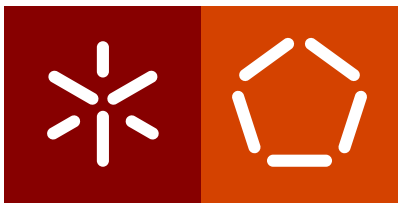

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with Autism Spectrum Disorders

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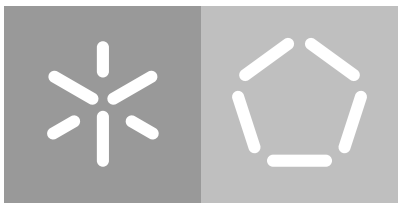

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A Task Recommendation System for children and youth

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Master dissertation
Master Degree in Medical Informatics

Dissertation supervised by
Professor Doutor Paulo Jorge Freitas Oliveira Novais
Professor Doutor Vicente Julián Inglada

May 2017

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ABSTRACT

Current studies indicate that about 1 in 68 children have Autism Spectrum Disorder (ASD). It is known that early diagnosis and intervention can alter the course of development and significantly improve the prognosis of the disease. Usually, the treatment is about skill-building and educational sessions, trough the use of different techniques and principles to bring positive changes in the behavior. Often, this involves language therapy, occupational therapy, and a very regular training and support from parents in their daily lives. However, those traditional learning tools can be monotonous and, thus, little motivating for children and therapists. For parents, it can be very time-consuming, stressful and expensive. Given these obstacles and lack of support programs for autistic children, this thesis aims to overcome this gap and create an innovative companion and support system for children and young people with ASD.

There are already many mobile applications directed for children to help them acquire skills in different domains; and some others for behavioral data collection, analysis and data sharing more directed for parents and clinicians. In the present dissertation an Android application, called *myOT*, which joins all these functionalities was developed. This application is a Task Recommendation System, which takes use of Case-based Reasoning machine learning technique, in order to supplement the child's regular therapy. With this technology it is possible to make an individualized intervention, recommending appropriate, necessary and enjoyable activities for each child. Besides that, it allows a closer monitoring by parents and a better coordination with the therapists, contributing to improve the child's development.

Although there are still some concerns about the early exposure of children to electronic stimuli, through scientific research and a survey done with parents, caregivers and health and education professionals who deal with children with ASD, it was concluded that *myOT* is attractive for children and operates in important areas of development: daily activities, social and cognition domains and responsibility. Furthermore, the importance given to the communication between parents and therapists was evidenced in this survey.

However, as future work it is extremely important to test the application with chil-

dren, to monitor their progress and prove that this supplement system can improve the results of regular therapies.

RESUMO

Estudos atuais indicam que cerca de 1 em cada 68 crianças sofrem de Perturbações do Espectro Autista (PEA). Sabe-se que o diagnóstico e a intervenção atempada podem alterar o curso do desenvolvimento e melhorar significativamente o prognóstico da doença. Normalmente, o tratamento baseia-se em sessões de terapia educacionais, tais como a terapia da fala e a terapia ocupacional. Estes instrumentos tradicionais de aprendizagem podem ser monótonos e portanto, pouco motivantes para as crianças e para os seus terapeutas. Para além disso, estas crianças requerem um apoio contínuo por parte dos pais nas suas vidas diárias, sendo este um processo muito desgastante e economicamente difícil de suportar. Assim, dada a falta de meios de tratamento e apoio a estas crianças, com esta dissertação pretende-se criar um sistema inovador de monitorização e apoio para crianças e jovens com PEA.

Já existem muitas aplicações móveis especialmente desenvolvidas para crianças com TEA, com o objetivo de as ajudar a adquirir competências em diferentes domínios. No mercado, encontram-se também aplicações direcionadas para a recolha e análise de dados comportamentais, dirigidas para pais e terapeutas.

Na presente dissertação foi desenvolvida uma aplicação Android - a *myOT* - uma plataforma para crianças, pais e terapeutas, que engloba todas estas funcionalidades. Para além disso, esta aplicação possui um Sistema de Recomendação de Tarefas, que utiliza a técnica de aprendizagem de Raciocínio Baseado em Casos, para propor uma intervenção individualizada, recomendando atividades apropriadas, necessárias e divertidas para cada criança em particular. A *myOT* pretende proporcionar um acompanhamento mais próximo por parte dos pais e uma melhor coordenação com os terapeutas, contribuindo assim para melhorar os resultados das terapias regulares, com vista a aumentar os progressos no desenvolvimento da criança.

Embora ainda existam algumas preocupações com a exposição precoce das crianças aos estímulos eletrónicos, através de pesquisas científicas e de um inquérito realizado com pais, cuidadores e profissionais de saúde e ensino, que lidam regularmente com crianças autistas, concluiu-se que a *myOT* é atraente para crianças e atua em importantes áreas do desenvolvimento como: atividades da vida diária, domínio social, cog-

nitivo e da responsabilidade. Além disso, a importância dada à comunicação entre pais e terapeutas foi evidenciada nesta pesquisa.

Como trabalho futuro, é extremamente importante testar a aplicação com crianças e monitorizar os seus progressos para que se possa provar que este sistema suplementar pode melhorar os resultados das terapias tradicionais.

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ACRONYMS

AAC Augmentative Assisted Communication.

AAP American Academy of Pediatrics.

ABAS-II Adaptive Behavior Assessment System-II.

ABS-S Adaptive Behavior Scales - School Version.

AD Autistic Disorder.

ADI-R Autism Diagnostic Interview-Revised.

ADOS Autism Diagnostic Observation Schedule.

ASD Autism Spectrum Disorder.

CDCP Centers for Disease Control and Prevention.

DSM Diagnostic and Statistical Manual of Mental Disorders.

ICD-10 International Classification of Diseases.

IDE Integrated Development Environment.

JSON JavaScript Object Notation.

MRI Magnetic Resonance Imaging.

PDDNOS Pervasive Developmental Disorder Not Otherwise Specified.

PEDI-CAT Pediatric Evaluation of Disability Inventory-Computer Adaptive Test.

SIB-R Scales of Independent Behavior- Revised.

VABS-II Vineland Adaptive Behavior Scales - Second Edition.

1

INTRODUCTION

The present dissertation reports the process of development and implementation of a task Recommendation System and an Android application to support children with ASD and also their caregivers.
In this first chapter, the context, motivation and objectives behind the development of this application will be described, as well as the structure of the present document.

1.1 CONTEXT

ASD is a neurodevelopmental disorder which is characterized by deficits in social interaction, in the communication domain and by behavior impairments. [11].
In 2014, the Centers for Disease Control and Prevention (CDCP), in the United States, released new data on the prevalence of autism. This surveillance study identified 1 in 68 children aged 8 years, (1 in 42 boys and 1 in 189 girls) as having ASD [12]. In Portugal, the prevalence of ASD has not been estimated in recent years, but the last numbers, from 2007, estimated 10 per 10 000 children [13].
Although there is still no cure for autism, it is known that an early diagnosis and intervention can alter the course of the children development. That is why therapy and regular training and support from parents can significantly improve the prognosis of the disease [14].
Children with autism often need external stimulus to initiate, maintain, or finish an activity and technological advancements have given devices the ability to deliver visual, tactile and mechanic feedback, which can be used for children with autism, since this kind of stimulus is generally even better received than human stimulus [15].

1.2 MOTIVATION

Combining the advantages of technology - seen in the previous section - with the necessities of a child with special needs, the motivation for the development of this application arose. After some research in the scientific community one could note that there isn't an application that can simultaneously help parents, therapists and children in the task of improving the development of autistic children. In order to do that, the most important obstacles to this process had to be identified. Each one of this obstacles and necessities were a motivation to find possible solutions that could be implemented through an application program:

- **children must be motivated and traditional learning tools can be monotonous [16].** Receiving activities through an electronic device, in a very intuitive and attractive interface, would be by itself more exciting for the children.
- **children need a continuous and repetitive work not only with specialists, but also at home, which can be very stressful, time-consuming and expensive for parents [17].** Therefore, helping parents (or other educator) choose appropriated activities for the child would be very useful.
- **monitoring their behaviors is complicated thanks to very irregular patterns [14]** so, a tool which would help parents evaluate the results of the therapies and understand which are the areas that their children experience more difficulties, would be useful.
- **the regular communication between parents and therapists is not always possible thanks to very busy lives.** This is a crucial point, so that parents can accompany their children progresses and important episodes of the child in the therapies. Through an application it would be possible to improve the communication between the educators without forcing them to have personal meetings, which would optimize their work.

1.3 RESEARCH HYPOTHESIS

The obstacles present during the therapeutic process of children with ASD have been identified as the central problem of this dissertation, and are the following:

1. difficulty in keeping children and therapists motivated;
2. necessity of a very continuous work;
3. difficulty in monitoring their behaviors;
4. communication issues between parents and therapists.

The proposed solution is the creation of a companion and support application, bringing together parents, therapists and children on a platform with solutions for the main four obstacles identified. The intention of this scientific work is to prove that the application is appropriated to be used as a reinforcement for the therapy sessions that children already attend and also that it will increase the interaction and responsiveness between all the users involved in the therapeutic process.

1.4 OBJECTIVES

The final result of this dissertation should be an application which supports both children, parents and therapists in the task of improving the results of therapy in children with ASD. In order to achieve this purpose, the following objectives have been defined:

1. Development of a recommendation system, capable of suggesting appropriate, necessary and enjoyable activities for each children.
   - 1.1. Literature review in order to find parameters that relate autistic children characteristics with therapy activities.
   - 1.2. Creation of a database of appropriate activities for children with ASD.
   - 1.3. Development of a Learning algorithm.
2. Creation of a software application, which includes different interfaces for children, parents and therapists with the following functionalities:
   - 2.1. Show the suggested tasks in Kids, Parents and Therapists interfaces, by integrating the task recommendation system;
   - 2.2. Allow parents to evaluate if children did the tasks and with which difficulty;
   - 2.3. Give children rewards for their concluded tasks;
   - 2.4. Allow the analysis of children progress;
   - 2.5. Allow the communication between parents and therapists.

3. Usability study
   3.1. Inquiry about the application usability.
   3.2. Analysis of survey results.

1.5 DISSERTATION ORGANIZATION

The present dissertation is divided into seven chapters. Chapter 1 presents the problem to be solved, as well as the motivation, the Research Hypothesis, the objectives of the project and the general organization of the dissertation. In chapter 2, ASD is explained in detail, beginning with a brief historical contextualization, the symptomatology and causes of the disease. Then the complex diagnostic process is described and the state of the art of the available diagnostic tools is presented, finishing with a comparative study. Chapter 3 presents some related work: application to support children with ASD and some studies to apply machine learning to the diagnosis process. Chapter 4 presents the research methodology considered in the development of this work. Subsequently, a brief presentation of the computational tools used for the development of the the recommendation system and the application, as well as to storage data is done. In chapter 5 the solution proposed, that is the development of the application with the recommendation system is descried. This chapter includes a brief description of the application architecture, the Android visual interfaces and its explanation, and an explanation of the CBR mechanisms which integrate the Recommendation System. Chapter 6 presents an usability study made through an inquiry.
The last section of this paper, chapter 7, draws the conclusions and highlights relevant future work to be done. This dissertation is concluded with the presentation of the bibliography consulted, followed by the annexes considered relevant and complementary to the work.

2

AUTISM SPECTRUM DISORDER

ASD is a chronic and severe neurodevelopmental disorder. The term "spectrum" is used to classify a broad concept of autism which includes Autistic Disorder (AD), Asperger syndrome, and Pervasive Developmental Disorder Not Otherwise Specified (PDDNOS) [11, 18]. This syndrome with a wide clinical phenotype causes deficits in social interaction, communication and behaviors, which have a significant social impact on patients and families lives [11, 18].

Leo Kanner, an Ukrainian psychiatrist born in 1894, was the first to study this disease. In 1943, he published one study that discarded the possibility of ASD to be a mental retardation, thanks to the good performance some patients had presented in intelligence quotient tests [4].
In 1994, Hans Asperger, an Austrian pediatrician, reported the behavior of four children who, despite maintaining their intellectual abilities intact, demonstrated a lack of non-verbal communication, restricted interests and lack of motor coordination. This study had evidenced the social interaction deficit as a symptom of ASD [4].
In the 1990's, family bonding studies and DNA screening led to the suspicion of single genes as the cause of intellectual disorders associated with autism. Most of these studies focused on X chromosome genes [4].
Nowadays, there are three main criteria, defined by the 5th edition of Diagnostic and Statistical Manual of Mental Disorders (DSM) and by International Classification of Diseases (ICD-10), to characterize ASD [11, 18]:

1. **"verbal and non-verbal communication problems":**
   Verbal communication problems are characterized by late language learning and a very repetitive use of it. Sometimes, also happens that children use language not for communication purposes [4].

Concerning the non-verbal communication one of the most notable signs is that children frequently do not point when they wish for something, which is a normal behavior in children with no disabilities [4].

2. **"difficulties in relating to people, things and events"**:
   One of the most common symptom of deficits in social interaction is the tendency to avoid eye-contact. Children with ASD have difficulties in creating strong relationships with colleagues and with their siblings. Usually, they do not share their interests and do not create emotional bonds, because they prefer to be alone focused on their own activities [4].

3. **"repetitive body movements or behaviors"**:
   A pattern of restrict and repetitive behaviors is characteristic of children with ASD. Stereotypy behaviors can be a from self-stimulation or a way for the children to calm down. Sometimes motor incoordination is also a symptom. They have strong deficits in imagination and for this reason the way they play can be strange, like for example using toys not to play but to order and stack them. Sometimes, they can demonstrate interest in very specific areas, with which they can become obsessive [4].

The clinical differences between the the three syndromes belonging to ASD - AD, Asperger syndrome, and PDDNOS - are specified in the DSM.
Asperger's syndrome is characterized, such as AD by deficits in social interaction, interests and behaviors. However, unlike AD, its development is marked by normal patterns in the production and reception of language, cognitive development, personal care skills, and curiosity about the environment. These individuals express an interest in meeting people and making friends, yet they use inappropriate and eccentric ways of approaching them, being unable to understand their feelings. This leads to failure in interpersonal relationships and consequent frustrations [4].
The PDDNOS is used to include a large heterogeneous group of children with poorly defined criteria that exhibit a pattern of development and behavior similar to that observed in autism [4]. The described differences are evidenced in table 1.

Table 1.: Clinical differences between the the three syndromes belonging to ASD (adapted from [4])

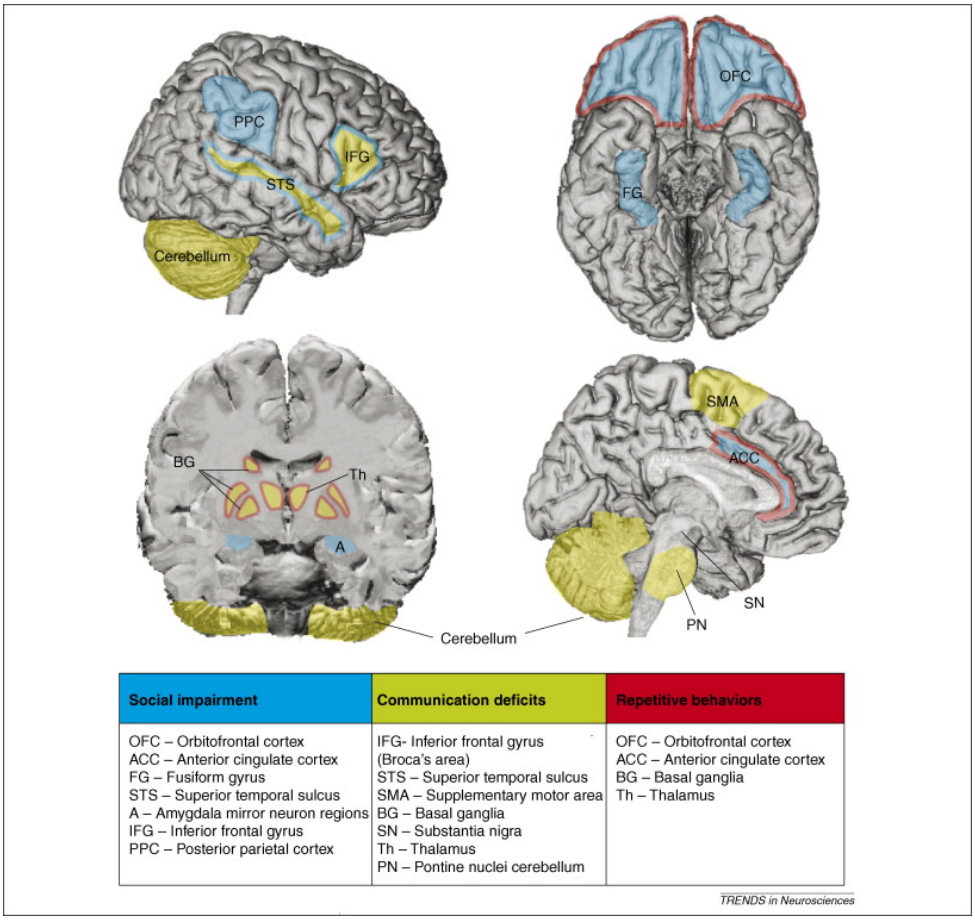
	AD	Asperger syndrome	PDDNOS
Socialization	Very weak	Weak	Variable
Comunication	Verbal and non-verbal deficits	Without delays in first years; Late pragmatics difficulties;	Variable
Behavior	Larger deficits than Asperger Syndrome and PGDSOE	Variable; Restricted interests	Variable
Intelectual Deficit	High	Moderate to nonexistent	Moderate to high

2.1 CAUSES

The **causes** for ASD are not yet fully known but it is certain that they are multi-factorial [17].

A study had revealed that for parents of children with ASD the risk of a second child with the same diagnosis is 20 to 50 times bigger considering the normal probability. This discovery had evidenced the strong hereditary origin of ASD, making this syndrome the neuropsychiatric disorder most affected by genetic factors [17]. However, it is known that most of these chromosomal abnormalities occur spontaneously, that is, they arise for the first time in the autistic individual. This means that the mutation occurs as a result of a DNA change in the germ cell or in the fertilized egg [4]. Factors like toxic ambients or intensive stress can be the cause for the genes alteration, in a gene–environmental interaction, but this is still an area in study [17].

In order to understand the neuro-anatomical changes which are related to ASD, the brain regions responsible by the affected functions were identified. Regarding the communication functions, the cortical and sub-cortical regions are implied [1]. The broca's area, located in frontal inferior zone, and some regions of the motor cortex are responsible for the language expression, while the Wernicke area is responsible for its reception [1]. The social function is controlled by the frontal, parietal and temporal lobes and by the amygdala. Finally, the repetitive behaviors are related to alterations in the orbitofrontal cortex and the nucleus accumbens [1]. Figure 1 shows the regions of the neural systems associated with autism. Neuro-anatomical studies also revealed that children



Social impairment	Communication deficits	Repetitive behaviors
OFC – Orbitofrontal cortex ACC – Anterior cingulate cortex FG – Fusiform gyrus STS – Superior temporal sulcus A – Amygdala mirror neuron regions IFG – Inferior frontal gyrus PPC – Posterior parietal cortex	IFG- Inferior frontal gyrus (Broca's area) STS – Superior temporal sulcus SMA – Supplementary motor area BG – Basal ganglia SN – Substantia nigra Th – Thalamus PN – Pontine nuclei cerebellum	OFC – Orbitofrontal cortex ACC – Anterior cingulate cortex BG – Basal ganglia Th – Thalamus

TRENDS in Neurosciences

Figure 1.: Brain regions responsible by the affected functions in ASD [1].

with ASD present a normal or reduced perimeter of the brain at birth, but then experiment an abnormal growth since the first year of life. Thanks to neuroimaging this abnormal growth was attributed to the excess of cortical white matter and abnormal patterns of growth in the frontal lobe, temporal lobes, and limbic structures such as the amygdala - the brain regions implicated in the development of social, communication, and motor abilities [1].

