Development of a Home Accompaniment System Providing Homework Assistance for Children with ADHD

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Abstract. This manuscript presents a system for homework assistance for children with Attention Deficit Hyperactivity Disorder - ADHD. This system consists of a robot and a set of smart objects constantly monitoring the child's activities during the performance of his tasks. The design of this system is focused on creating a robot-child relationship. It is possible for the child with this type of disorder to acquire the different capacities that allow him to carry out his tasks independently and effectively through short instructions and different methodologies (such as short physical exercise). Besides, it is a support tool for parents and therapists to better comprehend the behavior of their children and patients, respectively. This system allows a better understanding of the patient's clinical characteristics, his evolution, and the therapeutic options that may have a greater effect on him. This project is focused on the implementation of an information processing software and a User Interface UI for the Atent@ robot. Thanks to the software the robot is provided with many functionalities for inter-acting with the child. This system is based on IoT architecture. Both the robot and the smart objects are connected to a Realtime Database so that the data can be processed and shared with parents and therapists in real-time through a mobile application. This work shows the entire design and implementation of this software as well as the functional tests and their results.

Keywords: ADHD · Software development · Human-machine interaction · Robotic assistance · UIX

1 Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a conduct disorder with a growing number of detected cases over the last years. Generally, its diagnosis and therapy require human involvement in most cases. The symptoms of this behavioral disorder are inattention, hyperactivity, and impulsiveness, all of which seriously interfere with the

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child's learning. This in turn leads to lower school performance than the average. Due to recent cataloging, this disorder was not included in the American Academy of Psychiatry Manual of Classification and Diagnosis of Mental Disorders (DSM-V) until 2000. ADHD is a disorder that raises great social attention as it mostly occurs in children. It commonly leads to the overdiagnosis of this disorder and, consequently, to the abuse of psychotropic treatments [1].

The treatment is carried out exclusively in a therapeutic center. This treatment consists of teaching the child guidelines that help him carry out daily activities such as cleaning up the room, doing homework, eating, etc. The fact that the child has to move for regular follow-ups makes the treatment not as effective as it could be since it is not practiced in the child's natural environment. The environment plays a truly important and strategic role, especially if we consider that the evaluation of ADHD symptoms, according to the DSM-V, must be carried out, in different settings and contexts to obtain an accurate diagnosis. This project seeks to transfer the therapy environment to the patient's home where he can put into practice the guidelines recommended by his therapist in carrying out daily tasks. In this project, the day-to-day task that becomes relevant is performing homework.

On the other hand, Robotics has experienced greater importance in its application in the therapeutic and educational field. The therapy robot for children with autism spectrum disorders called Aisoy is a clear example of this [2]. As ADHD is a much more recent disorder than Autism Spectrum Disorder, it has been less immersed in research and the advancement in assistant robots helping therapy for children with this type of disorder has not been developed yet. Therefore, this work focuses especially on children with ADHD.

It is very important that the child feels comfortable and enjoys interacting with the robot. For this reason, this project implements the software and the design of an easy, friendly, and fun graphic interface that encourages the child to interact with it. The user interface increases participation and helps the child to associate the robot as a necessary element when performing his homework. Through this adaption, the information collected is much more in line with reality. All this information is accessible from a mobile application. The parents and therapists can monitor and evaluate the interaction with the robot, the information collected and processed during homework sessions, and the autonomy advances that the child develops throughout the therapy with the system.

2 Attention Deficit and Hyperactivity Disorder - ADHD

ADHD is a neurobiological behavior disorder with a genetic component caused by the existence of an imbalance between two brain neurotransmitters: norepinephrine and dopamine [3]. These substances do not work adequately in the prefrontal cortex of the brain, directly affecting self-control and avoiding inappropriate behavior. This leads to a lack of control in functions such as attention, hyperactivity, and impulsivity [4].

2.1 ADHD Statistics

ADHD is one of the most frequent psychiatric disorders in the world, ranking above schizophrenia or bipolar disorder. Furthermore, it constitutes the most frequent neuropsychiatric diagnosis of childhood [5]. ADHD affects between 3 and 12% of children and adolescents, having a worldwide prevalence of 5.3% according to the World Health Organization (WHO) [6]. Although ADHD is a disorder that predominates in childhood, it has been shown that between 4 and 5% continue to show symptoms in adulthood [7].

Today, diagnosing this type of disorder continues to be very difficult due to the great comorbidity that exists with other disorders. In a study carried out in Sweden by the Gillberg group, it was shown that 87% of children who met all the criteria for ADHD had at least one comorbid diagnosis and that 67% met the criteria for at least two comorbid disorders [8].

2.2 ADHD Types

The core symptoms of ADHD are independent of each other and therefore occur in different combinations, at different levels, and with different types of associated problems. However, most people with this type of disorder show symptoms of both, inattention and hyperactivity-impulsivity. According to the Manual of Classification and DSM-V [9], there are three presentations or subtypes of ADHD:

1. ADHD with a predominance of attention deficit
2. ADHD with predominantly hyperactive-impulsive
3. ADHD combined type

2.3 Treatments

The treatment which has proven to be most effective, both in children and in adults with ADHD, is a multisystem treatment which is a pharmacological and psychosocial treatment. Pharmacological treatment helps to compensate for the irregular production of the neurotransmitters involved in this disorder; dopamine and norepinephrine. In people with ADHD, stimulants calm them and tranquilizers make them more nervous, as stimulants raise and balance the level of neurotransmitters [10]. The most widely used drug in these treatments is methylphenidate, but it can have side effects [10]. Effective non-pharmacological treatments are essential, especially in those patients who are resistant to the use of medications to treat ADHD.

Psychosocial treatment includes psycho-pedagogical, neuropsychological, cognitive, behavioral, and family therapies that help decrease the symptoms of this disorder [10]. Specific behavioral approaches are important to focus on areas such as social relationships and organizational skills [11].

Another approach includes intensive computerized training of attention, inhibition, working memory, and neurofeedback. Computerized training approaches operate on the principle that underlying deficits in brain networks and associated cognitive processes can be remedied by structured exposure to repeated cognitive tasks, in which task's difficulty is continually raised to challenge but not to overwhelm the child's abilities [11].

