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A Framework to Assist Therapists with the Applied Behavioural Analysis

Tesi di Laurea Magistrale in
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Dedica

Dedico questa tesi a tutti i bambini autistici e alle terapiste di Spazio Autismo che seguono i loro piccoli pazienti con una dedizione ed un amore che vanno oltre la professionalità.

Abstract

This Master Thesis presents the development and implementation of the Applied Behavioral Analysis (ABA) Service System, designed to assist therapists and children with autism spectrum disorder in their therapy. This project is the outcome of a collaborative effort between Politecnico di Milano and Spazio Autismo, an autism center located in Mantova, Italy. The goal of this project is to develop an organic system that allows the transition from the current paper-based to digital-led therapy. This goal is achieved by implementing a system comprising of a mobile app, a website and the infrastructure required to run them.
The technical requirements for the system are formulated to strictly adhere to the principles of the ABA therapy used in the center. For this reason, the mobile app offers a game experience designed to keep the patients focused on their therapy sessions. Recognizing that handling patients profiles, monitoring progress, and generating objective reports might be distracting for the patients, a dedicated website has been created to offer therapists a user-friendly platform to efficiently manage these aspects of their work. In a 4 months period, 18 children diagnosed with classic autism, ranging from 4 to 7 years old, tested this system with the center therapists. Based on this test, the system is proved able to successfully automate learning materials preparation, data acquisition, and data reporting. It improves the efficacy of the therapy sessions, reducing non-therapeutic time, increasing patient focus, and quickening the completion of the assigned objectives. Moreover, the system demonstrates improved privacy and security of patients data while maintaining reliability.

Keywords: Autism, Digitalization, Mobile App, Website, ABA.

Abstract in lingua italiana

Questa Tesi di Laurea Magistrale presenta lo sviluppo e l'implementazione dell'Applied Behavioral Analysis (ABA) Service System, progettato per assistere terapisti e bambini autistici nella loro terapia. Questo progetto è il risultato di una collaborazione tra il Politecnico di Milano e Spazio Autismo, un centro per il percorso riabilitativo di pazienti autistici situato a Mantova, in Italia. L'obiettivo di questo progetto è sviluppare un sistema organico che consenta la transizione digitale dalla terapia ad oggi basata su carta. Questo obiettivo è raggiunto mediante lo sviluppo di un sistema composto da un'app mobile, un sito web e l'infrastruttura necessaria per il loro funzionamento.
I requisiti tecnici sono stati formulati per rispettare rigorosamente i principi della terapia ABA utilizzata presso il centro. Per questo motivo, l'app mobile offre un'esperienza di gioco progettata per mantenere i pazienti concentrati durante le sessioni di terapia. Dal momento che gestire i profili dei pazienti, monitorarne il progresso e generare report sugli obiettivi da loro raggiunti, potrebbe distrarre i pazienti, è stato necessario creare un sito web dedicato, che fornisca ai terapisti una piattaforma user-friendly per gestire in modo efficiente questi aspetti del loro lavoro.
In un periodo di 4 mesi, 18 bambini diagnosticati con autismo classico, di un'età compresa tra 4 e 7 anni, hanno testato questo sistema con i terapisti del centro. Basandosi su questa esperienza, il sistema ha dimostrato di essere in grado di automatizzare con successo la preparazione dei materiali didattici, l'acquisizione dei dati e la relativa reportistica. Ha inoltre migliorato l'efficacia delle sessioni di terapia, riducendo il tempo impiegato in attività non terapeutiche, aumentando la concentrazione dei pazienti e accelerando il completamento degli obiettivi assegnati. Infine, il sistema si è dimostrato affidabile e ha permesso un miglioramento della privacy e della sicurezza dei dati dei pazienti.

Parole chiave: Autismo, Digitalizzazione, App, Sito Web, ABA

Contents

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder. According to the Centers for Disease Control and Prevention (CDC) [1], the number of individuals diagnosed with autism has increased fivefold since the year 2000. As this phenomenon gains prominence, new strategies are continually being developed to support individuals with ASD in achieving their self-sufficiency goals, while also equipping their families and therapists with the necessary skills for effective interactions. When dealing with individuals suffering from ASD, medical professionals have a range of approaches at their disposal, based on the patient observable behavior. These approaches encompass behavioral, developmental, educational, socio-relational, pharmacological, and psychological strategies, as outlined in the CDC website[2].

In recent years serious games have been introduced to facilitate behavioral intervention in learning, demonstrating encouraging outcomes [3], [4], [5], [6]. Serious games refer to computer games created with a specific educational purpose rather than solely for entertainment [7]. A personalized path in behavioral learning through serious game has been proved to be also very efficient with patients with autism, as they effectively engage with various available technologies.

A particular focus in this field is given to serious games developed for mobile devices such as smartphones and tablets. As the popularity of mobile devices continues to grow, it is possible to notice a proliferation of studies aimed at harnessing the potential of mobile technology to deliver impactful learning experiences. Researchers have been exploring innovative ways to leverage the ubiquity and accessibility of these devices to enhance educational outcomes. Apps can be designed to have short activities that can be done whenever during the day. Users can also learn by enjoying what there are doing: a secure game in a mobile app can leverage from good-looking visual effects to keep players (in this case patients) engaged with the app. This keeps the patient focused for a longer time while learning. [8], [9], [10], [11]. Mobile devices also facilitate team-based communication and learning, aiding users in integrating into their social surroundings. This is especially beneficial for autistic children with strong visual capabilities who are drawn to the engaging and user-friendly environments provided by smartphones and tablets [12].

Given the promising premises described above, this project, Applied Behavioral Analysis (ABA) Service System, represents a comprehensive initiative within the domain of computer science and engineering, aimed at addressing the needs of individuals with ASD. This project is the outcome of a collaborative effort between Politecnico di Milano and Spazio Autismo, an autism center located in Mantova, Italy. The teamwork between those two parts has played a pivotal role in the success of this project. The regular interaction with the therapists of the center during their sessions with the patients has ensured a deep understanding of their specific requirements and insights.
The goal of this project is to develop an organic system that allows the transition from the current paper-based to digital-led therapy. Rigorous ethical standards are upheld throughout this research. To ensure patient privacy and confidentiality, each identifying information is meticulously kept anonymous. This ethical approach safeguards the welfare and anonymity of the research subjects.
In *Chapter 1*, ABA therapy (the current therapy method applied in Spazio Autismo) is described and some insights about autism and ABA interventions are reported. A brief description of the current paper-based therapy is provided. To better fit Mantova center needs in the development phase of ABA Service System, some requirements, as discussed with the therapists, are listed.
Projects based on similar needs are evaluated at the beginning of *Chapter 2*, the focus then shifts on the technical requirements drawn from the previous discussions with the therapists. Following this, a description of the overall digital system is presented, which includes a mobile app, a website and the necessary infrastructure for their operation. At last, the objectives of this project are defined, based on the regular interaction with the therapists.
The mobile app designed for tablets is described in *Chapter 3*, the developed games are designed to target and improve children's behavioral skills, focusing on talking, social playing and the ability to labeling items. All the interactions are aligned with the principles of ABA therapy, highlighting how different solutions have been evaluated and discussed with the therapists to reach a final result that best fit Mantova center needs. The mobile app is developed in Unity, with each game having its own class. This design makes it well-suited for easy adaptation and rescaling to meet various ABA therapy objectives.
In addition to the mobile app, ABA Service System incorporates a web-based platform, described in *Chapter 4*, serving as a centralized hub for patient data management. This website not only facilitates the input and storage of patient data, but also provides educational resources about the therapy and insights about the project. The web-based platform is developed with Nuxt3 framework and the interaction with the database is managed with Prisma, an Objective Relational Mapping (ORM).

The details of the database infrastructure, that underpins the entire system, are reported in *Chapter 5*, it ensures the secure storage and retrieval of patient data, vital for tracking progress and optimizing interventions. Notably, it allows to add new therapeutic objectives through the website, further enhancing the adaptability and relevance of the intervention. Therapists, through secure logins, have the capability to continually refine and tailor the patient experience. MySQL relational database management system is chosen, and the infrastructure is developed in Docker.
In *Chapter 6*, the efficacy of the ABA Service System is evaluated by assessing the initial goals shared with the therapists. The focus remains on extracting meaningful insights from user interactions, with a keen eye toward uncovering patterns and trends that can inform and optimize future ABA interventions.
Finally, *Chapter 7*, summarizes the most important points of strength and weakness of this project, and it suggests possible future developments to face the limitations of this first implementation.

1 | Project Background

The ABA Service System is developed based on the collaboration with Spazio Autismo, a center located in Mantova with decentralized branches in various municipalities within the province. The center specializes in supporting individuals of all ages with ASD. Its mission is to enhance the quality of life for individuals with autism and their families by promoting a cohesive and integrated approach. This is achieved through collaborative efforts, with a strong focus on working together with families as the initial step towards creating a meaningful life plan. Spazio Autismo is staffed with a team of professionals, including psychologists, consultants, and educators, who act as case managers for the families of individuals with autism. They promote networking and coordination of services to reduce fragmentation in interventions and improve the overall quality of life for these families.
The idea of integrating the new opportunities offered by a serious game on a mobile device in their traditional therapy method is the point of interest. The project started from scratch, and in 4 months the first experimental trial has been deployed to be used by Spazio Autismo experts. To thoroughly understand the development of this project, it is essential to explain the characteristics of behavior and learning patterns for an individual with autism. Specifically, it is necessary to analyze the ABA methodology used at the center and the assessment methods employed.

1.1. Autism and Applied Behavioral Analysis (ABA)

Autism is a neurodevelopmental disorder characterized by challenges in social interaction, communication difficulties, and repetitive patterns of behavior or interests. It is typically diagnosed in early childhood, and its exact cause is still not fully understood. From a medical perspective, autism is considered a spectrum disorder, meaning that it manifests differently in each individual [13].

1.1.1. Autism Spectrum Disorder

Autism encompasses a spectrum of disorders, each with its own unique characteristics. The three main types of autism are autistic disorder (classic autism), Asperger's syndrome,

and pervasive developmental disorder not otherwise specified (PDD-NOS). While they share common features, they also have distinct differences [14].

Autistic Disorder, or classic autism, is characterized by significant impairments in communication, social interaction, and the presence of repetitive behaviors. Individuals with classic autism may exhibit delayed language development, difficulty forming relationships, and repetitive movements or fixated interests. This type of autism is often associated with intellectual disability.

Asperger's Syndrome is typically considered a milder form of autism. Individuals with Asperger's may have average to above-average intelligence, but struggle with social interaction and communication. They may display interest in specific subjects and have difficulties understanding nonverbal cues or social norms. Language development is usually within the normal range, and individuals with Asperger's may excel in certain areas.

PDD-NOS is a diagnosis given when an individual does not meet the criteria for either classic autism or Asperger's syndrome, but still exhibits some autism-related characteristics. It is often used for individuals with milder symptoms or those who do not fit the specific criteria for the other two types. PDD-NOS encompasses a wide range of symptoms and may involve social and communication challenges, repetitive behaviors, and sensory sensitivities.

Distinguishing between these types of autism can be challenging, as their symptoms can significantly overlap. The diagnostic process involves careful evaluation by healthcare professionals, including observations of behavior, interviews with caregivers, and standardized assessments. Differences in language development, social interaction abilities, and cognitive functioning are among the factors considered during diagnosis [15]. While the diagnostic criteria may vary, the overall goal is to understand an individual's strengths and challenges to provide appropriate support and intervention. The specific type of autism diagnosed may guide treatment planning, educational support, and therapy choices. However, it is essential to recognize that individuals with autism are unique, and their experiences and needs can vary widely. A comprehensive assessment that considers personal strengths and challenges is crucial for understanding and supporting children with autism.

Interventions and Strategies

In recent years, there have been significant advancements in understanding and supporting individuals with autism. While the concept of a complete autism cure may not currently exist, various interventions and strategies can greatly improve the lives of individuals on

the spectrum [16].

Early intervention is key. Identifying autism at a young age allows for timely interventions. Behavioral therapies can help individuals develop communication skills, improve social interactions, and reduce challenging behaviors. Speech therapy can address language and communication difficulties, while occupational therapy can assist with sensory sensitivities and motor skills development. Educational settings play a crucial role. Special education programs and individualized education plans provide tailored support and accommodations to meet the unique needs of autistic individuals. Inclusive classrooms with additional supports promote socialization and foster a sense of belonging. Supportive environments are essential and creating sensory-friendly spaces can help reduce anxiety and sensory overload. Visual supports, such as schedules and social stories, aid in understanding routines and social expectations. Assistive technologies, such as communication devices, can enhance communication abilities.[17] [18].

1.1.2. Applied Behavior Analysis (ABA)

Among the possible strategies, one of the most effective behavioral therapies is the Applied Behavior Analysis (ABA) [19]. "Applied Behavior Analysis is a scientific approach for discovering environmental variables that reliably influence socially significant behavior and for developing a technology of behavior change that takes practical advantages of those discoveries" [20]. ABA utilizes principles of learning theory to generate positive behavior changes and improve the quality of life for individuals with autism and other developmental disorders. ABA is a data-driven, evidence-based approach that aims to bring about meaningful and lasting behavior changes in individuals. By applying scientifically validated strategies, ABA helps individuals with autism and other developmental disorders to improve their skills, enhance their independence, and lead fulfilling lives [21].

Strategic ABA Principles

ABA involves systematic assessment and intervention strategies to target socially significant behaviors. It begins with a comprehensive assessment to identify the individual's strengths, challenges, and specific behaviors that need to be addressed. Data collection and analysis are integral components of ABA, as they provide objective information about behavior patterns, progress, and the effectiveness of interventions.

Based on the assessment, individualized goals and intervention plans are developed. ABA interventions are highly individualized and tailored to the unique needs and abilities of each person. These interventions can include various techniques[20] such as:

- **Reinforcement:** Reinforcement is a fundamental principle in behavior analysis. It involves providing a consequence, such as rewards or praises, to increase the likelihood of a desired behavior occurring again in the future. Positive reinforcement involves adding something rewarding, like a token or verbal praise, to strengthen the desired behavior. Negative reinforcement involves removing or avoiding something aversive, like turning off an alarm, to increase the occurrence of the desired behavior.
- **Prompting:** Prompting is a technique used to assist individuals in learning and performing a desired behavior. It involves providing cues or hints to guide the individual towards the correct response. Prompts can be physical, verbal, or visual, depending on the individual's needs. Over time, prompts are gradually faded to allow the individual to respond independently.
- **Shaping:** Shaping involves gradually guiding and reinforcing behaviors that are steps towards a desired target behavior. It is often used when the individual does not initially exhibit the complete desired behavior. Through reinforcement, successive steps of the target behavior are improved until the final behavior is achieved. For example, in shaping communication skills, initial reinforcement may be given for vocalizations, then for single words, and eventually for complete sentences.
- **Fading:** Fading is the process of gradually reducing or removing prompts or reinforcement that were initially provided to support a behavior. It aims to promote independence and the maintenance of the behavior without constant prompts or reinforcement. Fading can involve reducing the intensity or frequency of prompts, fading out visual cues, or transitioning from continuous to intermittent reinforcement.