Researchers have also noted cytoarchitectural abnormal findings in the cortical mini-columns. The cerebral cortex or gray matter is composed by the cellular corps of the neurons and by the neuroglia cells, organized in vertical mini-columns, which are the functional units of the brain. The mini-columns formation is associated with the proliferation of neuronal precursor cells, in the early stages of cortical development. In the brain of an autistic child a greater number of mini-columns can be observed, but of smaller size and less compacted, which implies the existence of a bigger number of

neurons in this area [1].
Regarding the amygdala, although it presents an atypical growth in the first years of life, this limbic structure doesn't experience the typical development of the adolescence phase. The bigger amygdala is associated with anxiety and with social and communicative deficits characteristic of ASD. In regards to nucleus accumbens, its atypical growth is associated with repetitive behaviors and motor execution difficulties (praxes), as it was mentioned before [1].
Besides the anatomic differences, individuals with ASD also present some alterations in patterns of activation and timing of synchronization across cortical networks. Functional Magnetic Resonance Imaging (MRI) is used to quantify the neural activity through the blood flow. During a test to the fusiform face area where, in response to the visualization of face figures, it is supposed to occur the activation of this area, autistic individuals had shown hypo-activation of the same. This is related with deficits in the perception of people and may be related to the social difficulties presented [17].
Concluding, genetic and environmental factors seem to be affecting the neuro-anatomic and neural activity of the ASD patients, causing deficits in the information processing of the nervous system. These changes are probably responsible for altering the normal developmental trajectory of social and communication domains [17].

2.2 DIAGNOSTIC AND EVALUATION TOOLS

Due to ASD variability in type of symptoms and severity, the diagnostic of this disease is a complex process. The challenges of evaluating ASD symptoms are innumerable because behaviors seen in a child are often dependent on a number of non-autism-specific factors, including cognitive functioning and age, but also because many of the early behaviors associated with ASDs overlap with those associated with the diagnose of language delay and intellectual disability [19].
The American Academy of Pediatrics (AAP) recommends the education of doctors and families for the numerous ASD alert symptoms that are defined as "red flags" and are detailed in Table 2, and further recommends that children between 18 and 24 months are all screened for this spectrum [19].
Usually, autism is diagnosed in childhood, during the first three years of life, because parents notice that their child is showing some of the enumerated unusual behaviors, but there is not a medical test to perform it [19]. Sometimes DNA analysis and

Table 2.: Early Signs of Autism ("Red Flags") (adapted from [5])

Social-communication	a lack of atypicalities in... - Eyegaze and shared/joint attention; - Affect and its regulation (eg, less positive and more negative affect); - Social/reciprocal smiling; - Social interest and shared enjoyment (in absence of physical contact such as tickling); - Orienting to name called; - Development of gestures (eg, pointing); - Coordination of different modes of communication (eg, eye gaze, facial expression, gesture, vocalization).
Play	- Reduced imitation of actions with objects; - Excessive manipulation/visual exploration of toys and other objects; - Repetitive actions with toys and other objects.
Language and cognition	a lack of delays or atypicalities in... - Cognitive development; - Babbling, particularly back-and-forth social babbling; - Language comprehension and production (eg.: odd first words or unusually repetitive); - Unusual prosody/tone of voice;
Regression/loss of early words and/or social-emotional engagement	Inability to relate.
Visual/other sensory and motor	- Atypical visual tracking, visual fixation (eg, on lights) and unusual inspection of objects; - Underreactive and/or overreactive to sounds or other forms of sensory stimulation; - Decreased activity levels and delayed fine and gross motor skills; - Repetitive motor behaviors and atypical posturing/motor mannerisms.
Regulatory functions related to sleep, eating and attention	Atypicalities in regulatory functions.

also high resolution chromosome analysis can be done, in order to rule out Fragile X Syndrome, and Electroencephalogram can be used in case of children who have convulsions associated to the autistic diagnose. CAT scan and RMI are also very commonly used in order to rule out other comorbidities [4], but the ASD diagnosis should be made through autism-specific behavioral evaluations and scales [14]. These instruments evaluate the possibility of one individual to have ASD through direct behavioral observation or interviews to parents/primary caregivers and should be administered by trained clinicians [14, 19]. The number of diagnostic and evaluation tools available is so big that it can be difficult, even for a clinician, to choose the best. Some of the evaluated domains are body functions, adaptive behaviors, participation levels and family related issues. Inside these domains there are tools to measure very specific sub-domains like sensory levels, emotional regulation, cognitive level, physical skills, social communication, social inclusion, behavior, parenting stress, among many others [20]. Many of these are overlapping concepts, and the degree to which they overlap relates to the type of use given to the measures [21] The recommendations given by the AAP and the American Psychological Association in regards to the use of diagnostic tools involve the use of instruments designed to assess multiple domains of functioning and behavior [22].

Next, a systematic review was done in order to identify the tools used to date in the evaluation of autistic children and youth. The research methodology was directed to select tools which aim to measure adaptive behavior[1] and ASD symptoms severity, because, in general, they are global measures that assess multiple domains. Besides the types of measurement, the types of studies were also an inclusion criteria. Searches were limited to English-language:

- validation studies;
- comparative studies;
- review studies;
- and manual books.

Figure 2 illustrates the systematic review methodology [20].

Next, some of the diagnostic and evaluation tools to measure Adaptive behaviors and ASD symptoms severity which met the requirements imposed will be described:

1 Adaptive behavior is the capacity of the person to perform everyday skills in social and practical domains [21, 23].

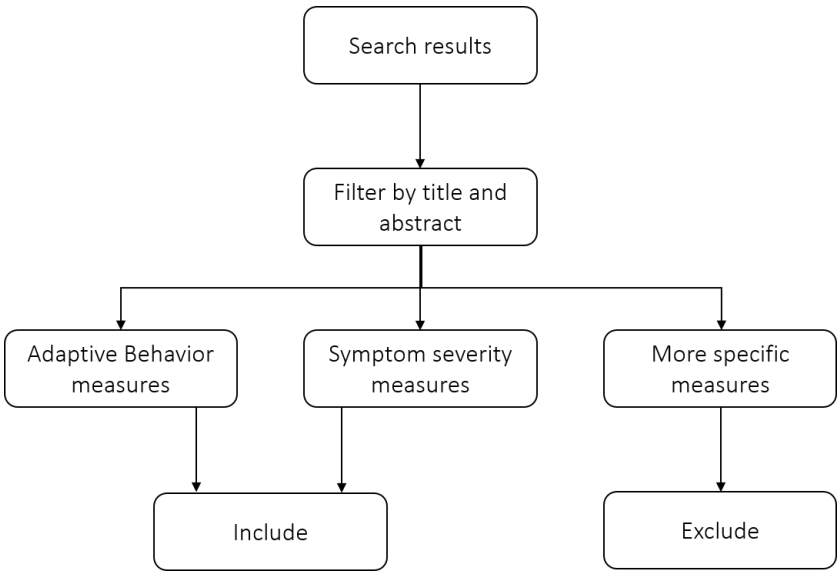


Figure 2.: The search methodology.

2.2.1 *Scales of Autism Symptoms Severity*

This section includes tools that measure symptom severity in ASD, which are somehow global measure of outcome across the whole spectrum, in order to have the ability to discriminate the three major criteria of ASD [20]. Next, Autism Diagnostic Interview-Revised (ADI-R) and Autism Diagnostic Observation Schedule (ADOS) measures will be presented.

Autism Diagnostic Interview-Revised

The ADI-R is a standardized, semi-structured interview, which is administered by a trained clinician usually to parents or other caregivers whom autism or pervasive developmental disorders is a possible diagnosis for their children [24, 25].
The interview contains 93 items and focuses on behaviors in the three main affected domains, according to DSM and ICD-10: reciprocal social interaction, language and communication, and stereotyped repetitive behaviors or interests. The measure also includes other domains relevant for treatment planning, such as self-injury and over activity [25, 26].
ADI-R takes two to three hours to complete and can be used for individuals with a mental age of at least 24 months, but some items have age specifications. For example, questions about group play are only displayed for ages between 4 and 10 years; ques-

tions about reciprocal affections only make sense for ages above 5 years; and questions about specific interests are scored only for children with more than 3 years [24].
The responses are scored by the clinician based on the caregiver's description of the child's behavior with a rating scale which includes the following options [26]:

- 0 = "Behaviour of the type specified in the coding is not present";
- 1 = "Behaviour of the type specified is present in an abnormal form, but not sufficiently severe or frequent to meet the criteria for two";
- 2 = "Definite abnormal behaviour";
- 3 = "Extreme severity of the specified behaviour".

In some cases the scale could have

- 7 = "Definite abnormality in the general area of the coding, but not of the type specified";
- 8 = "Not applicable";
- 9 = "Not known or asked".

At the end, the ADI-R interview generates scores for each of the three content areas. A classification of autism is given when scores in all three content areas of communication, social interaction, and patterns of behavior meet or exceed the specified cutoffs [24, 25].

Autism Diagnostic Observation Schedule

The ADOS is another standardized autism severity measure used to diagnosis purposes, recommended by several of the best practice guidelines [27].
This measure differs significantly from ADI-R in the administration mode, since in this case the examiner observes directly the child's behavior and interactions. There is no involvement of a third person, usually the parents or other close caregiver [27].
In order to analyze the developmental level and age of the child, standardized interactive activities are proposed by the examiner, designed to deduce social interactions, communication and repetitive behaviors for the purpose of diagnosing an ASD. The suggested activities vary based on the language level and chronological age of the child, according to four different modules [27]:

- Modules 1 and 2 are designed for use with children with a language level of less than 48 months.
- Modules 3 and 4 are designed for older children, adolescents, and adults who have the ability to use complex sentences and perception about emotions and relationships.

In Luyster et al. [28] a new Toddler Module for the ADOS is presented. The Toddler Module is supposed to work in the same way and with the original tasks of the ADOS, but is intended for use in children under 30 months of age who have nonverbal mental ages of at least 12 months.
Although the ADOS is standardized in terms of the materials and activities presented, the administration can take 30 to 60 minutes depending on the child's initiative and interactivity. The scoring methodology is also standardized. Behaviors are coded using a 0 to 3 point coding system, where:

- **"0"** indicates that the behavior is not abnormal in the way specified in the coding description [27];
- **"3"** indicates that the behavior is abnormal and interferes in some way with the child's functioning [27].

At the end, three scores are obtained according to the scoring algorithm, the Communication score, a Reciprocal Social Interaction score and a Total score (a sum of the Communication and Reciprocal Social Interactions scores). If the child's Total score meets or exceeds cut-offs he is considered to meet criteria for ASD classification [27].
The ADOS has shown strong predictive validity against best estimate diagnoses, making it a common choice between other measures [29].

2.2.2 *Scales of Adaptive Behavior*

One of the biggest concerns of parents and therapists of children with ASD is that they have the ability to demonstrate age and culturally appropriate behaviors, required for self sufficiency. For this reason, this measures play an important role not only in diagnostic, but also in treatment planning and research related to ASD [21].
Although there are many adaptive behavior measures, only a few of them are normed

on a representative sample of population and have been developed with the purpose of assessing individuals with ASD. Some of the normalized instruments are: (1) Vineland Adaptive Behavior Scales - Second Edition (VABS-II); (2) Scales of Independent Behavior- Revised (SIB-R), (3) Adaptive Behavior Assessment System-II (ABAS-II); (4) Adaptive Behavior Scales - School Version (ABS-S) and (5) Pediatric Evaluation of Disability Inventory-Computer Adaptive Test (PEDI-CAT) [21, 30].

Vineland Adaptive Behavior Scales-Second Edition

The VABS-II is a standardized norm-referenced assessment tool to measure adaptive behavior. It can be used from birth to age 90 to diagnose ASD and other genetic disorders, to measure individual's daily functioning, to evaluate development progresses and to plan treatments [31].
Vineland-II assesses 5 main domains which are Communication, Daily Living Skills, Socialization, Motor Skills and optionally Maladaptive Behavior. Table 3 specifies the sub-domains and the skills which are in fact evaluated inside each domain [6].
This assessment is designed to be administered by an examiner graduated in test administration and interpretation to a parent/caregiver or a teacher. The caregiver can be anyone (parent, grandparent, nurse, social worker, etc.) as long as they are familiar with the every-day life activities and behaviors of the patient [6].
According to the person being assessed and the length of the test the VABS-II is available in four formats:

- **Parent/caregiver interview** assesses the four main domain areas and provides a targeted assessment of adaptive behavior. The survey is administered using a semistructured interview format, which gathers more in-depth information thanks to the open-ended questions, which promote a fluent conversation between the interviewer and respondent [31].

- **Parent/caregiver rating form**: covers the same content as the Survey Interview, but uses a rating scale format which is a better approach when the time is limited. Usually the Survey Interview Form is used in the initial assessment and the rating form to track progress [31].

- **Expanded interview** measures the broad domain areas in a deeper way and provides a basis for developing educational, residency or treatment programs. It is particularly suitable to the ages from 0 to 5 [31].

Table 3.: Assessed domains and sub-domains in VABS-II [6].

Domain	Sub-domains	Evaluates...
Communication	Receptive	listen, pay attention and understanding capacities
	Expressive	vocabulary use and phrasic building capacities
	Written	read and write capacities
Daily Living Skills	Personal	eat, dress and personal hygiene capacities
	Domestic	participation in household tasks
	Community	the use of time, money, telephone, computer and job skills
Socialization	Interpersonal Relationships	interaction with others
	Play and Leisure Time	how to play and use leisure time
	Coping skills	responsibility and sensitivity to others
Motor Skills	GrossMotor	arms and legs movements and coordination
	Fine Motor	use of hands and fingers to manipulate objects
Maladaptive Behavior (Optional)	Maladaptive Behavior Index	composite of undesirable behaviors
	Maladaptive Behavior Critical Items	composite of more severe maladaptive behaviors.
	Adaptive Behavior Composite	composite of the communication, daily living skills, socialization, and motor skills domains

- **Teacher rating form** is specifically designed for educational setting. Besides the other four domains, this form also includes items pertaining to academic functioning. The teacher rating form is for students aged 3 to 21 years [31].

The adaptive and maladaptive composites are outcome measures which describe the test results.

After the test is finished, the scores for each of the sub-domains are added in order to form the domains composite scores. The four domains composite scores then combine to form the adaptive behavior composite for those children aged from birth to 6 years. For individuals aged 7 through 90 only three domain composite scores (communication, daily living skills and socialization) are combined to achieve the adaptive behavior composite [6].

The Maladaptive Composite is a descriptive measure in which maladaptive behaviors are rated as average, elevated, or clinically significant.
These composites can still be converted to derived scores, standard scores, V-scale scores, percentile ranks and age equivalents. Also, confidence intervals can be constructed for scores [6].

Scales of Independent Behavior - Revised

The SIB-R is a revision of the original SIB scale that was published in 1984. It is a comprehensive norm-referenced test primarily designed to measure functional independence and adaptive functioning at home, school and place of employment from 3 months until 80 years. It is also used for clinical diagnosis, planning training programs, classification for research programs and in monitoring programs [7].
SIB-R is composed by fourteen sub-scales of adaptive behavior distributed into four domains: Motor Skills, Social and Communication Skills, Personal Living Skills and Community Living Skills. Besides that, it also contains eight sub-scales for maladaptive behavior [20].
The test is administered by a trained and certificated examiner in the format of questionnaire or structured interview, in the full or short form, which take 45-60 minutes or 15-20 minutes, respectively. There are also adaptive versions of the survey for children and for blind people.
The respondent, usually a parent or other caregiver, should evaluate each questioned item with the rating scales presented in Table 4.

Finally, the given answers are translated into age equivalents and Standard Scores like Percentile ranks, Broad Independence Scores, Relative Mastery Indexes (RMI) and a Support Score. The Support Score provides information about the level of support a person will require based on the limitations he or she presents in adaptive behavior and on the impact of maladaptive behaviors on adaptive functioning [7].
The strengths of this tool are centered in the fact that it is useful and accurate according to the standardization study with 2,182 individuals nationwide. The biggest weakness is the long time of execution of the full version [32].
Although this is one of the most widely used adaptive behavior assessments in the United States there are very little research articles available to support his claim [32].

Table 4.: SIB-R Rating Scales [7]

Adaptive Rating Scale	Does (or could do) the task completely without help or supervision?	0 – Never or rarely,Even if Asked
		1 – Does, not well or about 1/4 of the time may need to be asked
		2 – Does fairly well or about 3/4 of the time may need to be asked
		3 – Does very well always or almost always without being asked
Maladaptive Rating Scale	Frequency or How Often?	1- Less than once a month
		2 -One to 3 times a month
		3- One to 6 times a week
		4- One to 10 times a day
		5- One or more times an hour
Behavior Rating Scale	Severity or How Serious?	0- Not serious, not a problem
		1- Slightly serious, a mild problem
		2- Moderately serious, moderate problem
		3- Very serious, severe problem
		4- Extremely serious, a critical problem

Adaptive Behavior Scales - School

There are two versions of ABS: the School and Community and the Residential and Community. Only the first one is analyzed below.

The ABS-S was designed in order to assess adaptive behavior by evaluating personal and community independence, and personal and social performance of school-aged children and adolescents, from 3 to 18 years [8]. This scale is divided in two parts: Part One consists of 67 items (plus one supplemental item for females) and is focused on personal independence and responsibility in daily living; Part Two is related to the manifestation of personality and behavior disorders [8]. The domains included in each of the parts are evidenced in Table 5.

This survey takes about 15-30 minutes to be completed and at the end five factor scores are obtained: Personal Self-Sufficiency, Community Self-Sufficiency, Personal-Social Responsibility, Social Adjustment and Personal Adjustment [8].

The ABS-S was standardized on children from 3 to 21 years, from 31 states, attending public schools with and without developmental disabilities: 2,000 children with developmental disabilities and more than 1,000 students who have no disabilities [8].

Table 5.: Represented domains in ABS-S [8].

Part	Domains
One	Independent Functioning;
	Physical Development;
	Economic Activity;
	Language Development;
	Numbers and Time;
	Prevocational/Vocational Activity;
	Self-Direction;
	Responsibility;
	Socialization
Two	Social Behavior;
	Conformity;
	Trustworthiness;
	Stereotyped and Hyperactive Behavior;
	Self-Abusive Behavior;
	Social Engagement;
	Disturbing Interpersonal Behavior

Pediatric Evaluation of Disability Inventory-Computer Adaptive Test

Published in 1992, at Boston University, the Pediatric Evaluation of Disability Inventory (PEDI) was a paper-pencil survey, which asked the caregivers of children and youth with disabilities about their difficulty in doing an extensive list of activities [9]. Later, its computerized version, PEDI-CAT, has been created to increase efficiency and reduce respondent burden, since it utilizes Item Response Theory (IRT) statistical models to reduce the questions to a minimal set number of activities within each domain [33].
The PEDI-CAT is directed to children and youth between 1 and 21 years of age, to be response by their caregivers within quantitative scales, that enable clinicians to construct a description of the child's current functional status or progress in acquiring functional skills that are part of everyday life. The activities repository of PEDI-CAT is called "item bank" and it is an extensive list of 276 activities in the domains of: Daily Activities, Mobility, Social/Cognitive and Responsibility [9]. The domains, sub-domains and response scales in use in this survey are represented on Table 6 [9].
There are two versions of the PEDI-CAT:

Table 6.: PEDI-CAT domains, sub-domains and response scales [9].

Domains	Items	Sub-domains	Response Scale
Daily Activities	68	Getting dressed;	Difficult scale: 1 = ”Unable”; 2 = ”Hard”; 3 = ”Little hard”; 4 = ”Easy”;
		Keeping clean;	
		Home tasks;	
		Eating and mealtime;	
Mobility	75	Basic movement and transfers;	
		Standing and walking;	
		Steps ans inclines;	
		Running ans playing;	
Social/ Cognitive	60	Interaction;	
		Communication;	
		Everyday cognition;	
		Self management;	
Responsibility	51	Organization and playing;	Responsibility scale: 1 = ”Adult/caregiver has full responsibility; the child does not take any responsibility”; 2 = ”Adult/caregiver has most responsibility and child takes a little responsibility”; 3 = ”Adult/caregiver and child share responsibility equally”; 4 = ”Child has most responsibility with little direction and supervision from parent/caregiver”; 5 = ”Child takes full responsibility without any direction and supervision from parent/caregiver”;
		Taking care of daily needs;	
		Health management;	
		Staying safe;	

- the **Speedy (“Precision”) CAT**, which is the most efficient version since it is the quickest way to get a score estimate. Using this version, only 10-15 items per domain are administered [9].
- the **Content-Balanced (“Comprehensive”) CAT**. Using this version approximately 30 items per domain, distributed from each of the content areas, are administered [9].

After the completion of one PEDI-CAT, a score report is available for each domain administered, which includes three distinct types of scores:

- **Scaled Scores:**
  The scaled score is the result of the caregivers responses to the questioned items (for each domain), calculated through a statistical model, in a metric scale from 20 to 80. This score is not aged related, it represents the child's current functional skills. For that reason, differences in scaled score from an assessment to another mean the absolute amount of change for that child [9].

- **Normative Scores:**
  Normative scores are given by the comparison of the child obtained scaled score, with the standard scaled score for that child's age. These type of scores can be provided as age percentiles and T scores [9].