2.4 Robotic Therapeutic Assistance

One of the fastest-growing technological areas today is robotics. Although robotics has been more widely used in general industrial sectors due to its ability to perform repetitive tasks, which need to be very precise and sometimes contain dangers, a special interest has been awakened by the contributions of robotics in educational processes since the 1970s, generating a new area of study: educational robotics [12].

Educational robotics or pedagogical robotics is a discipline that creates and operates robotic prototypes as well as specialized programs for pedagogical purposes. Pierre Nonnon and Jean Pierre Theil affirm that the use of robotic tools favors the teaching and learning process since they allow easy integration of the theoretical with the practical [13]. Educational robotics is strongly linked to the theories of constructivism. Jean Piaget's constructivist theory ensures that learning is not the result of a transfer of knowledge, but rather an active process of constructing learning based on experiences. Constructivism maintains that learning manifests as the student interacts with his reality and performs activities on it. From constructivist theory, the use of technological tools provides an alternative way of learning and creates experiences for students to build knowledge [13].

The development of therapies carried out with robots allows the reduction of prevalent disorders in society intuitively and pedagogically [14]. This allows us to provide a feasible solution to combat prevalent disorders such as ADHD. They also help to maintain greater attention in the performance of their tasks thanks to the manipulation, experimentation, and interaction with this type of tool, acquiring capabilities and methodologies that help them to carry out the different procedures. The robot becomes the therapist and at the same time a therapeutic tool.

Currently, there is a wide variety of techniques and resources that are used as technological support to promote academic learning [12]. A current example is PAT, a robotic assistant that supports children in the initial age on the prevention of traumatic accidents [15]. This project has had very promising results, overcoming traditional prevention teaching methodologies inside pre-scholar schools.

3 Methodology

3.1 Scenario

The setting of this project is based on the need to make an exhaustive observation of children with ADHD in their natural environment which is of great importance for further treatment by therapists and specialists. Currently, this is not done as children with ADHD must go to a therapeutic consultation for diagnosis and treatment. This, in particular, restricts the correct care of the patient, and the extrapolation of the results is influenced by an environment with which the child is unfamiliar.

The proposed scenario for the implementation of the system is shown below (Fig. 1).

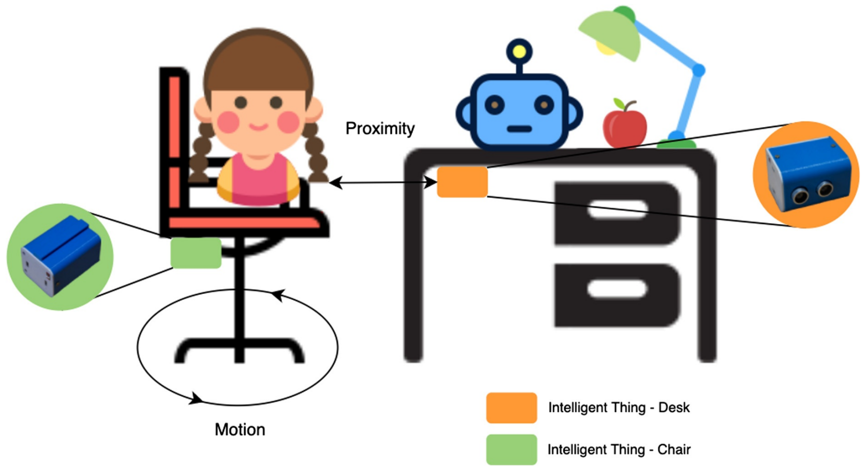

Fig. 1. Scheme of the project scenario. The system implemented in this scenario is made up of the Atent@ robot and the two smart objects, one under the desk and the other under the chair.

3.2 Atent@ Robot

The Atent@ robot is an intelligent device whose main function is to serve as a support tool to help children with ADHD to carry out their school tasks. This element is the basis of the project [16]. It carries the intelligence of the homework process and is in charge of carrying out all the necessary interactions with the child. Being an essential element placed in the workspace, its dimensions are small and are made for being portable while at the same time it does not represent a distraction when the child gets to work. The robot has a touch screen so that the child can enter the different activities he wants to do, such as starting the homework, going to the bathroom, asking for help, etc.

The robot allows him to apply organizational and planning techniques that reinforce the therapy sessions carried out by his therapist, at home. Also, it allows the parents and therapists to carry out constant monitoring of the child's behavior during the performance of his duties, which can help gain more detailed information about the case, observe the progress, and reroute his therapy if necessary [16].

3.3 Intelligent Things

Intelligent Things are two devices connected to the internet just like Atent@, which have been placed under both the desk and the chair. Their main function is collecting data while the child performs his tasks. They are not perceived by the child, therefore not causing any distraction during the tasks. The devices are continuously measuring the parameters and sending all the information for further processing into the cloud [16]. The intelligent thing installed in the chair allows detecting movements. This object has an integrated accelerometer sensor, which obtains the acceleration values and the orientation of the object, thus being able to determine if the child is moving with the chair or not.

The intelligent thing installed in the desk detects the distance between the child and the desk, by using an ultrasonic proximity sensor (hc-sr04). This sensor obtains the distance between the child and the desk, allowing the observation to detect whether the child is in his working position or if he has moved away from the desk.

The information obtained from both intelligent objects allows us to know: Whether the child is concentrated on doing his homework, has been distracted, or left his workplace. Besides, it allows the collection of very important information for the therapists. Since they are quantifiable it can be verified whether the therapy is effective, or if, on the contrary, improvements have to be made since no progress can be seen in the child.

3.4 Proposed System

An intelligent software system is designed and developed, which implements all the functionalities required for assistance in carrying out school tasks in children with ADHD between the ages of 6 and 9 years. This system is not only designed to teach but is also a source of information for both parents and therapists. Parents are informed of the progress of their children, while therapists will be able to continuously monitor the child in more realistic ways and environments.

