smoothly, observing the options and trying to compare them with the complete house image and there were fewer random choices. He only failed 13 times, and previous best was 20 on the easy tasks, not only did he make fewer random choices also made fewer mistakes.

The medium tasks outperformed as well, with 12 errors in total, despite of low number of errors the user barely hesitated while choosing the options which might indicate that he was able to memorize the options, which can be positive in terms of cognitive development, or the user made more random choices. By the end of the medium tasks, the user was showing signs of disinterest. At this point, the verbal feedback was pretty much the same as the previous session, but this time

he was more interested in the stars, at the end of the tasks, when the stars were activated, the user said a few times "estrela" in a cheerful tone.

in the difficult tasks, the user went back to normal, proving to be more bored and less interested in playing, making more random choices in a fast pace, it averaged a time of 10 seconds per task, which is significantly lower than the average of the high functioning users, and made a total of 43 errors. Through this data and observation of his behavior, it is obvious to say that the user had already lost total focus of the tasks at this point.

Curiously, when he had finished all the tasks, he autonomously decided to continue playing, but he wasn't focused on trying to play correctly, he was just looking for auditory and visual stimuli. The rewards in this session were not enough to make the user want to repeat the levels and try to play correctly.

### 8.3.5 Session 5

The performance in this session was worse. In the morning, the association's children took part in activities outside the association, which required physical effort. This user was more electric and agitated.

In all tasks, the player was clicking in a hurried manner, hardly interacting with the therapist, something that was recurrent in the other sessions. It was noticeable that the player didn't feel like playing.

On the easy and medium tasks, the user didn't do much worse than the previous session, at the beginning he tried to understand which options corresponded to the image, but throughout the game, the randomness has become more frequent. On the hard tasks the user only played till the 3rd task.

### 8.3.6 Data discussion

This user had difficulty maintaining focus on the game, at first, he played more calmly, but as he progressed through the game, he became more distracted and impatient, making his choices randomly, with the therapist's verbal instructions the user became more focused again, something that only lasted a short time.

This user tends to click randomly, so it is hard to evaluate which options he did by discriminating the cues and the ones by clicking randomly, so comparing the number of errors and task times may not be appropriate for analyzing whether there has been any improvement, it's better to analyze the player's behavior and the way he makes his choices. On this user faster times didn't mean that he was doing better or improving his processing speed, it meant that the user was losing interest in the game and playing randomly.

There were moments where the user was using his logic to complete the tasks, for example in tasks in which the correct options had a regular pattern (consecutively the 1<sup>st</sup> option, 2<sup>nd</sup> option, 1<sup>st</sup>, 2<sup>nd</sup>) then he tried to replicate the same pattern in the next level without even noticing if the option was correct, that might mean that he was working on his short term memory and logic, despite not playing the game properly and failing the tasks, the player having or developing this type of reasoning is a positive.

## 8.4 User 4

Low-functioning autistic female child of 10 years old. She cannot communicate verbally properly and uses few words and gestures to communicate and interact with her peers. She also has difficulties in processing visual and auditory information.

### 8.4.1 Session 1

This user had the most difficulty interacting with the device, had trouble understanding the dynamics of the game, and the order in which the game should be played, and had difficulty identifying numbers, even with the therapist's instruction.

In the beginning, the user didn't feel comfortable, seemed embarrassed and looked at the therapist quite often and the therapist had to instruct the user to play. On the page task selection, the user had difficulties understanding the order of the tasks, for example, after completing the first task, the second task unlocks but she couldn't perceive that visual information and despite the therapist asking which is the number 2, the user could not identify it, she "freezes" and make circular movements with her finger, like she is trying to guess but afraid to answer.

For the easy tasks, the user made 26 errors (the first task with fewer errors, 2, and the last task with 6 errors.) with a time average of 21 seconds per task, she takes more time per task than the other users, but no random responses were noticed.

On the medium tasks, the user was already understanding better the dynamic of the game, but the intervention of the therapist was required in some moments, when choosing the task number, she tended to select the number 5 despite being locked. At this level the user began to respond randomly and made more stops during the levels, his interest and concentration was becoming increasingly disconnected. She took on average 32 seconds per task and made 38 mistakes in total, the last 3 tasks she was completely off, even selecting the same wrong option more than 3 times, which means that she was not paying attention to the game feedback.