- **Item Maps** ***(only available in the Content-Balanced version):***
  There are four established Item Maps, one for each domain, which define the expected level of difficulty/ responsibility for each activity, based on the child's obtained scaled score [9].

In order to validate the PEDI-CAT, a Normative and a Disability Sample of children were collected. The normative sample was comprised by an American representative sample of children (N=2,205) with less than 21 years of age, without any disability; The disability sample was comprised by 703 American children and young people, with less than 21 years and behavioral, intellectual or physical disabilities, including 108 children with autism [33]. The parents/caregivers of these children were asked to complete PEDI-CAT and those results were used to standardize the scores, per domain, for ages of 0 to 21, and to elaborate the standard Item Maps (see Appendice A) [9].
In Kramer et al. [34], published in February 2012, a study was done to evaluate the applicability of the PEDI-CAT assessment in children with ASD, and so the PEDI-CAT-ASD came to life. Only the domains of Daily Activity, Social/Cognitive, and Responsibility were evaluated, due to the irrelevance of the Mobility domain in this context [34]. A research multidisciplinary team made of 7 occupational therapists, 5 speech-language therapists, 4 psychologists, 2 special education professors, 1 social work professional, 1 physical therapist and a total of 18 parents of children with ASD reviewed the totally item bank of PEDI-CAT. The main objective was to identify new items, existing items needing clarification and the value that each activity had in the everyday life of an autistic child [34]. The results of the reviewed item pool are presented in Appendices A. New items considered important activities for everyday life were added to the pool;

specific directions were added to several items (e.g. "When responding to these items, consider your child's performance using their primary mode of communication. This could include augmentative communication devices (AAC), sign language, or use of the Picture Exchange Communication System (PECS).") and additional directions were added to the rating scales of Daily Activity and Social/Cognitive Domains [34].
In 2015, in Coster et al. [23] a new study to evaluate the appropriateness of the new version of PEDI-CAT for children and youth with ASD's was done, with a sample of 365 children, aged from 3 to 21 years. The results suggested that PEDI-CAT-ASD is appropriate to assess children and youth with ASD among an heterogeneous range of age and severity.

2.2.3 *Summary*

On this state of the art various diagnostic and evaluation tools were described and analyzed, chosen based on the criteria defined previously. It is not possible to generalize and define one of these tools as the best, because each one of them can be more appropriate to a specific case [24]. Moreover, studies reveal that no single method should ever be used independently to diagnose Autism Spectrum Disorder and highlight the importance of using caregivers interviews and direct observation of patients' behavior, as complementary measures [22, 24]. One example of a typical administration protocol is, for example, the initial administration of the ADI-R and the VABS-II to a parent or caregiver, and then the evaluation of the child behavior through the ADOS [29].
On De Bildt et al. [35] a study about the interrelationship between the ADI-R, ADOS and the clinical classification of ASD was done. The study done with 184 children and adolescents concluded that, compared with the DSM-IV classification of AD, both instruments measure it validly and reliably and that interrelationship between the instruments and the clinical classification was satisfactory. This study also suggests that the combination between ADI-R and ADOS identifies AD most appropriately.
In Wells et al. [21] a study done to examine three of the most known measures of adaptive behavior - VABS-II, SIB-R and ABS-S - found moderate correlations among adaptive functioning, cognitive level, and severity of autism. One of the limitations concerning the most widely used measures is the fact that the concept of "adaptive behavior" can be subtly different to the constructors of the different measures, due to the nonexistence of a clear definition [21]. Other important limitations, comparing

this measures to PEDI-CAT, is the administration and scoring requirements. These measures require trained professionals to administer and score the assessment, which increases the burden and the costs of the process and turns it unpractical for routine use [34]. Finally, most measures of adaptive behavior adopt scoring models that compare the performance of children with ASD with children with no disabilities. Although this is essential for the diagnostic process, once again they are not appropriate for treatment (routine use), because norm-based scores do not give any information about what a child with ASD should be capable to do, neither can quantifier their own progress [34].

Table 7 highlights the main key aspects addressed about each one of the diagnostic and evaluation tools.

Table 7.: A comparative study between the diagnostic and evaluation analyzed tools.

Papers	Scale	Age Range	Administration Mode	Administration Mean Time	Evaluated Domains	Outcome Measures	Provide access to normalization data?	Provide access to the bank of items?
[20, 24–26]	ADI-R	Above 24 months (mental age)	Interview to parents/ caregiver	2-3 hours	Communication; Social/ Emotional; Repetitive body movements.	Communication Score; Social Interaction Score; Patterns of behavior Score;	X	X
[20, 27–29]	ADOS	Above 48 months	Observation of children's behavior	30-60 minutes	Communication; Social/ Emotional; Repetitive body movements	Communication Score; Reciprocal Social Interaction Score; Total Score	✓	✓
[20, 21, 31?]	VABS-II	0-90 years	Interview to parents/ caregiver	20-60 minutes – Survey Interview and Parent / Caregiver Rating Forms; 25-90 minutes - Expanded Interview Form; 20 minutes -Teacher Rating Form	Communication; Daily Living Skills; Socialization; Motor Skills ; Maladaptive Behavior	Composite Scores; Adaptive Composite; Maladaptive Composite	X	X
[7, 20, 21, 32]	SIB-R	3 months - 80 years	Interview to parents/ caregiver	45-60 minutes - Full Form; 15-20 minutes - Short Form	Motor Skills; Social and communication; Personal Living; Community Living; Maladaptive Behavior	Age equivalents; Percentile Ranks; Broad Independence Score; Relative Mastery Indexes; Support Score	X	X
[8, 21, 32]	ABS-S	3 - 18 years	Interview to parents/ caregiver	15-30 minutes	Independent Functioning; Physical Development; Economic Activity; Language Development; Number and Time; Prevocational/ Vocational Activity; Self-direction; Responsibility; Socialization; Social Behavior; Conformity; Trustworthiness; Hyperactive Behavior; Self-Abusive Behavior; Social Engagement; Disturbing Interpersonal Behavior;	Personal Self-Sufficiency; Community Self-Sufficiency; Personal-Social Responsibility; Social Adjustment; Personal Adjustment	X	X
[9, 23, 30, 33, 34]	PEDI-CAT	1-21 years	Interview to parents/ caregiver	12 minutes - Speedy CAT; ? - Content-Balanced CAT;	Daily Activities; Mobility; Social/Cognitive; Responsibility;	Scaled Scores; Age Percentiles; T-scores; Item Maps;	✓	✓

3

RELATED WORK

Currently there is a huge number of applications which were specially developed for children with ASD. In general, all of them have the purpose of teaching them behavioral or cognitive skills, in different domains. Coppin [2] defends that it is important to select the applications based on the unique learning needs of the student and, accordingly, he developed a list of available applications based on the learning characteristics and traits that are typical for students with ASD, divided into following domains and represented in figure 3:

- Communication;
- Social Skills;
- Need for Sameness and Routine;
- Sensory/Sensitive;
- Difficulty with traditional Learning Methods;
- Behavior

Most of these tools are gaming mobile applications like *Autism Therapy with MITA* and *Social Skills for Autism*:

AUTISM THERAPY WITH MITA was developed by a group composed by a neuroscientist, an early-child-development specialist, artists, developers and therapists. Mental Imagery Therapy for Autism (MITA) is based on Pivotal Response Treatment which has as target three critical areas of development: response to multiple cues, motivation and self-management [36]. This application includes nine adaptive games

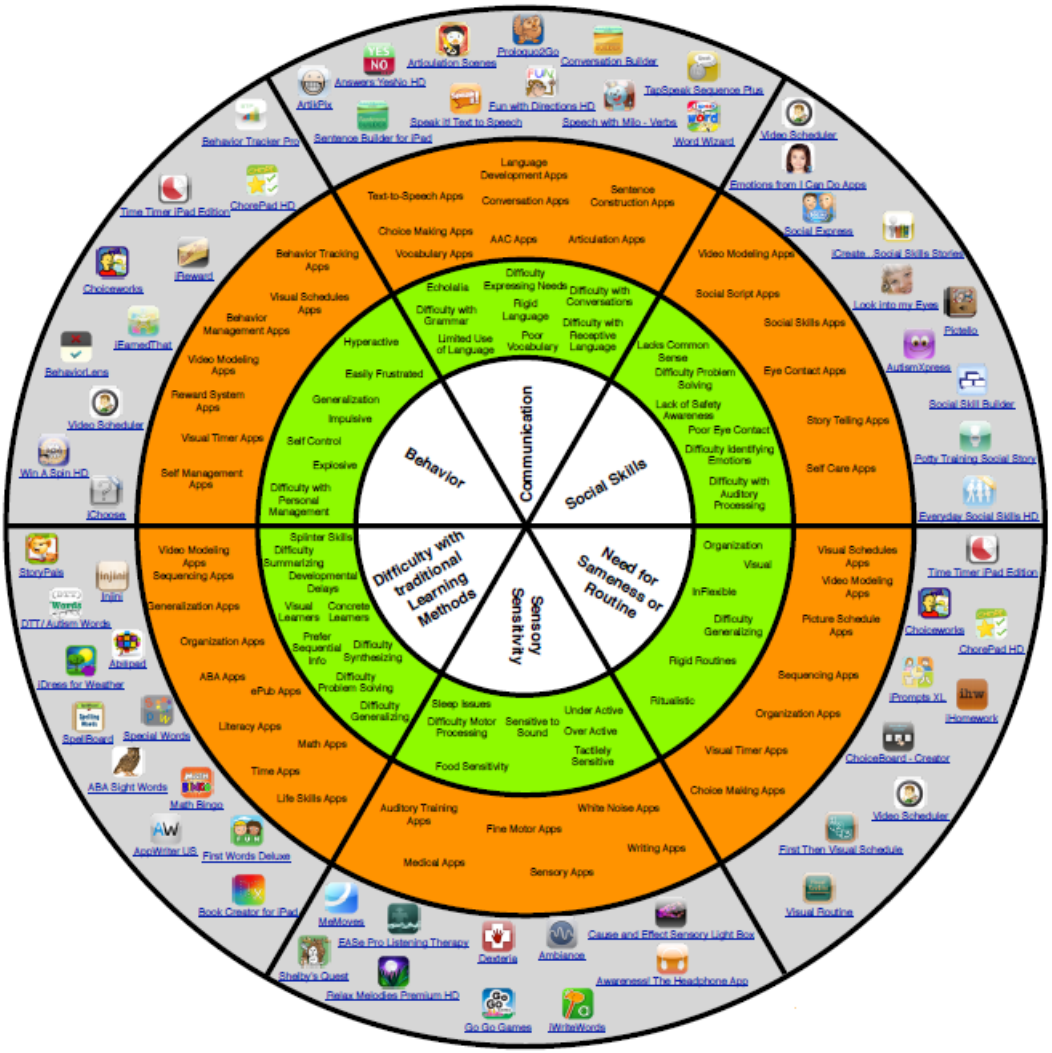


Figure 3.: List of applications for children with ASD [2].

that, over time, get more difficult and aim to improve the child's development specifically in the areas of language, attention and visual skills. Autism Therapy with MITA is appropriated for children from 2 to 17 years old and is available for Android, iPad, iPhone and iTouch [37].

SOCIAL SKILLS FOR AUTISM has been developed by the Shine Centre for Autism, in Ireland, and is based on the Personal & Life Skills Programme (PALS) [38]. This application has 17 individual lesson plans, each one covering a required social skill. When children complete one plan it gives them a reward. Social Skills for

Autism is appropriated for children from all ages and is available for Android, iPad, iPhone and iTouch [39].

Choiceworks its another example of application but with a different format. It is a platform for both autistic children and parents which aims to improve the communication between them:

CHOICEWORKS has been created by Bee Visual company with the support of hospitals and child development specialists. It aims to help caregivers provide their children clear and easy rules and timetables which allow them to be more independent and to adapt their emotions and behaviors according to different situations. This application is provided with three customizable boards - Schedule, Waiting, and Feelings - and a library of images and audio which parents can use, together with other personal media in order to fill the boards. It allows to create profiles, manage multiple users and save an unlimited number of boards for multiple children or different situations. It can also be adapted for the usage of teachers in a school setting. Choiceworks is available for iPad, iPhone and iTouch [40].

There are also applications aimed at logistic and organizational issues with functionalities in the areas of Behavioral Data Collection, analysis and scheduling. Some examples are Autism Tracker Lite and Pathfinder, directed to caregivers, like parents and therapists, of children with ASD:

AUTISM TRACKER by Track & Share Apps company, allows users to explore autism, tracking and analyzing a large collection of data such as sleep, stress, sensory arousal, happiness, activity level and behavior. It has a visual calendar that can summarize totals, averages and statistics over a select period of time, as well, scheduling activities. It also offers the possibility of sharing data with the other users through social networks. Autism Tracker is appropriated for children of all ages and is available for iPad, iPhone and iTouch [41].

PATHFINDER was specifically developed to provide technology solutions for administrative and data collection issues, for behavioral health providers, like occupational therapists. It is provided with easy interfaces that enable the data storage and the creation of documents which facilitate the analysis of the therapy progress.

Pathfinder also allows multiple users to communicate, organize therapy teams, and schedule and notify therapists where they need to be and what they need to do for the day. Besides it alerts all members of a therapy team about important changes in behavior and skill acquisition of a patient in real-time. Pathfinder is available only as a web application [42].

With regard to applications which provide solutions for both, children, parents, and therapists in the same platform, no results were found.

Support and companion systems using Artificial Intelligence were also searched and *Aacorn* was found - the first 'intelligent' Augmentative Assisted Communication (AAC) solution. AAC solutions are alternative communication methods to oral speech, for people with impairments in the production or comprehension of spoken or written language. There are diverse AAC forms and systems like picture and symbol communication boards and electronic devices [43].

AACORN was specially developed for children with autism, apraxia, down syndrome and developmentally delayed speech - and their families. It is a revolutionary AAC solution with a very child friendly design that encourages children of all ages and abilities to expand their vocabulary, and help them to construct sentences. Aacorn is a revolutionary system, because it presents words 'as they are needed', using artificial intelligent algorithms [43].

Learning algorithms have also been used in order to facilitate ASD diagnostic. Such algorithms operate by constructing a model based on examples of previous inputs, making predictions, rather than following strictly static program instructions [44].
In Wall et al. [45] and Wall et al. [46] Machine Learning was used with the aim of accelerating the diagnostic process respectively in ADOS and ADI-R. In both studies the Weka toolkit was used in order to classify the more severe Autism cases and Non-ASD cases. The middle-severity cases were excluded, due to insufficient data samples, which is the biggest conceptual problem in these studies.
At Wall et al. [45] authors tested 16 tree-based classifiers with the default parameter settings, and then chose the one with best accuracy - an Alternating-Decision Tree. In 1,000 simulated controls, it was achieved 99.7% of accuracy classifying children with an ADOS Autism diagnosis and 94.4% detecting ADOS Non-Spectrum diagnosis.

Regarding the Wall et al. [46] the authors used 15 tree-based classifiers, finding the ADTree to perform best. They found that only seven attributes were needed for a classifier to produce 100% accuracy classifying children with Autism and 98.7% in detecting ADI-R Non-Autism diagnosis.
At the end, those applications all have the same purpose: improving the daily living quality of children with ASD.

4

RESEARCH METHODOLOGY

Methodology is the guiding body of research that, by obeying to a system of norms, makes possible the selection of techniques, with the aim of achieving the objectives outlined in section 1.4 and producing new knowledge.
In the development of this project, a research-action methodology was adopted. This methodology is characterized by a research focused on the progressive resolution of a problem, a cycle process that includes: the identification of a problem, the application of facts to the practical resolution of the problem, the planning of actions to solve it and the examination of the effects of these actions. Throughout the development of the project, it involves a constant evaluation and adjustment of research and practice until the best solution for the problem is found.
The problem in study in this dissertation can be divided in two main subproblems:

- ***How to build a system capable of recommending appropriated activities for children and youth with ASD?***
- ***How can this system be integrated in an application that simultaneously helps parents, therapists and children with ASD improving the results of their therapies?***

4.1 DEVELOPMENT OF THE RECOMMENDATION SYSTEM

For the Task Recommendation system the Case-based Reasoning machine learning technique was selected as the more appropriate one, since it applies previous experience in form of cases to understand and solve new problems and that's what happens in medicine: the knowledge of experts does not only consist of rules and theory, the experience is a very valuable tool. Therefore, one can compare the learning process

Table 8.: Mean Scaled scores per age and domain for children with ASD and children with no disabilities [10]

Domain	Age	Group	Mean Scaled Score
Daily Activities	5	ASD	49.78
		No-Disability	50.69
	10	ASD	54.96
		No-Disability	59.37
	15	ASD	60.14
		No-Disability	68.06
Social/Cognitive	5	ASD	53.55
		No-Disability	54.20
	10	ASD	57.00
		No-Disability	61.92
	15	ASD	60.46
		No-Disability	69.64
Responsibility	5	ASD	40.63
		No-Disability	41.02
	10	ASD	46.20
		No-Disability	49.85
	15	ASD	51.77
		No-Disability	58.68

of experts - which take into account their previous experiences to apply in new cases, comparing cases in order to adapt solutions and absorb new knowledge when dealing with new clinical conditions - with the CBR learning system [47].
The PEDI-CAT-ASD framework was selected as the start point to develop this system, because it provides a lot of useful tools such as a complete bank of activities, a model of classification by points and the item-maps, explained in section 2.2.2. Besides that, it is a tested technology in children with autism, so it is a way to access to real data. A representative sample of American parents of autistic children (N=105) complete the PEDI-CAT survey and that way, the predicted PEDI scaled scores, per domain, for the ages of 5, 10 and 15 years, presented in table 8, were obtained. In order to build this intelligent system three steps were defined:

1. choose the relevant attributes which find the appropriate task for each child at a given moment;
2. build the repository of cases - the case base;
3. develop the CBR methods.

When selecting the attributes, one attempted to characterize the most important aspects that would help choose, for each child, the activity that should be performed and the moment to perform it. In addition, the selection of attributes had to take into account the data available to build the case base and if it would be possible to have access to the same data when parents, children and therapists were using the application. Considering this, the following attributes were chosen:

Age: The age of the child was chosen because it relates the children with the suitable mean scaled score;

Gender: The gender of the child was chosen because is an attribute that can characterize if one activity is more enjoyable and appropriated than others, once boys and girls usually have different tastes and abilities.

Moment of the day (morning/afternoon/night): The moment of the day is an important attribute in order to help the system know if one activity is appropriated to the moment of the day in which is being recommended.

Part of the week (work days/weekend): This attribute helps the system know if one activity is more appropriated for weekends than work days, since there are activities which require more time and attention of the caregivers.

Difficulty level: The difficulty level was chosen as an attribute because is important to adequate it to the child and it can be linked, by using the scaled score, to each activity.

Classification: The classification of each activity, given in terms of difficulty, is very important to the learning process of CBR, in order to help the system understand if the supposed level of difficulty of the activity is correct.

Frequency: The frequency is the number of times that a case of the repository was applied to another recommendation. It was chosen to help the system classifying the cases.

Once the attributes were chosen, the next step was to construct case base for the CBR system. The case base is a collection of cases, that was saved in *mySQL* database. Each of the cases are composed by the previous attributes and the respective solution: one

appropriate activity for the given facts.
The case base was developed doing extrapolations between the Activities Bank, the Autistic Sample and the Item Maps. Figure 4 represents this process: Given a **certain activity** from the repository of activities, the Autistic Sample was used in order to obtain the scaled sores, per **ages** for the domain to which the activity belongs. Finally, in the appropriated Item Map, according to the domain of the activity and given the obtained Scaled Score, the **difficulty level** was extrapolated.