To achieve this child-parent-therapist communication, a mobile application is designed and developed allowing to consult, in real-time, the data from the session with the robot. Besides, the stored local data from previous sessions can be consulted later, making the monitoring by the therapy much more effective.

The following figure shows which are the interactions that take place in the system (Fig. 2).

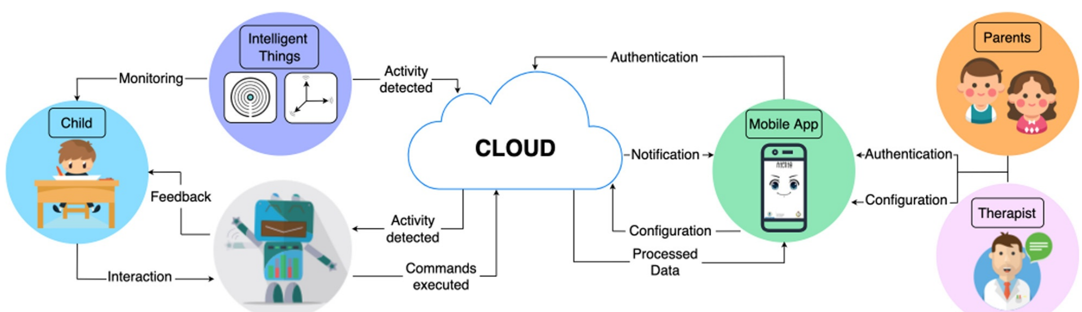

Fig. 2. Scheme of the system and the main interactions between its elements.

3.5 System Architecture

The global architecture of the system takes the IoT layer model as a reference. This architecture is subdivided into three main layers:

The first, called the acquisition layer, is responsible for collecting all the information from the robot, through the instructions indicated by the child, and collected thanks to the touch screen, as well as through the sensors inside the smart objects. This data is sent to the knowledge layer through the internet connection.

The second, knowledge layer, encompasses the processing of the data collected by the sensors as well as storing this information to obtain knowledge. It is proposed to perform Edge Computing, locating the main computation in the robot. Thus, it will be avoided that the behavior of the robot depends on a connection to the network, ensuring that in the event this connection does not exist, the robot can still perform all its tasks correctly. Besides, a massive upload of data will be avoided, sending only the data which is considered to be of interest to the cloud.

The third layer, of services, is in charge of providing the necessary information through different types of interaction to different users. In the case of the robot, these interactions can be sound or audiovisual type.

The following figure shows the architecture of the system discussed previously (Fig. 3).

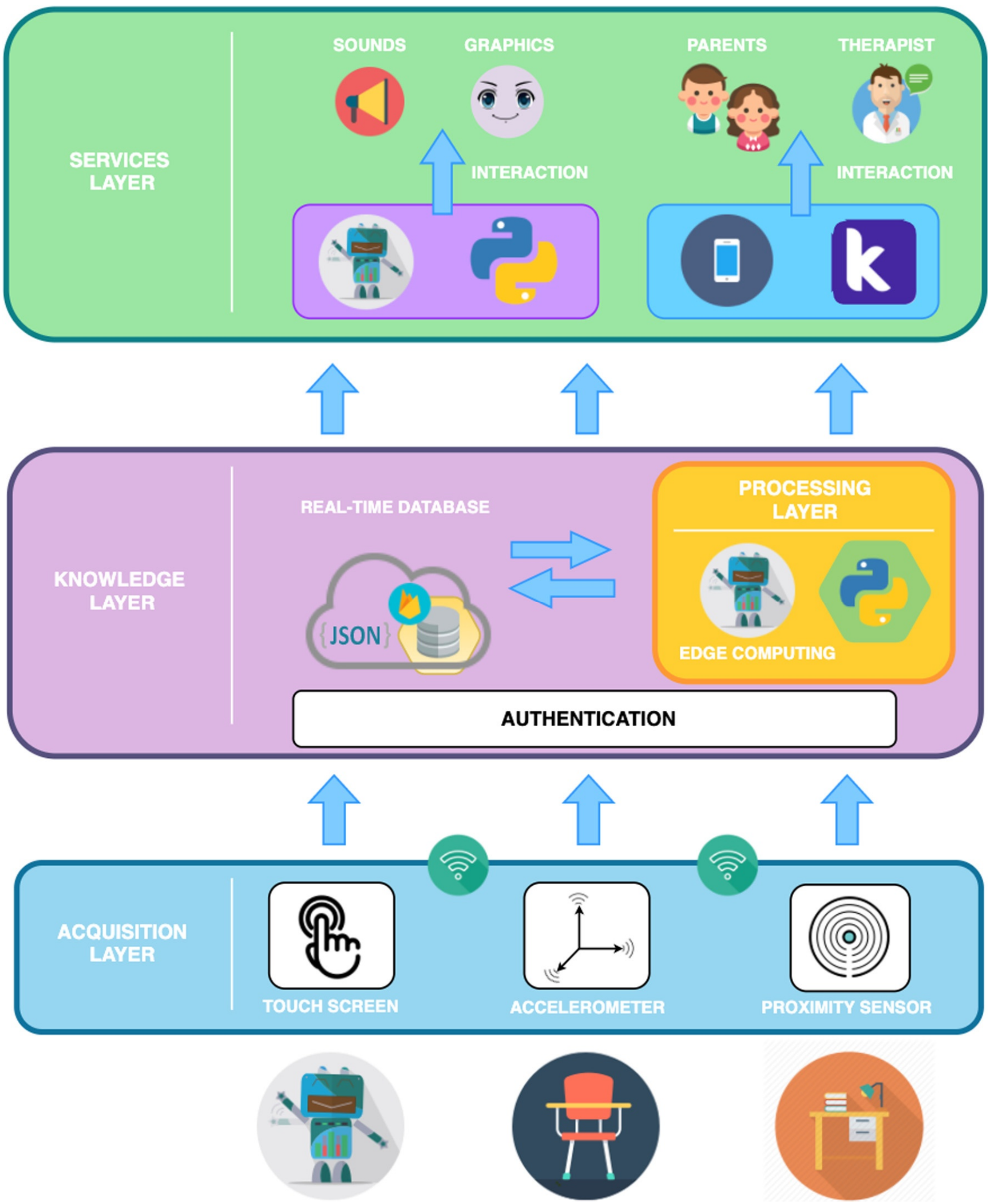

Fig. 3. The global architecture of the system taking the IoT layer model as a reference.