The session ended in medium tasks because the user did not want to continue to play, so it was important not to force as it could create emotional instability and impair the following sessions.

### 8.4.2 Session 2

The second session went better than the first, she was more willing to play. As in the first session, the therapist intervened at times, mainly to ask questions or indicate the next level.

On easy tasks the user mistaken 23 times with a time average of 20 seconds per task. The tasks in which therapist helped by asking her to do them more calmly and helping them with questions, such as "What shape is the house?", "which of the doors is the same as the picture?", the user performed significantly better, in task number 2 with no intervention she made 7 mistakes, in the third task with intervention the user made 2 mistakes.

In the medium difficulty tasks, the user began to rush through their answers and become more distracted, blocking more often within tasks and between tasks, and even with the therapist's intervention, her attention to the game lasted only a short time.

so far, the user has not provided any verbal feedback or asked for help, nor has he shown any reaction to either visual or audio feedback. On these tasks, the user made a total of 36 mistakes and averaged a time of 40 seconds per task.

In the last tasks, the user was completely disconnected from the game, playing randomly and it was noticeable signs of frustration, like lowering his head and taking his hands of the table. In both sessions the user had difficulties staying engaged during the entire game session, despite playing the last category, her will was almost nil.

#### 8.4.3 Session 3

The first interaction with the screen was easier, identified the buttons and the order of the tasks and the therapist did not have to intervene often. In comparison with the previous session, the user had better results on the easy tasks, the first and third tasks were completed with no mistakes. In total made 15 mistakes with a time average of 25 seconds. Her behavior improved slightly; she did not need much time to discriminate between the options.

Despite the better performance on easy tasks, when the user was about to start the first task of medium level, she froze and was not able to continue, so the medium and hard tasks were not played in this session. Emotional state is very important in an autistic child, depending on it the child may or may not engage with the game or other type of therapy which affects the evolution throughout the sessions.

#### 8.4.4 Session 4

In this session the user was more comfortable playing, initially showing no signs of boredom or frustration. She was playing slightly faster and making fewer errors, even though some of her selections were random, but when the therapist helped her, she became more attentive to the cues, making fewer mistakes and clicking less randomly, so verbal instructions impact positively user sustained attention.

On easy tasks, she made a total of 15 mistakes with an average time of 15 seconds per task. Despite improving on task play she kept struggling with the task menu, she had the same behavior with her finger, pointing around, and sometimes took more than 30 seconds to understand which was the following task. Usually when the therapist asks, “Where is the number 2” or “Where is the number 3”, the user tent to click on the number 5. This lack of understanding and difficulty in identifying the numbers has been recurring since the first session. On medium tasks, the user was showing signs that was enjoying the game, there were moments when she smiled and laughed. She performed better than the previous session, was more excited and was interested in the rewards. As she didn’t manage to earn the rewards the first time, she agreed to repeat the levels, when asked by the therapist, to try to earn the rewards. Having the rewards in a physical format is positive, it is a more tangible format which helps to engage with it and understand that she is being rewarded for playing correctly. By the end of the medium tasks, the user was getting into the same routine, choosing randomly and in some cases following a pattern like user 3 (first option, second option, first, second). As in the previous session, the user did not want to play the hard tasks, probably due to cognitive overload, so the session ended at the end of task 6 of medium difficulty.

#### 8.4.5 Session 5

The last session was the best, there was an evolution in behavior and sustained attention compared to the first one. On easy tasks, the user was cheerful, she laughed a few times, and she was more interested in the rewards especially the third one, always picking up that one. In total made 13

mistakes, the first three tasks were the best and the last three were the worst (0 on 1<sup>st</sup>, 1 on 2<sup>nd</sup>, 2 on 3<sup>rd</sup>, 3 on 4<sup>th</sup>, 4 on 5<sup>th</sup>, and 3 on 6<sup>th</sup>).

On medium tasks, the user interacted more with the therapist and the researcher, and it was in this session that she communicated more verbally. Some of the verbal feedback; “uau”, meaning that she was impressed or liked something, usually happened at the end of the tasks and when she earned the rewards. “olha”, to call the research to look at the rewards that she won. And “aqui” means the place that she wanted to place the reward.