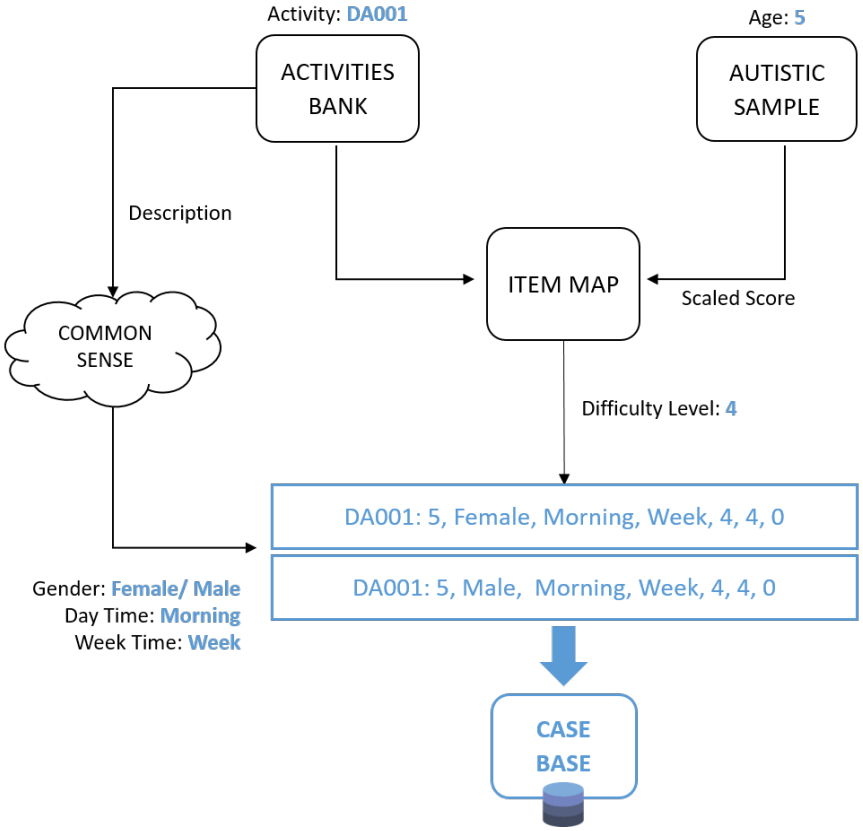


Figure 4.: Construction of the case base.

According to PEDI-CAT-ASD, only the activities in the domains of Daily Activity, Social/Cognitive, and Responsibility were used. However, the data was not complete enough to recommend appropriate tasks, therefore some common sense associations between each activity of the bank, the **gender** of the child and the most suitable **moment of the day and week** to perform it, were made. The **classification** was inserted with the same value of the difficulty and the **frequency** was zero for every case.
Finally, the third and most important point to develop the Task Recommendation Sys-

tem, was the development of the CBR methods. In order to do that, the specialized tool in CBR systems, *jCOLIBRI*, was used. Those methods will be explained in detail in section 5.4.

4.2 DEVELOPMENT OF THE APPLICATION

Next, will be in focus the methodology followed for the development of the application which integrates the task recommendation system.
After the idealization of the application and the delineation of objectives, the next step was to develop sketches in order to visually conceptualize the main features and the approximate layout and structure of the application. The application was called "myOT: Occupational Therapist", because it aims to be a supplement to the therapy sessions of the children with ASD, and, therefore, the aim is that children see this application like their second therapist.

Figure 5.: myOT logotype.

Then, a research phase took place with the purpose of evaluating which technology should be used in the development of "myOT", find similar applications and get some inspiration for the design. The most relevant characteristics in regard to the usability were defined:

Interactivity: In order to be used by children with ASD the app must be very interactive and intuitive.

Regular Usage: Since this application should serve as a monitoring system, it is supposed to have a regular usage by the users.

Off-line Access: Children, parents and therapists should be able to access the proposed tasks without requiring an Internet connection.

Given the highlighted characteristics, a mobile application was the best option, because it provides more interactivity with the user, allows an easy and fast access to the platform and it can operate without Internet connection in some activities. The Android operative system was chosen since it is an open source project.
The next step was the creation of mockups and of a storyboard, in order to help understand the connection between each screen and how the user can navigate through the app.
Finally, the back end for the application was defined, taking into account the sketch of servers, API's, and database diagrams. The Firebase was selected because it is an innovative and very complete platform.

Next, the technologies adopted for each of the previously identified subproblems will be described.

4.3 TECHNOLOGIES

After defining the methodologies and selecting the most appropriate technologies for each problem selected, a brief explanation about the operation mode and main functions of each one will be given. CBR, jCOLIBRI and mySQL were the technologies chosen to develop the Task Recommendation System. Android, Firebase and JSON Databases were the ones used in order to develop the main application.

4.3.1 *Case-based Reasoning (CBR)*

The basic idea of CBR is that for a particular domain, the problems that arise tend to be recurrent and repeated with minor changes from their original version. This way, previous solutions can be reapplied even with small modifications [44, 48].
A case-based Reasoning system incorporates a library of past cases, rather than a set of rules to apply, for a variety of situations. Each case included in the library typically

contains a description of the problem, a solution and a specific field to justify the adaptation of the problem to a case in the repertoire. The description of the problem should identify its main characteristics, its main purpose and possible restrictions on its resolution [48].
When a new case arises, the problem is compared with cases in the repertoire, and similar cases are recovered to suggest possible solutions. These solutions will be reused for the new problem, tested and, if necessary, adapted. Finally, the current problem and the final solution are retained as part of the case-base, the database of cases.[48]. CBR is thus a cyclic problem-solving process, with five well-defined steps shown in the figure 6.

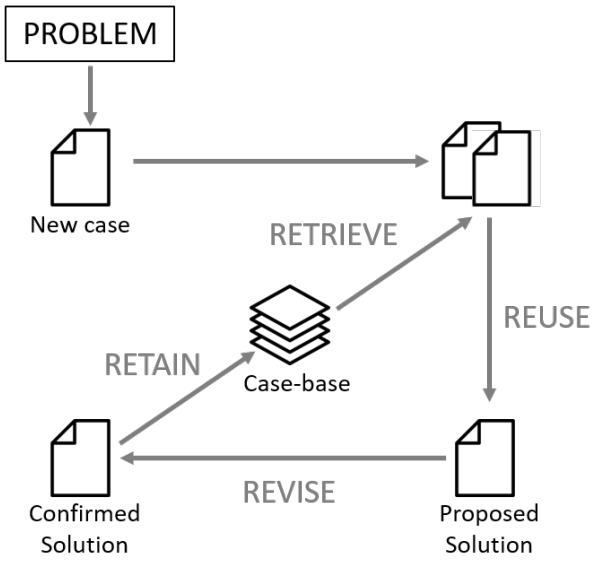


Figure 6.: The CBR cycle.

This technology is essentially for the for the good performance of this application because, in order to generate new suggestions, these should be based on real cases.

4.3.2 *MySQL*

MySQL is an Open Source Relational SQL database management system, which uses a standard form of the well-known SQL data language.
It enables the user to implement a database - a separate application that stores a collection of data in tables - and it guarantees the referential integrity between rows of various tables. Those applications are called relational databases because when data is

stored into different tables the relations are established using primary keys and foreign keys. MySQL also interprets SQL queries to help users access the data.
The developed database for the task Recommendation System has only one table which stores each attribute that composes one case and its solution, the proposed activity, in different columns and each case in a different row.

4.3.3 *jCOLIBRI and Hibernate*

jColibri is a powerful CBR engine in terms of flexibility, scope and usability. It allows developers to build a basic CBR application without having to touch the internal processes, however it also offers the possibility of building more complex applications, programming new methods and incorporating them in the framework [49].
Developing a CBR system is a complex task in which many decisions must be made. The use of jCOLIBRI helps the developer in the main steps that comprise the development of a CBR system, which are the following [3]:

1. **Representation of the cases:**

   jCOLIBRI already defines the basic structure of the cases as Description, Solution and Result, each one of this defined as compound attributes. The developer just needs to add a set of simple attributes inside those compound ones [3, 49].

2. **Connection to the Case Base**

   The cases of the case base can be stored in relational databases, ASCII text files, XML files, and others.
   In jCOLIBRI the case storage, the indexing structure and the problem solving methods (the methods that defines the different steps of CBR cycle) are independent structures. Connectors are objects provided by jCOLIBRI that know how to access and retrieve cases from the storage and return those cases to the CBR system (Figure 7).
   There are specific connectors to work with the selected storage method. Once mySQL data base is used, a Data base connector is necessary, which must be implemented with the Hibernate technology[49].
   Hibernate is an Object/Relational persistence service that takes care of the mapping from Java classes to database tables, and also provides data query and re-

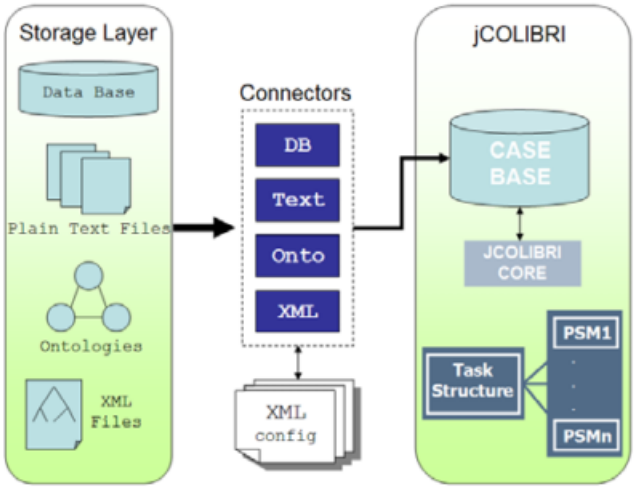


Figure 7.: jCOLIBRI connector architecture [3].

trieval facilities [50].
jCOLIBRI offers a graphical tool that is used to easily configure connectors to load existing case bases in different formats [3, 49].

3. **Similarity measures**

   One of the most important tasks to be solved in a CBR system consists on retrieving from the case-base the most similar cases to the new one given. Usually different similarity functions are used to compare the attributes of the cases. jCOLIBRI provides a list of similarity functions, so that designer can choose the more appropriate ones. These functions implement the *jcolibri.similarity.SimilarityFunction* java interface [3, 49].

In the end, all of these configurations, that can be done through graphical and intuitive interfaces provided by jCOLIBRI, will result in three XML files: one for the case structure configuration, another for the connector configuration and finally one for the similarity functions configuration. When the application is executed, the framework core reads these files to build the Java project and configure the CBR system [3].

4.3.4 *Android*

Android is a popular, Linux-based mobile phone operating system , widely-adopted open-source project that can be divided into the four areas as depicted bellow:

SYSTEM APPS is the layer which contains the main applications like the Browser, Camera, Gallery, Music and Messaging. Although these applications are in a different layer they have no special status among the apps the user chooses to install [51].

JAVA API FRAMEWORK is where an Android application developer typically works. The contained APIs written in Java language are open source and provide the building blocks needed to create new Android applications [51].

NATIVE C/C++ LIBRARIES These libraries contain framework functions like graphic rendering, data storage and web browsing [51].

ANDROID RUNTIME is written to run multiple virtual machines on low-memory devices by executing DEX files, a bytecode format designed specially for Android. For devices running Android version 5.0 (API level 21) or higher, each app runs in its own process which creates its own instance of the Android Runtime [51].

HARDWARE ABSTRACTION LAYER consists of multiple libraries, that implement interfaces for specific types of hardware components, like the camera and the bluetooth module [51].

LINUX KERNEL is the communication layer with the underlying hardware [51].

App components are the essential building blocks of an Android app. Each component serves a distinct purpose and has a distinct life-cycle that defines how the component is created and destroyed. There are four different types of app components: Activities, Services, Content providers and Broadcast receivers [51]. To build myOT only several Activity components were used. An activity is the visual representation of an Android application [51].
Google also provides an Integrated Development Environment (IDE) called Android Studio, which was used to build ”myOT”.

4.3.5 *Firebase*

Firebase is a platform designed to help developers build iOS, Android, and web apps [52].
Firebase is made up of complementary features which developers can choose to work independently, or mix-and-match to fit their needs. These features are Analytics Tools

that provide results about the user's behavior; Development Tools which provide easy solutions to implement automatic data synchronization, authentication services, messaging, file storage and others in the application; Grow Tools which aim to acquire and engage users and Earn Solutions that help developers earn money by displaying engaging ads to a global audience [52].
In "myOT", the Firebase Development Tools were used as a backend service, particularly the Real-time Database and the Authentication tools. While in some traditional models a communication layer between the mobile application and the backend service is necessary, Firebase provides easy APIs that simplify this process [52]. The Realtime database is a cloud-hosted NoSQL database. Data is stored as JSON, it is synced across the connected devices in milliseconds, and is rendered available even with no Internet connection.

4.3.6 *JSON Database*

JavaScript Object Notation (JSON) is a lightweight text-based format. It is widely used for data interchange on the modern web, since it is a human and machine-readable text format [53].
Unlike a Relational Database, JSON makes no use of tables or records. The basic structure of a JSON database is a tree and when data is inserted it becomes a node in the structure with an associated key [53].
JSON supports all the basic data types: numbers, strings, and boolean values, as well as arrays and objects. While strings, numbers, booleans and null can be used as values, objects are a list of label-value pairs and arrays are list of values. JSON also supports nested objects, which occurs when an object contains another object with several key-value pairs [53].

5

MY**OT**

The solution found to minimize the obstacles which complicate the therapy process was to develop an Android application that integrates every stakeholder of this process - children, parents and therapists - in a unique platform.
The aim is to produce a companion system that is used as a reinforcement for the therapy sessions that the children attend which combine the main functionalities:

- recommendation of activities;
- use of rewards as a positive reinforcement;
- improve the communication between parents and therapists;
- and help monitor the acquired skills.

The purpose behind this system is to increase the interaction and responsiveness of all users involved and give them the opportunity to monitor their children more closely, thus optimizing the therapy procedures and, consequently, the children's prognostic.

5.1 SYSTEM ARCHITECTURE

A client-server platform has been developed: the client side is the Android Application and the server side the Recommendation System, capable of suggesting activities that are appropriate, necessary and enjoyable for each children, using CBR.
The communication between these two layers is made with Java Class *Socket*.
The system described in Figure 8 operates in the following way:

1. The user *Parent* introduces the child's data (age, gender) in the system and selects his therapist (that must be registered in the app);

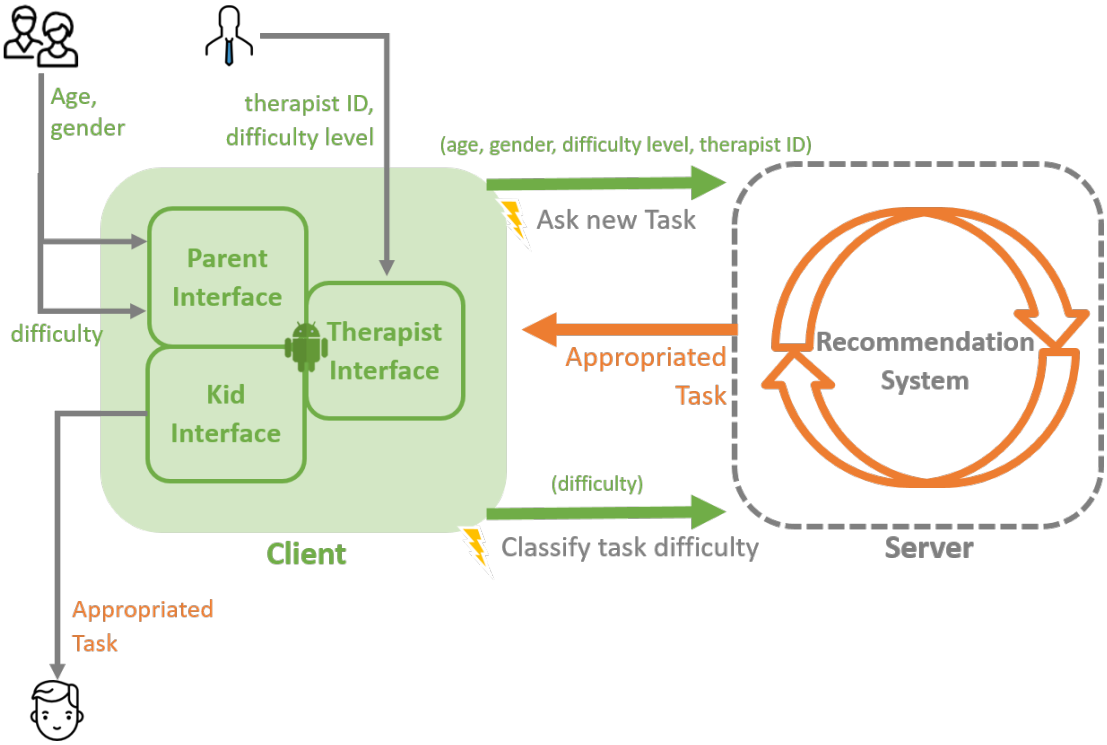


Figure 8.: Client-server system architecture.

2. The user *Therapist* introduces the difficulty level that he considers appropriate for the child in the system;

3. When the user *Parent* asks for a new suggestion of task, the attributes *age, gender, difficulty level* and *therapist ID* are sent to the server;

4. The server receive the data sent by the application, calculates the *day time* and the *week time* attributes and a new case goes into the CBR system. The CBR retrieves the most appropriate solution, in this case the most appropriate task for the child, which is replied to the application. In case the recommendation system does not find any activity adequate enough, it saves the best match as a new case, starting the *Retain* phase of the CBR system, explained in detail in section 5.4;

5. The user *Kid* receives appropriate, necessary and enjoyable tasks to do, as part of his continuous therapy programme and the users *Parent* and *Therapist* also receive this information in order to monitor the therapy;

6. After the user *Kid* completes the task, the user *Parent* is notified to classify the difficulty level the child experienced;

7. The classification given by the *Parent* user is send to the server and updated in the CBR repository of cases.

5.2 ANDROID APPLICATION

The android application serves as the graphical interface to the users, presenting a fluid interaction with the platform. It enables the different users to login as a *Parent*, a *Kid* or a *Therapist* (Fig. 9 a,b). The Kid's accounts can only be created by their parents, requiring the input of personal data, such as: their age, gender and one of the therapists available in the system (Fig. 9 c).

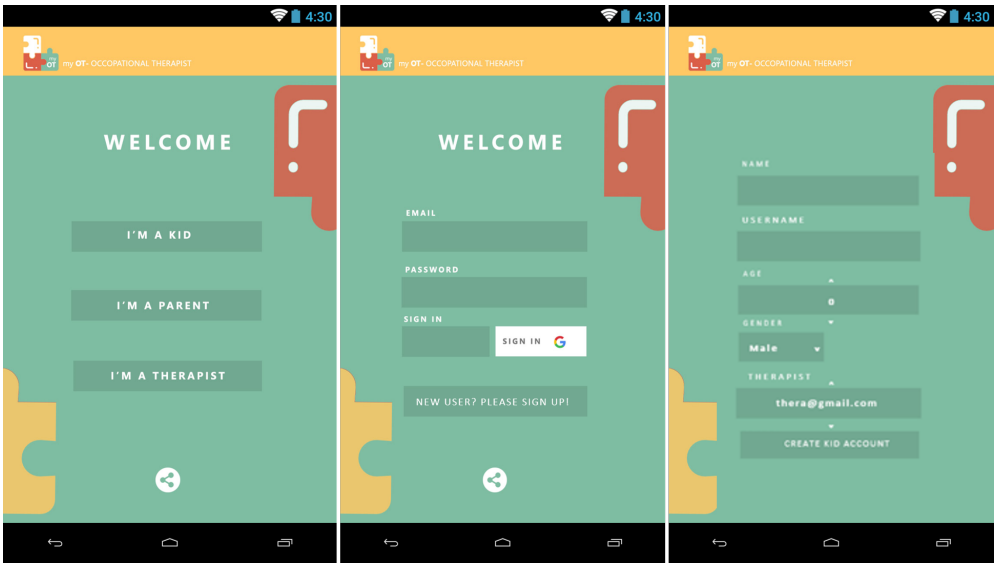


Figure 9.: (a) Choose type of user, (b) login and (c) Create kids account interfaces.

After login, Parents and Therapists have an interface with the list of their children. They should choose one, to enter in his main page. Figure 10 shows the main page for the user Kid "Carol" (10 a) and for her Parent and Therapist (10 b).