ABA Therapy Design

It is important to note that ABA should be delivered by qualified professionals who have received appropriate training and certification in ABA principles and techniques. Ethical considerations, including respect for individual autonomy and dignity, are integral to the practice of ABA. The frequency of ABA sessions can vary depending on several factors, including the individual's needs, goals, and available resources. There are different points of view regarding the optimal frequency of ABA sessions[22], and the decision should be based on the unique circumstances of each individual. Some professionals recommend more intensive ABA programs, involving multiple sessions per week, especially for young children with significant developmental delays or challenging behaviors. Intensive programs often involve 25-40 hours of therapy per week, with therapists providing one-on-

one sessions in various settings. The rationale behind intensive ABA is to maximize the learning opportunities and capitalize on the brain's plasticity during early development. On the other hand, some individuals may benefit from a lower intensity approach, such as two to three sessions per week. This may be appropriate for individuals who have milder challenges or those who are already making progress with the existing intervention plan. Additionally, factors such as financial constraints or limited availability of qualified professionals may influence the frequency of sessions. The duration of ABA therapy is another consideration. ABA is typically viewed as a long-term intervention rather than a short-term fix. Consistency and continuity of therapy are important for skill development and behavior change. For some individuals, ABA may be needed for several years to address a range of skills and maintain progress over time.

In addition to the frequency and duration of sessions, the quality of the therapy and the overall approach are essential. A multidisciplinary approach that involves collaboration between behavior analysts, speech therapists, occupational therapists, and other professionals can provide a more comprehensive treatment plan. Integration of ABA principles into daily routines and activities is crucial to promote generalization of skills beyond the therapy sessions. ABA can be implemented across various environments, including homes, schools, clinics, and community settings, to support individuals in developing essential skills, such as communication, social interaction, self-help, and academic abilities.

When approaching a child to ABA, it is important to consider individual factors and preferences. Establishing a positive and trusting relationship with the child is crucial for successful therapy. Gradual and systematic introduction to therapy, allowing the child to become familiar with the therapist and the environment, can help reduce anxiety and resistance.

It is also beneficial to incorporate the child's interests and strengths into the therapy sessions. This can help increase engagement and motivation, making the learning process more enjoyable. Structured activities, visual supports, and consistent routines are often used to create a predictable and supportive environment for the child.

Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP)

The Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP) is a criterion-referenced assessment based on typical language development, thus measuring how well an individual performs against an objective rather than another student. In practice, the tool provides an extensive checklist for tracking progress over time. The

following categories are suggested by the VB-MAPP guidelines [23]:

- Tact: tact is the ability to label or describe objects, actions, or events in the environment. It involves expressing what one observes using language.
- Listener: listener skills refer to receptive language abilities where an individual responds appropriately to verbal stimuli or instructions from others. This includes following directions and understanding spoken information.
- Visual-Perceptual Matching to Sample (VP-MTS): VP-MTS tasks involve matching or identifying objects, pictures, or symbols based on visual cues, often used for learning and discrimination tasks.
- Math Skills: ABA therapists teach mathematical concepts, including arithmetic operations, problem-solving, and numerical understanding.
- Writing Skills: this category focuses on developing handwriting, letter formation, and other writing-related abilities.
- Reading Skills: ABA therapy targets reading skills, encompassing phonics, sight word recognition, comprehension, and fluency.
- Mand: manding involves requesting desired items, activities, or information using language or other forms of communication.
- Independent Game: this refers to the ability to engage in play or activities independently, without constant guidance or prompts.
- Social Behavior/Game: ABA therapists work on social skills and behaviors, including sharing, taking turns, and interacting with peers during play or social activities.
- Imitation: imitation skills involve copying or mimicking the actions, gestures, or behaviors of others, which is fundamental for learning and social interaction.
- Echoic: echoic refers to repeating words or sounds that are heard, helping individuals develop their language skills by imitating spoken language.
- Spontaneous Speech: this category relates to the ability to initiate and produce speech or communication without external prompts.
- Requesting, Answering, Filling in, Commenting, and Correcting (RAFCC): RAFCC encompasses various types of responses to verbal stimuli, including requesting items, answering questions, filling in missing information, making comments, and providing corrections.

- Intraverbal: intraverbal skills involve responding to verbal stimuli with relevant words or phrases, such as answering questions or engaging in conversation.
- Routines in Class or Game: this refers to an individual's ability to follow established routines or procedures in a classroom or game setting, which can support organization and predictability.

Each of the categories listed above is comprised of 15 objectives to be completed in a predetermined order. When writing about these objectives in the next technical chapters, they will be referred as "levels", a term typically used in the serious game field.

1.2. ABA and Spazio Autismo

Being familiar with the concepts of ABA therapy and VB-MAPP categories, it is possible to describe how they are implemented by the Mantova center and which are the requests made by the therapists for this project. While this represents an integrated experience, the division of the patient care process into two phases is proposed here: therapy sessions with the children and data reporting by the therapist.

1.2.1. Therapy Sessions

The patients at the Spazio Autismo center have been diagnosed with "classic autism." Furthermore, all of them have high support needs, which means they face significant challenges in social communication and interactions. Many of them may be non-verbal or have very limited speech, and they encounter substantial difficulties in performing daily tasks, such as self-care and vocational activities. The primary point of contact with these young patients at the center occurs during sessions with the therapists. In most cases, these are one-to-one (patient-therapist) meetings that last for approximately one hour. These sessions involve the implementation of ABA activities, which are closely monitored using the VB-MAPP categories.

The tool used by the therapist for interacting with the patients is a deck of cards. Each card features a white background with a clipart-style image of a common object. The therapist presents these cards to the patient, selecting them based on the exercise being conducted and, when possible, the child's interests (e.g., cards with images of vehicles for children who show curiosity towards cars).

As beforementioned, each category of the VB-MAPP consists of 15 levels of increasing difficulty. The completion of each level is achieved when the specified number of correct responses, as defined by the therapists, is attained. These values are determined for each

category and for each level and are not dependent on the specific patient. During the session, the therapist only records the correct responses by marking them with checkmarks on an unstructured tracking paper sheet. Incorrect responses, which include both incorrect answers and unanswered questions, are not recorded.

1.2.2. Data Reporting

Once the session is completed, the therapist has a sheet on which the correct responses obtained from the patient are written down. In preparation for the next session, the therapist reviews the sheet to avoid proposing the same responses that the patient has successfully completed in the previous sessions. This tracking process must be repeated until that level is completed. Based on the information provided by the center, this tracking process can span up to several months.

Upon completing the level, the therapist shares the correct responses obtained with the supervisor and the patient's family. To do this, the therapist transcribes all the correct responses obtained by the child during the period required to complete the level into a standardized form in Microsoft Word, as established by the center. The file is then printed and handed to the family.

1.2.3. Therapists Requirements

Below are the requirements expressed by the therapists for the development of the ABA Service System. For consistency with the therapy process phases described in the previous paragraphs, they are presented in three different categories: therapy session, data reporting, and privacy, security and reliability.

- **Therapy Session**: The digitalization of the therapy session has focused on faithfully replicating what previously occurred, to maintain adherence to ABA principles. At the same time, leveraging the possibilities offered by technology, therapists envisioned to replicate the game experience of the deck of cards in a newly developed gaming app. Moreover, from their own point of view, they wished to simplify the material preparation phase. As they do not need physical cards anymore, they expected to directly access the patient therapy materials when switching on the technological tool used during the session. Additionally, therapists requested the ability to automatically collect positive and negative responses during the session. To avoid impacting the center costs, therapists stated that they already have two iPads available at the center that they could use with the patients during the newly digitalized sessions.

- **Data Reporting**: The therapists requested to automatically track the correct responses given by the patients during the session. Moreover, they were interested in automatically generate the standard report shared with the family. However, no changes to the format of this report were requested.
- **Privacy, Security and Reliability**: From the perspective of privacy and security, therapists emphasized the need to access only the performance data of their own patients. Furthermore, the identities of the children must be kept anonymous. To avoid interrupting their sessions due to possible technical failures, the therapists asked for a smooth and issues-free implementation.

2 | Project Overview

Based on the requirements presented by the therapists, a research on mobile apps already available on the marketplaces is conducted to verify if there was already a solution that could meet their needs. After defining the technical requirements of the project, the overall design of the system is illustrated. The list of the objective of this project concludes this chapter.

2.1. Similar Projects

This section analyzes some mobile app available on the marketplaces that share common ground with ABA Service System, while also considering those that exhibit different characteristics.

ABA Service System is specifically tailored to the requirements and challenges associated with autism therapy as applied in Spazio Autismo. It is imperative, however, to position this project within the broader context of technological interventions aimed at assisting children with autism in all the aspects of their lives [24] [25].

This examination of other apps developed for children with autism encompasses their features, methodologies, and outcomes. Through this comparative lens, it is possible to discern patterns, best practices, and areas of differentiation, ultimately extracting valuable insights that can inform and enrich the ABA Service System. These insights may encompass various aspects, ranging from user experience design and data management to therapeutic efficacy and privacy considerations.

2.1.1. AutiSpark: Kids Autism Game

AutiSpark [26] developed by IDZ Digital Private Limited represents an educational mobile app designed specifically for children with the autism spectrum disorder (ASD). It offers a rich collection of learning games. The app provides a multitude of engaging and interactive learning games tailored to meet the child's learning needs. Its content spans a wide array of concepts, including image association, emotional comprehension, sound recognition,

and much more. It touches many fields like spelling, math, memory, sorting, matching and puzzles.

The app is exceptionally engaging, featuring a variety of vibrant colors and animated elements on the screen. This characteristic led the therapists involved in ABA Service System to suggest that the app was designed for children who have already made some progress in their ability to discern between essential and non-essential elements. Furthermore, the app lacks a clear differentiation between the various areas of focus within ABA therapy. AutiSpark is designed as an app to entertain children with autism while also ensuring they learn and enhance certain skills. However, it is not meant to adhere to the ABA therapy guidelines.

2.1.2. Autism BASICS: Learning app

Autism BASICS [27] is a mobile app developed by a team of psychologists, speech, behavioral, and occupational therapists. It aims to engage children with autism and other special needs, enabling parents to work closely with their children. In essence, the app provides daily activities assigned by the child's therapist or parent, a library of learning-focused activities crucial for the development of a child with autism, and a parent's corner with educational videos and content to facilitate collaboration between parents and their children. Parents or therapists assign tasks from the library, specifying the time the child should dedicate to these daily activities. Therapists can define multiple levels within a particular category for the child to focus on. Each day, the child completes these tasks presented in an engaging and enjoyable game format. The app offers thousands of activities categorized by their significance in early childhood development for children with autism or developmental delays. These activities are covering areas like alphabet, spelling, math, and more, focusing on behavioral, academic, sensory, independent/self-help, communication, and social skills. According to the therapists of Spazio Autismo, some of these activities can be applied to the ABA therapy.

2.1.3. Autism ABC App

The ABC App [28], an app designed for children with autism, encompasses a range of essential features tailored to enhance their learning and development. The ABC App offers a diverse selection of learning activities designed for children with autism. These activities span a wide range of cognitive, linguistic, and motor skills. The app is highly adaptable, making it suitable for children of various age groups and autism spectrum levels. It ensures inclusivity by providing content that aligns with different developmental stages. The ABC

App places a strong emphasis on data collection and analysis. It meticulously tracks and records each child's results for every activity, presenting them through user-friendly charts and indexes. These data-driven insights are valuable for assessing a child's progress. The app incorporates the concept of positive reinforcement, making learning engaging and enjoyable for children. This approach motivates children to actively participate in activities. However, it was not found to strictly adhere to the ABA therapy guidelines.

Each of the evaluated autism therapy apps brings a unique set of strengths, but also areas for improvement with respect to the needs of Spazio Autismo. AutiSpark impresses with its personalized learning approach and diverse content, yet it may benefit from increased data sharing and classification of games under the naming of ABA therapy. Autism BASICS excels in providing comprehensive content and user-friendliness, but could enhance its adaptability and engagement. Finally, ABC App distinguishes itself with data-driven insights, though diversifying content and strengthening data anonymity could further enhance its appeal. None of these apps meet the requirements of the therapists of Spazio Autismo, as they do not faithfully align with the type of therapy used (ABA). Therefore, it became necessary to develop an integrated system to meet their needs.

2.2. Technical Requirements

In this section the needs of the therapists, described in Section 1.2.3, are reformulated in technical requirements. To be coherent with the classification previously proposed, they are divided into the same three categories: therapy session, data reporting and privacy, security and reliability. Moreover, separating users requirements from software requirements ensures a better clarity of the project. Requirements Engineering approach has been used to develop all the software concerning ABA Service System[29].

2.2.1. Therapy Session

User:

1. Each patient should have an individualized profile.
2. Each profile should contain the patient progress, including completed objectives, the current objective, and the success percentage.
3. The app should align with the VB-MAPP, ensuring a one-to-one correspondence between game activities and therapeutic objectives.

4. The app should include a minimum of two categories from the VB-MAPP.
5. The app should be designed to record the progress of each child when they respond correctly or perform the appropriate actions within the game they are playing.
6. The app should be designed to record the errors of each child when they respond incorrectly or perform the wrong actions within the game they are playing.
7. The app should be designed to be user-friendly and intuitive for ASD patients, with the primary goal of helping children improve in the specific category they are working with.

Software:

1. The app should be developed for iOS devices.
2. The app should efficiently store data in the database without causing any lag during gameplay.
3. The app should be capable of reproducing audio prompts.
4. To use the app effectively for therapy, a login feature for the therapist is required.
5. The app must display only the objectives relevant to the logged-in user.
6. The app should provide a distraction-free gaming experience in accordance to the ABA therapy.

2.2.2. Data Reporting

User:

1. A website must be accessible by therapists to administer patient's accounts.
2. While logged into the website, therapists should have the ability to add and remove objectives and patients from their accounts.
3. Therapists should have the capability to access the site from both their personal computers and smartphones.

Software:

1. The website should be hosted online and consistently accessible.
2. The website should feature three pages containing information about ABA and an overview of the project.

3. The website must enable therapists to log in to their personal area.
4. The website should allow logged-in users to add new patients to their roster.
5. Logged-in users in the website should be able to view all the objectives for each patient, including the percentage of progress.
6. The website should permit logged-in users to add new objectives for specific patients.
7. The website should offer the functionality to download a PDF file for each objective, containing all the words learned by the patient in that particular objective.
8. The database must always be available to save and retrieve data for patients and therapists.
9. The database should be designed to accommodate growing data volumes and increasing user traffic as the project expands.

2.2.3. Privacy, Security and Reliability

User:

1. Each therapist must have an individual account to access the website.

Software:

1. The app should demonstrate reliability on at least a five-day-per-week basis.
2. The database should not include any references to real individuals; all data should be saved with acronyms or pseudonyms.
3. The website should display the therapist's patients with their nicknames and brief descriptions for each patient upon logging in.
4. Access controls and user authentication should be enforced within the database to prevent unauthorized access.
5. Regular backups of the database should be performed on a weekly basis.