This session was only the second time that she wanted to play the hard tasks, initially, she was excited, clapping hands and laughing, but slowly losing interest. The user was able to play until the third task, and in these tasks, the number of random clicks was higher. At the end of the third task, she asked “já está?” which means “is it done?”, this response is understandable because the user is tired and doesn’t want to play anymore. The session ended with the third task of the hard category.

#### 8.4.6 Data discussion

There were some significant improvements with this user, at the beginning the user struggled a lot to play, had difficulties in understanding instructions and identifying the game progress route, and didn’t provide much verbal feedback and session by session she improved slightly in some respects. Like the previous user, it was more important to analyze and observe her behavior, interaction, and reactions to the game.

In terms of cues, the user had more difficulties in discriminating objects with similar colors and spatial orientation (mirrored objects were the most difficult to compare), objects with more details like doors and windows were the ones that the user struggled more, but in last session, the user was having less trouble in discriminate some of these objects. In the first session, on easy tasks, the user had a total of 26 errors and in the last session, that number decreased by half. Not only did the number of wrong clicks decrease but also the randomness was lower, possibly due to the verbal instructions that helped her reasoning.

After implementing the rewards, her behavior and social interaction improved, she became more motivated to play and sometimes even wanted to repeat some levels. The last two sessions were the ones in which she communicated verbally and provided feedback, so despite limited speech skills, she tried to initiate conversation and social interaction.

Something that the user didn’t improve through the sessions was the capacity to understand which task she had to select. After completing task one she could not understand that she had to click on number 2, even with other visual cues that indicated the next task she didn’t process that information and got stuck a few times with that part of the game.

### 8.5 User 5

Low-functioning autistic male child of 7 years old. This child shows ease in handling mobile devices, does not communicate verbally but only reproduces some sounds related to their mood, and sometimes exhibits aggressive behavior. This user only attends three test sessions.

### 8.5.1 Session 1

At the beginning of the session, the user immediately exited the game and tried to open YouTube app, he did this 2 to 3 times before starting to play the game, indicating that he was not interested in playing.

With the help of the therapist, the user started playing, but he was not attentive to the cues, since the beginning he was clicking randomly, and even with the intervention of the therapist he maintained the same behavior and sometimes showed signs of irritation, stopping a few times while playing the tasks. As expected, due to his behavior, on easy tasks the user made a lot of mistakes, a total of 20 wrong clicks, averaging 15 seconds per task.

On medium tasks, the therapist was able to calm him down, he was not angry anymore, but he was focused on the tasks and continued to click randomly. The user was interested and happy when stars were triggered, saying “wow” when a star was displayed but he didn’t know what the star indicated about his performance.

In the hard category, the behavior was the same, the user couldn’t focus on the tasks or didn’t understand their objective, even when the therapist gave him instructions he was confused and just looked at her smiling. In these categories, the user made a total of 27 errors and a time of 13 seconds per task.

### 8.5.2 Session 2

In the second session the results were pretty much the same, at the beginning he repeated the same action, exited the game and opened Youtube, which indicates that is something that the user is used to and is interested in.

The number of errors and time were very similar, and the user didn’t show any signs of improvement, moreover, in these sessions the user was angrier, even with the help of the therapist, the user continued to get angry and there was a moment when he knocked on the table. He had some repetitive gestures, like staring at his hands.

in the medium tasks, and with the help of the therapist, the user became calmer, even managing to answer some tasks correctly, looking at the images before choosing. He made a total of 13 mistakes and averaged a time of 20 seconds per task.

In the last category the user became less focused again, the attention was recovered for brief moments when the therapist called his attention and asked him to play more calmly. The repetitive gestures that were observed appeared, it seems that these behaviors are more frequent when the user is bored or uninterested in the task.

### 8.5.3 Session 3

In this last session, unlike the previous sessions, he didn’t leave the game to look for YouTube or another app, this time he started playing straight away. In this session, the user was calmer, but the tendency to play randomly was the same.