In their main page, children have access to their tasks and rewards. In the Tasks page, they have a list of suggested activities, which they can select and mark as done or undone. When a task is marked as "done" it is removed from that list and added to "Tasks to approve" list in the parents' interface. Each task has a symbolic value which is given according to the activity difficulty. After the approval, the child wins that

Figure 10.: (a) Kids Application main page; (b) Parents/Therapists main page

value in “coins” which can be used to buy any reward available in the ”Rewards” area. The Parents’ and the Therapists’ main pages have four buttons - Tasks, Rewards, Diary and Statistics. In Tasks’ area, Parents should propose new tasks for their children, automatically chosen by the Recommendation System, or manually chosen from the item bank. In this same area, there are two separated lists of tasks: ”Tasks to do” and ”Tasks

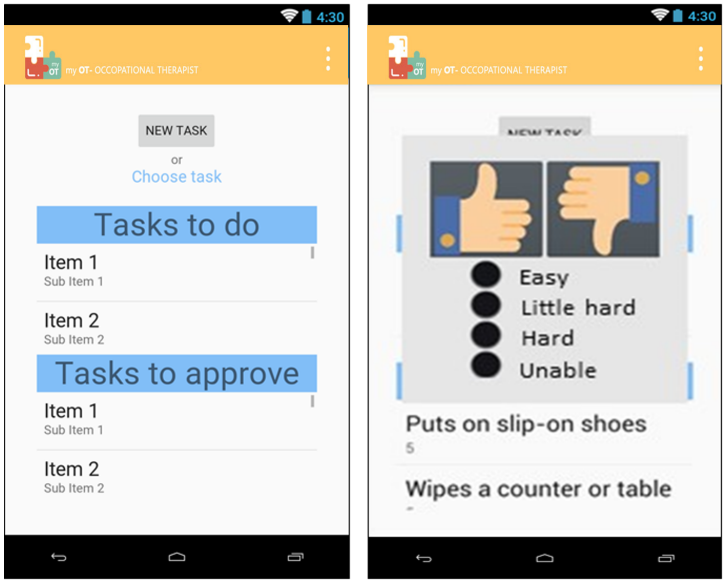


Figure 11.: Tasks activity interface.

to approve", presented in Figure 11 a. The second list is selectable, so that parents can mark a task as "done" or "undone". In case of selecting "done", a menu, which allows parent to classify the child difficulty on doing the respective activity, appears (Fig. 11 b). The therapists area for "Tasks" is the same, but without buttons to propose new tasks nor the option to classify them. Therapists have just access to the tasks lists, in order to follow the work done by the patient, at home.
In the Rewards area, parents and therapists can always add new prizes to the rewards bank (Fig. 12 a).
The Diary button, opens a log book, where therapists should registry the most important points and working goals of each session. This way, parents can play a more active role in the development of the child even if they don't have the necessary time to personally interact with the therapist (Fig. 12 b).
The statistics area, is the same for both users (Parents and Therapists). On the top of the page, it has an option to select the domain that the user wants to analyze. The statistics show the frequency of each level of difficulty, in the activities done for the selected domain and its sub-domains (Fig. 12 c).

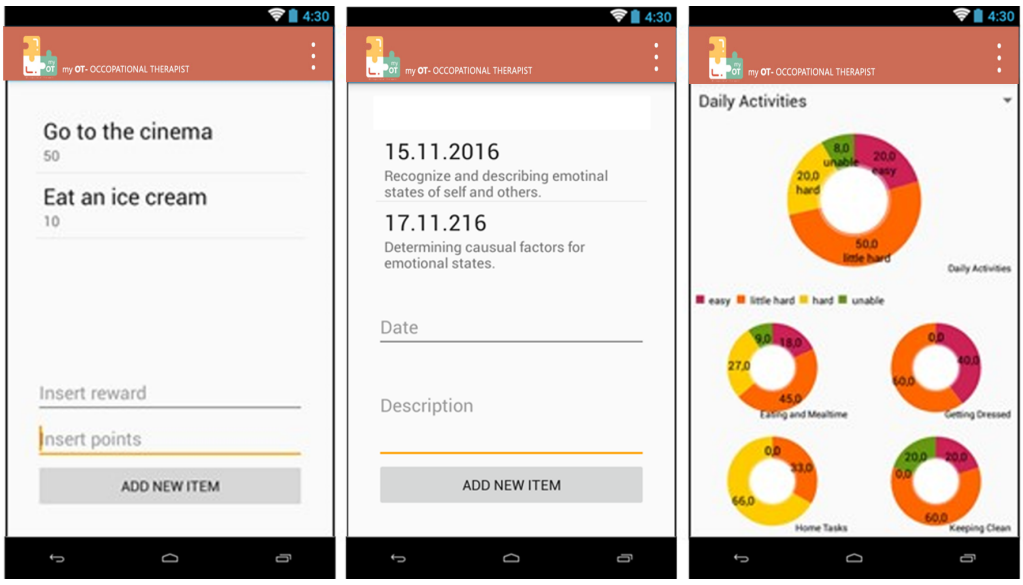


Figure 12.: (a) Rewards, (b) Diary and (c) Statistics areas.

5.3 INFORMATION SYSTEM

The information system of this application was developed with the *Real-time Database* tool of the *Firebase* backend platform, which takes use of JSON databases.

5.3.1 *Data Source*

The data source, as the name implies, is the source of all information provided by the platform, in this case the list of activities from PEDI-CAT.
Figure 13a shows the *ItemBank* database. Under the main node, there are three secondary nodes for each of the domains and inside them are the respective lists of activities. The keys, defined by the PEDI-CAT, are given according to the domain prefix ("DA", "RS" or "SC") and then the activities are enumerated.
Inside each domain, there are different sub-domains, so another node called *Content Areas* was created and, for each key activity, the respective description of the content area was inserted (Fig. 13b).

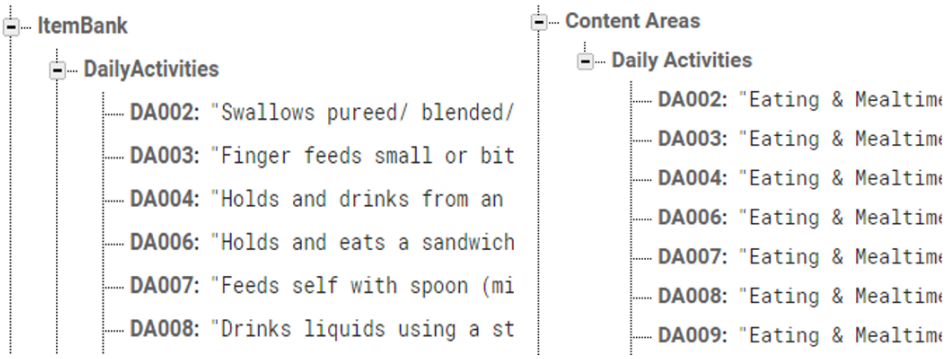


Figure 13.: (a) Item bank of activities and (b) corresponding content area.

5.3.2 *Dynamic Data*

A node for each type of users - *Kids*, *Parents* and *Therapists* - was created, in order to save each user's objects and their login informations for quick access. When a new user does his registration in the application, the user object is saved in the correspondent node, with an automatically chosen id.

Figure 14.: Users databases.

In order to aggregate each child with his parent and therapist the ”Groups” node was created (Figure 15). Under each child ID, parent and therapist define the relations between the three types of users.

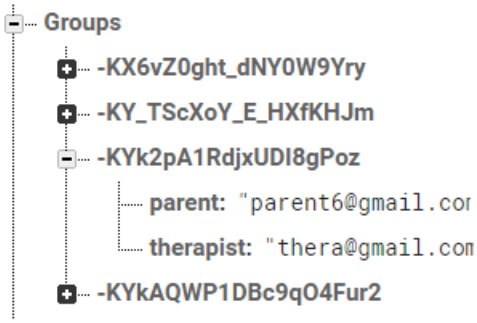


Figure 15.: Groups node: the association between the three entities.

When a task is suggested it is immediately saved in the ”TasksList” node. As one can see in Fig. 16, under the main node, there are the children IDs, and for the child *-KYk2pa1RdjxUNDI8gPoz*, a list of suggested tasks, each one also characterized by an automatically chosen ID. For the task object *-Kabn6YJhuRo8SuofBjR* the following attributes are presented: *approvedDate*, *classification*, *done*, *doneDate*, *key*, *points* and *sendDate*. At this point, the *approvedDate*, *classification*, *done* and *doneDate* attributes have a temporary value, which will be updated later. The *key* ”DA068” is the key of the suggested activity, which have a correspondent description under the node ”ActivitiesBank”; the *points* are the value in ”coins” that the child will receive in case of completion the task and the *sendDate* corresponds to the date and hour when the activity was suggested.

Figure 16.: Suggested tasks database.

When a child marks a task as ”done”, the object is moved from the ”SuggestedTasks” node to the ”WaittingApproveTasks” node. At this moment, the logic attribute *done* stays ”true” and the *doneDate* is filled in. The task object remains under the ”WaittingApproveTasks” node, until the parent confirms or denies the task as ”done”. At this moment the object is deleted from ”WaittingApproveTasks” node and added to ”DoneTasks” or ”UndoneTasks” node. The boolean attribute *done* is ”true” or ”false” according to the parent's decision; the *approvalDate* is filled in and the classification, which ranges from 0 to 4, according to the difficulty level that parents consider his child has experienced, is also filled in, in case the task has been completed.

Another two main nodes - ”Diary” and ”RewardsList” - were created to save the entrances written on those sections. Again, the entrances were written under each child ID, each one represented by one automatically chosen ID. Figure 18 shows that child *-KYk2pa1RdjxUNDI8gPoz* has three entries on the diary and two on the Rewards List.

Figure 17.: Done and undone tasks databases.

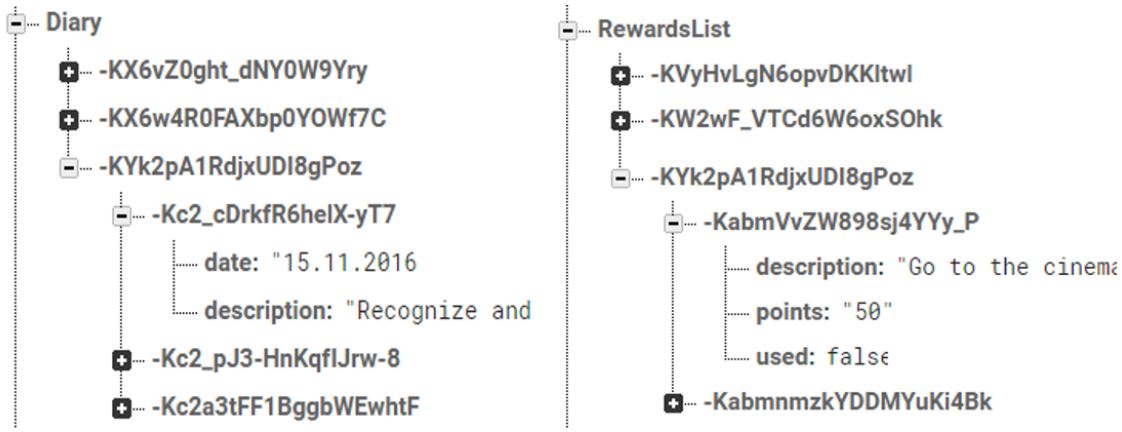


Figure 18.: Diary and Rewards databases.

5.4 CBR METHODS

The CBR methodology was adopted to give more interesting and real-world activity suggestions, since people with the same profile tend to choose identical activities.
In the CBR engine, a case is the representation of a set of situations that have the same features and the same successfully applied solution. Each case is represented by a set of attribute-value pairs that describe the features of a problem. The set of attributes that form the proposed case, have been defined in section 4.1. The problem of suggesting appropriate activities for children and young people with ASD has been

described by **age**, **gender**, **moment of the day** (morning/afternoon/night), **part of the week** (week/weekend), **difficulty level**, **classification** and **frequency** of recommendation; the solution is represented by one **task ID**.

Table 9.: A Case base example.

Description								Solution
caseID	age	gender	momentOfDay	parOfWeek	difficultyLevel	classification	frequency	taskID
c0001	5	0	1	1	4	4	0	DA001

In table 9, an example for the stored case *c0001* is shown. The **gender**, **momentOfDay** and **parOfWeek** are binary attributes. For **gender**, 0 represents "female" and 1 "male"; for **momentOfDay**, 0 means "afternoon", 1 "morning" and 2 "night" and for **parOfWeek**, 0 represents "weekend" and 1 "working days".
For the retrieval algorithm, the most similar cases are selected by means of a k-nearest neighbor algorithm using the local similarity measures to compute the similarity among cases.
For the **age**, **difficultyLevel** and **classification** attributes an *interval* function has been applied. This function calculates the similarity of two numbers inside an interval which returning

$$1 - \mid difficulty_{new} - \ difficulty_{caseBase} \mid / \ k$$

. For the **age** attribute k value was defined as 16, once our system supports ages from 3 to 18 years old. For the **difficultyLevel** and **classification** attributes the value of k was defined as 4 since our difficulty scale has four stages. In the rest of the attributes, an *equal* function was used, which retrieves 0 in case of unequal attributes, and 1 in case of equal attributes.
The global similarity is calculated through a weighted average function with the values of the local similarity and the respective weights of the attributes. In consensus with a team of therapists it was decided the weight of each attribute, according to the importance it have in order to find similar cases. Therefore, **age**, **difficulty** and **classification** attributes weigh 1; *dayTime* and *weekTime* weigh 0.75; *gender* and *therapistID* weigh 0.5 and *frequency* weigh 0, because it must not influence on the search for similar cases. The global similarity retrieves a value between 0 and 1, where 1 means a perfect match.

Once the most similar case is selected, its solution (the **taskID**) is suggested to solve the new problem.
By means of the revision and retention phases, the system can learn the degree of suitability of the responses that the CBR provides. To initiate the revision phase, after a solution has been applied, the user *Parent* must indicate to the system the difficulty experienced by the child performing the activity. Each time that one solution is classified, its **frequency** is incremented and the **classification** attribute is updated averaging the old and new values. When a stored case has a difference between the two *difficulty* attributes superior of 1, for a *frequency* superior to 50 suggestions, the system will notify the therapist, in order to revise this case. In regard to the retain phase, if the similarity between the new case and all the stored cases is below the acceptance threshold of 60% of similarity, the system selects the most similar solution and saves it as a new case, gathering the acceptance information in the next cycle.

6

USABILITY STUDY

With the objective of understand if *myOT* is an useful and necessary tool to support children with ASD, their families and therapists, an usability study was conducted. This study consisted in the realization of a survey aimed at people who have direct contact with children with ASD and for autistic adults. Through the divulgation in Associação Portuguesa para as Perturbações do Desenvolvimento e Autismo (APPDA) and other national associations, Facebook groups for autism, Esfera Saúde Clinic and in the university community, a total of 121 responses were obtained. The differences between the opinion of parents/other relatives and professionals had also been in study. This survey is available from the following url: https://goo.gl/forms/txaZylCULQUFtj0t1

1. **What is the degree of affinity you have with one or more autistic children? (121 responses)**

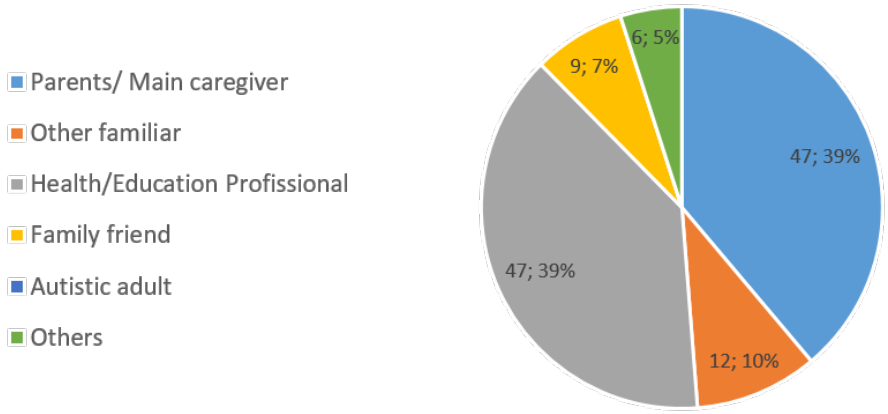


Figure 19.: Degree of affinity of the inquired persons with children with ASD.

The first question aim was to separate the inquired persons into different groups so that the following questions would be more suitable to the respondent.
Figure 19 shows that the main respondents were parents or main caregivers and health or education professionals, both with 39% of the answers. No response from an adult autistic was obtained.

The next questions were only directed to those respondents who chose one of the options Parent/Main caregiver, Other familiar, Family friend or **Others**:

1. **In what age group is the child? (74 responses)**

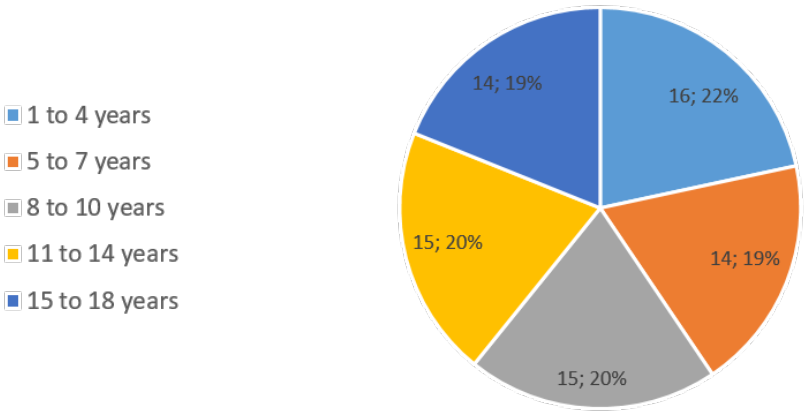


Figure 20.: Age distribution of children with ASD.

Figure 20 shows that the distribution of children with ASD's ages were quite uniform among the defined groups.

2. **Does the child in question like to interact with mobile devices (mobile phones, tablets, etc.)? (74 responses)**
   Figure 21 evidenced the theory that children with ASD are drawn to technological devices, theory in which this project is based on. Only 7% of the respondents affirmed that there children doesn't like to interact with mobile devices like phones and tablets.

3. **Does the child in question present difficulties in any of these areas? (73 responses)**

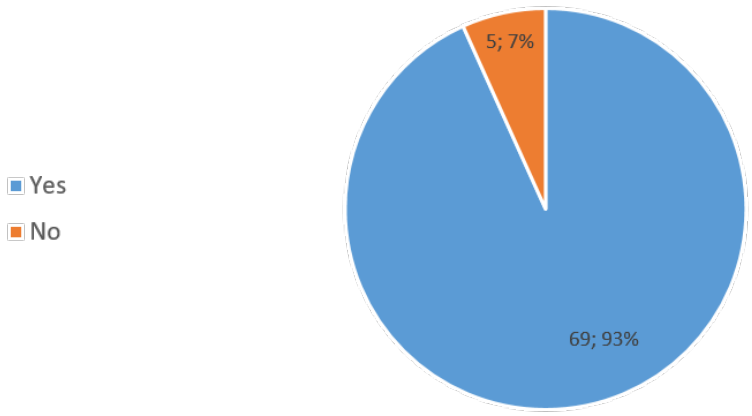


Figure 21.: Do children like mobile devices? - Parents/caregivers/other relatives opinion.

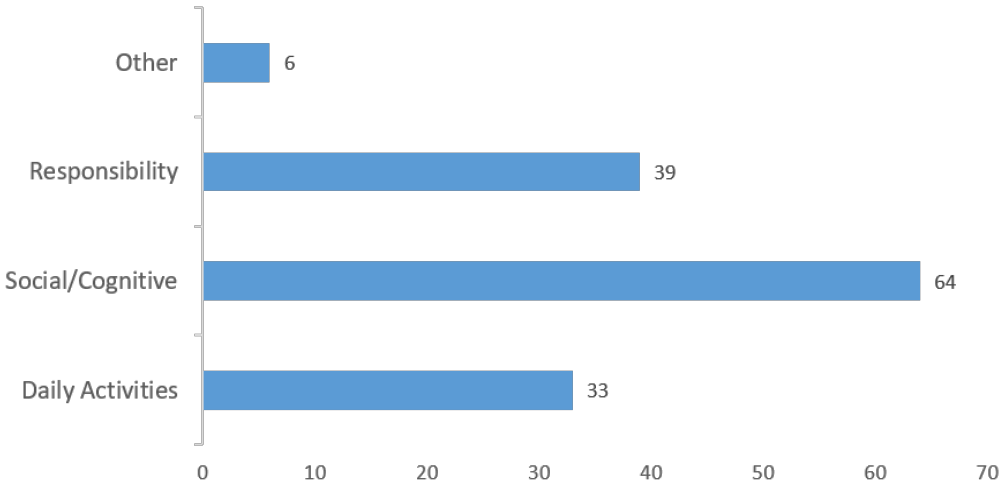


Figure 22.: The most problematic domains given by parents/caregivers and other relatives.

When questioned about the difficulties in the domains that *myOT* provides support to, family/other relatives of children with ASD confirm that Responsibility, Social/Cognitive and Daily Activities are the three main areas with deficits. Figure 22 shows the results to this question, where only 6 individuals answered that his child had difficulties in another different domain. The Social/ Cognitive is considered the most problematic domain. No pattern was identified when trying to establish a correlation between problematic domains and the group age of the children.