2.3. ABA Service System Framework

As shown in Figure 2.1, the ABA Service System is an organic system that consists of three different components: a mobile app, a website, and the infrastructure that enables communication between these two. The creation of the mobile app and the website became necessary to replicate ABA therapy in the digital format. The mobile app is exclusively

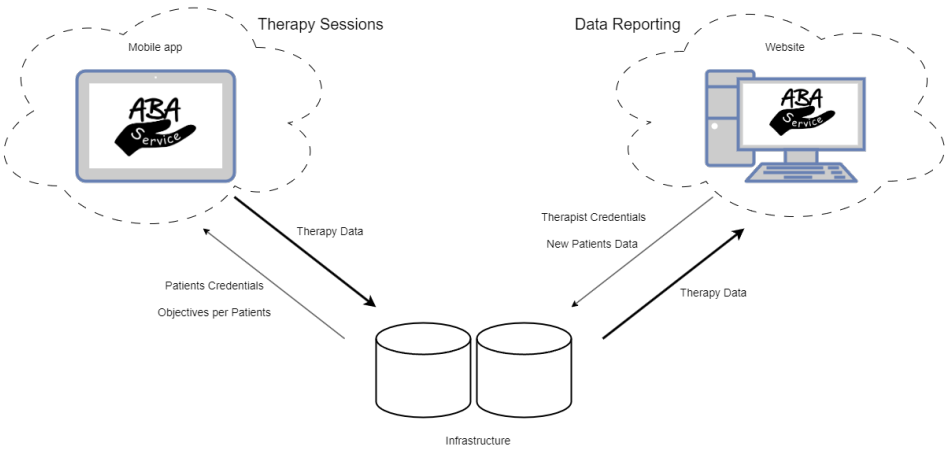


Figure 2.1: Data flow diagram

intended for gaming by patients during their therapy sessions, and it is deliberately designed to be free of stimuli that could impact children's ability to maintain concentration in their therapy activities. Therefore, the development of a second environment, the website, was necessary to provide the therapists with a space where they can manage data before and after the therapy. It is primarily accessible from a laptop, but can also be accessed from a mobile device if needed during the session.

At the beginning of each session, the therapist logs into the mobile app using the patient's credentials on an iPad at the center. This allows the therapist to access the patient data and view the planned and achieved objectives, which are stored in the database of the infrastructure. During the session, while the patient plays ABA games on the tablet, the app sends the patient performance data to the same database. Once the session is completed, the therapist can access the patient performance data from the website. When the patient successfully completes an objective, the therapist can then download the report from the website to be shared with the supervisor and the family. If necessary, the therapist can add or modify the patient's objectives from the website, which will automatically update them in the database. Additionally, in the case of a new patient, the therapist can create a new profile directly from the website.

2.4. ABA Service System Objectives

The technical and therapeutic teams agreed on the five objectives listed below. The first three objectives are defined to assess the implementation of ABA Service System during the session between the patient and the therapist. The fourth objective measures the level of success of the data reporting. The last one evaluates whether the privacy, security and

reliability requirements are met.

1. Automation of learning materials preparation.
2. Automation of data acquisition.
3. Efficacy of the therapy:
    - Reduced time spent on non-therapeutic activities.
    - Increased patient focus during therapy.
    - Reduced time to complete the objectives.
4. Automation of data reporting.
5. Improved privacy and security of data while keeping the system reliable.

3 | Mobile App

In ABA Service System, the mobile app plays a key role in engaging patients during their therapy sessions. The tools used during the development phase and the motivations of their choice are illustrated in the first section of this chapter. Based on the therapists feedback, three of the VB-MAPP categories listed in Chapter 1, are then selected for the implementation. Each category comes with its own specific learning objectives, thus corresponding in different game designs. The description of the mini-games' structure and rules accurately illustrates the digital adaptation of the paper-based therapy experience onto the iPad. At last, some examples of how the app frameworks have changed during the User Interface (UI) design process are reported.

3.1. Development Tools

This section provides a comprehensive overview of the tools employed in the development of the ABA Service App. It encompasses a wide range of software and graphic design resources essential for implementing the app. While additional tools have been utilized for physical prototyping in certain instances, their details are omitted as they are beyond the scope of this chapter.

In the subsequent paragraphs, the specific software, applications, and design tools employed throughout the development process are described. These tools are pivotal in ensuring the successful creation of the ABA Service App, encompassing various aspects such as coding, user interface design, and visual representation.

3.1.1. Unity Engine

In selecting Unity as the development platform for the ABA Service App, a deliberate and thoughtful choice is made. The decision is based on a careful consideration of the app unique requirements and objectives. Unity has come a long way since its inception in 2005, when it was first unveiled at an Apple conference, initially targeting OS X development [30]. Over the years, it has evolved into a versatile and widely adopted

engine, supporting as many as 27 platforms, including the new world of virtual reality. Unity's most defining quality, and its greatest strength, is its remarkable ease of use, especially for mobile platforms. The engine projects are compact, and the game build process is straightforward. Perhaps one of Unity's best achievements is its component-based architecture, which is appealing to both newcomers and experienced developers. Coupled with the efficient scripting capabilities of C#, Unity empowers developers to bring their ideas to life swiftly and effectively [31]. A pivotal aspect of Unity's allure is its vast and active community. When faced with challenges or in need of guidance, developers can turn to Unity forums to acquire insightful answers and solutions. This extensive support network substantially streamlines the debugging process and provides an invaluable resource for game developers. Additionally, Unity offers the Asset Store, full of resources that can significantly expedite development. This marketplace is not only rich in content but also budget-friendly, making it accessible to developers of all sizes. Whether art assets, plugins, or even entire game templates are required, the Asset Store has them available. However, no tool is without its drawbacks, and Unity is no exception. One notable limitation is its graphical 3D capabilities, which, when compared to engines like Unreal or Cry Engine, may leave some desiring more visual fidelity [32].

In conclusion, the choice of Unity as the development platform for the ABA Service App is a well-considered decision based on the app's specific requirements and objectives. Unity's ability to efficiently handle non-graphically intensive apps, its integrated deployment tools, and its extensibility through external tools make it the ideal choice for the project.

3.1.2. Localization Package

The demand for apps that refers to diverse audiences with varying languages and cultural backgrounds has grown exponentially. One of the critical challenges in mobile app and game development is ensuring that an app can be accessed and understood by a global audience. The Localization Package in Unity is used to make ABA Service App available in both Italian and English, ensuring accessibility to a wider and more diverse user base.

3.1.3. Figma

Figma is a powerful cloud-based design and prototyping tool that is primarily used for creating User Interfaces (UI) and User Experiences (UX) for digital apps such as websites, mobile apps, and desktop software. It is widely popular among designers, developers, and product teams for its collaborative features and versatility in designing UI components and entire apps. ABA Service App is completely sketched in Figma as showed in Section

3.3, to prototype it and to preview what the games would look like.

3.2. Implementation

ABA Service App implementation is made in Unity, while developing authentication and game algorithms is done with PHP and C#.

3.2.1. Authentication

Authentication is a core feature due to the critical data stored through ABA Service App. It is implemented using PHP hosted on a private Docker image as described in Section 5.2. The use of Docker further enhances the authentication system's reliability and scalability. By hosting the authentication component within a private Docker container, several advantages are achieved. While stringent security measures are in place, the authentication process is designed with user-friendliness in mind. The goal is to strike a balance between robust security and a seamless, intuitive UX. This ensures that therapists can access the app features without unnecessary obstacles.

This pivotal process begins when a user provides both their username and password during login. Subsequently, PHP executes a comprehensive series of checks within a single query. The initial step involves confirming the existence of a user with the provided username within the database. This foundational check ensures the user is a legitimate entity within the system. Upon confirming the username's presence, the authentication process seamlessly proceeds to the next level. In the subsequent phase, PHP examines the entered password against the stored password associated with the located username in the database. This comparison serves a dual purpose: it not only verifies the user's existence, but also ensures that the individual attempting to log in is indeed the rightful owner of the account. Nowadays connecting to a database using PHP is often a suggested option, as explained in [33]. MySql's databases can be easily queried using PHP, moreover MySql and PHP are often used in web development. Since ABA Service System has both a web and a mobile application, PHP has been considered the best option. The snippet of code to connect to a database using PHP can be read in Listing 3.1. Using only 4 lines of code a connection with a MySql database is established, from which data can be retrieved and stored.

```
//values with sampling purpose
$conn = new mysqli("42.42.42.42", "username", "password", "
    ABA_Service_DB");
if($conn->connect_error){
    die("Connection Failed: ". $conn->connect_error);
}
```

Listing 3.1: Connection to database

3.2.2. Images

The images present in the app were provided by the therapists at the center. These images are stored within the app to reduce the load on the center's internet network, where ABA Service App is used. The images are the same as the ones reported on the deck of cards used during ABA therapy prior to the development of the app, to maintain continuity in the process.

Images that a patient successfully identifies will never be presented to the same patient again in the same objective, as they are considered learned for the current objective. However, these images may be reintroduced in subsequent objectives.

3.2.3. Games

Games are strategically implemented based on the VB-MAPP framework, as elaborated in Section 1.1.2. This decision derives from an extensive collaborative effort involving multiple experts consultations. Through a series of meetings and deliberations, three primary categories emerge as the most promising starting points for ABA Service App implementation. These selections aare guided by the careful consideration of three critical parameters:

- How many patients are currently working on each category;
- Which categories are the easiest for a new patient;
- Which categories can have a real improvement if done using electronic devices.

To facilitate the decision-making process, a grade (1-5) is assigned to each category-parameter combination. These grades allow to compute and identify the top three categories that warrant immediate attention and game development efforts. Table 3.1 presents a comprehensive overview of the assigned grades, including the calculated "Overall" column. The "Overall" score is determined by summing the grades across the three parameters, providing a holistic assessment of each category suitability for game development and

prioritization. The analysis of the three categories -TACT, LISTENER, and VP-MTS-, selected based on their higher overall grades, reveals their significance in the context of digitalization. Collaborative efforts with experts illustrate the specific characteristics of each category and the types of games required to address therapeutic objectives effectively.

- TACT: This category focuses on improving patients ability to label or describe objects, actions, or events in their environment. Games designed for TACT aim to enhance patients vocabulary, observational skills, and their capacity to express themselves verbally.
- LISTENER: audio interventions concentrate on enhancing receptive language skills. Patients work on comprehending and responding to spoken language and auditory cues. Games within this category may aim to improve listening comprehension, the ability to follow instructions, and responsiveness to auditory stimuli.
- VP-MTS: Visual Perceptual - Matching-to-Sample interventions are concerned with improving visual perceptual skills, including pattern recognition and matching. Games in this category would likely be designed to enhance patients ability to recognize similarities and differences in visual stimuli.

Category	Patient working on	Easiest for new	Improve using tech	Overall
MAND	3	1	2	6
TACT	4	3	3	10
LISTENER	5	3	5	13
INDIVIDUAL GAME	2	2	4	8
VP-MTS	4	4	5	13
SOCIAL BEHAVIOUR	4	1	1	6
READ	2	1	4	7
WRITE	2	1	3	6
IMITATION	3	3	2	8
ECOIC	1	1	4	6
NATUAL SPEAKING	3	2	1	6
RAFCC	3	2	4	9
INTRAVERBAL	1	2	2	5
ROUTINES OF GROUPS	1	2	1	4

Table 3.1: Evaluation of each category following 3 different parameters

The primary objective is to ensure that the games seamlessly align with the established practices of the therapists, who previously relied on physical tools for therapy sessions. By mirroring the therapist's physical tools, the games aim to provide a sense of continuity and familiarity for the therapists, enabling them and their patients to adapt to the digital platform effortlessly. This approach aims to preserve the efficacy of ABA therapy while embracing the advantages that electronic devices bring to the table, ultimately benefiting both therapists and the patients they serve.

Classes

Each class representing a game in the Unity engine is designed with comprehensive parameterization options available in the Unity editor. This approach significantly enhances the versatility and scalability of the games within the app. By allowing new levels with the same mechanics to be created without additional coding, it streamlines the game development process and empowers developers to focus on content creation within the Unity editor.

TACT

The significance of therapist interaction within the TACT category cannot be overstated, as it plays a pivotal role in the game's functionality. Therapists are required to make confirmations by pressing buttons when patients provide correct or incorrect answers. This aspect of the game design underwent careful consideration, with alternative options explored. One of the explored alternatives involved creating a separate app that would communicate with the main iPad app via Bluetooth. This additional app would serve as a control interface for therapists, allowing them to select actions, such as confirming correct or incorrect answers. However, this option was ultimately discarded due to practical considerations. The primary reason for dismissing the separate control app was the challenge it posed to therapists in managing multiple devices simultaneously. Therapists already have the responsibility of overseeing and guiding the patient interaction with the main iPad app. Introducing another device for control would have added complexity and potentially disrupted the therapy process. Managing both the main device (iPad) and a separate control device simultaneously was deemed impractical and could potentially detract from the therapeutic experience. As a result, the decision was made to streamline the interaction process within the main app, allowing therapists to confirm patient responses directly on the iPad. This approach ensures a more efficient and user-friendly experience, enabling therapists to focus on guiding the patient progress without the added complexity of managing multiple devices. It reflects a thoughtful consideration of the practical realities of therapy sessions and aims to maintain a smooth and effective therapeutic process within the digital environment. As shown in Figure 3.1, the development process has yielded three distinct classes, each tailored to create three unique mini-games. These mini-games are designed to replicate specific activities that the therapists traditionally employed to facilitate TACT achievements.

NameWhatSee serves as the foundational TACT game within the app. In this game, a random image selected from the appropriate level's set is presented to the patient. A voice prompt then instructs the patient to verbally identify the objects or elements depicted in

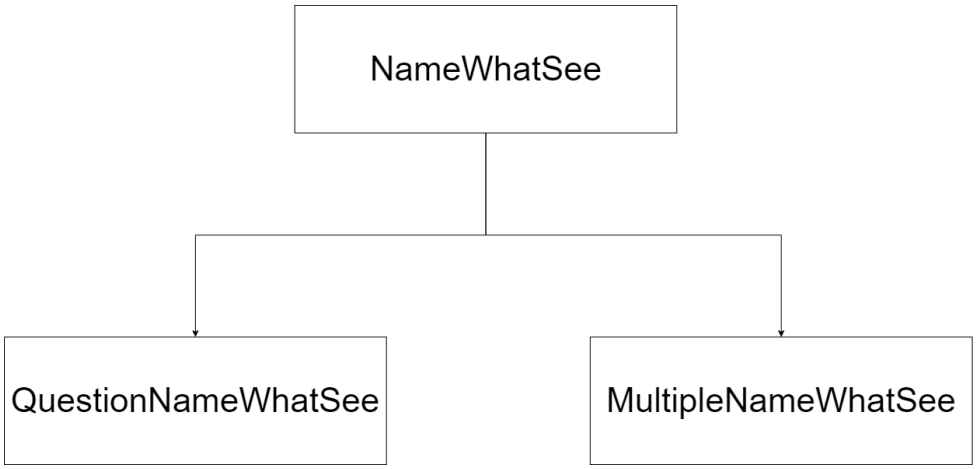


Figure 3.1: UML of TACT games

the image displayed on screen. This game provides the therapists with the flexibility to offer additional prompts and cues to assist the patient during the activity. Once the patient provides an answer, the therapist can conveniently press the corresponding button to indicate whether the answer is correct or incorrect. This interactive and responsive game design supports the therapy process by promoting patient engagement and facilitating real-time feedback from therapists.

MultipleNameWhatSee, as an extension of the NameWhatSee game, maintains the core activity of identifying objects depicted in images while introducing a nuanced difference in how data are stored in the database. In this game variant, the set of images is composed of groups containing three distinct images, each representing the same object category. For instance, one group might include images of a soccer ball, a volleyball, and a tennis ball—each portraying a different type of ball. The primary objective of MultipleNameWhatSee remains consistent with its predecessor: the patient is tasked with recognizing and naming objects within these images. However, the twist lies in the grouping of images by category. Once the patient successfully identifies all the objects within a category (e.g., all the different types of balls), the app triggers an acknowledgment mechanism that records this achievement in the database.