In this session, the rewards were already in physical format, and it was something that caught the player’s attention, as they were on the table, the user interacted with them even though he hadn’t won them. This can be a positive thing because it’s a sign that he’s interested in that

element of the game, but on the other hand, it can be negative because it takes the focus away from the game and as the user has attention deficits, having the rewards on the table didn't help.

in the easy tasks, the user performed similarly to the previous ones, not only in terms of results but also in his actions (random choices), with no sign of evolution between sessions.

In the medium tasks, when he tried to play correctly, he showed difficulties in discriminating similar colors and sometimes made his choices based on the colors he liked best (clicking repeatedly on that option). In this session, the number of errors increased slightly.

In the latter category, the user was more disinterested, took more breaks between tasks also in the middle of some tasks, and resumed repetitive gestures.

#### **8.5.4 Data discussion**

Although the number of sessions is not sufficient to have more concrete data, this user demonstrates significant difficulties in sustaining focus on a task from start to finish. Their attention is easily affected by other visual and auditory stimuli. This user exhibits signs of hyperactivity, which makes it challenging to conduct these sessions unless they are engaged with the game right from the beginning. When the therapist intervened, there were brief moments when the user understood the instructions and attempted to play more accurately and logically. In this case, there is a significant dependency on a therapist to keep the user engaged in the game from start to finish. It would require an additional 2/3 sessions to gather more conclusive data regarding the effectiveness of this game for this user.

## 9 Discussion

The user tests provided interesting data on the impact of digital games in teaching conditional discrimination as a complement to the therapy of children with autism, although the number of users tested was very limited, it was possible to detect some cognitive and behavioral improvements in the users, some with improvements were more noticeable and others less evident.

Initially, and after several research studies on the impact of digital games and technologies, the game was conceptualized and designed to target high-functioning autistic children, but after the test sessions, it was possible to analyze that low-functioning children can also benefit, without having to make adaptations to the game's functionalities, mechanics, or graphics.

Every child has a different level of impairment from one another. Some have a more severe profile than others, and since the difficulties in visualizing and processing information or performing certain tasks vary, the way a type of therapy benefits the child can also differ. In other words, therapies must be tested with a variety of children with different profiles, because even if a particular therapy may not be the most suitable, it can still help develop certain skills, which may not be the primary goal of their development, but it can serve as a complementary aspect in their evolutionary process.

In this study, as expected, the high-functioning children had less difficulty playing this game, completing tasks faster and more accurately than the low-functioning autistic children. However, improvements were noticeable in the last level category which had, not only more similar cues but also more options to discriminate. In the first sessions, the users needed more time to identify which of the three options was the correct one, because they had more similar features the children needed more time to process all that information, but throughout the sessions, they were able to improve, they were able to improve their response times and did not hesitate as much when selecting. That might mean that their reasoning and processing speed had improved or long-term memory, which means they were able to memorize the position of the correct options, which is unlikely since there was a gap of one week between sessions.

The rewards had an overall positive impact, with some users finding them motivating, leading them to take the initiative to keep playing and repeating tasks in which they hadn't earned rewards and when they repeated the task, usually, they were more focused than the first attempt. The introduction of physical rewards changed the way they perceived them, when there were only digital rewards, their reactions were minimal, that could be because of how the reward system was designed, maybe they could not comprehend those rewards related to their performance. But making them tangible and giving instructions on what was needed to win them, helped the children to understand that those medals were elements achievable by playing correctly, and provided an experience not entirely digital. Interacting with physical objects in the middle of sessions can be a way of relieving the cognitive effort required by the game's tasks.

In the case of low-functioning children, the game was more demanding. They faced greater difficulties in discriminating the characteristics of objects, made more errors, and had a lower level of concentration.

However, the game also had a positive impact on these children in some respects. There were cases in which both children attempted to replicate patterns from previous levels to solve the next

level, which may indicate a slight development in short-term memory and their problem-solving reasoning.

For these users, the presence of a therapist was essential because there was a trusted relationship that was important for understanding some verbal instructions. For example, when the therapist noticed that the child was playing randomly, she would intervene and draw the child's attention to play more calmly and pay attention to the shapes of the objects. This type of intervention was positive, and sometimes the child regained focus for brief moments.

On user 4, the behavior changed throughout the session, the first one she did not interact nor provide any verbal feedback, but in the last session, she was already trying to initiate social interaction, although more sessions were needed to assess whether the game provided this behavior change or if it was something occasional from that session.