4. **Do the child attend occupational and/or other therapy sessions? (73 responses)**

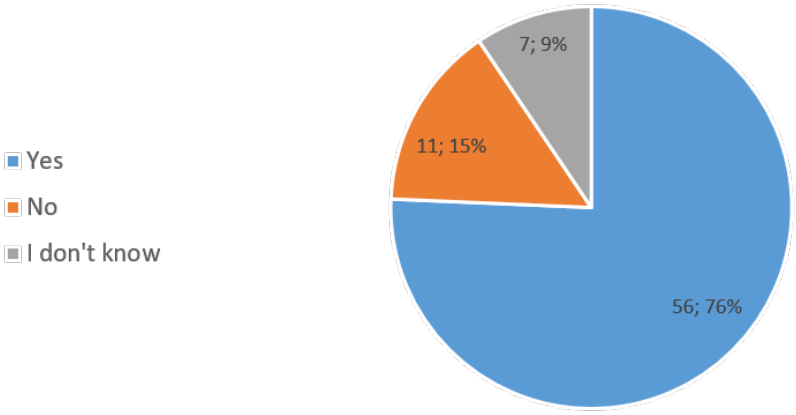


Figure 23.: Attendance in Occupational and other therapy sessions.

Almost 80% of the respondents answered that their children attend occupational and other therapy sessions and only 15% said that their children do not attend therapies (Figure 23). This means that it make sense to create a system to operate as a supplement to their regular therapies.

4.1. **If yes, how many times a week? (56 responses)**

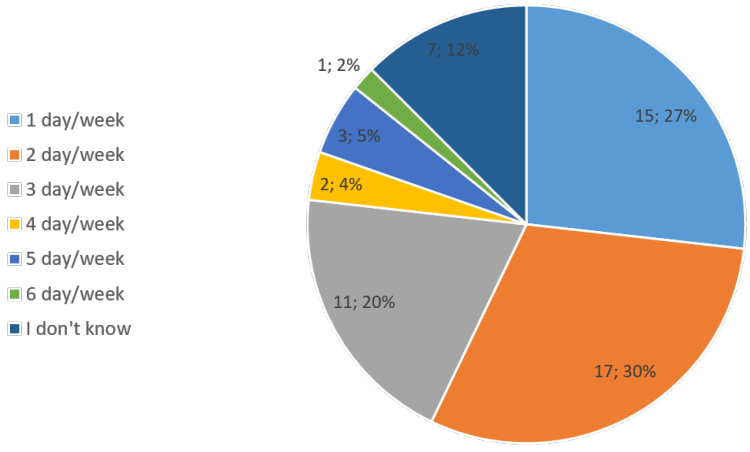


Figure 24.: Number of therapies per week.

As shown in the figure 24 the majority of the children have therapies one or two days per week, respectively 27% and 30% of the answers. Children with therapies three time in a week also represent a considerable group, with 20% of the answers. Children with more than 3 times per week therapies represent a minority and so it is possible to conclude that children need more support. The less time of therapy they have, the more support they will need from their parents/families, so it is important that they have supplementary activities to stimulate their more often.

4.2. **If you asked the child's therapist to join myOT, do you think he would do it?**

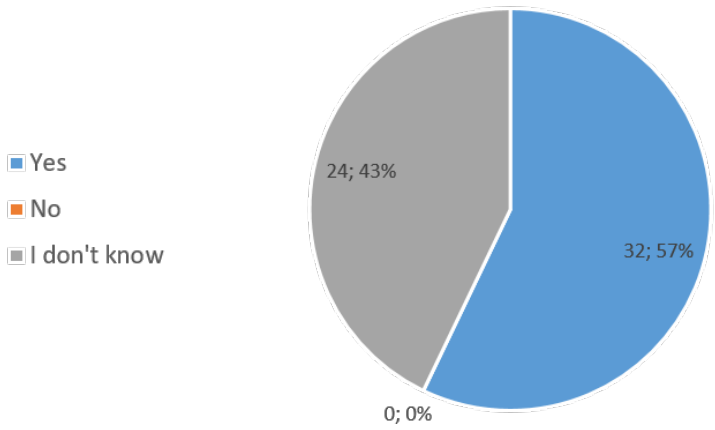


Figure 25.: Opinion of familiars about the adherence of therapists to myOT.

Regarding the adherence of therapists to myOT application, 57% of the parents/other relatives consider that the answer would be positive and 43% of the respondents have not sure if the therapist would accept the challenge.

The next questions were only directed to Healthcare/Education professionals:

1. **What is your profession?**
   Figure 26 reveal that the professions with a more significant representation in this survey were Occupational Therapist (26%), Special Education Teacher (17%), Speech Therapist (13%) and Psychologist (11%). But doctors, regular teachers and one nurse

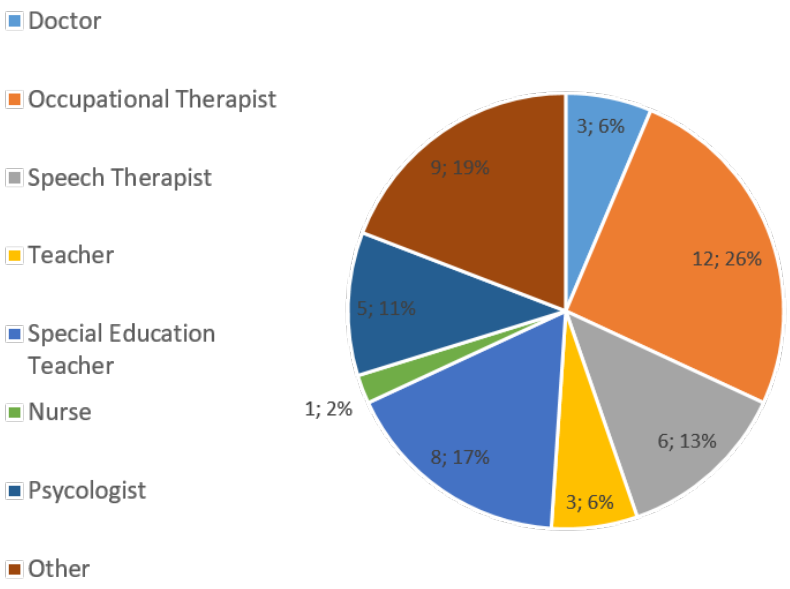


Figure 26.: Professions of the inquired health and education professionals.

have also been inquired. The range of professionals covered by the survey was very satisfactory and it is important to remember that only people who deal with autistic children were asked to fill the inquiry.

2. **Overall, autistic children like to interact with mobile devices (mobile phones, tablets, etc.)?**
   Health and education professionals answered with 100% of frequency "Yes" (Figure 27). Comparing with parents/caregivers/other relatives answers, the health/education professionals were more convinced of this fact. The opinions from the two different groups will be equally valued, once parents/caregivers/relatives have a closest relationship with the children, while health/education professionals know a bigger number of cases and can generalize their opinion.

3. **In general, do autistic children have difficulties in at least one of the domains: activities of daily living, responsibility or communication?**
   Figure 28 shows that 100% of the health and education professionals said "yes",

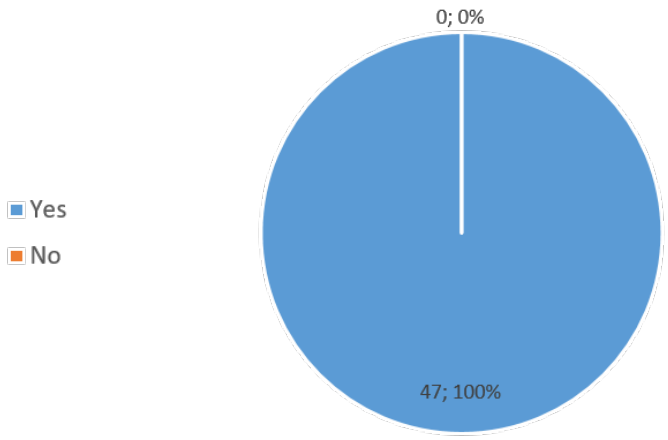


Figure 27.: Do children like mobile devices? - Health/Education Professionals opinion.

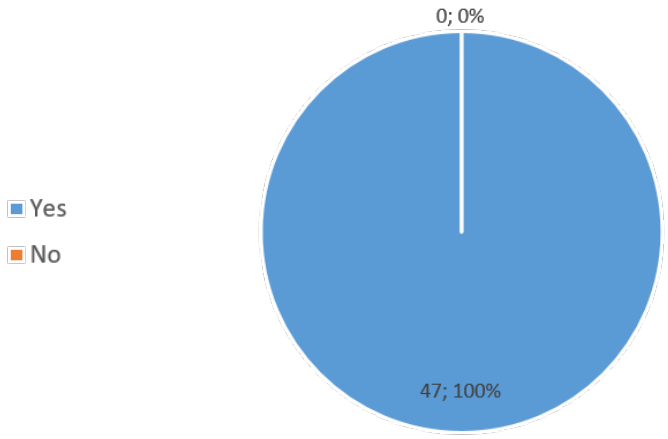


Figure 28.: Do children have difficulties in daily living activities, responsibility or communication?

which confirms that *myOT* works in crucial development areas.

4. **If you recommend this mobile application to the parents of an autistic child, do you think they would adhere? (47 responses)**
   Therapists considered parents more available to use *myOT* than the opposite. Even so, a big percentage of the respondents can not predict what would be the answer and the same happened when parents were questioned about the availability of ther-

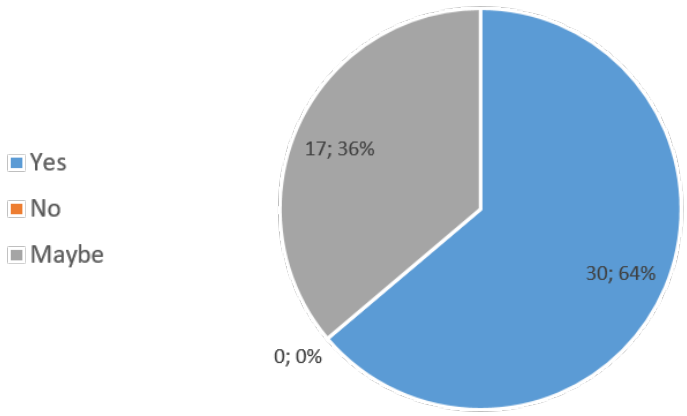


Figure 29.: Opinion of the professionals about the adherence of parents to *myOT*.

apists. This may suggest that the relationship between parents and therapists is not very close, which can be improved with myOT.

5. **Given your experience, do you think that the more you practice behaviors with an autistic child, the bigger is the probability of him becoming independent and demonstrate behaviors appropriate to his age? (47 responses)**

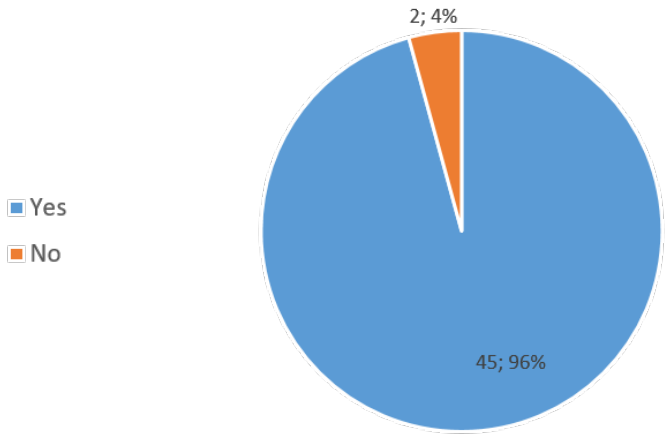


Figure 30.: Does practice improves behaviors?

Figure 30 shows that only 2 professionals in 47 answered "No". The professionals opinion about this fact is very important because they observe and monitor children

with ASD who have very different educational approaches at home, school and therapies and so, they can compare results. This confirms that *myOT* can improve the prognosis of this disease.

6. **Do you consider that a stimulus coming from a technological device (mobile phone, tablet) can be more effective than a human stimulus, in order to motivate the child to do certain activity? (47 responses)**

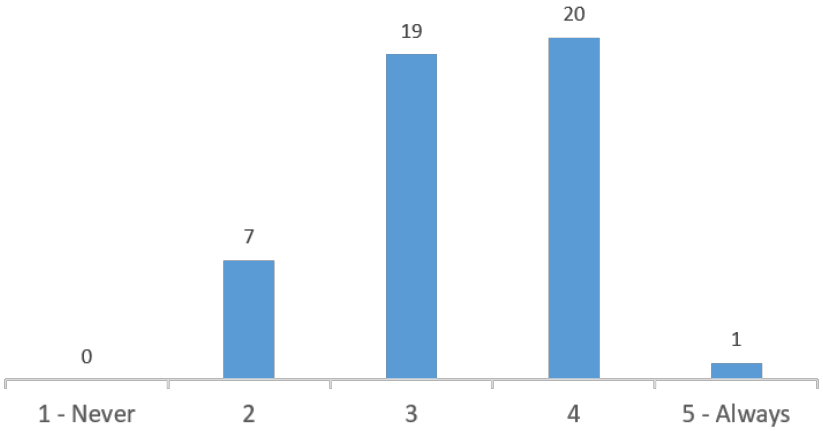


Figure 31.: Are technological device stimulus better than human stimulus?

This question could be a little controversial, that's why almost no one chose the extremes. Even so, analyzing figure 31 it is possible to see that one professional answer "5- Always" and 20 professionals answered "4 - Almost always", totalizing 21 positive answers. 19 professionals had a divided opinion and 7 said "2 - Almost never".

The following group of questions was directed to all participants of the inquiry:

1. **From 1 to 5, how useful do you consider ...**

   1.1. **a mobile application that suggests activities appropriate to each child and time of day? (121 responses)**

   Figure 32 suggests that people who deal with autistic children consider important the creation of a mobile application that supplements the therapy, suggesting appropriate tasks for children to complete. 48 responses of "5 - very useful"

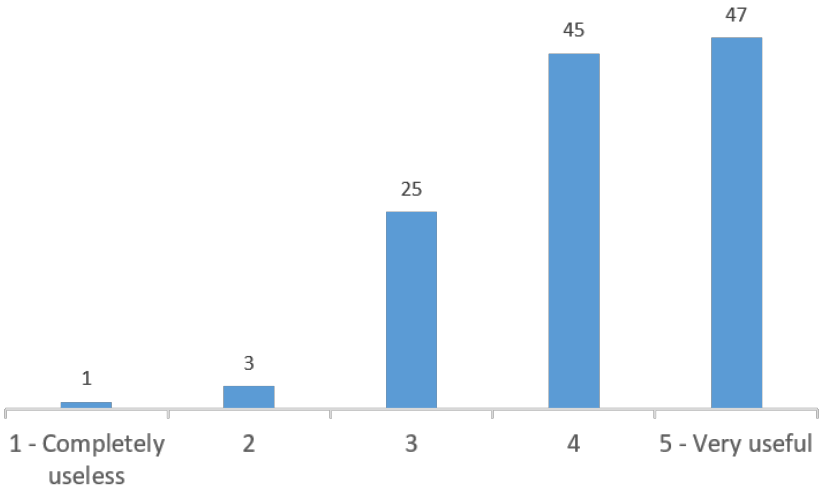


Figure 32.: Usability of an application which suggests appropriated tasks.

and other 48 of ″4 - Useful″ were obtained.

1.2. **a mobile application that rewards the child when they finish a task? (121 responses)**

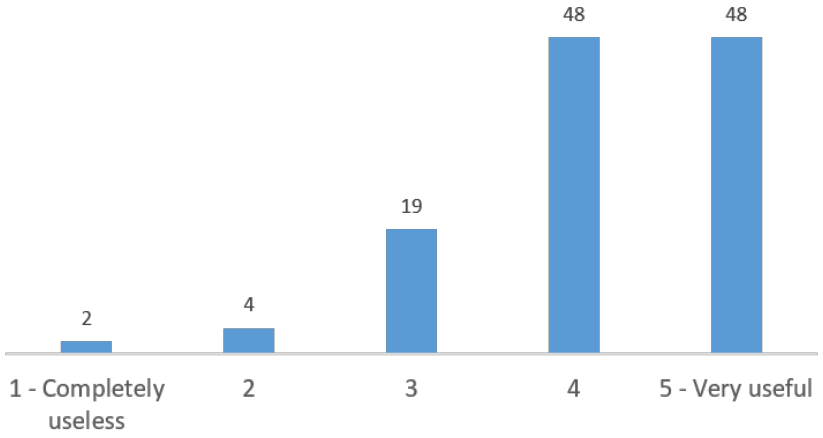


Figure 33.: Usability of an application which award children for doing tasks.

Figure 33 suggests that people who deal with autistic children consider important the positive reenforcement when children finish the proposed activities, with 48 responses of ″5 - very useful″ and other 48 of ″4 - Useful″.

1.3. **a mobile application that allows the therapist to make a small report of each session so that the parents can follow? (121 responses)**

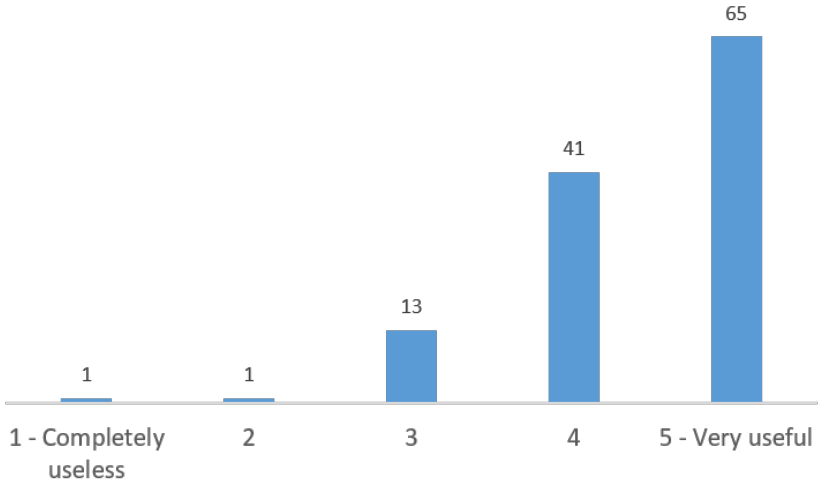


Figure 34.: Usability of an application which promote the communication between parents and therapists.

Figure 34 shows that the question of the communication between parents/therapists was the most appreciated characteristic of *myOT*, with 65 responses of "5 - very useful" and 41 of "4 - Useful".

2. **Would you use this application? (121 responses)**

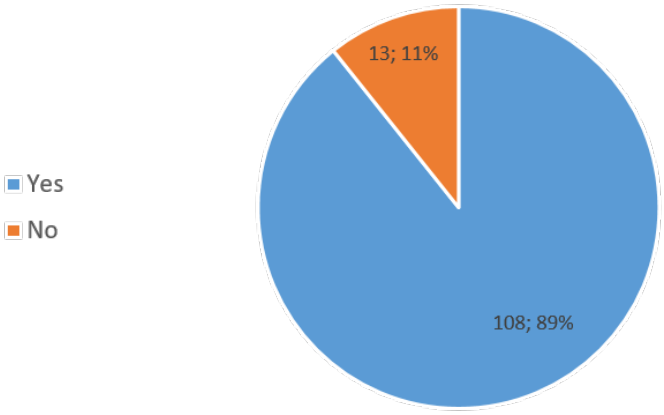


Figure 35.: Perspective of public adherence to *myOT*.

The graph presented on figure 38 evidences that people who deal with children with ASD consider *myOT* an useful tool to give support in the therapeutic process. In 121 responses, 108 of the respondents who deal with autistic children said that they would use this application.

3. **Why? (73 responses)**
   Finally, an open-text, non-obligatory question was done to know the reasons why people would or would not use *myOT*. Some of the explanations were:
   - (No) "Ideally I would try to avoid because children are too exposed to technology, but I would ponder depending on the child and on parents' availability".
   - (No) "Because more and more these and all the children are becoming dependent on technologies, and it makes their fine motrocity more difficult, which by itself is not very good."
   - (Yes) "Because it is useful and stimulating for child and therapist."
   - (Yes) "I have obtained very positive results with the use of other applications with autistic children."
   - (Yes) Using technology approaches, "it's the only way I see my son repeating a word."
   - (Yes) "Because of the dynamism that would be created in the relationship with the therapist, making possible the continuity of the work in a familiar environment."
   - (Yes) "Because it would be the best way to follow my child regularly."
   - (Yes) "Because it is a tool that aims to give continuity to the work done in therapy sessions. It would be good for the child and his family."
   - (Yes) "Because I know how complicated it is for parents to often realize and be able to follow the therapist's directions. It is also complicated to pass on information to therapists. It would have been helpful to my nephew. As a mother of a hyperactive child, I think it would be interesting to develop an application for hyperactive children too. Thank you!"