QuestionNameWhatSee inherits from the NameWhatSee class, introducing a notable shift in the patient interaction flow. In this game variant, a selected image from the designated level is presented, but contrary to the previous ones, the patient must provide three correct answers for each displayed image to mark it as completed. The questions themselves are audibly delivered to the patient via voice prompts, ensuring clarity and consistency in communication. Additionally, a key reference accompanies the image, typically displayed at the top of the screen. This reference serves as a contextual guide for the therapist,

providing pertinent information related to the posed questions. The fundamental objective here is for the patient to successfully respond to all three questions reported in Table **??** associated with a single image. When this criterion is met, the image is recorded as "achieved" in the database, signifying the patient accomplishment. This game variation enhances cognitive engagement by necessitating multiple correct responses per image, thereby enriching the therapy experience and offering comprehensive progress monitoring.

Question	Key word
What colour is it?	Color
What shape is it?	Shape
What is it for?	Use

Table 3.2: Tact questions for QuestionNameWhatSee games

LISTENER

Within the LISTENER mini-games category, the audio component assumes paramount significance. A button to re-listen the current audio prompt is present in all the mini-games of these category. This emphasis on audio derives from the primary objective of these games: to develop the patient ability to comprehend and respond effectively to external communication. In each of these games, audio prompts play a central role, requiring the patient to react appropriately based on the auditory cues provided. The ultimate goal is to enhance the patient listening and communication skills, fostering their capacity to interpret and respond to spoken prompts. This auditory focus ensures that patients actively engage with and respond to various verbal stimuli, contributing to the attainment of therapeutic objectives related to listening comprehension and appropriate responsiveness. In all the LISTENER mini-games, if the patient mistakenly selects an incorrect image, there is a provision for re-recognition. In such cases, the patient can attempt to re-identify the image or images requested from the mini-game. Importantly, only when all the images have been correctly recognized they are sent to the database for storage. Errors made by the user prevent the images from being recorded in the database, maintaining data accuracy and reflecting the patient progress accurately.

GameImagesAndAudio serves as the foundational class for the LISTENER mini-games category. As an abstract class, it cannot be instantiated directly, but it provides essential functionalities that serve as the building blocks for creating games within this category. These fundamental functionalities encompass the integration of audio prompts, images,

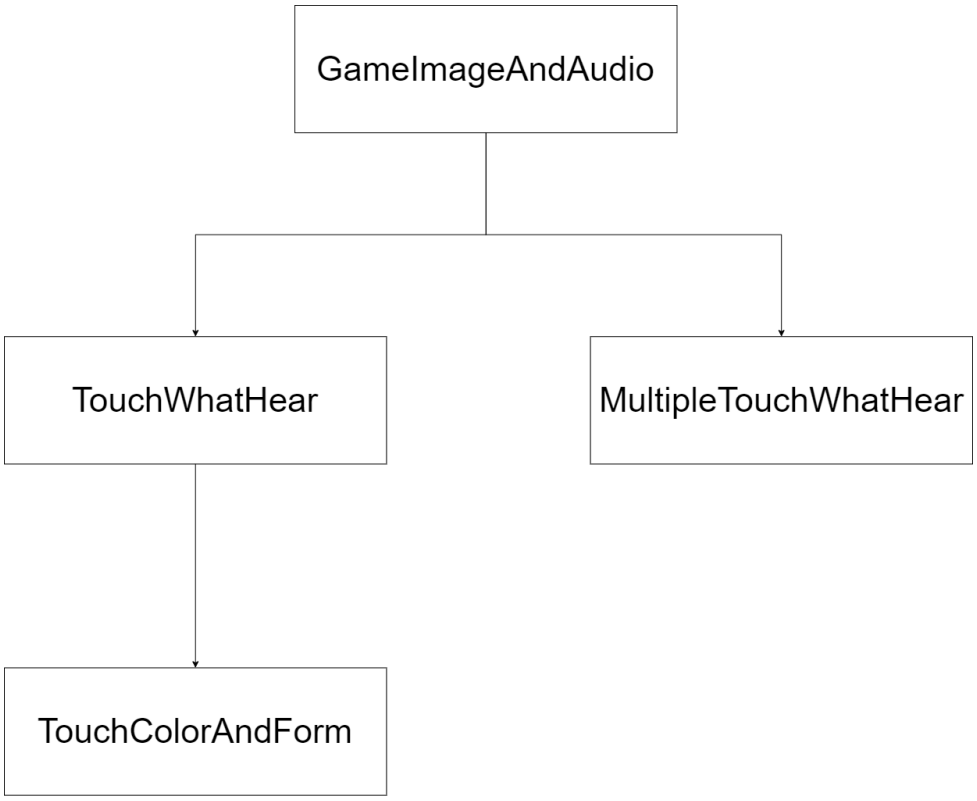


Figure 3.2: UML of LISTENER games

and interactive image-touch interactions, all of which are crucial components for the successful implementation of these games. The class establishes a common structure that simplifies the development process for LISTENER mini-games, streamlining the incorporation of audiovisual elements and data storage interactions.

TouchWhatHear represents an implementation derived from the GameImagesAndAudio class, designed to provide a versatile and configurable experience within the LISTENER mini-games category. This class facilitates the presentation of a customizable set of distinct images to the patient, accompanied by audio prompts that instruct the patient to select a specific image in response. What sets TouchWhatHear apart is its comprehensive parameterization capabilities directly accessible through the Unity Inspector. This parameterization feature empowers developers to fine-tune various aspects of the game, adapting it for use in a diverse range of therapy levels and scenarios. As a result, "TouchWhatHear" has been effectively utilized across multiple levels, each with distinct parameters, as detailed in Table 3.3. This adaptability underscores the class's versatility and its role in providing tailored LISTENER mini-games that cater to the unique needs and progressions of individual patients during therapy sessions.

Level	# of images	# of correct needed
5	4	20
6	6	40
9	6	50
13	3	8

Table 3.3: Parameters for games Touch What Hear

MultipleTouchWhatHear, inherits from the GameImagesAndAudio class as depicted in Figure 3.2. This game variant introduces a distinctive gameplay mechanic, where a grid of nine different images is presented to the patient. Among these images, three images share a common subject, such as a house, forming a recognizable group. In MultipleTouchWhatHear, audio prompts are delivered to the patient, instructing them to identify a specific item within the grid of images. The challenge lies in discerning the correct images related to the audio prompt. Once all the images representing the specified subject have been successfully recognized by the patient, the entire group is considered acknowledged, and this achievement is recorded in the database for tracking.

TouchColorAndForm inherits its foundation from the TouchWhatHear class, further extending the capabilities and objectives within the LISTENER mini-games category. In this mini-game variant, the primary goal is to cultivate the patient proficiency in recognizing specific geometric forms and colors within a set of images. The gameplay unfolds in two distinct phases, each designed to enhance specific cognitive skills: initially, the patient is tasked with identifying the correct shape from a collection of images, all possessing the same color but featuring different shapes. The patient progress is gauged based on the successful identification of the shapes. Once the patient achieves the 50% milestone in recognizing shapes, the game proceeds to the next phase. In the second phase, the focus shifts to color recognition. The patient is presented with a set of images, all sharing the same shape but distinguished by different colors. The audio prompt provided specifies both the color and shape that the patient must identify within this array of images. This phase of the game aims to enhance the patient ability to accurately associate color information with visual stimuli, improving their overall capacity to respond to color-related hints. TouchColorAndForm aligns with the overarching objective of LISTENER mini-games by fostering the patient competence in responding to audio prompts that convey specific attributes of visual elements, in this case, color and form.

VP-MTS

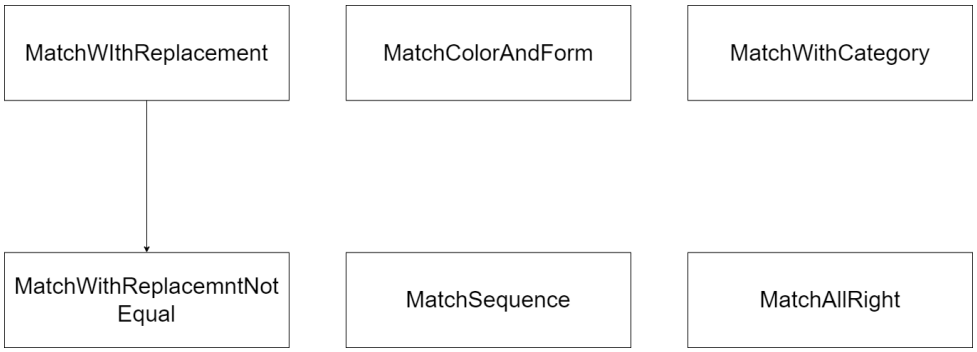


Figure 3.3: UML of VP-MTS games

The Visual Perceptual - Matching-to-Sample encompasses a range of mini-games designed to target and develop the patient ability to identify and connect similar or identical objects. As patients progress through the levels, the complexity of the matching tasks evolves. In more advanced stages, patients are challenged not only to match similar objects but also to associate an image with the broader set to which it belongs. For instance, a patient may be asked to identify that a fish is part of the sea category. To facilitate these matching exercises, all games within the Visual Perceptual - Matching-to-Sample category implement a drag-and-drop system. This system enables patients to interact with the images on the screen, providing a tactile method for recognizing when patients move images to make connections. The UML schema are reported in Figure 3.3.

In MatchWithReplacement a predefined number of images, a parameter adjustable within the Unity Inspector, are displayed in a grid format on the screen, and one to the bottom. The patient objective is to identify and match the images correctly. Utilizing intuitive drag-and-drop functionality, patients can select the image from the bottom of the screen and move it to its identical counterpart located in the grid displayed on the upper part of the screen. The critical aspect of this exercise lies in ensuring the match is made accurately on the first attempt. When a patient successfully accomplishes a correct match on the initial try, the pertinent data are promptly transmitted to the database. This achievement signifies that the image has been effectively recognized and associated within the patient cognitive framework.

MatchWithReplacementNotEqual expands upon the foundational concept introduced by MatchWithReplacement, offering a similar gameplay experience while incorporating a distinctive twist. In this mini-game, patients are presented with a grid of images, along with a single image placed separately at the bottom of the screen. However, the task now involves matching two different images that represent the same object or concept. These two images may depict the same object but are drawn or presented in distinct ways,

challenging the patient to discern the underlying similarity despite visual differences.

MatchAllRight unfolds in a sequential manner, with each image from the grid being revealed one by one at the bottom of the screen. The patient task is to actively match each displayed image to its corresponding counterpart within the grid. Successful matching is essential to scoring a point and achieving the set objective. If the patient successfully matches all the images within the grid, a point is awarded, and this accomplishment is promptly transmitted to the database for recording. This mechanism not only encourages precise recognition, but also reinforces the concept of visual-perceptual matching. In the event that the patient is unable to match all the images on the screen, a new set of images is presented, and the matching process begins anew. This cyclical structure adds an element of challenge and repetition, encouraging patients to refine their matching skills and strive for continuous improvement.

MatchColorAndForm is a mini-game designed to empower patients to enhance their capacity for autonomously matching colors and shapes. Within this interactive activity, patients are presented with a targeted image that serves as the reference point for the matching task. Accompanying this reference image are eight different options, each with varying combinations of colors and shapes. The gameplay dynamically adjusts based on the patient performance and success rate within the game. As the patient progresses through different levels, the game intelligently tailors the challenges to the individual's skill level. If a patient demonstrates a high level of proficiency in matching colors, the game may respond by presenting a reference image with varying shapes but consistent colors. Conversely, if the patient excels in matching shapes, the game could introduce diverse colors while maintaining the same shape.

MatchItemWithCategory is a captivating mini-game designed to enhance the patient ability to categorize and classify various items effectively. Within this interactive activity, the patient is presented with a visual display featuring five distinct categories, each uniquely represented. The primary objective of this game is to encourage precise categorization. To achieve success and consider an image as recognized, the patient must align it with the correct category in the first attempt. This challenge requires the patients to engage their cognitive skills, visual perception, and categorical thinking to swiftly and accurately match each item to its appropriate category.

MatchSequence is designed to challenge the patient sequencing abilities. In this interactive activity, the patient is presented with a sequence of three distinct images. To successfully complete the game, the patient must replicate the given sequence by arranging three copies of each image in the correct order. This game places a strong emphasis on memory

recall and sequencing skills. Patients are required to match the precise order of images in the given sequence and then accurately reproduce it by dragging and arranging the images in the corresponding slots on the screen. By challenging patients to replicate sequences, this game encourages the development of concentration and problem-solving skills in a fun and interactive manner.

3.3. User Interface

In this section, the design and development of the ABA Service App are described, exploring the principles applied to ensure the creation of a user-friendly and effective tool for children with ASD.

Interaction Design (IxD) [34] for children with ASD is a specialized field within interaction design that focuses on creating digital interfaces and apps tailored to the unique needs and challenges of individuals on the autism spectrum, particularly children. Interaction designers working in this area aim to design user interfaces and experiences that are accessible, engaging, and supportive of the developmental and educational goals of children with ASD. The UI design of this app is developed following the 15 design principles proposed by Hussain *et al.* in 2016 [34]. During the development of the ABA Service App, several design proposals were taken into account, while others were somewhat restrictively applied due to decisions made in consultation with the therapists. Table 3.4 shows which design principles have been completely satisfied.

Design Principles	ABA Service App
User Interface simple	UI has been minimized to reduce distractions for the patient.
Number of picture in each page	Depending on the game's requirements, a maximum of nine pictures are displayed on the screen. At lower levels, the maximum number of displayed pictures is limited to three.
Screen size, images large on screen	The pictures are always visible and easily recognizable for the user.
Icon	The app does not include any icons; instead, it solely features buttons, which are exclusively used by therapists.
Colour	The colors used for the UI is a palette of green with 3 different shades.
Guide the user through the app	The therapist is present during all the process, so no guide is provided.
Admin section	ABA Service System provides a website to customize and check the progression of the patient, no admin section is provided.
Picture Exchange	All the pictures were chosen by the therapists and many of them were already used in the physical games before the app.
Audio	Audio prompts are present in games where it has been considered useful.
Language	Few word are written in the app so the use of them cannot be considered a parameter for ABA Service App.
Upload photo	Due to the category chosen according to Table 3.1 uploading images is unnecessary.
Pronunciation	Audio prompts are recorded using Amazon Polly.
Evaluating parameter	The patient evaluation is accessible through the website, rather than the app.
Image life, representation of reality	The images have been selected by the therapist, encompassing both drawings and actual photographs.
Navigation intuitive	The app, after a sign in, has only a main menu from where the level can be selected.

Table 3.4: Interaction design principles in ABA Service App

Another analyzed approach is User-Centered Design [35]. UCD is a human-centric approach to designing products, interfaces, and systems that prioritizes the end user's experience and needs. In UCD, designers begin by thoroughly understanding the users, their behaviors, goals, and challenges through methods like research on users and interviews. The design process is iterative, involving the creation of prototypes and usability testing to gather user feedback and make continuous improvements. Collaboration among multidisciplinary teams is integral, ensuring that design decisions align with both user requirements and technical constraints. UCD also emphasizes the importance of adaptability, recognizing that user needs may evolve over time. By placing users at the center of the design process, UCD aims to create products and interfaces that are intuitive, efficient, and ultimately enhance the user's experience. These approaches have been partially implemented in the development of the ABA Service App's UI and prototyping. Many of the games already had a physical version, making it easy to ascertain that the mechanics were effective for patients. The primary task was to adapt and transition these games to electronic devices.