The observational guide model used in the sessions (see appendix C) was not the most appropriate because registering the number of errors and time per task is not properly relevant for all users, other variables are more important and relevant to observe, for instance, facial expressions. However, to protect children's privacy the researchers were not allowed to record the children's faces. The guide helped register this information, and in fact, facial expressions might indicate how the child is feeling throughout the game, taking note of moments when the user was not interested in playing or was playing randomly. As a result, a more relevant and updated version of the observational guide was created to accommodate this interesting finding which was possible due to the work conducted (See Appendix D).

#### **Recommendations:**

- When testing with low-functioning autistic children it is important to have a therapist who can intervene when it is needed to get the user's attention and provide verbal instructions.
- Provide physically tangible rewards, since autistic children as users are more attracted to objects they can touch, and play physically rather than just digital ones.
- Understand user difficulties and define goals for each session, for example, if the user has a lot of difficulties on the easiest level, then the focus of the session should be on improving the performance on that level before continuing. In-game progression should match cognitive development.
- Conducting testing sessions in controlled environments where it is possible to isolate external sensory stimuli that may affect the child's performance.
- Implementation of verbal instructions in-game, this mechanic might help to guide the user through the game and make them more focused, it may also reduce dependency on the therapist, so children can have more hours of therapy outside the therapeutic environment.
- Use of an eye tracker device, which may help get more accurate data in terms of attention and quality of the user responses, understand in which moments the user lost attention, the eye movement throughout the game, and which graphics the user was more attracted to.

#### **Limitations**

However, there were some limitations in this study, such as the user sample size being very small, which was not ideal for a study involving this type of children with diverse profiles. Therefore, there was a need to test with more children to identify improvement patterns in specific groups of autistic children (low and high-functioning).

An additional limitation was the lack of iterations designing the game, and it would be important for the outcome of the game to increase the number of iterations. The time during which this game was developed and tested was not sufficient to carry out the necessary iterations. With more time, it would be possible to adapt, enhance, and delve deeper into the concept, and design of the game to provide a better user experience.

The results obtained were not validated by the therapist. Although the therapist was present during the sessions, the researcher collected and validated the data, so a qualitative analysis may not fully correspond to the reality of the children's progress or lack of progress.

The introduction of rewards were not randomized, instead it was introduced linearly, first and second session with no rewards, then the third digital rewards and the fourth and fifth, tangible rewards, which may not be the best way to test the real impact of the rewards, because the children might like the reward for being a new feature in the game and not because of the reward itself, so in long term play the children might lose interest on the rewards.

## 9.1 Future Work

Further iterations would be important to add additional features to the game and the testing sessions. In the gameplay it would be important to develop the game narrative, adding a main character that would help the user provide instructions and guidance while playing. Also, add transitions between tasks, for example, a short cutscene could be added of the house that the user has built being added to a neighborhood, so it would probably give a better meaning to the tasks that the users were doing. Cutscenes can be used as a cognitive relief because having tasks one after the other without something to break the pace of the game can cognitively overwhelm the user, and make the game more boring due to the monotony of in-game events.

As in the sessions conducted, it was observed that verbal instructions from the therapist were effective at times. It would be interesting to test implementing verbal instructions in the game; if successful, there would be less dependence on the presence of the therapist.

Another component that could be added in the future is the variety of levels. If the game were to be continued, it would be interesting to change the game dynamics. The first part would involve building the house's structure, and then it would move on to the interior of the house, where there would be levels in which the player had to construct the living room, bedroom, bathroom, etc. In this way, the game would become more dynamic and would demand a higher cognitive capacity from users due to the complexity and detail that can be added to the interior objects of the houses.

In the implementation, there could be an action where when users made mistakes, the options were destroyed, and new options were generated. This way, it would be easier to analyze whether the user succeeded by correctly discriminating, or if they were playing by trial and error.

In future sessions, it would be important to have an eye tracker since it could help in gathering more accurate data about the user's attention, and understanding which assets the user would be most interested in, and which moments the user lost attention, or got distracted by other stimuli.