The obtained answers show that parents and therapists feel the necessity of the creation of a new and innovative support system to help them with the therapeutic

process.
The two main facts in which this dissertation was based on, were confirmed by the valuable opinion of those who deal directly with children and young people with ASD.

1. mobile devices are appropriate individuals with ASD.
2. the continuous practice may improve the child's development.

This was a very important endorsement, which renders this study even more valuable. Based on this survey, it was also possible to draw some other conclusions, which will be described in the next section.

7

CONCLUSION

The present dissertation reported the process of development and implementation of a therapy support system directed for children with ASD, their parents and therapists. All the outlined objectives were fulfilled: a task recommendation system was developed; an application to increase the interaction of all users was created and an usability study was conducted. In order to prove the established Research Hypothesis the next section reveals the main contributions of this work.

7.1 CONTRIBUTIONS

Through scientific research and real reports from parents, familiars, therapists, doctors, psychologists and teachers it is legitimate to conclude that *myOT* can have a positive impact in the therapeutic process of children and youth with ASD because:

- it is attractive for children, so it motivates them to practice in a funny way;
- it operates in the most important areas of development: daily activities, communication and social domains;
- it give parents and therapists the opportunity of monitoring their children more closely;
- it provides a tool to improve the communication between parents and therapists;
- its architecture encourages to a regular usage, which give children more chances of improving their outcomes, and, thus, they are more likely to achieve the ability to demonstrate age appropriate behaviors required for self-sufficiency;

Comparing with other solutions available in the market, *myOT* is a very complete tool. Although there are already studies to apply Machine Learning to the diagnostic process of this syndrome and to an AAC solution, in order to make them more efficient systems, this technology has never been applied to a task recommendation system for autistic children. *myOT* joins different functions available in other applications - skill learning, data collection and analysis - in a unique product, with a huge difference: the skill learning is made through an automated recommendation system which makes an individualized work, recommending appropriated, necessary and enjoyable activities for each child.
This dissertation has allowed the study of the applicability of Machine Learning into the area of e-health applications, showing that this is a promising area and opening the way to apply this kind of solutions to other diseases. Therefore, it is fair to say that this work represents an added value to our society.
Some educators and parents still worry about the dependency that an early exposure to constant electronic stimuli creates in their children. However, fighting against evolution is never a reliable answer, so the solution found is to take the youngest generation's addiction to technology and use it as an educational advantage. Technology is just a tool and, if well used, it can support the healthy development of a child.

The work and knowledge developed in this dissertation had originate a relevant paper for the ISAMI International Conference, which is available for consult on the next section.

7.1.1 *ISAmI Paper*

Title: A Task Recommendation system for children and youth with Autism Spectrum Disorder

Authors: Margarida Costa, Ângelo Costa, Vicente Julian e Paulo Novais

Abstract: Current studies indicate that 1 in 68 children have Autism Spectrum Disease. It is known that early diagnosis and intervention can alter the course of development and signicantly improve the prognosis of the disease. It is our intention to develop a task Recommendation System, which will use a Case-based Reasoning ma-

chine learning technique, in order to supplement the child's regular therapy. Besides the tasks' recommendation, this application will allow a closer monitoring by parents and a better coordination with the therapists, contributing to improve the results on child's development.

Keywords: Autism, Case-based Reasoning, Decision Support System, Mobile Computing

State: Submitted and accepted

7.2 PROSPECT FOR FUTURE WORK

The work done in this dissertation is a prototype of the application to be develop, which means that it is still not tested and there are a lot of improvements to do.
As future work, in order to make our Recommendation System more efficient, it would be important to improve the quality of the cases in the CBR. As mentioned before, data from a validation study of PEDI-CAT with children with ASD was used, together with activities bank and item-maps and some common sense associations, in order to built the necessary case base. The ideal situation would be to have a more complete sample with a bigger number of participants and more available information about them.
Another aspect that will be important to reinforce is the data protection because, since *myOT* works with patient data, it is very important to ensure that the application is secure for all the users.
On the other hand, less technical issues also need improvements. The language used in PEDI-CAT item bank is directed for parents/caregivers and not for children, so its important to adapt it. PEDI-CAT also provides illustrations for almost all activities, so it is important to insert them in the system.
Finally, the last objective is to test *myOT* in a representative sample of children and youth with ASD, in order to monitor their progress, analyze the results and prove that this support and supplement system can optimize regular therapy results.

BIBLIOGRAPHY

[1] David G Amaral, Cynthia Mills Schumann, and Christine Wu Nordahl. Neuroanatomy of autism. doi: 10.1016/j.tins.2007.12.005. URL http://www.cell.com/trends/neurosciences/pdf/S0166-2236(08)00038-6.pdf.

[2] Mark Coppin. Apps for Students with Autism Spectrum Disorders, 2012. URL https://www.autismspeaks.org/sites/default/files/pedagogy_wheel.pdf.

[3] Juan A Recio, Antonio Sánchez, Belén Díaz-agudo, and Pedro González-calero. jCOLIBRI 1 . 0 in a nutshell . A software tool for designing CBR systems. *Proceedings of the 10th UK Workshop on Case Based Reasoning*, pages 20–28, 2005.

[4] Sara Weisz Sampaio Estrela Rego. Autismo: fisiopatologia e biomarcadores. page 66, 2012.

[5] CDC — Signs & Symptoms — Autism Spectrum Disorder (ASD) — NCBDDD. URL https://www.cdc.gov/ncbddd/autism/signs.html.

[6] Community-University Partnership for the Study of Children and . Families. Review of the Vineland Adaptive Behavior Scales-Second Edition (Vineland-II). *Edmonton, Alberta, Canada.*, pages 1–6, 2011.

[7] Johnny L. Matson. *Handbook of assessment in persons with intellectual disability. Volume 34*. Elsevier/Academic Press, 2007. ISBN 9780080552125.

[8] T. A. Stinnett. Book Review: AAMR Adaptive Behavior Scale-School (2nd ed.). *Journal of Psychoeducational Assessment*, 15(4):361–372, 12 1997. ISSN 0734-2829. doi: 10.1177/073428299701500409.

[9] Stephen M Haley, Wendy J Coster, Helene M Dumas, and et al. PEDI-CAT version 1.3.6: Development, standardization and administration manual. *Health and Disability Research Institute, Boston University School of Public Health, Boston University Medical Center, Boston, MA Funded*, 2012. URL http://www.pedicat.com.

[10] Ying Chia Kao, Jessica M. Kramer, Kendra Liljenquist, Feng Tian, and Wendy J. Coster. Comparing the functional performance of children and youths with autism, developmental disabilities, and no disability using the revised pediatric evaluation of disability inventory item banks. *American Journal of Occupational Therapy*, 2012. ISSN 02729490. doi: 10.5014/ajot.2012.004218.

[11] American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*. Arlington, VA: American Psychiatric Publishing, 2013.

[12] Deborah L. Christensen, Jon Baio, Kim Van Naarden Braun, Deborah Bilder, Jane Charles, John N. Constantino, Julie Daniels, Maureen S. Durkin, Robert T. Fitzgerald, Margaret Kurzius-Spencer, Li-Ching Lee, Sydney Pettygrove, Cordelia Robinson, Eldon Schulz, Chris Wells, Martha S. Wingate, Walter Zahorodny, and Marshalyn Yeargin-Allsopp. Prevalence and Characteristics of Autism Spectrum Disorder Among Children Aged 8 Years - Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2012. *Morbidity and mortality weekly report. Surveillance summaries*, 65(3):1–23, 2016. ISSN 1545-8636. doi: 10.15585/mmwr.ss6503a1. URL http://www.cdc.gov/mmwr/volumes/65/ss/ss6503a1.htm%5Cnhttp://www.ncbi.nlm.nih.gov/pubmed/27031587.

[13] Guiomar Oliveira, Assunção Ataíde, Carla Marques, Teresa S. Miguel, Ana Margarida Coutinho, Luísa Mota-vieira, Esmeralda Gonçalves, Nazaré Mendes Lopes, Vitor Rodrigues, Henrique Carmona Da Mota, and Astrid Moura Vicente. Epidemiology of autism spectrum disorder in Portugal: Prevalence, clinical characterization, and medical conditions. *Developmental Medicine and Child Neurology*, 49 (10):726–733, 2007. ISSN 00121622. doi: 10.1111/j.1469-8749.2007.00726.x.

[14] American Psychiatric Association. What Is Autism Spectrum Disorder?, 2016. URL https://www.psychiatry.org/patients-families/autism/what-is-autism-spectrum-disorder.

[15] Tr Goldsmith and La LeBlanc. Use of Technology in Interventions for Children with Autism. *Journal of Early and Intensive Behavior*, 1(2):166–178, 4 2004. ISSN 1814232X. doi: 10.2989/1814232X.2011.572353. URL http://eric.ed.gov/?id=EJ848688.

[16] Igor Zubrycki and Grzegorz Granosik. A Robotized Environment for Improving Therapist Everyday Work with Children with Severe Mental Disabilities. *Proceed-*

ings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction Extended Abstracts, pages 203–204, 2015. ISSN 21672148. doi: 10.1145/2701973.2702717.

[17] Susan E Levy, David S Mandell, and Robert T Schultz. Autism. *Lancet (London, England)*, 374(9701):1627–38, 2009. ISSN 1474-547X. doi: 10.1016/S0140-6736(09)61376-3. URL https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2863325/pdf/nihms196323.pdfhttp://www.sciencedirect.com/science/article/pii/S0140673609613763.

[18] ICD-10 Version:2010. URL http://apps.who.int/classifications/icd10/browse/2010/en#/F84.0.

[19] Lonnie Zwaigenbaum, Susan Bryson, Catherine Lord, Sally Rogers, Alice Carter, Leslie Carver, Kasia Chawarska, John Constantino, Geraldine Dawson, Karen Dobkins, Deborah Fein, Jana Iverson, Ami Klin, Rebecca Landa, Daniel Messinger, Sally Ozonoff, Marian Sigman, Wendy Stone, Helen Tager-Flusberg, and Nurit Yirmiya. Clinical assessment and management of toddlers with suspected autism spectrum disorder: insights from studies of high-risk infants. *Pediatrics*, 123(5):1383–91, 2009. ISSN 1098-4275. doi: 10.1542/peds.2008-1606. URL https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2833286/pdf/nihms175064.pdfhttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2833286&tool=pmcentrez&rendertype=abstract.

[20] Helen McConachie, Jeremy R. Parr, Magdalena Glod, Jennifer Hanratty, Nuala Livingstone, Inalegwu P. Oono, Shannon Robalino, Gillian Baird, Bryony Beresford, Tony Charman, Deborah Garland, Jonathan Green, Paul Gringras, Glenys Jones, James Law, Ann S. Le Couteur, Geraldine Macdonald, Elaine M. McColl, Christopher Morris, Jacqueline Rodgers, Emily Simonoff, Caroline B. Terwee, and Katrina Williams. Systematic review of tools to measure outcomes for young children with autism spectrum disorder. *Health Technology Assessment*, 19(41):1–538, 2015. ISSN 20464924. doi: 10.3310/hta19410.

[21] Kerry Wells, Rosemary Condillac, Adrienne Perry, and David C Factor. A comparison of three adaptive behaviour measures in relation to cognitive level and severity of autism. *Journal on Developmental Disabilities*, 15(3):55–63, 2009.

[22] Marisela Huerta and Catherine Lord. Diagnostic evaluation of autism spectrum disorders. *Pediatr Clin North Am*, 59(1):103–11, 2012. ISSN 1557-8240. doi: 10.1016/j.pcl.2011.10.018.

[23] Wendy J . Coster, Jessica M. Kramer, Feng Tian, and et al. Evaluating the appropriateness of a new computer-administered measure of adaptive function for children and youth with autism spectrum disorders. *Autism*, 20(1):14–45, 2016.

[24] Jessica Weeks, William R Jenson, Elaine Clark, and Julia Hood. *Evidence-Based Assessment for Autism Spectrum Disorders*. PhD thesis, University of Utah, 2013.

[25] Anne Le Couteur, Catherine Lord, and Michael Rutter. About the ADI-R, 2003. URL https://research.agre.org/program/aboutadi.cfm.

[26] Joanna McClintock, M and John Fraser. *Diagnostic instruments for autism spectrum disorder*. Number April. JohnWiley & Sons, Ltd., wiley edition, 2011. doi: 10.1002/14651858.CD012036.www.cochranelibrary.com.

[27] Natacha Akshoomoff, Christina Corsello, and Heather Schmidt. The Role of the Autism Diagnostic Observation Schedule in the Assessment of Autism Spectrum Disorders in School and Community Settings. *The California school psychologist : CASP*, 11:7–19, 2006. ISSN 1087-3414. URL http://www.ncbi.nlm.nih.gov/pubmed/17502922http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC1868476.

[28] Rhiannon Luyster, Katherine Gotham, Whitney Guthrie, Mia Coffing, Rachel Petrak, Karen Pierce, Somer Bishop, Amy Esler, Vanessa Hus, Rosalind Oti, Jennifer Richler, Susan Risi, and Catherine Lord. The Autism Diagnostic Observation Schedule-toddler module: a new module of a standardized diagnostic measure for autism spectrum disorders. *Journal of autism and developmental disorders*, 39(9):1305–20, 9 2009. ISSN 1573-3432. doi: 10.1007/s10803-009-0746-z. URL http://www.ncbi.nlm.nih.gov/pubmed/19415479http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC2893552.

[29] Katherine Gotham, Andrew Pickles, and Catherine Lord. Standardizing ADOS scores for a measure of severity in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 39(5):693–705, 2009. ISSN 01623257. doi:

10.1007/s10803-008-0674-3. URL https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2922918/pdf/nihms223753.pdf.

[30] Jessica M. Kramer, Kendra Liljenquist, and Wendy J. Coster. Validity, reliability, and usability of the Pediatric Evaluation of Disability Inventory-Computer Adaptive Test for autism spectrum disorders. *Developmental Medicine and Child Neurology*, 58(3):255–261, 2016. ISSN 14698749. doi: 10.1111/dmcn.12837.

[31] Sara S Sparrow, Domenic V Cicchetti, and C. A. Saulnier. *Vineland Adaptive Behavior Scales, Third Edition (Vineland-3)*. 2016.

[32] Dennis R. Dixon. Adaptive Behavior Scales. *International Review of Research in Mental Retardation*, 34(December 2007):99–140, 2007. ISSN 00747750. doi: 10.1016/S0074-7750(07)34003-2.

[33] Stephen M. Haley, Wendy J. Coster, Helene M. Dumas, and et al. Accuracy and precision of the Pediatric Evaluation of Disability Inventory computer-adaptive tests (PEDI-CAT). *Developmental Medicine and Child Neurology*, 53(12):1100–1106, 2011. ISSN 00121622. doi: 10.1111/j.1469-8749.2011.04107.x.

[34] Jessica M Kramer, Wendy J Coster, Ying-Chia Kao, and et al. A new approach to the measurement of adaptive behavior: development of the PEDI-CAT for children and youth with autism spectrum disorders. *Physical & occupational therapy in pediatrics*, 32(1):34–47, 2012. ISSN 1541-3144. doi: 10.3109/01942638.2011.606260. URL http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3272487&tool=pmcentrez&rendertype=abstract.

[35] Annelies De Bildt, Sjoerd Sytema, Cees Ketelaars, Dirk Kraijer, Erik Mulder, Fred Volkmar, and Ruud Minderaa. Interrelationship between Autism Diagnostic Observation Schedule-Generic (ADOS-G), Autism Diagnostic Interview- Revised (ADI-R), and the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) Classification in Children and Adolescents with Mental Retardation. *Journal of Autism and Developmental Disorders*, 34(2), 2004. URL https://pdfs.semanticscholar.org/2de6/987519113675457d01fb758cd838110f720a.pdf.

[36] Rita Dunn and Andrey Vyshedskiy. Mental Imagery Therapy for Autism (MITA) - An Early Intervention Computerized Brain Training Program for Children with

ASD. *Autism-Open Access*, 05(03), 2015. ISSN 21657890. doi: 10.4172/2165-7890.1000153.

[37] Autism Therapy with MITA – Aplicações Android no Google Play. URL https://play.google.com/store/apps/details?id=com.imagiration.mita.

[38] The Shine Centre — Cork. URL http://shineireland.com/pals/.

[39] Social Skills for Autism – Aplicações Android no Google Play. URL https://play.google.com/store/apps/details?id=com.rescue.kloog.

[40] BeeVisual. URL http://www.beevisual.com/.

[41] TracknShare. Autism Tracker. URL http://tracknshareapp.com/autism-tracker/.

[42] Pathfinder Health Innovations. All-In-One Therapy Solutions. URL https://pathfinderhi.com/.

[43] aacorn. URL http://www.aacornapp.com/#solution.

[44] Tomas M. Mitchell. *Machine Lerning*. McGraw-Hill, Inc., New York, 1 edition, 1997.

[45] Dp Wall, J Kosmicki, Tf Deluca, E Harstad, and Va Fusaro. Use of machine learning to shorten observation-based screening and diagnosis of autism. *Translational Psychiatry*, 2, 2012. doi: 10.1038/tp.2012.10. URL https://pdfs.semanticscholar.org/8434/467a8304f5fc564abfcb02819d4657b0e038.pdf.

[46] Dennis P. Wall, Rebecca Dally, Rhiannon Luyster, Jae-Yoon Jung, and Todd F. DeLuca. Use of Artificial Intelligence to Shorten the Behavioral Diagnosis of Autism. *PLoS ONE*, 7(8):e43855, 8 2012. ISSN 1932-6203. doi: 10.1371/journal.pone.0043855. URL http://dx.plos.org/10.1371/journal.pone.0043855.

[47] R Schmidt and L Gierl. Case-based reasoning for medical knowledge-based systems. *Studies in health technology and informatics*, 77:720–5, 2000. ISSN 0926-9630. URL http://www.ncbi.nlm.nih.gov/pubmed/11187647.

[48] Agnar Aamodt. Case-Based Reasoning : Foundational Issues , Methodological Variations , and System Approaches. 7:39–59, 1994.

[49] Juan a Recio-García, Belén Díaz-Agudo, and Pedro González-Calero. *jCOLIBRI2 Tutorial*. 2008. ISBN 9788469162040.

[50] Hibernate. Everything data. - Hibernate. URL http://hibernate.org/.

[51] Introdução ao Android — Android Developers. URL https://developer.android.com/guide/index.html.

[52] Firebase — App success made simple. URL https://firebase.google.com/.

[53] JSON. URL http://www.json.org/.

A

SUPPORT MATERIAL

A.1 PEDI-CAT - ITEM-BANK

Table 10.: Daily Activities Items.