3.6 UIX

The user interface offers the child with ADHD a unique experience because as Atent@ can perform gestures while reproducing feedback sounds. In this way, the child associates Atent@ as an important member when doing homework.

These are the designs created to represent Atent@ (Fig. 4).

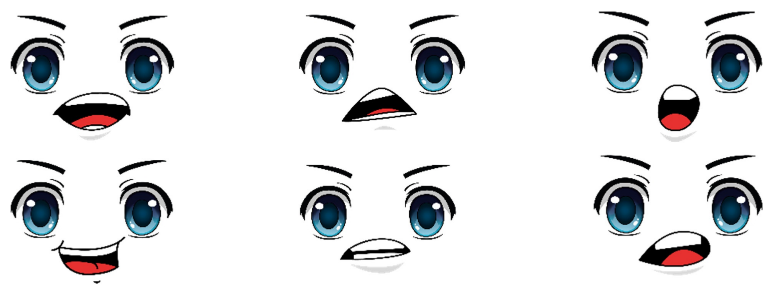

Fig. 4. Screenshots of some of the gestures that Atent@ can perform while interacting with children.

The user interface has several screens and options that give the child a more complete user interface experience. The child can indicate to the robot his state of mind before starting any activity. Additionally, the child can indicate whether to do homework, a relaxation activity, or consult his parents for help during any activity. If the child selects the task activity, a menu will be displayed to start new homework, continue with another one, or check pending tasks. Finally, the child can display a menu at any time to indicate if he needs help from his parents, drinks water, or use the bathroom.

Below are the graphical interfaces of the designs designed (Fig. 5).

Fig. 5. UI. a. Initial screen when the mood of the children is chosen. b. Screen for asking which activity the child wants to do. c. Screen with the homework menu. d. Screen menu with options between tasks.

In the homework scenario, Atent@ first prepares the child before starting any task. First, it reminds the child to check his schedule (Fig. 6 a) for pending tasks. In this way, the child will be able to mark on the next screen in which subjects he has pending tasks (Fig. 6 b). The next instruction recommends that the child prepares things to start (Fig. 6 c). Finally, Atent@ asks him if there is a need to go to the bathroom before starting the work session (Fig. 6 d). After this preparation, the child is ready to start (Fig. 6 e).

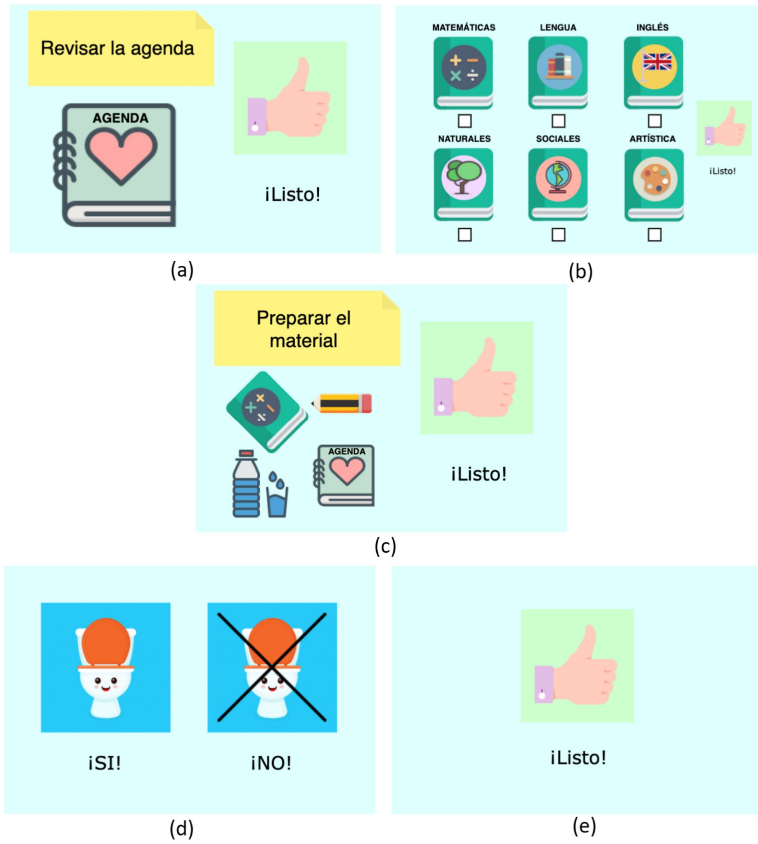

Fig. 6. Menus of preparation for carrying out tasks.

4 Implementation

The entire system is put into operation for functionality tests with a real 9-year-old child. Due to the health crisis, the functional test has been carried out in a child without ADHD but as he is the age required, it allows us to evaluate other aspects such as usability, the language used, etc. The intelligent things and Atent@ are located around the child's workspace. These devices need to be turned on to start acquiring information, then they automatically connect to the internet, process information, and interact with the child.

The following image shows the child using Atent@ and with the two intelligent things connected (Fig. 7).