## 10 Conclusion

During the research phase, various types of therapy that have emerged over the years were analyzed. These have evolved and adapted as the understanding of this subject has also evolved. One of the types of therapy with more studies and positive data regarding the cognitive and behavioral development of a child was PRT (Pivotal Response Treatment).

Something that can also be beneficial for the development of an autistic child is game-based therapies, or those that incorporate gamification elements, as it makes the process more natural and enjoyable for a child. Video games also provide an alternative way to promote and assess cognitive skills because, due to their impairments, interacting with other children and processing information around them can be stressful, and digital games can serve to distract them from these situations. So, a gap was identified, and something that has not been extensively studied is the development of therapies that incorporate the principles of PRT applied within digital games.

This study aimed to develop a digital game incorporating PRT principles and assess how it can assist in the development of cognitive and behavioral skills. To develop a game of this nature, it is necessary to go through several stages. First, defining the game's concept, structure, visual language, mechanics, and narrative is essential. Having a well-defined concept facilitates the design process because we already have a verbalized idea about the game.

Designing this game was a rather complex task, as there were many aspects to take into consideration. For instance, the interface had to be clean to avoid cognitive overload, or distracting the user from the main objective. The levels had to progressively increase in difficulty so that users would have to discriminate more cues.

This game was conceptualised and designed with a focus on high-functioning autistic children, as they are more autonomous and cognitively advanced, allowing the user to play at any time without needing a therapist's supervision. However, during the testing sessions, improvements were observed in cognitive and behavioral aspects, not only in children with high-functioning children but also in low-functioning children, who were accompanied by a therapist. This is indicative that, if provided with the appropriate conditions, digital games can be a promising avenue for the development of autistic children. Another iteration, applying the methods described previously might enhance the outcomes achieved in this study.

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## A Appendix

### Interview Guide

#### Questions related to association

- How many children with autism attend APPDA?
  
- In general, are these children highly or minimally limited? Both cognitively and physically.
  
- Are the children diagnosed beforehand, or does the association perform this assessment?
  
- How many hours per week/day of therapy are provided?
  
- Is there any observation process for the child before any type of therapy is initiated? Or is there a more generalized type of therapy for everyone?
  
- What activities do the children excel in, show the most interest in, and engage with the most?

#### Questions related to autism spectrum

- What are the most common indicators in diagnosing a child with autism?
  
- What is the importance of stimulating the senses of a person with autism?
  
- Are the experiences sensory, cognitive, or both?
  
- Are technologies beneficial for the treatment of children with autism?
  
- Can digital games bring benefits to the development of children with autism?
  
- What is the greatest challenge in supporting a child with a higher level of autism? (e.g., non-verbal or significant cognitive difficulties)

Questions related to autism spectrum

- When should a child with autism begin speech therapy, if needed?
  
- Are there differences in the therapy provided to children with autism compared to non-autistic children?
  
- Does age play a role in how therapy is conducted?
  
- What are the typical therapy sessions like, and what are the most commonly used methods?
  
- For a therapist, what factors or signs indicate that a child is ready for the next level of therapy?
  
- What is the biggest challenge in therapy for children who communicate solely through gestures, and is it possible for a child to transition away from gestural communication?
  
- Can occupational therapy sessions help with speech and communication development, and if so, how?
  
- What types of technology and/or apps are used in therapy sessions?
  
- What are the advantages of using apps compared to traditional methods?
  
- Are there any particularly effective apps for speech therapy?
  
- Are there any game-based apps for speech development, or are they primarily educational in nature?
  
- Are alternative communication apps used only for non-verbal children?
  
- Can these apps lead to dependency or do they encourage a child to communicate?

## B Appendix



### Declaração de Consentimento para Menores

Eu, \_\_\_\_\_ declaro ter lido e compreendido este documento, bem como as informações verbais que me foram fornecidas pela(s) pessoa(s) que abaixo assina(m). Foi-me garantida a possibilidade de, em qualquer altura, recusar que o menor participe neste estudo sem qualquer tipo de consequências. Desta forma, aceito que o menor participe neste estudo e permito a utilização dos seus dados, que de forma voluntária são fornecidos, confiando em que apenas serão utilizados para fins científicos e publicações que delas decorram, com as garantias de confidencialidade e anonimato que me são dadas pelo/a investigador(a).