Item Number	Content Area	Item
DA002	Eating & Mealtime	Swallows pureed/ blended/ strained foods
DA003	Eating & Mealtime	Finger feeds small or bite-sizepieces of food
DA004	Eating & Mealtime	Holds and drinks from an opencup or glass
DA006	Eating & Mealtime	Holds and eats a sandwich orburger
DA007	Eating & Mealtime	Feeds self with spoon (minimalspilling)
DA008	Eating & Mealtime	Drinks liquids using a straw
DA009	Eating & Mealtime	Feeds self with fork (minimalspilling)
DA010	Eating & Mealtime	Uses a knife to butter breadand spread jam
DA011	Eating & Mealtime	Cuts vegetables or meat with afork and table knife
DA012	Eating & Mealtime	Inserts a straw into a juice box
DA013	Eating & Mealtime	Pours liquid from a large cartoninto a glass

Continued on next page

Table 10 – Daily Activities Items

Item Number	Content Area	Item
DA014	Eating & Mealtime	Stirs to mix ingredients
DA015	Eating & Mealtime	Empties food from mixing bowl to baking pan
DA016	Eating & Mealtime	Pulls open a sealed bag ofsnack food
DA019	Eating & Mealtime	Removes lid from plastic foodcontainers
DA020	Eating & Mealtime	Opens sealed cardboard foodboxes
DA021	Home Tasks	Cuts with scissors to open hardplastic packaging
DA022	Eating & Mealtime	Closes a bottle with a twist-offcap
DA025	Eating & Mealtime	Peels foods such as potatoesor carrots
DA026	Eating & Mealtime	Chops or slices hard fruits orvegetables
DA027	Eating & Mealtime	Uses a can opener to open acan
DA028	Keeping Clean	Rubs hands together to clean
DA030	Keeping Clean	Wipes nose thoroughly withtissue
DA031	Keeping Clean	Turns the water on and off atsink
DA034	Keeping Clean	Puts toothpaste on brush andbrushes teeth thoroughly
DA036	Keeping Clean	Trims fingernails on both hands
DA039	Getting Dressed	Fastens hairclips or barrettes
DA040	Getting Dressed	Puts hair up in a ponytail
DA044	Keeping Clean	Shaves face using electric orsafety razor
DA046	Getting Dressed	Fastens watch band
DA047	Getting Dressed	Fastens a necklace or chain
DA049	Keeping Clean	Trims toenails on both feet
DA051	Keeping Clean	Cleans body thoroughly in bathor shower
DA052	Keeping Clean	Dries hair with a towel

Continued on next page

Table 10 – Daily Activities Items

Item Number	Content Area	Item
DA054	Keeping Clean	Obtains shampoo, washes andrinses hair
DA055	Keeping Clean	Dries hair with a hair dryer
DA057	Getting Dressed	Removes socks
DA058	Getting Dressed	Takes off a t-shirt
DA060	Getting Dressed	Puts on a t-shirt
DA061	Getting Dressed	Puts on and buttons a frontbuttoningshirt
DA062	Getting Dressed	Removes pants with elasticwaist
DA064	Getting Dressed	Puts on and fastens pants
DA065	Getting Dressed	Fastens belt buckle
DA066	Getting Dressed	Tucks in shirt or blouse
DA067	Getting Dressed	Puts on socks
DA068	Getting Dressed	Puts on slip-on shoes
DA069	Getting Dressed	Connects and zips zippers that are not fastened at the bottom
DA070	Getting Dressed	Ties shoelaces
DA072	Getting Dressed	Inserts laces into sneakers or boots
DA073	Getting Dressed	Puts on winter, sport, or workgloves
DA074	Getting Dressed	Puts on bra and fastens in frontor back
DA075	Getting Dressed	Puts on tights or pantyhose
DA079	Keeping Clean	Wipes self with toilet paper aftera bowel movement
DA081	Keeping Clean	Opens, closes and latches public bathroom stall doors
DA083	Home Tasks	Uses a TV remote control
DA084	Home Tasks	Operates a video game controller
DA086	Home Tasks	Uses a computer mouse to click on icons or links
DA087	Home Tasks	Uses a computer keyboard to type

Continued on next page

Table 10 – Daily Activities Items

Item Number	Content Area	Item
DA089	Home Tasks	Wipes a counter or table
DA091	Home Tasks	Stacks breakable plates or cups
DA092	Home Tasks	Opens door lock using key
DA093	Home Tasks	Changes pillow case on pillow
DA094	Home Tasks	Replaces (unscrews andscrews) the bulb in a table lamp
DA095	Home Tasks	Tightens loose screws using ascrewdriver
DA096	Home Tasks	Puts a bandage on a small cuton hand
DA097	Home Tasks	Opens childproof medicine orvitamin containers
DA098	Home Tasks	Presses buttons to operate akey-pad such as phone or ATM
DA100	Home Tasks	Removes a single bill fromwallet

Table 11.: Social/Conitive Items.

Item Number	Content Area	Item
SC001	Communication	Uses words, gestures or signs to ask for something
SC002	Communication	Uses several words or signs together such as ”go home now” and ”daddy go”
SC004	Communication	Uses words or signs to ask questions such as ”Where’s Mommy?” or ”What’s that?”
SC005	Interaction	Carries on a conversation with a familiar person by listening and responding appropriately
SC008	Communication	Teaches another person a new game or activity by giving examples and explanations
SC010	Interaction	Greets new people appropriately when introduced

Continued on next page

Table 11 – Social/Conitive Items.

Item Number	Content Area	Item
SC011	Everyday Cognition	Follows directions given by adult leader of a small group
SC012	Interaction	Asks permission before using someone else's property
SC013	Everyday Cognition	Attends to and follows direction given by a coach or teacher while in a large group
SC014	Interaction	Uses language appropriate to the situation such as formal language at a job interview or informal language when hanging out with friends
SC016	Interaction	Asks for a change in plans or responsibilities in a respectful way such as asking a teacher to extend a deadline
SC018	Interaction	Follows gaze of another person to look at the same place or object
SC019	Interaction	Plays peek-a-boo or pat-a-cake
SC020	Interaction	Interacts briefly with a peer during play
SC021	Interaction	Asks one or more peers to play using words or gestures
SC022	Interaction	Takes turns sharing a favorite toy with peers
SC023	Interaction	Participates in role-playing activities such as playing school or acting out famous characters
SC024	Interaction	Plays with one or more children of the same age for several hours on their own

Continued on next page

Table 11 – Social/Conitive Items.

Item Number	Content Area	Item
SC025	Interaction	Takes turns and follows rules while playing simple board, card, or video games
SC026	Interaction	Uses strategy and follows strict rules while playing complex board, card, or video games
SC028	Interaction	Shows positive reactions to friends' success such as congratulating a peer for scoring a goal or doing well on a test
SC029	Interaction	Works with friends to reach an agreement when they have different ideas
SC030	Interaction	Maintains friendships that involve give-and-take, compromises and loyalty
SC031	Interaction	Tries to resolve a conflict with friends or classmates
SC032	Everyday Cognition	Recognizes his/her printed name
SC033	Everyday Cognition	Prints first and last name legibly
SC035	Everyday Cognition	Writes a legible 3-4 item list
SC036	Communication	Writes short notes or sends text messages or email
SC037	Everyday Cognition	Communicates ideas in a 2-3 page written assignment or report
SC038	Everyday Cognition	Recognizes numbers such as on a clock or phone
SC039	Everyday Cognition	Counts out the correct coins to pay for an item that costs x or less

Continued on next page

Table 11 – Social/Conitive Items.

Item Number	Content Area	Item
SC040	Everyday Cognition	Understands signs in the community such as Restrooms or EXIT
SC041	Everyday Cognition	Counts out the correct amount of bills and/or coins to pay for an item of food
SC042	Everyday Cognition	Uses a map to plan a route to a new place
SC043	Everyday Cognition	Finds a phone number or address using the phone book or computer
SC044	Everyday Cognition	Follows written directions of 2-3 steps
SC045	Everyday Cognition	Follows complex written instructions such as to set up new computer software or complete a school project
SC047	Communication	Uses the words yesterday/ tomorrow/ today correctly
SC048	Everyday Cognition	Associates days of the week with their typical activities such as football practice on Tuesday, chores on Saturday
SC049	Everyday Cognition	Associates a specific time with a specific activity such as a favorite TV show starting at 3 pm
SC051	Everyday Cognition	Uses a watch or clock to be ready for an activity such as catching school bus or watching TV show
SC056	Self-Management	Accepts the need to wait an hour or two before a request can be met
SC057	Self-Management	When upset, responds without punching, hitting, or biting

Continued on next page

Table 11 – Social/Conitive Items.

Item Number	Content Area	Item
SC058	Self-Management	Accepts advice or feedback from a teacher, coach, or boss without losing temper
SC059	Self-Management	Keeps unsafe objects and household materials out of mouth
SC060	Self-Management	Behaves safely when falling is possible, such as on a playground slide or near stairs
SC063	Everyday Cognition	Checks traffic in both directions and knows when to cross street
SC064	Everyday Cognition	Shows interest in objects held close by looking, touching, or listening
SC065	Everyday Cognition	Tries to make toys work by pressing, pushing, or squeezing
SC066	Everyday Cognition	Puts together an unfamiliar 5-10 piece puzzle with interlocking pieces
SC067	Everyday Cognition	Uses toys in simple pretend play such as putting doll to bed or driving a toy truck
SC068	Everyday Cognition	Builds simple structures from objects such as building a tower or a house from blocks
SC071	Communication	Uses single words, gestures or signs to show what he/she wants
SC072	Communication	Describes what help is needed to solve a problem such as approaching store staff to locate item or asking a friend to borrow a book needed for homework

Continued on next page

Table 11 – Social/Conitive Items.

Item Number	Content Area	Item
SC073	Everyday Cognition	Tries to do things a different way when not successful such as turning a puzzle piece in a different direction or trying a different route in a video game
SC074	Everyday Cognition	Uses a calendar or datebook to record and keep track of appointments, assignment or events
SC076	Communication	Explains reasons behind actions or such as why he/she spent money on a particular item
SC077	Self-Management	Stays quiet in public places when expected
SC078	Communication	Provides own address and telephone number when asked
SC079	Self-Management	Transitions from one familiar activity to another such as playground to classroom, bath time to bed time

Table 12.: Responsibility Items.

Item Number	Content Area	Item
RS001	Organization & Planning	Getting ready in the morning on time
RS002	Organization & Planning	Keeping track of time throughout the day
RS004	Organization & Planning	Planning and following a weekly schedule so all activities get done when needed
RS005	Organization & Planning	Having all items that will be needed before leaving home for the day
RS006	Health Management	Managing routine health appointments and related activities

Continued on next page

Table 12 – Social/Conitive Items.

Item Number	Content Area	Item
RS007	Taking Care of Daily Needs	Eating and drinking appropriate foods to maintain health and energy
RS008	Health Management	Following health and medical treatment requirements
RS009	Health Management	Taking care of minor health needs
RS010	Health Management	Seeking medical help for serious illness or injury when needed
RS011	Staying Safe	Staying safe in a familiar location that is known to be safe such as friend's home or local park
RS012	Staying Safe	Determining the safety of a new location such as an unfamiliar neighborhood or a large event with many people, and responding appropriately to stay safe
RS013	Organization & Planning	Choosing and arranging own social interactions
RS014	Taking Care of Daily Needs	Fixing simple meals that do not involve cooking such as cereal or a sandwich
RS015	Taking Care of Daily Needs	Following a recipe or cooking instructions that includes 3-4 ingredients and steps such as macaroni and cheese or brownies
RS016	Taking Care of Daily Needs	Managing kitchen appliances such as stove, microwave, or dishwasher safely
RS017	Taking Care of Daily Needs	Using utensils such as a knife or grater safely during food preparation
RS018	Taking Care of Daily Needs	Managing food needs for the entire week
RS019	Taking Care of Daily Needs	Using safe food handling practices in the kitchen

Continued on next page

Table 12 – Social/Conitive Items.

Item Number	Content Area	Item
RS020	Taking Care of Daily Needs	Maintaining cleanliness and upkeep of living space
RS022	Organization & Planning	Putting items and objects away after use
RS023	Taking Care of Daily Needs	Selecting clothing that is appropriate given the weather, daily schedule, and activities
RS025	Taking Care of Daily Needs	Recognizing when appearance or hygiene needs attention and taking steps to correct
RS026	Taking Care of Daily Needs	Cleaning and caring for clothes
RS027	Organization & Planning	Developing and following a plan to reach a specific goal (e.g. buying a bike, earning a place on a team)
RS028	Organization & Planning	Prioritizing and coordinating multiple goals at the same time such as keeping up grades as well as after school activities
RS029	Staying Safe	Supervising or caring for another person (e.g., sibling or other child, grandparent)
RS030	Taking Care of Daily Needs	Managing bowel and bladder through the night
RS031	Taking Care of Daily Needs	Managing bowel and bladder through the day
RS033	Taking Care of Daily Needs	Managing menstrual cycle
RS034	Health Management	Taking precautions to avoid sexually transmitted diseases and/or unwanted pregnancies
RS036	Organization & Planning	Tracking spending and managing money
RS037	Organization & Planning	Paying bills and other accounts on time

Continued on next page

Table 12 – Social/Conitive Items.

Item Number	Content Area	Item
RS038	Organization & Planning	Managing daily expenses
RS039	Organization & Planning	Completing legal and/or other personal paperwork
RS040	Staying Safe	Taking precautions to protect the privacy of personal information
RS041	Organization & Planning	Locating needed services or supports (e.g. finding a community program or repair business)
RS042	Organization & Planning	Resolving errors in personal business such as billing, registration and other accounts
RS043	Organization & Planning	Organizing important papers and information and finding them when needed
RS045	Staying Safe	Traveling safely within the community
RS047	Staying Safe	Eating safely without choking or burning self
RS048	Taking Care of Daily Needs	Packing all the items needed for an overnight stay
RS049	Taking Care of Daily Needs	Buying clothing at a store, from a catalog or online
RS050	Organization & Planning	Keeping personal electronic devices in working order (e.g., cell phone, computer)
RS051	Health Management	Coping with stress, worry, or anger
RS052	Health Management	Communicating health needs and seeking information and services as needed
RS053	Health Management	Making healthy choices to maintain health and wellbeing
RS054	Organization & Planning	Seeking out and joining a club, community organization, or other social group for fun, leisure, and social networking

Continued on next page

Table 12 – Social/Conitive Items.

Item Number	Content Area	Item
RS055	Organization & Planning	Voting in local and national elections
RS057	Staying Safe	Using the internet safely
RS058	Staying Safe	Testing and adjusting water temperature before taking a shower or bath
RS059	Organization & Planning	Informing home, school, or work when he or she will be late or absent

A.2 PEDI-CAT - ITEM MAPS

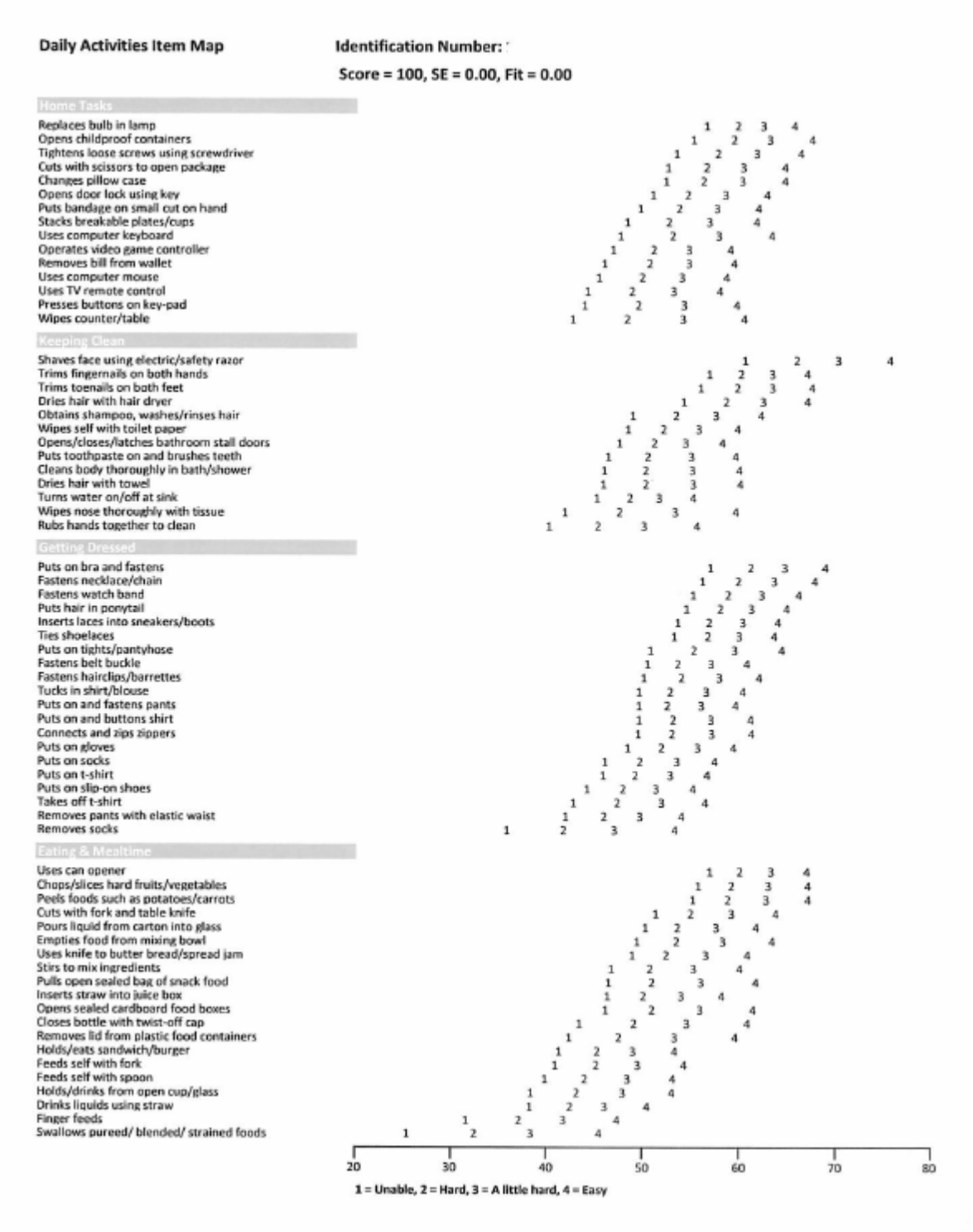


Figure 36.: Item Map for Daily Activities domain.

Figure 37.: Item Map for Social/Cognitive domain.

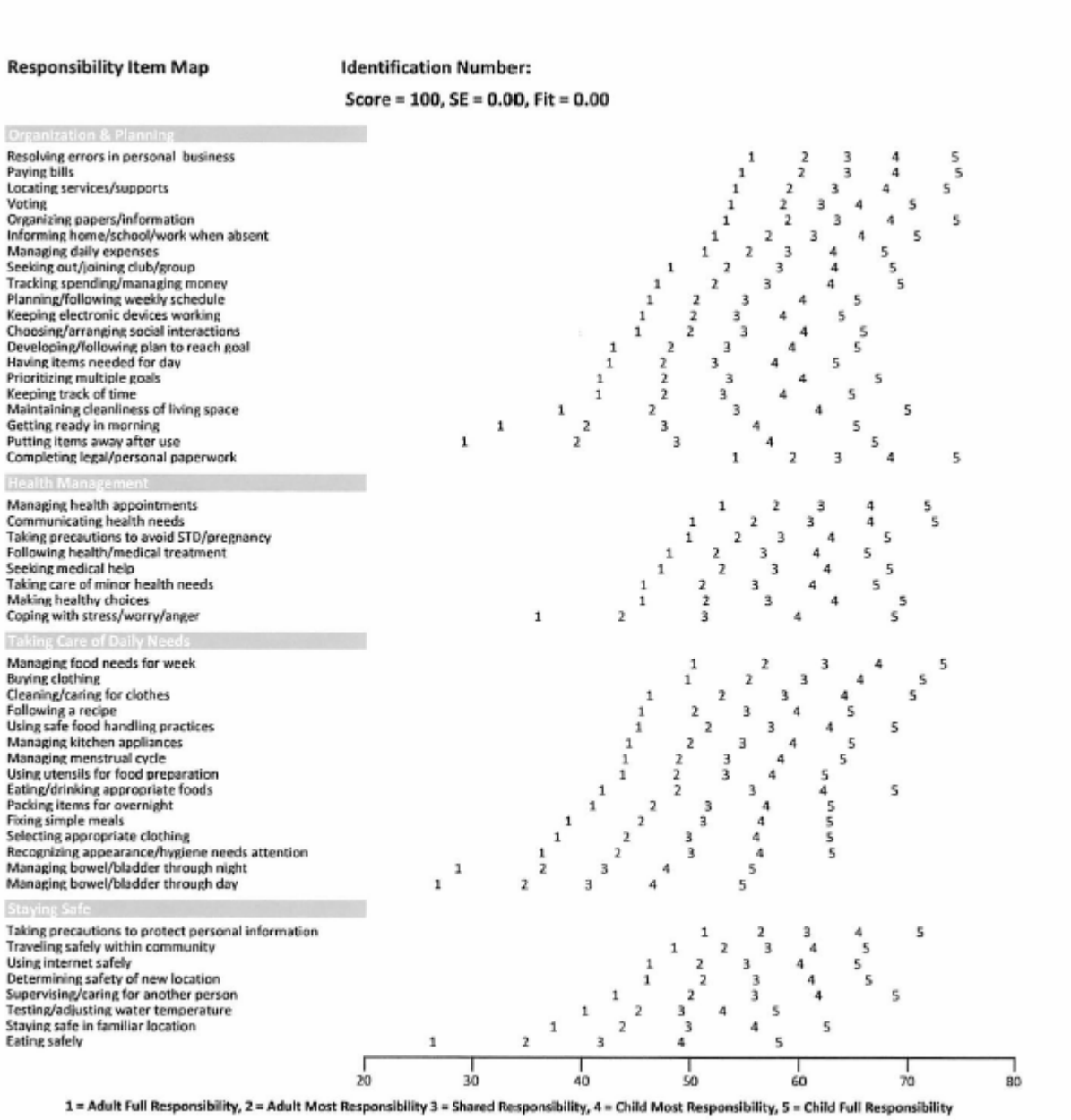


Figure 38.: Item Map for Responsibility domain.