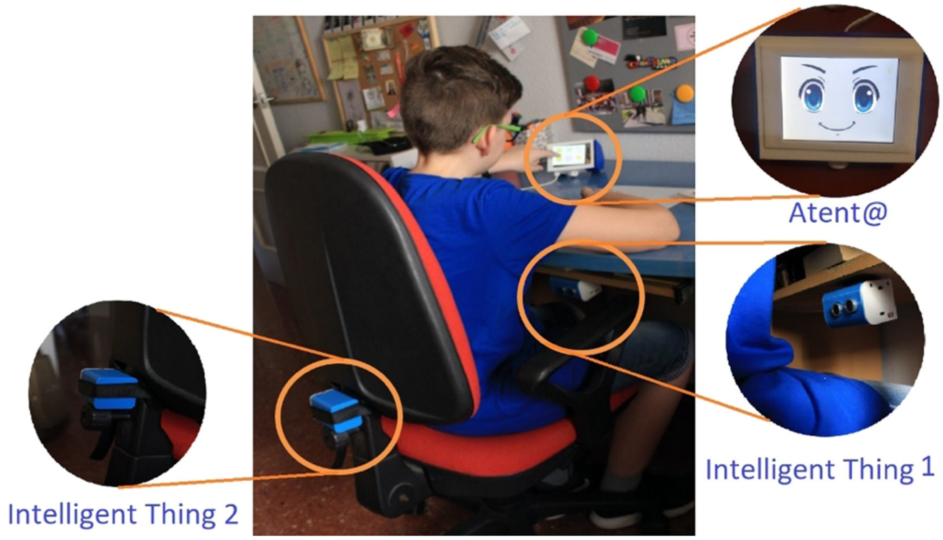

Fig. 7. Implementation of Atent@ and intelligent things in the child's workspace.

In the functional test, the child carried out a full cycle of homework with a total number of 2 tasks. The child was able to develop perfectly with the robot, he did not encounter usability problems and he found in Atent@ a clear and concise language with a pleasant voice. His final impression was that Atent@ had helped him to prepare well to carry out his duties and had guided him correctly. The parents and the therapist followed closely the steps that the child was taking while the performance of homework and verified the values collected by the system when the child performed his duties in an everyday place for him.

4.1 Monitoring Process

Intelligent Things are responsible for capturing information related to the child's movement. Thanks to this information and through Edge Computing in the Atent@ robot, we will obtain knowledge that allows us to determine different events. These events occur asynchronously in the program execution so that, if either is accomplished during homework, the normal program execution will be interrupted to provide the child with the necessary feedback. The following table of possible scenarios depending on the behavior performed by the child has been defined with the occupational therapist (Table 1).

All these events are gathered by the Realtime Database in Firebase. Following the flow of events, this information is updated constantly, allowing the robot to use this knowledge to provide feedback to the child during the homework sessions.

The following figure is a screenshot of the Realtime Database in Firebase (Fig. 8).

The Firebase Realtime Database is structured in four blocks:

– Activities: Shows the data of interest corresponding to the three main activities. Homework, going to the bathroom, and going to drink water.
– Intelligent Objects: Shows the data collected from the sensors under the chair and the desk.

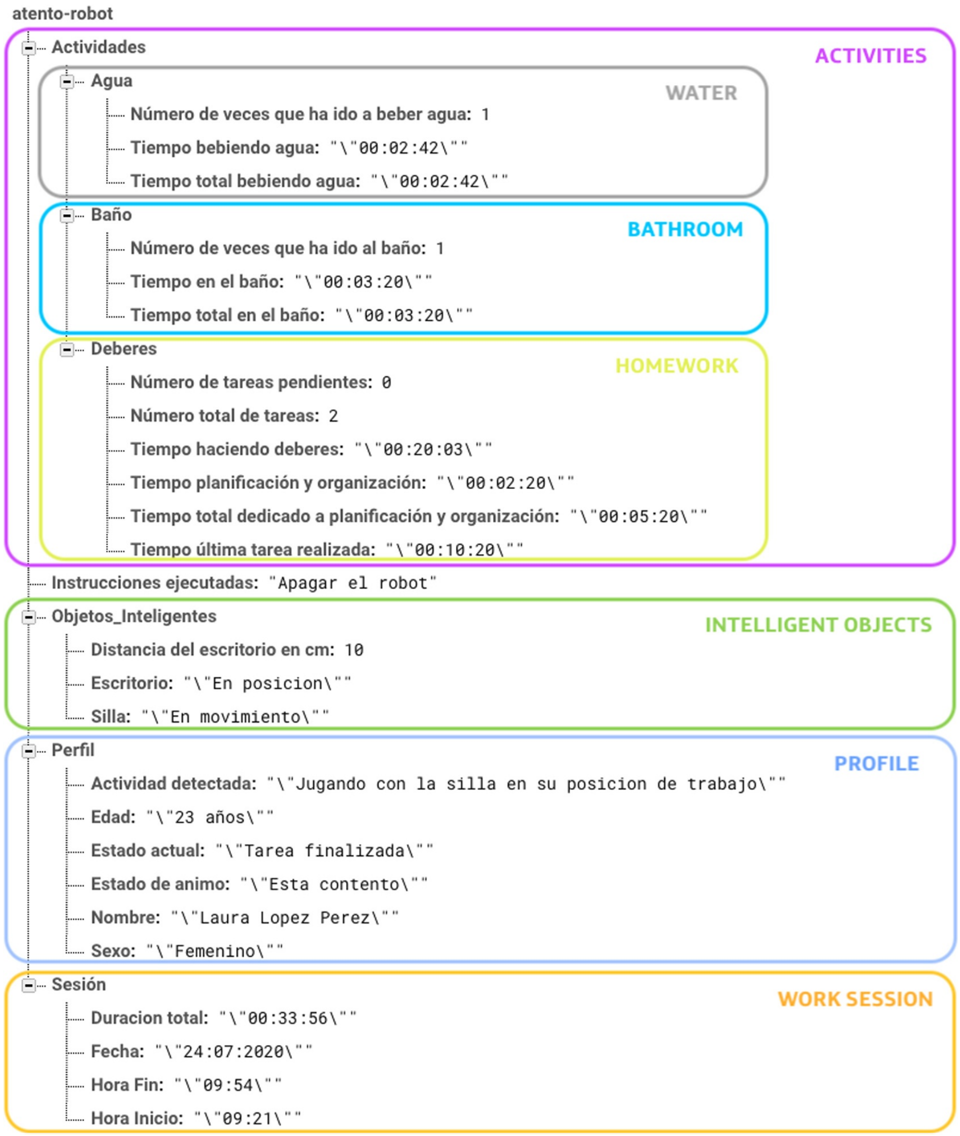

Fig. 8. Screenshot of the Realtime Database with all the information acquired by Atent@ and the Intelligent Things.