3.3.1. Framework

In the realm of mobile app development, having a clear understanding of the UI design is crucial to ensure a cohesive and intuitive UX. To achieve this goal, creating a framework or visual blueprint of the app's UI becomes an essential step in the development process [36]. In this section, the process of creating a framework using Figma is explored. Figma stands out as a versatile and collaborative design tool that facilitates the creation of high-fidelity UI mockups, prototypes, and design systems. By leveraging Figma's capabilities, it is possible to create a visual representation of ABA Service App's UI, to identify potential design flaws, refine the layout, and ensure consistency across different screens and sections of the app, before diving into the actual implementation.

Figures 3.4, 3.5, 3.6 show the first frameworks done in Figma for ABA Service App.

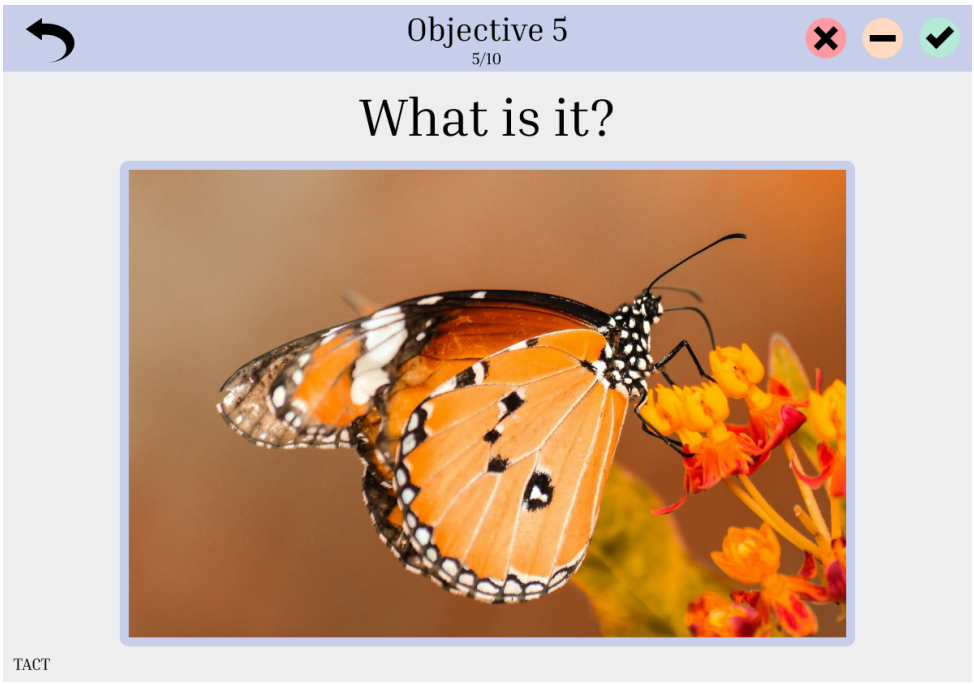


Figure 3.4: TACT Framework

Figure 3.5: LISTENER Framework

Figure 3.6: VPMTS Framework

Figures 3.7, 3.8, 3.9 shows the final UI of the mobile app, as designed after several iterations of testing and feedback with the therapists. The comparison with the initial frameworks showcases the importance of prototyping and iterating upon initial ideas, allowing for refinement and improvement. The initial frameworks displayed an excessive amount of on-screen information during the game, potentially causing distractions for the patients. To mitigate this issue, all images borders are removed, rendering them transparent. Additionally, the colorful bar previously present at the top of the screen is eliminated, as it has been identified as an unnecessary distraction during therapy sessions. Furthermore, buttons, when required, are resized and positioned at the screen's edges to minimize the risk of children randomly pressing them. The presence of on-screen text is significantly reduced and retained only when deemed absolutely necessary for the UX.

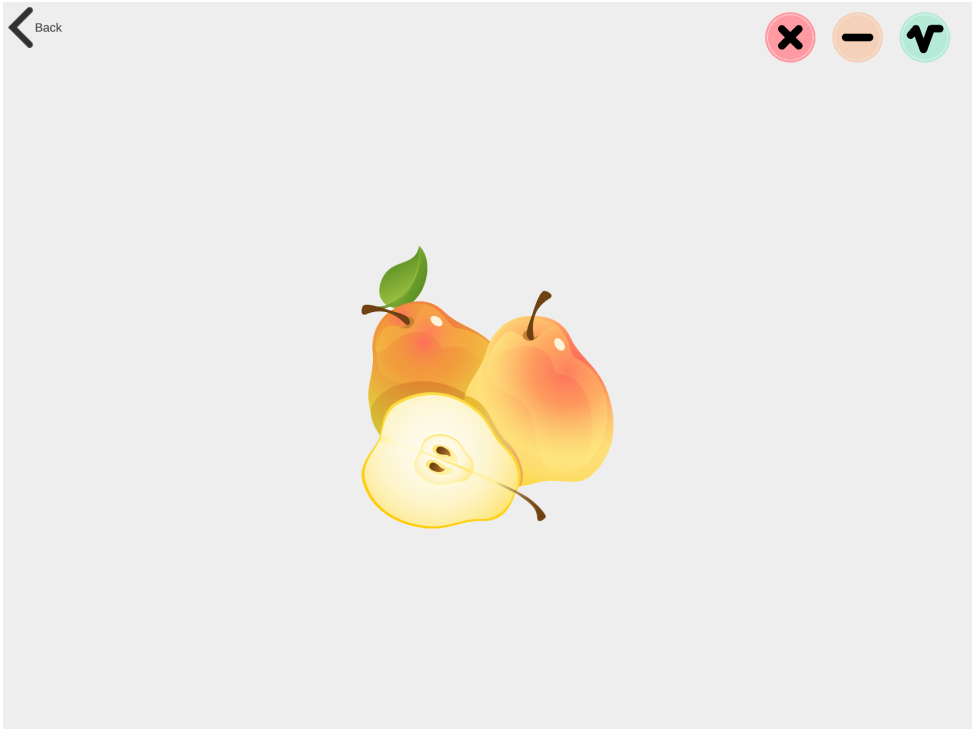


Figure 3.7: TACT game example

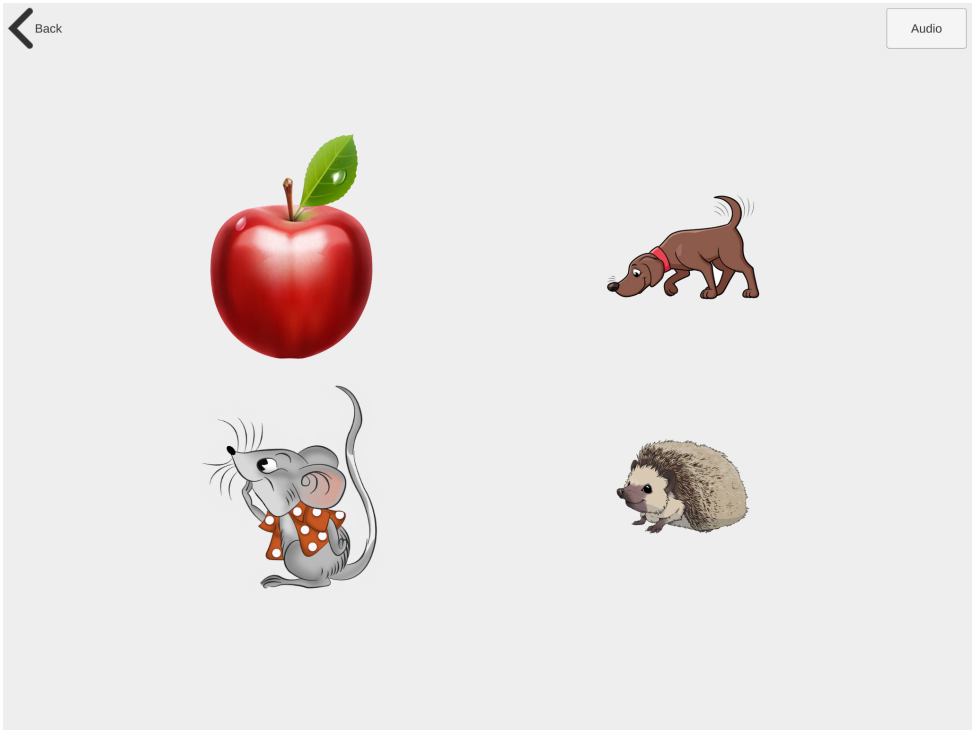


Figure 3.8: LISTENER game example

Figure 3.9: VPMTS game example

4 | Website

This chapter delves into the critical decisions made during the development of the ABA Service Website. It plays a fundamental role in the project system, serving as the central hub for the therapists to customize patient's profiles. The therapists, in particular, utilize this platform to add patients to their caseload and define specific objectives tailored to each individual. It is important to note that the creation of therapist profiles is exclusively administered by the developing team. The website primarily aims to provide therapists with an intuitive interface for effectively managing their patients' profiles. Additionally, for users without therapist profiles, the website offers a valuable resource where they can access pertinent information about ABA methodologies and insights into the ABA Service System itself.

The website offers 4 sections:

- ABA: a short description of the method and its purpose.
- Technology: an overview of the ABA Service System development and implementation to let the users know the project background.
- Therapists: a Q&A page where the therapists have collected a list of frequently asked questions and their exhaustive answers.
- Spazio Autismo: a log in form to the therapists personal area and a presentation of the Mantova center, participating in the creation of ABA Service System.

4.1. Development Tools

The website is developed using the latest version of the Nuxt framework, which is a well-known tool for building server-rendered Vue.js applications. Nuxt3 was released at the end of 2022 [37], and it undergoes frequent updates to its codebase and features. This provides end users with a variety of small plugins that can greatly simplify their workflow. Vue.js is known for its flexibility, progressive adoption, and a smooth learning curve, making it a popular choice for developers building modern web applications. Together, these two

tools provide a powerful and versatile toolkit that greatly assists developers in their work.

The website is connected to a MySQL database, and to maintain data structure consistency with the database, an Object-Relational Mapping (ORM) tool was essential. Prisma [38], an open-source ORM, is compatible with any Node.js application. This tool recreates the database schema within a file located inside the Nuxt project. When changes are made to this file or to the database structure, a simple command can be executed from the project's root to revalidate the database schema, ensuring synchronization. Prisma also includes a system that captures snapshots of the database structure in migration files. With each synchronization, a new migration file is generated, allowing for a comprehensive project history to be maintained. Furthermore, Prisma offers an extension called Prisma Client, which simplifies interactions with the database. It provides a set of functions for performing CRUD operations (create, read, update, delete) with ease.

Another useful tool employed during the development of the website is jsPDF, a JavaScript library for generating PDFs. This tool was particularly useful in creating downloadable reports for each patient and objective. JsPDF allows to generate and customize PDF files using scripts. The documents created with jsPDF are presented in a table format, featuring the patient's nickname, the category they are working on, the game level, and all the words they have achieved.

Finally Netflify platform [39] is used to host the website online and make it accessible to end users (therapists and people interested in ABA). Netflify is a web development platform that helps realize a full scalable and customizable web architecture. In particular ABA Service Website has been deployed from the origin branch of the GitHub repository where it has been implemented.

4.2. Technical Analysis

Each component of the website is developed from scratch. Components in Vue.js offer a way to break down the UI into self-contained and reusable units, allowing to focus on and manage each unit independently. This approach often results in an app structure that resembles a tree of nested components. While the concept is similar to nesting native HTML elements, Vue,js introduces its own component model, which provides the ability to encapsulate custom content and logic within each component. Additionally, Vue.js seamlessly integrates with native web components, further expanding their capabilities and interoperability. Components in Vue.js are highly customizable and allow to define parameters or props that can be used to tailor sentences, colors, images, and other content within them. This parameterization feature enables to create versatile and reusable

components that can adapt to different scenarios and requirements by simply adjusting the provided parameters. Furthermore, the website is developed with a specific focus on component scalability. It is crucial to ensure that the site remains user-friendly and intuitive for the therapists, allowing them to access patient data seamlessly, whether they are using a smartphone, tablet, or any other device with varying screen sizes. All components and the website itself have been designed to adapt dynamically to different layouts and screen dimensions, ensuring a consistent and optimal UX across various devices.

A short description of each component developed is provided in the following paragraph.

4.2.1. Component

CardOverview is a component, as showed in Figure 4.1, representing a box with a title, a small description and an icon. It is used to highlight the main section of ABA Service Website: the home page. It's fully customizable through the parameters listed in Table 4.1.

Figure 4.1: Card overview component

Name	Type
title	String.
description	String.
color	Hex or String for custom css color.
image	String, url of path.
link	String, the link to be redirected after a click.

Table 4.1: Parameters of Card Overview

CardImageLeft is a component, as showed in Figure 4.2, representing an image on the left of the screen and an information card with a title and description. It is used in multiple pages. It is fully customizable through the parameters listed in Table 4.2.

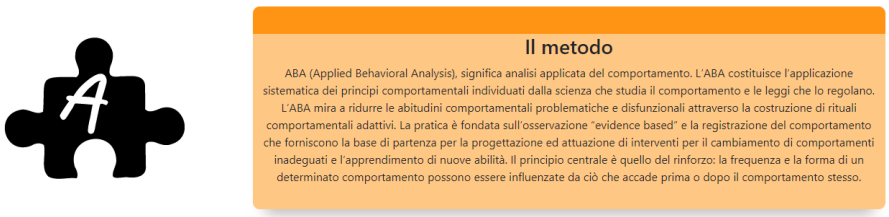


Figure 4.2: Card Image Left

Name	Type
title	String.
description	String.
colorBackground	Hex or String for custom css color.
colorTopBorder	Hex or String for custom css color.
image	String, url of path.

Table 4.2: Parameters of Card Image Left

Card Progress Objective is a component, as showed in Figure 4.3, representing a patient information and it is used in the therapists' personal area. It is fully customizable through the parameters listed in Table 4.3.

Figure 4.3: Card Progress Objective

Name	Type
nameCategory	String.
nameObjective	String.
colorDark	Hex or String for custom css color.
colorLight	Hex or String for custom css color.
currentScore	Number.
maxScore	Number.
level	Number.
startDate	Date, clamped in DD/MM/YYYY.
endDate	Date, clamped in DD/MM/YYYY.

Table 4.3: Parameters of Card Progress Objective

A comprehensive explanation of these three components shows how their design can be extensively customizable. Using these components, it becomes straightforward to create new pages with additional content, such as pages dedicated to specific categories of ABA therapy. Several other components have been developed for the ABA Service Website, and a list of these components is provided below.

- ImageTitle: image and title on top of each page.
- TitleSection: title aligned with other components of a particular paragraph.
- Carousel: a carousel showing multiple cards with information.
- PatienCard: a card representing a patient in the therapists' personal area.
- CardBubble: a bubble speech component for the Q&A page.
- Breadcrumbs.
- FormArea: a box containing all the input tags required for a form.