**Nome:** \_\_\_\_\_

**BI/CC N.º** \_\_\_\_\_ **Data ou validade** \_\_\_ / \_\_\_ / \_\_\_\_\_

**Grau de parentesco ou tipo de representação:** \_\_\_\_\_

**Assinaturas legíveis e manuscritas dos investigadores/responsáveis do estudo**

\_\_\_\_\_

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

## C Appendix

### Observation Checklist

User testing sessions

2022/2023

User session n°:

Age of participant:

Previous experience with videogames:

How frequently does the participant play? (Select best option)

Every day, twice a week, Once a week, Every two other weeks, Once a month

Overall session duration:

List of criteria	User Session
<b>Level 1</b>	
Number of errors	
Error severity	
Asked for help	
Number of correct answers	
Perceived user facial expression and feelings (select best option):	unsatisfied/ satisfied frustrated/ motivated confused/ determined annoyed/ excited disinterested/ interested
Verbal feedback	
Time spent in task	T1: T2: T3: T4: T5: T6:
Clarity of rules	
Clarity of the effects of actions in the game	
Difficulties in understanding the game's actions	
<b>Level 2</b>	
Number of errors	
Error severity	

Asked for help	
Perceived user facial expression and feelings (select best option):	unsatisfied/ satisfied frustrated/ motivated confused/ determined annoyed/ excited disinterested/ interested
Verbal feedback	
Time spent in level	T1: T2: T3: T4: T5: T6:
Clarity of rules	
Clarity of the effects of actions in the game	
Difficulties in understanding the game's actions	
Level 3	
Number of errors	
Error severity	
Asked for help	
Perceived user facial expression and feelings (select best option):	unsatisfied/ satisfied frustrated/ motivated confused/ determined annoyed/ excited disinterested/ interested
Verbal feedback	
Time spent in level	T1: T2: T3: T4: T5: T6:
Clarity of rules	

Clarity of the effects of actions in the game	
Difficulties in understanding the game's actions	

General Criteria	
<b>The user understood the mechanics?</b>	
Difficulties	
<b>The user has understood the objective?</b>	
Difficulties	
<b>The user was confused by the game's graphics</b>	
which one?	
Did the user stay focused until the end of the session?	
Level of attention (1-10)	
The user was motivated/interested in the game	
Feedback/Emotions in relation to game sounds	

## D Appendix

### Observation Checklist

User testing sessions

2022/2023

User session n°:

Age of participant:

Overall session duration:

List of criteria	User Session
<b>Level 1</b>	
Perceived user facial expression and feelings (select best option):	unsatisfied/ satisfied frustrated/ motivated confused/ determined annoyed/ excited disinterested/ interested other:
Verbal feedback	
<b>Behaviors while playing (ex: clap hands, head shake, laugh...)</b>	
<b>triggered by what?</b>	
Moments of hesitation/difficulties	
<b>Focused on every task?</b>	
<b>If not, which task and why?</b>	
Level 1 time	

List of criteria	User Session
<b>Level 2</b>	
Perceived user facial expression and feelings (select best option):	unsatisfied/ satisfied frustrated/ motivated confused/ determined annoyed/ excited disinterested/ interested other:
Verbal feedback	
<b>Behaviors while playing (ex: clap hands, head shake, laugh...)</b>	
<b>triggered by what?</b>	
Moments of hesitation/difficulties	
<b>Focused on every task?</b>	
<b>If not, which task and why?</b>	
Level 2 time	

List of criteria	User Session
<b>Level 3</b>	
Perceived user facial expression and feelings (select best option):	unsatisfied/ satisfied frustrated/ motivated confused/ determined annoyed/ excited disinterested/ interested other:
Verbal feedback	
<b>Behaviors while playing (ex: clap hands, head shake, laugh...)</b>	
<b>triggered by what?</b>	
Moments of hesitation/difficulties	
<b>Focused on every task?</b>	
<b>If not, which task and why?</b>	
Level 3 time	

General Criteria	
<b>Understood the mechanics?</b>	
which did not?	
<b>The user was confused by the game's graphics?</b>	
which one?	
When did the therapist intervene the most?	
The user was motivated/interested in the game	