Table 1. Identification of events through Intelligent Things.

	Desk	Chair	Time	Knowledge
Events	In position	Without movement	<20 min	Doing the tasks
	In position	Without movement	>20 min	Need a break
	In position	With movement	<30 s	Getting into place
	In position	With movement	>30 s	Playing with the chair
	Move away	Without movement	>30 s	Gone away from the desk
	Move away	With movement	>30 s	Playing

– Child's profile: All the data related to the child's profile, name, age, mood, etc. are shown.
– Work session: Shows the information related to the session, start time, duration, etc.

The collected data is relevant to check the child's evolution and it is stored locally at the end of the work session in Excel. In this way, we managed to obtain a database that would serve for subsequent studies on the evolution of the child. The data corresponding to the work session is stored, as well as other data of interest, such as mood, duration times of the activities, etc. The local database's summary is shown below (Fig. 9).

Session				Activities								
Date	Start time	End time	Total time	Mood	Total number of tasks	Time planning and organization	Time doing homework	Number of times bathroom	Total time bathroom	Number of times water	Total time water

Fig. 9. Collected data organization to store the information of each homework session.

4.2 Mobile App

The developed mobile application allows access to the Firebase Realtime Database to observe the behavior of the child during the work session. Additionally, and only previously starting a new session, it is possible to consult the information collected in the previous sessions.

Below are the screens from each of the submenus of the mobile application (Fig. 10).

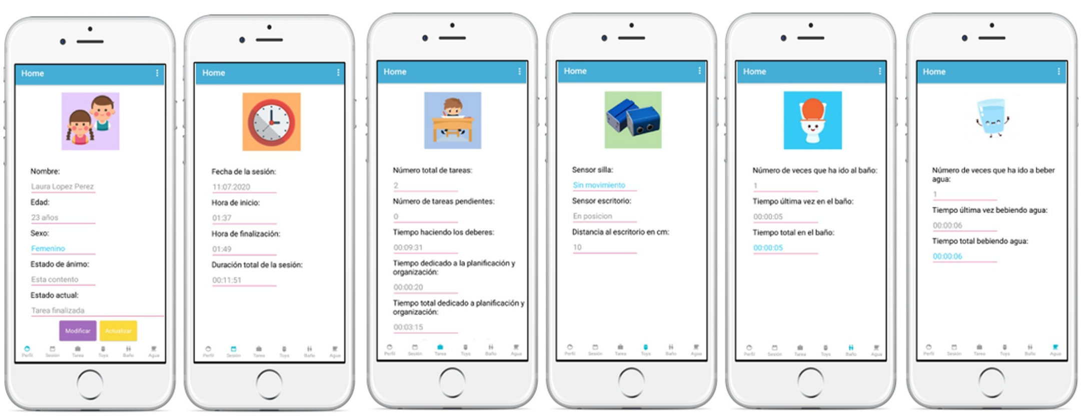

Fig. 10. The user interface of the developed mobile app for monitoring children with ADHD during a task session.

5 Results

This chapter summarizes the resulting system and systematically mentions the most significant tests that the system has been subjected to as well as showing the observed results. Firstly, a system has been designed and implemented for the Atent@ robot that accomplish the objectives set out in this project which helps children with ADHD to carry out their duties effectively. Besides, the data from the sensors have been collected to obtain knowledge: Whether the child is doing homework or, on the contrary, is being restless and distracted.

Secondly, a database has been created for the local storage of the data of interest collected by the sensors as well as a mobile application, which has been designed and implemented to display the data from the Firebase Realtime Database. This application was created for parents and therapists to track and monitor the child and his activities in real-time.

Regarding the tests carried out on the system, numerous performance tests have been carried out with different assumptions to verify that the system responds as expected. It has been verified that the developed system is a robust system that reacts correctly while being confronted with different scenarios.

As an example, the tests performed on the to-do button are presented:

- Assumption 1. Include the pending matters before starting the homework: The system stores the corresponding matters, showing them as pending matters by the time the homework has started. The assignment of the subjects by priority is done correctly (the trunks first).
- Assumption 2. Add pending matters after starting the homework. The system updates the number of pending tasks and the total number of tasks to be performed correctly. When changing tasks (Next task), the system takes into account the new subjects added and prioritizes the trunks correctly.
- Assumption 3. Add pending subjects after completion of homework: The behavior is the same as expected in assumption 1.

Regarding the performance and acceptance tests carried out, a test of the correct operation of the system has been carried out with a 9-year-old child.

6 Conclusions and Future Work Lines

The main objective of this project is to help children with ADHD with tools that allow them to organize themselves and plan correctly to carry out their duties. Also, provide parents and therapists with the information necessary to contribute to the treatment of children with ADHD.

The development of the intuitive and user-friendly interface with audiovisual variables has generated a unique user experience for the child where it shares the experience of performing homework efficiently with Atent@.

The mobile application serves as a source of information for parents and therapists, allowing them to see the information coming from the robot in real-time through their mobile phones. All the information from different sessions stored locally will serve as a study tool for proposals for updates on therapies with children with ADHD.

As future work lines are proposed:

– Optimizing the application to improve its efficiency as well as including new functionalities.
– Including Bluetooth technology in intelligent things.
– Developing an intelligent thing to interpret movement and gestures' meaning.
– Developing push notifications in the mobile application.