4.3. User Interface

As for the mobile app UI 3.3, all the website pages have been drawn before their implementation to plan the material to place in each one. The frameworks, as for the mobile app, have been made in Figma, a free software that allows users to customize web pages

and test them out on many different display resolutions. In Figure 4.4 some of the developed frameworks are reported, and Figures 4.5 4.6 4.7 show the final representation of those same frameworks. During the development of the ABA Service Website, it became evident that not all the original frameworks and components could be used as initially envisioned. In response to evolving requirements and the need for enhanced functionality, new components were developed to provide therapists with more comprehensive information in their persona area. Simultaneously, existing components were fine-tuned to optimize their efficiency in accommodating the wealth of information they were designed to contain. This adaptive approach ensures that the website better serves its intended purpose and provides a more enriching experience for the users.

Figure 4.4: Framework of website.

Figure 4.5: Screenshot of the home page.

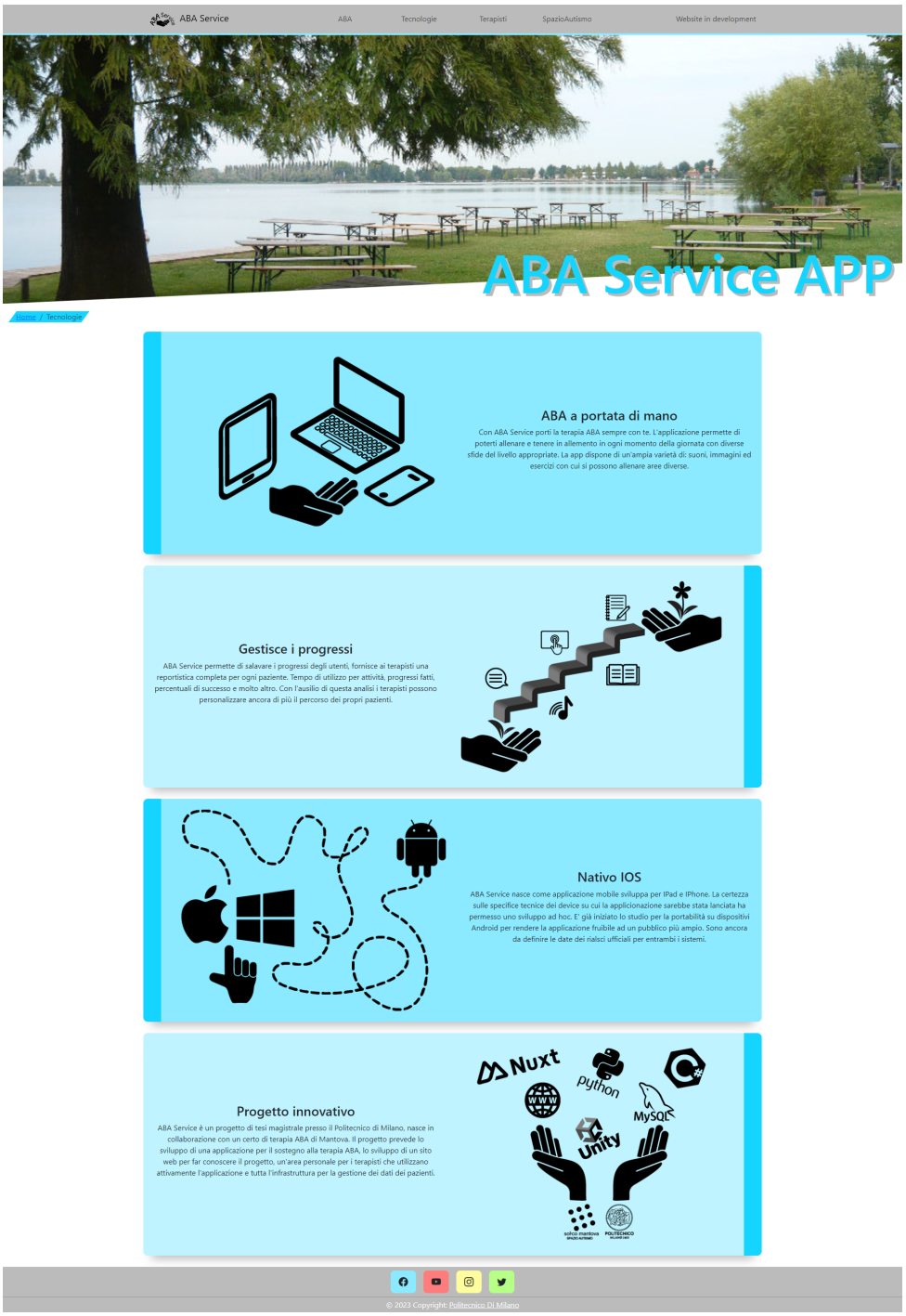


Figure 4.6: Screenshot of technology page.

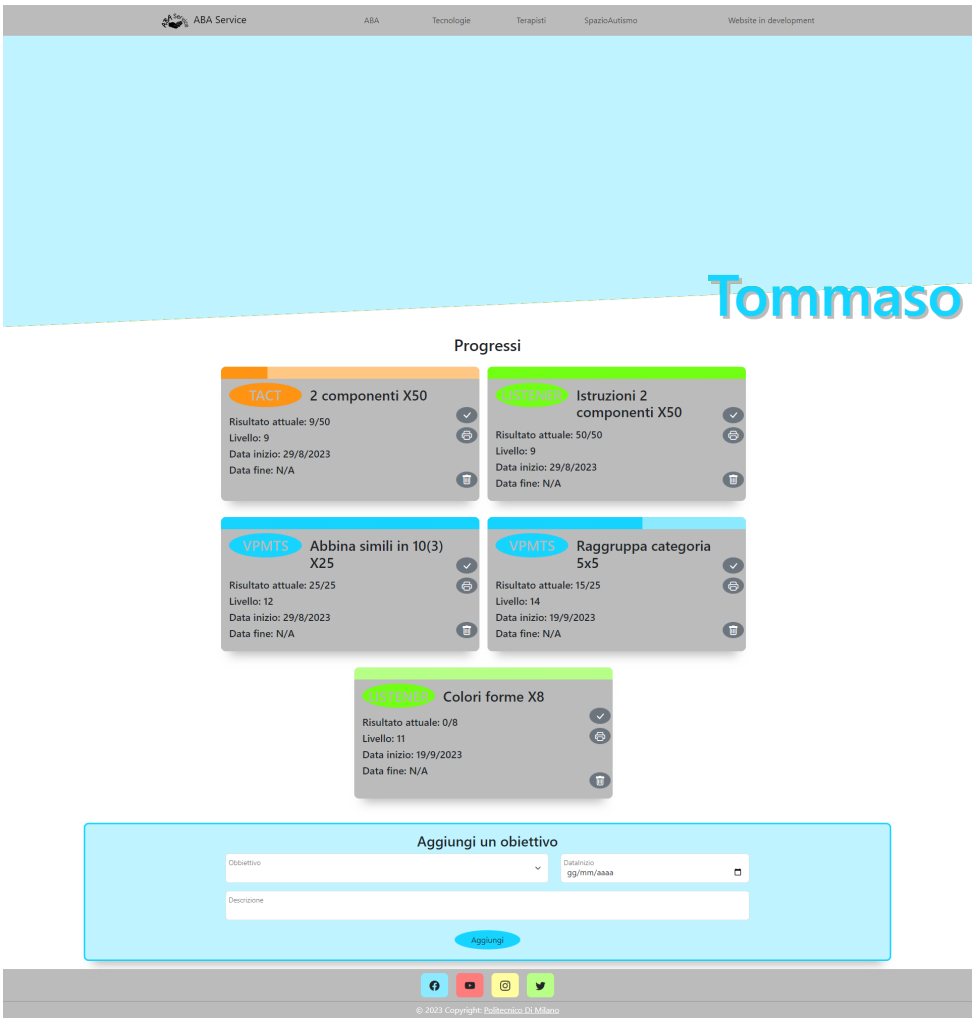


Figure 4.7: Screenshot of the patient page.

The ABA Service Website is implemented with a strong focus on usability and UX. In the development process, particular attention was given to adhering to the renowned Nielsen Heuristics for User Interface Design [40] [41] [42]. Nielsen's Heuristics, often referred to as Nielsen's 10 Usability Heuristics for User Interface Design, are a set of principles or guidelines for designing user-friendly and effective UIs. These heuristics are used in the field of UX design to evaluate and improve the usability of websites, software applications, and other digital products. Those heuristics serve as a valuable framework for UX designers and evaluators to assess the usability of a user interface and identify areas for improvement. While they are not rigid rules, following these guidelines can lead to more user-friendly and efficient digital products that enhance the overall user experience. Designers frequently leverage Nielsen's heuristics in conjunction with usability testing and other evaluation techniques to enhance their designs and rectify usability concerns. Table 4.4 enumerates all 10 of these heuristic principles, each accompanied by a brief description.

These principles served as focal points throughout the development of the website, guiding the design process and ensuring that the final product aligned with established usability standards.

Name	Type
Visibility of system status	The design should always keep users informed about what is going on, through appropriate feedback within a reasonable amount of time.
Match between system and the real world	The design should speak the users' language. Use words, phrases, and concepts familiar to the user, rather than internal jargon. Follow real-world conventions, making information appear in a natural and logical order.
User control and freedom	Users often perform actions by mistake. They need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process.
Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions.
Error prevention	Good error messages are important, but the best designs carefully prevent problems from occurring in the first place.
Recognition rather than recall	Minimize the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another.
Flexibility and efficiency of use	Shortcuts — hidden from novice users — may speed up the interaction for the expert user, so that the design can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
Aesthetic and minimalist design	Interfaces should not contain information that is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information and diminishes their relative visibility.
Recognize and recover from errors	Error messages should be expressed in plain language (no error codes), precisely indicate the problem, and constructively suggest a solution.
Help and documentation	It is best if the system does not need any additional explanation.

Table 4.4: Nielsen's 10 Usability Heuristics

5 | Infrastructure

In this chapter, the focus is on the decisions, tools, and selections that comprise the ABA Service Infrastructure. The discussion encompasses three key elements that play an important role in shaping the overall functionality and performance of the system:

- databases, which serve as repositories for patient data.
- server infrastructure, which manages the tools and methods used to ensure the effective availability and usability of the mobile app and website.
- networking, which manages domains, sub-domains, data integrity, and data routing for the website, all while ensuring public access and security.

5.1. MySql Database

MySQL, a robust open-source relational database management system, offers several notable advantages making it a suitable choice for diverse applications. Its open-source nature and cost-effectiveness make it accessible to startups, small businesses, and projects with budgetary constraints. An active and extensive community provides substantial support, ensuring access to an array of resources and solutions. MySQL exceptional performance, efficient query optimization and indexing capabilities position it favorably for applications demanding rapid data retrieval [43]. Its ability to support both horizontal and vertical scaling enables it to adapt to the evolving requirements of applications, accommodating projects ranging from small-scale endeavors to large-scale enterprises. Known for its well-established reputation for reliability and stability, MySQL has demonstrated its efficacy in mission-critical applications. Robust security features encompass user authentication, encryption, and access control, addressing data privacy concerns and compliance requirements [44]. MySQL strictly adheres to ACID principles, assuring data integrity and reliability, a critical feature for transactional applications. Its user-friendly nature simplifies the processes of installation and management, offering a variety of convenient tools and graphical interfaces. Cross-platform compatibility facilitates deployment across various environments, while support for multiple storage engines provides versatility to

cater to diverse use cases. MySQL benefits from an extensive ecosystem that includes third-party applications, libraries, and tools that seamlessly integrate with it, thereby enhancing its functionality. Collectively, these advantages establish MySQL as the ABA Service database system. As mentioned in Chapter 3, a third party tool has been used to manage the database: phpMyAdmin, a free software tool coded in PHP, that is designed to facilitate MySQL administration through web-based interfaces. This tool is capable of managing a diverse array of tasks related to MySQL [45]. Common database operations such as handling databases, tables, columns, relationships, indexes, user management, and permission assignments are achievable using the user-friendly interface. Moreover, phpMyAdmin retains the flexibility to execute SQL statements directly for more specialized tasks.

The Entity-Relationship (ER) schema, showed in Figure 5.1, offers a structured representation of the database key entities, their attributes, and the relationships between them. By providing a clear and comprehensive view of the data model, this schema is a foundational reference for database design, development, and management. It enables a deeper understanding of how data are organized, stored, and interrelated, which is essential for efficient data retrieval and informed decision-making within the ABA Service System. Throughout this documentation, an exploration of the entities that make up the ABA Service Database, the attributes associated with each entity, and the relationships that connect them are provided.

Figure 5.1: Entity relationship of ABA Service Database.

Doctors

The "Doctors" table serves as a repository for therapists and professionals who are the users of the ABA Service Website. It stores their unique IDs, usernames, and securely hashed passwords. Therapists utilize this system for access and management of patient-related information and treatment plans.

Patients

The "Patients" table is designed to maintain records of the patients who are the recipients of the ABA Service App. A unique ID and a nickname are assigned to each patient, to grant its anonymity. Moreover, hashed passwords are stored for secure access to their individual profiles and therapy-related data.

Doctors_Patients

The "Doctors_Patients" table enables the association between therapists and professionals and their respective patients. It establishes a many-to-many relationship, allowing multiple doctors to collaborate and provide care to multiple patients. This table is pivotal in ensuring coordinated care and support within the ABA therapy context.

Categories

The "Categories" table is responsible for categorizing the various objectives within the ABA therapy program. Each category is assigned a unique ID and a name, enabling the organization and grouping of objectives based on common themes or areas of focus. This table provides a structure for better management and categorization of therapy goals.

Objectives

The "Objectives" table defines the specific objectives that patients aim to accomplish during their ABA therapy journey. Each objective is assigned a unique ID and associated with a name, a category ID (reflecting the category to which it belongs), a level, and a target number. This table is fundamental in structuring and managing the therapy goals for patients, allowing for systematic tracking and progress assessment.

Image_Objective

The "Image_Objective" table facilitates the linkage of images to specific therapy objectives within the ABA program. It stores image IDs and associates them with corresponding objective IDs. Images are essential visual aids that assist patients in achieving their therapy goals, making this table a valuable resource for therapy planning.

Objectives_Patients

The "Objectives_Patients" table establishes a vital link between specific patients and their targeted therapy objectives. It records crucial details, including the start date and, if completed, the end date, current progress status, and a descriptive element that outlines the specific objective. This table plays a central role in tracking and managing each patient therapy goals and progress.

ImageObjective_ObjectivePatient

The "ImageObjective_ObjectivePatient" table provides a direct connection between spe-

cific image objectives and individual patients' therapy objectives. Additionally, it indicates whether the selected image aligns with the therapy goal, thereby measuring the patient progress and the effectiveness of image-based interventions.

5.2. Server

A server infrastructure is crucial for reliability, scalability, and performance of software systems. For the ABA Service System, this critical component manages the flow of data, the execution of tasks, and the interaction with the users. In this section, a detailed explanation of the server infrastructure that powers the ABA Service System is presented, as shown in Figure 5.2. The examination focuses on the interaction between server resources, containerization, and a range of tools to showcase how this framework facilitates the operation of the mobile app and website. This analysis explains the reasons behind the architectural and technological choices that have shaped the ABA Service Infrastructure.