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Creation of an Intelligent System to Support the Therapy Process in Children with ADHD

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Abstract. This article is a proposal for an intelligent system that facilitates the therapy process for children with Attention Deficit Hyperactivity Disorder - ADHD. This project focuses on the analysis, design, and implementation of an intelligent architecture, which uses machine learning techniques for a therapeutic robot to help develop new tests and other resources to support the treatment of ADHD. Its general purpose is to identify common patterns in the behavior of children with ADHD, between 6 and 9 years old during the performance of homework to help the therapist diagnose and predict the future behavior of children in this area. A system has been proposed whose development and implementation is carried out by a cloud computing platform, taking advantage of all its benefits such as low latency, unlimited storage, functionalities to deploy a project based on artificial intelligence and data security. Therefore, using these functionalities from the platform, a machine learning model has been deployed. This model is a binary classification since it groups the results according to the diagnosis (ADHD or not ADHD). However, what this model provides are the rules that compare the data obtained from the robot's sensors to the set of results expected to be obtained (ADHD or not ADHD). To obtain these rules, an algorithm already developed by this platform and a set of data will be used. This first part is known as model training, in which the model has been built. Once the rules are obtained, another set of data will be used for testing. In this second part, the model will be able to identify whether the new data entered matches the criteria of a child with ADHD or with a typical development. The data processing is carried out from the cloud platform, offering data availability and accessibility at all times. The results of the correlation between the obtained data and the predicted diagnosis showed remarkable results.

Keywords: Machine learning · Automatic learning · Artificial intelligence · Cloud computing · IoT · ADHD

1 Introduction

One of the most common disorders which are diagnosed today in children and adults is attention deficit hyperactivity disorder (ADHD). As its name indicates, the symptoms

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that characterize this disorder are attentional difficulty, impulsiveness and motor agitation, as well as hyperactivity. This disorder affects more than 5% of children in the world and 6% of children in Spain, between 6 and 17 years of age [1]. Some of the symptoms usually appear before the age of 12 and have a significant impact on the person, causing them to progressively deteriorate their performance [2].

Children with ADHD tend to underperform academically and also interfere in the family and social environment [3]. Sometimes they present difficulties in understanding instructions from their parents or teachers and stand out for being impulsive in the organization: they are not able to properly control time, they do not know how to organize tasks and they tend to live in a disorderly environment [4]. This in turn leads to a low mood, which can cause anxiety, stress, and frustration in most cases.

However, early diagnosis and adequate treatment for each case have shown a positive evolution of the disorder, which is the main motivation behind this project. Detection and diagnosis consist of carrying out a series of normative tests following the criteria set out in the Diagnostic and Statistical Manual Of Mental Disorders (DSM-V) [2]. Usually, the treatments are done in a therapeutic center which the child must visit regularly. Here the child learns to adequately carry out activities of daily life: eating, sleeping, doing her homework, etc. In this way, the therapist monitors the evolution of improving the performance of these activities.

The fact that the child has to go to a medical center for regular follow-up means that the treatment is not completely effective as it is not being implemented in the child's natural environment. Moving the therapy to their home would detach the treatment from a specific place and time. The environment in which the treatment is carried out must be strategic and plays a very important role in the therapy. Another additional benefit of performing therapy at home is being able to involve the family in it.

An alarming problem is the lack of knowledge of the average citizen about this disorder. In addition to that, there are not yet complete and entirely effective therapies which help to improve different cases and differentiate them from other disorders. A misdiagnosis makes the child responsible for its behavior which in turn seriously affects its consciousness by e.g. creating negative situations, which can even further harm the stability of children, making even every day or ordinary situations stressful.

2 Background

With the digital transformation and the evolution of information and communication technologies (ICT), which our society is experiencing, new techniques and technologies are being incorporated, which provide optimization and automation of the different processes that surround us. Robots that help with different treatments have been developed and incorporated in the academic and therapeutic sectors. Some examples we have based our research on are:

- A robot for therapy of children with autism spectrum disorder called Aisoy, which provides a breakthrough in therapy and can be used both at home and at school. It allows autistic children to relate differently: The robot, who can behave like the child, interacts with the child, recognizes it, communicates with the child, and helps to develop the children's intellectual abilities [5].

– An Expert system is based on signal processing techniques and deep learning that allows the detection of ADHD from the data of day and night activity of school-age patients. This project uses artificial intelligence techniques to identify and classify the data corresponding to ADHD patients [6].
– A lego robot developed to carry out neuropsychological evaluations that allow the detection and diagnosis of neurological and motor diseases in children between 6 and 12 years old. During its development, the robot was put into practice with boys and girls with ADHD. This project seeks the child's planning capacity through interactive playing scenarios [7].
– A web application that allows the monitoring of behavior in boys and girls with ADHD so that parents and therapists can better understand them [8].

Therefore, in the case of assistant robots that assist in the therapy of children with ADHD, there is very little research. Robots for diagnosis and treatment of children with autism spectrum disorder predominate. Therefore, to complement and improve the robots that are already developed, it has been decided to develop a proposal for an intelligent system for a robot assistant called Atent@ which helps children with ADHD to carry out their school tasks at home [9] (Fig. 1).

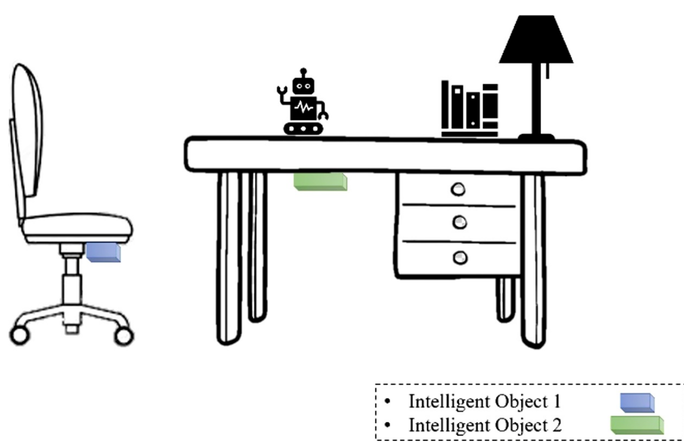

Fig. 1. Atent@'s workspace with its elements.

For this project, the data and information of the child will be collected, which we will use to develop the architecture to be deployed in the environment in which the assistant robot is to be used. Among its parts is the development of a system that, using Knowledge Engineering and Artificial Intelligence techniques, can provide intelligence to the robot which is based on the information collected. To carry out the entire deployment, a cloud computing platform is used to the resources and capacity necessary for the development. This platform will store the data and carry out the tests and steps necessary to deploy a first model based on which the system will be developed. This model is created from an algorithm based on machine learning. For the preparation and visualization of the data, the help of an occupational therapist has been required, who has pointed out the main characteristics of the database, as well as their visualization model. This data is used to make a therapeutic evaluation.