The majority of the tools used in the backend of ABA Service System are containerized on Dokers images running on an Intel Debian service managed on-premise. Docker is a platform and toolset for developing, shipping, and running applications within containers. Containers are lightweight, standalone, and executable packages that include everything needed to run a piece of software, including the code, runtime, system tools, libraries, and settings. Docker has gained widespread popularity in the world of software development and deployment due to its ability to streamline the process of building, packaging, and deploying applications in a consistent and reproducible manner. It also provides a level of isolation, ensuring that applications do not interfere with each other or with the underlying host system, which simplifies the management of multiple applications on a single host. Docker is often used in microservices architectures, where applications are broken down into smaller, independently deployable services, each running in its own container. This combination of features has made Docker a fundamental tool in modern software development and operations, leading to greater consistency, scalability, and efficiency [46]. Docker security relies on three factors: isolation of processes at the userspace level managed by the Docker Daemon (known also as Docker Engine), enforcement of this isolation by the kernel, and network operations security [47].

Figure 5.2: Infrastructure diagram of ABA Service System.

Docker containers are used to set up: mySql, phpMyAdmin, NGINX reverse proxy. MySql database is described in Section 5.1, phpMyAdmin is installed to ensure a user friendly interface to administrate the mySql database. At last, the NGINX reverse proxy manager is used to manage the request from the outside and forward them to the right server. Reverse proxy servers operate within private networks, directing client requests to the appropriate backend servers. This adds an extra layer of control and abstraction to ensure

the seamless flow of network traffic, making it especially pertinent in modern network management. Reverse proxy (NGINX) servers offer several essential functions, including load balancing, web acceleration, and security. Load balancing optimizes server performance by evenly distributing client requests across multiple backend servers, enhancing speed and capacity while preventing server overloads. Furthermore, they facilitate web acceleration by compressing data, caching frequently requested content, and offloading tasks such as SSL encryption, ultimately enhancing the performance of web servers. Security and anonymity are also paramount, as reverse proxy servers intercept requests aimed at backend servers, safeguarding their identities and acting as an additional line of defense against security threats. This setup further allows multiple servers to be accessed via a single URL, irrespective of the local network's structure.

5.3. Networking

This section explores a comprehensive networking architecture tailored for an on-premise server hosting a variety of Docker containers, while leveraging the capabilities of Cloudflare for DNS management. The integration of a registered domain and the establishment of a custom sub-domain facilitate public access and secure interaction with a database, including PHP script execution within a Docker container. This section not only describes the technical aspects of the network architecture, but also explains the strategic reasoning behind design choices and the significant benefits they impart. A registered domain, is required to establish a distinctive public web presence. Cloudflare, with its DNS management capabilities, acts as the guardian of the domain and the gateway for routing incoming requests. The establishment of a custom sub-domain is a crucial milestone. This sub-domain streamlines and secures interactions with the database. It finds its primary purpose in facilitating the execution of PHP scripts within a Docker container, thus ensuring data integrity and access control. Incoming requests, stemming from the public URL, embark on a well-controlled journey. The Cloudflare service intercepts these requests, setting the port for a routing process. A reverse proxy stands as the gatekeeper, capturing incoming requests and directing them to the pertinent Docker, in our case the PHP folder, where all the scripts are contained.

A web host is also needed to manage online the ABA Service Website. Netlify a versatile cloud-based hosting and automation platform has been chosen. Netlify simplifies the often complex process of deploying websites and web applications, offering a seamless integration with version control systems such as Git. The platform core strengths lie in the ability to facilitate continuous deployment, leveraging automatic building and

deployment of code changes. With Netlify, developers can harness serverless functions for dynamic server-side operations, all while benefiting from a global Content Delivery Network (CDN), that ensures fast and reliable content delivery worldwide. Netlify is renowned for its scalability, which effortlessly adapts to varying traffic loads, and its commitment to security through default HTTPS support. Additionally, Netlify empowers developers with features like deployment previews for thorough testing, custom domain support and asset optimization.

6 | Project Outcomes

After successfully developing the ABA Service System, it is now possible to test it to evaluate the attainment of the initially established goals. In this chapter, a brief description of the test sample is given, followed by extensive proves of the achievement of each objective to demonstrate the success of this project. According to the process described in the previous chapters, the first three objectives pertain to the session between the patient and the therapist. The fourth objective measures the reporting phase and the last covers the privacy, security and reliability features, as described in Chapter 2.
Reading the following analysis, it is important to keep in mind that, as of today, ASD is not considered reversible and there is not a consolidated protocol of therapy effective on each and every patient. As a consequence, the following observations must not be read as a prove of ABA therapy effectiveness. The main goal of this project remains evaluating the efficacy of the digitalization of the ABA therapy in Spazio Autismo. Whenever a consideration about ABA therapy is reported, it has been discussed with the therapist experts.

6.1. Test Sample

The beta testing was initiated in July 2023 and successfully concluded at the end of October 2023, encompassing a 4 months duration. However, it is worth noting that not all children enrolled in Spazio Autismo programs in Mantova were eligible to participate in the app testing, due to the specific requirements of their individual diagnoses. Consequently 18 children (7 female and 11 male), all falling within the age range of 4 to 7 years old, were identified as suitable candidates for testing the mobile application, as determined in collaboration with their respective therapists. It is important to emphasize that, in order to preserve the confidentiality and privacy of the participants, the children' names, as well as their individual diagnostic details, remain undisclosed. For research purposes, the therapists have confirmed that all the children involved in the beta testing phase could be collectively categorized under the diagnosis of classic autism. Moreover, all of them have high support needs, limited or no verbal communication abilities, and experience

significant obstacles in their day-to-day activities. The patients are listed in the following analysis with a unique number, called identifier, ranging 1 to 18.

6.2. Automation of Learning Materials Preparation

Before the ABA Service System, the entire session preparation process had to be manually handled by the therapists. Before each session, therapists had to go back to the notes they took during the previous sessions with the same patient to identify the level the child has reached. Then, they defined the objectives the patient had not met yet and selected the pictures to use from a set of cards. Throughout the session, this selection process continued, thus ensuring that activities were proposed to the patient until the end of the meeting. Now, the use of the application reduces the preparation of therapy materials. All the patient data, relating to progresses and objectives, are stored in the database of the ABA Service System. At the beginning of the session, the therapists can now login in their patient's accounts, select the category they wish to work on and directly start from the level left in the previous session.

Figure 6.1: Example of physical cards used by the therapists before ABA Service System. All the images are selected from the web by the therapists

6.3. Automation of Data Acquisition

Prior to the use of the system developed in this project, during the therapy sessions, therapists at Spazio Autismo used to take notes of their patients progress using pen and paper, writing down the correct responses given by the patients. Each therapist had a personal way of collecting these data on paper to maintain a historical record for the patient. An example of the paper report that therapists were used to create during therapy sessions can be seen in Figure 5.2. From this picture it is possible to observe how the human error could impact the data collection phase. A missing record or a mislabeled one could impact the assessment of the progress achieved by the patient. As of today, data collection and the storage of patient histories at the Mantova center are automated thanks to the ABA Service System. The data are automatically and instantly saved in the database while the patient interacts with the application. This completely eliminates the time therapists used to spend manually recording the correct responses given by the patients and the human errors that may have occurred.

6.4. Efficacy of the Therapy

This objective assesses the improvement of therapy efficacy during individual patient sessions. To evaluate it, three main sub-goals have been agreed upon with the therapists:

- Time Spent on Non-Therapeutic Activities: This includes the time invested in activities that do not directly contribute to the patient progress in therapy. Minimizing time spent on these non-therapeutic aspects can enhance the overall efficacy of the therapy, as the ASD patients can easily loose their focus when not directly engaged by the therapists.
- Patient Focus During Therapy: The level of engagement and focus exhibited by the patients during therapy is a crucial factor. The goal is to maximize the patient attention and active participation in therapeutic activities, as the therapists observed that this directly impacts the effectiveness of their intervention.
- Speed of Objectives Completion: Another key measure of therapy efficacy is the rate at which children achieve their therapy goals and objectives. Accelerating progress toward these objectives can signify a further step in the direction of achieving the patients self-sufficiency goal.

6.4.1. Time Spent on Non-Therapeutic Activities

The first point to demonstrate the efficacy of the application is the reduction of non-therapeutic time due to circumstantial factors. ASD patients are particularly prone to be distracted and, prior to using the app, many patients used to loose their focus during the preparation of the learning materials and the data collection phase. Thanks to the automation of these two processes, all the operations that previously consumed time and could lead to distractions have been either eliminated or reduced to the essential minimum. According to the therapists, the use of the application has not only reduced their preparation and recording time, but can also be considered as an element of improvement of therapy efficacy.

6.4.2. Patient Focus During Therapy

The second point by which therapists assess efficacy is the children's ability to maintain concentration on the activity they are engaged in. Before using the application, children would easily get distracted due to numerous stimuli in their learning environment. Unfortunately, the application can not entirely remove these distractions, but now during therapy sessions, the children appear more focused and engaged at the center thanks to the use of a technological tool (iPad).

It is possible to gauge children's attention and involvement during their therapy sessions, quantifying the amount of time patients spend actively engaged with the application, a metric recorded through timestamps within the app's database. The duration of this active interaction serves as an indirect measure of the child's attention and participation in the therapy process. The time spent in each therapy session is calculated by subtracting the timestamp of the first user answer from the timestamp of the last one. This subtraction provides the duration of time spent using the app with the accompanying therapist. Table 6.1 presents the average time spent before and after the app was introduced for each ABA therapy category. The "Before" time estimate is provided by the therapists at Spazio Autismo. These estimated times were gathered individually to ensure that one therapist's response did not influence the others.

Category	Before [min]	After [min]
TACT	5	5,5
LISTENER	10	13,2
VP-MTS	5	8,4

Table 6.1: Time spent on average per therapy session on each category

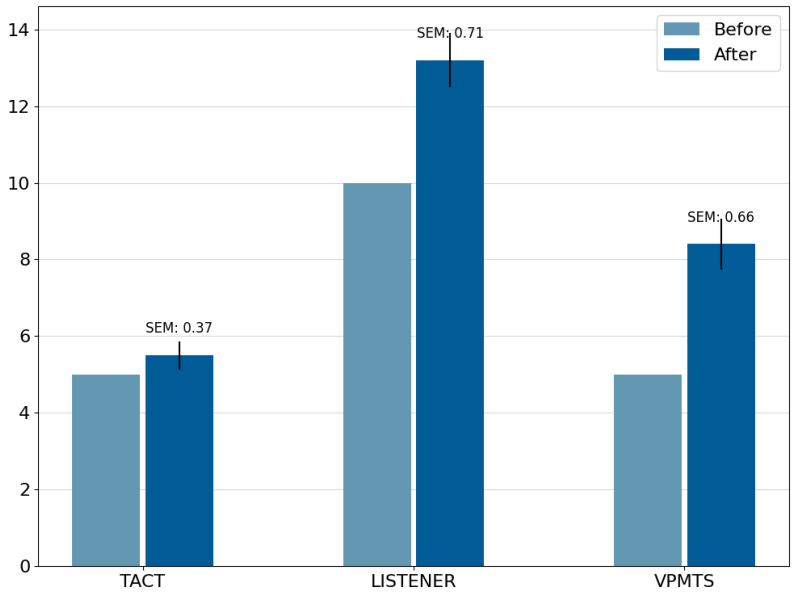


Figure 6.2: Average minutes per session per each category.

It is possible to observe in Figure 6.6 that for one category (TACT) the use of technology does not significantly alter the time spent actively engaged with the app. In this case, the app's role appears to be relatively neutral in increasing the focus during therapy. On the contrary, other categories (LISTENER and VPMTS) show that children seem to become notably more engrossed and immersed in the therapeutic activities, when utilizing the tablet as a supportive tool. This difference has been discussed with the therapists, who suggest that the category (TACT) reporting the smallest improvement derived from the digitalization is also the one where the children do not actively operates on the iPad. Therefore, showing the physical cards or the images on the iPad does not affect the efficacy of the therapy. On the other hand, categories (LISTENER and VPMTS) where children are more actively involved with the ABA Service App during the session show

a 32 to 68% of improvement in the amount of time patients spend actively engaged with the app. Comparing data collected from the ABA Service System with the information from Spazio Autismo, it appears that when patients become more engaged in interactive activities with the tablet, they tend to maintain their focus on the tasks at hand for longer time . This can lead to the conclusion that categories which can actively engage children in level completion on the app should be prioritized in the digitalization process.

6.4.3. Speed of Objectives Completion

The third point that, according to the therapists, is an indicator of the improvement in the efficacy of the ABA method is the speed at which patients can achieve their objectives. Some patients who had been stuck on certain objectives for months managed to complete them and progress in their therapy spending much less time using ABA Service System. As a reminder, objectives and levels refer to the same concept in this thesis. Completing an objective means reaching the goal set by the therapists. Completing a level means reaching the number of correct answers needed to achieve the same goal. The first word pertains to the educational field and directly relates to the VB-MAPP used by the therapists. The second, instead, refers to the game design field and it is typically used to indicate gamers skills.

In order to analyze the collected data in the testing, the following variables are introduced:

- $Patients$:= set of testers.
- $Tact_p$:= set of TACT objectives completed from user p.
- $Listener_p$:= set of LISTENER objectives completed from user p.
- $Vpmts_p$:= set of VPMTS objectives completed from user p.

Please note that the patients involved in this trial have different starting levels in different categories, as they may vary considerably depending on each patient diagnosis. The focus of the following analysis is therefore on the additional levels the children were able to achieve in the given time frame. In the 4 months of data collection, 119 levels were successfully accomplished and each patient has completed an average of *6,61* objectives, computed as in Equation 6.1, with a range of variation of 3, computed as in Equation 6.2 (min value observed is 5 and max is 8).

$$\frac{\sum_{p}^{Patients} |Tact_p| + |Listener_p| + |Vpmts_p|}{|Patients|} = 6,61 \tag{6.1}$$

$$\max_{p \in Patients}(|Tact_p| + |Listener_p| + |Vpmts_p|) - \min_{p \in Patients}(|Tact_p| + |Listener_p| + |Vpmts_p|) = 3 \tag{6.2}$$

To provide a direct comparison with similar previous data, a lengthy analysis of the paper reports produced by the therapists at the completion of each objective has been necessary. The data pertain to the same patients observed in the above mentioned test and refers to the 4 months prior to the beginning of this project. To be consistent with the assessment, the same VB-MAPP categories were analyzed. In the 4 months of data collection, 92 levels were successfully accomplished and each patient has completed an average of 5,11 objectives. It is possible to observe that after the digitalization, the average number of objectives completed by each patient is increased, thus confirming the positive impact the system has on therapy efficacy.

Given the limited dataset, the nature of the patients, and the short duration of the test, the limitations of this value are emphasized. It is suggested to interpret it only as an assessment of a positive trend, also perceived by the therapists during the sessions.

6.5. Automation of Data Reporting

The fourth objective set was to reduce the workload on therapists in the preparation of objective completion reports. Before having a platform for data retrieval, therapists had to meticulously transcribe on their laptops the notes taken by hand during therapy sessions with the children. Then, they had to collect all these data in the report template, standardized by the Mantova center. This report included information like the start and end dates of the accomplished goal, along with all the words that permitted the patient to successfully complete the level. As of today, the report is automatically generated, and it can be easily downloaded from the patient's profile within the therapists' personal area on the ABA Service Website. This automation has been made possible by the recording of every single interaction between the patient and the application during the therapy session. Consequently, the report not only is generated automatically, but it also includes the words that the patient struggled with in the considered level. The report is designed to closely resemble the original format, ensuring a seamless transition from the old approach to the new one, and minimizing disruption for the therapists and the families. This has represented a significant enhancement in the therapists' workflow process: less time can be invested and the procedure is much less error prone.

6.6. Privacy, Security and Reliability

The fifth and final objective of this project focuses on the security and privacy of therapy data, while ensuring the reliability of the entire system. Prior to the use of the ABA Service System, all data were collected on single copies of paper, which were then stored in the archives of the Mantova center. Only one copy of the patient progress was provided to the parents or legal guardians. These archived data were accessible for consultation only by physically entering the archive and searching for the required documents. Today, thanks to the ABA Service Website and Infrastructure, the patients data are more secure and protected. Therapists can access their patients data at any time and from anywhere, but only after logging into the portal with their credentials. This approach allows therapists to have easy and immediate access to the complete history of their patients data. This shift to digital record-keeping not only enhances security, but also provides greater accessibility and convenience for therapists while maintaining the necessary privacy safeguards. The initial concerns regarding the system robustness in terms of possible lags and technical issues were cleared. During the 4 months testing, the ABA Service System proved to be a reliable tool to run ABA therapy and to analyze collected data.

6.7. Leveraging New Data for Insights

Thanks to the introduction of the ABA Service System, the Mantova center now has access to all the data related to children's performance and playtime during therapy sessions. Some of these data have already been used to prove this project objectives, as described in the paragraphs above. However, since acquiring these data was very difficult or impossible previously, the center had never considered how they could leverage this information. In this paragraph, the results of some initial data analysis proposals, which were discussed with the therapists, are presented. Despite not being directly connected with the initial objectives, these findings can be valuable for center management and therapy design. It is important to highlight that it is not intended to provide therapeutic advice here, but rather to support the work of the Spazio Autismo center, albeit with a limited dataset available up to this point.

- Percentage of Completed Objectives per Category: In total, 119 levels were successfully accomplished and their distribution per category is illustrated in Figure 6.3. This representation demonstrates the validity of the initial category selection proposed by the therapists. In fact, the distribution of the three categories is in accordance with the prioritization of categories provided in 3 in Table 3.1. This

type of analysis can be utilized to reach different goals. For example, from Spazio Autismo point of view, this analysis can be used to rank the categories according to the number of objectives achieved in the therapists-patients sessions. In the long run, these data can help identifying which categories require more training for therapists, to make these sessions more effective.

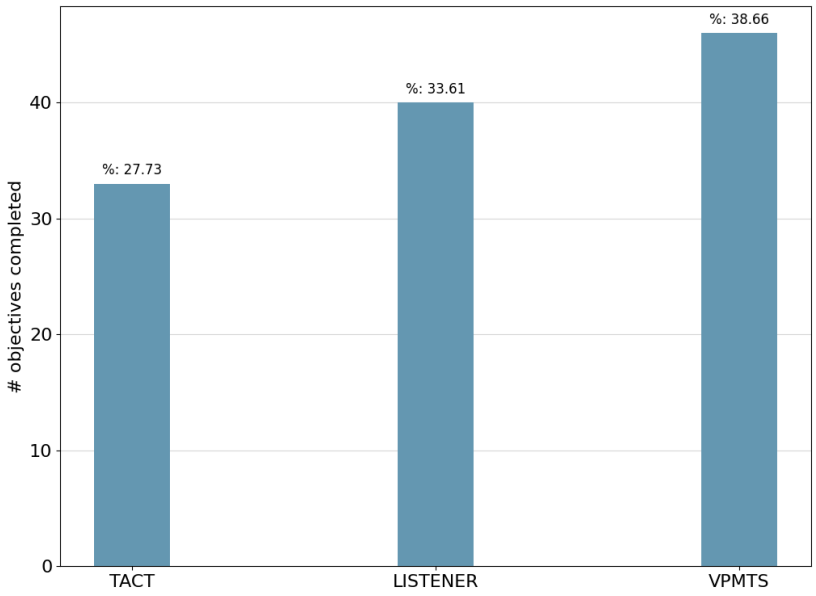


Figure 6.3: Percentage of completed objectives per category.

- Number of Objectives Completed per User: It is possible to organize the objectives completed per patient, showing how they are distributed per category. Figure 6.4 shows the improvements of the patients over the same amount of time. This dashboard highlights the category in which each child is making the most progress and the one in which the improvement is most stagnant. Moreover, it is possible to observe how different children perform in the same category and identify the outliers. This can help the therapist in assessing the performance of the patient in a set time frame, comparing this results with all the other children. The therapist can then use those information to make the appropriate adjustments to the patient therapy, if needed.

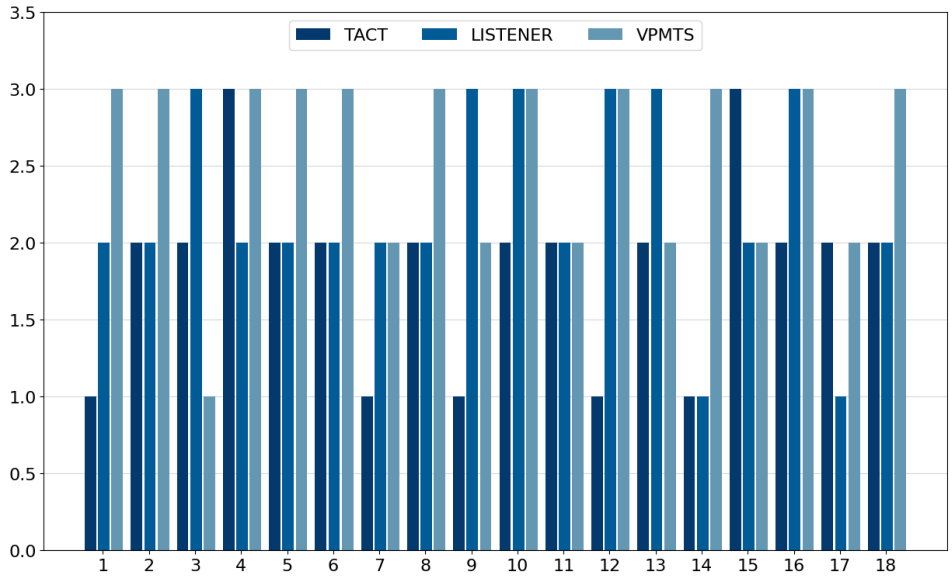
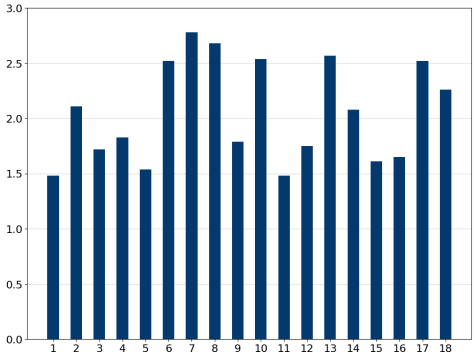


Figure 6.4: Number of objectives completed per user.

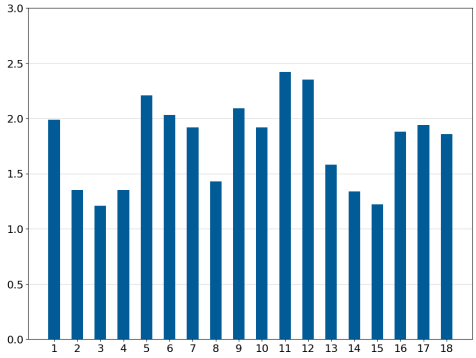
- Errors Rates per Category: ABA Service System introduces the collection of data regarding the errors made by the patients during their sessions. It is important to remind that errors were not manually recorded before. To leverage this new dataset, an analysis of the errors made by the patients is conduct to assess errors distribution across categories. In order to facilitate a standardized comparison of errors, a parameter denoted as ψ has been associated to each completed objective. This parameter is computed as follows:

$$\psi = \frac{\#ofErrorsDone}{\#ofRightAnswersRequired} \tag{6.3}$$

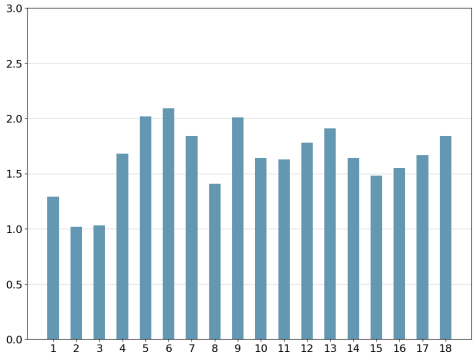
This parameter effectively quantifies the ratio of errors to the number of correct answers needed to fulfill that specific objective. If $\psi \leq 1$ then the patient made an equal or fewer number of errors compared to the correct answers. Conversely, if $\psi > 1$ then the patient committed more errors than the required number of correct answers. It is worth noting that the objective is considered completed once the patient attains the prescribed quantity of correct answers, regardless of the number of errors made in the process. After calculating the ψ for each completed objective and computing the average for each category across all patients, the results in Figure 6.5 represents the individual plots for each category.



(a) Tact errors per patients.



(b) Listener errors per patients.



(c) Vpmts errors per patients.

Figure 6.5: ψ average per patient

It becomes apparent that the three categories show different behaviors, meaning that mistakes occur in different magnitude for different categories, thus requiring a new calculation to illustrate the average values and the range of variation for each category. Figure 6.6 presents this graph, revealing that TACT exhibits the highest average with a value of *2.05*. This implies that for an objective requiring 50 correct answers, a patient would be presented with approximately $\sim$ 150 questions (50 answered correctly and 100 answered incorrectly). LISTENER has an average of *1.78* and VPMTS has *1.64*. According to the therapists, the significantly higher average in TACT can be attributed to various factors. TACT, as outlined in Section 1.1.2, primarily focuses on enhancing the patient ability to identify and name objects, actions, and events. This category often serves as one of the initial areas of intervention for patients who are new to ABA therapy and may encounter substantial challenges. Additionally, TACT games typically lack the captivating elements or actions that can engage children, making it more challenging for them to maintain their focus during these activities. In conclusion, TACT has exhibited the least favorable results from the perspective of patient outcomes among the three categories developed,

in alignment with the therapists expectations, that however have never been quantified before.

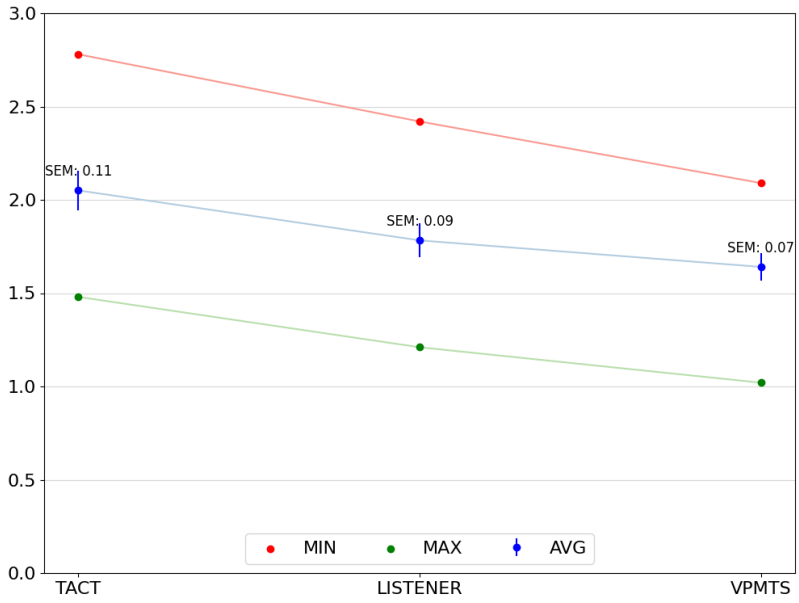


Figure 6.6: Comparison of ψ per category.

7 | Conclusion and Future Developments

This thesis has been developed thanks to a close collaboration with Spazio Autismo, an autism support center located in Mantova. The main objective is to create a system that can assist therapists in their application of ABA therapy for autistic children. This system includes a mobile application, specifically for the iPad, which therapists can use during therapy sessions with the children. The activities implemented for the patients are in the form of mini-games, providing safe and intuitive means for the children to learn and improve in various categories. The app also aims to offer therapists an efficient way to collect and subsequently retrieve therapy data. Additionally, the development of a website portal enables the therapists to monitor, update and report patients data.

The project has been successfully completed, resulting in the development of the app and the website, and the setup of an infrastructure that allows seamless communication between the two components, as well as the storage of patients data in a database. Not all ABA therapy categories are fully implemented; only TACT, LISTENER, and VPMTS are developed in their entirety.

The system has been tested at the Mantova center for a period of 4 months, with 18 children diagnosed with classic autism, ranging from 4 to 7 years old. The ABA Service System successfully satisfies the needs of the therapists. Thanks to the creation of a login based system and continuous backup, the project demonstrates improved privacy and security of patients data, while maintaining reliability. The efficiency of the automated data collection, learning materials preparation, and report creation functions is highly appreciated by the therapists. Furthermore, they praise the increased efficacy of the therapy. As supported in Chapter 6, data show that time spent on non-therapeutic activities has been reduced, patient focus increased by 10 to 68%, and speed of objectives completion accelerated, with an average of 6.61 objectives completed in 4 months, in contrast with the 5.11 prior to the digitalization.

Given these data, one conceivable approach could involve the development of a linear

model tracking the number of completed objectives per patient over time. However, it is important to highlight that attempting to predict how many objectives a patient will be able to complete within a specific time frame is, according to the therapists, a challenging and error-prone endeavor. The capacity of patients to accomplish objectives is influenced by a multitude of factors, many of which are deeply personal and linked to ASD. These factors are inherently unpredictable and cannot be quantified reliably. On any given day, as exemplified by a randomly selected sample, a patient may successfully complete an entire objective during a single therapy session. Conversely, there exists the possibility that the patient may not answer a single question correctly due to distractions, emotional crises, an inability to maintain focus, and numerous other variables.

Considering that ABA therapy is heavily data-driven, the paper-based data collection adopted by the Mantova center posed a significant limitation. Thanks to this project, the therapists have perceived how having more data can become an integral part of their patients analyses. Therefore, the idea of further analyzing these data, as started at the end of Chapter 6, naturally arises.

It is possible to imagine that by leveraging these data, therapists can tailor the therapy to each individual patient, something that is not currently possible. However, it is essential to acknowledge that it is not feasible to digitize all levels of every category, and the impact of technology may not be the same for all of them. Even within the three categories selected based on therapists' recommendations, as indicated in Chapter 3, it has been observed that two of them have yielded excellent results, while the third has maintained its effectiveness even after digitalization.

Given that the duration of therapy sessions is relatively brief, this system could also serve as a valuable tool to support home-based ABA activities. To leverage the ubiquity and accessibility of mobile devices, parents could utilize the ABA Service Application to offer short, engaging games that their children can play at any time during the day. This especially fits patients undergoing ABA therapy, which relies on the repetition of behaviors. To facilitate the broad adoption of this system, it is recommended that the ABA Service Application be made compatible with Android. Another tool that could be enhanced to better support the families of the Mantova center's patients thanks to the digitalization is the objects completion report. For the scope of this project, it has been decided to keep the same structure, to avoid disruptions for the therapists and families. Currently, the report lists the words learned by the patient in that level, but in the future, it could be redesigned to be more user-friendly and provide useful insights of the patient progress, thanks to the new data collected.

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