3 Methodology

In this project, an intelligent system is designed which performs all the functionalities related to data storage, treatment, and processing from a cloud platform, using artificial intelligence techniques (machine learning). Therefore, this project must meet the following specifications:

– The environment and the data that have been evaluated and analyzed for the development of this project is for children aged between 6 and 9 years.
– The data and results in the final report must be presented according to the needs of the occupational therapist or the child's guardians. Besides, the report is subject to modification at the request of users.
– The information displayed must be optimized and synthesized to clearly show the behavior of children.
– When selecting the cloud platform, we must consider the different restrictions that each one poses, taking into account the times of latency, the storage capacity, and its architecture. It is also important to consider the different functionalities that exist in each one and the compatibility with the rest of the applications and software used for the development of the project.
– Almost all platforms allow pay-per-use and many of them offer a trial period, making it easy to check whether they are suitable for the specific project.
– Code development platforms are freely distributed.
– When having multiple data sources (the robot and the smart objects), a combination of these should be made to consider all the possible options for information collection.
– The data, both input and output must be gathered.
– The algorithm developed must consider the processing of the data to solve possible writing errors that may exist.
– Security mechanisms must be applied to guarantee the confidentiality of the data.
– The evaluation of all these restrictions is recommended to guarantee the proper development and implementation of the project.

3.1 Proposed System

The objective of this project is to provide Atent@ with the necessary functionalities for the processing, integration, and representation of the data obtained by the sensors and the rest of the hardware that comprise it. The processed data will create relevant knowledge for the treatment and diagnosis of ADHD. Therefore, the main objective is to develop a model based on automatic learning that allows us to identify the behavior patterns that a child with ADHD presents when carrying out her school tasks. First, a set of data is obtained from the robot that will be analyzed and describe the behavior the child has had at the time of performing the duties. This data will be stored in a cloud platform for subsequent analysis.

Using machine learning (ML) techniques, the data is being processed (in case there are possible failures in the previous extraction of these). Second, the data will be used to create a first predictive model and, with another set of data extracted, an evaluation will be made. This evaluation provides information about which patterns are presented by children with ADHD and which ones are typically developed by children when doing homework (Fig. 2).

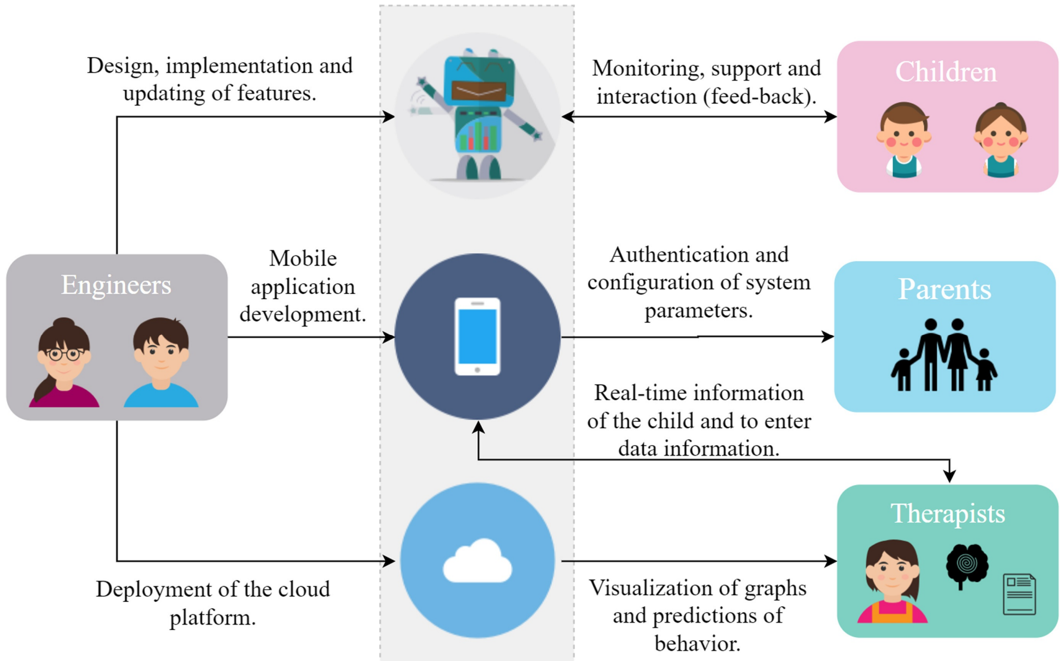

Fig. 2. The proposed system with the participants and the interaction among them.

The diagnosis of children with ADHD consists of objective observation of the behavior to determine what symptoms occur and how often. Our use case is to develop a system that identifies if the child has ADHD. The data correspond to children between 6 and 9 years old with a diagnosis of ADHD and without ADHD. Comparison and diagnosis with other treatments are outside the scope of this project and therefore not furtherly considered. To define our use case, the intervention of an occupational therapist was necessary to contrast our proposal and define the user's requirements.

To carry out this project, its development has been divided into five phases. These phases coincide with those necessary to create a machine learning model, in which it is necessary to: (1) explore and prepare the data, (2) training and model execution, (3) model evaluation, (4) obtaining predictions, and (5) visualizing the results.

3.2 Exploration and Data Treatment

Many ADHD diagnoses apply a protocol for observing impulsivity, attention, and mobility, which is based on the frequency register of Barkley (1990). This measures the frequency of behaviors considered relevant to the diagnosis during 15 min and at 15-s intervals [4]. For this reason, we have estimated times of no more than 15 min between tasks. This will not pose any problem since the objective will be to obtain an algorithm that, by employing and using the children's data, either theoretical or experimental, is capable of making predictions and inferences. The data that will be used to achieve our model is divided into data for training, validation, and testing. All these data sets are structured in the same number of characteristics, except for the "ADHD Diagnosis" characteristic that only appears in the training data set. Each data set shows different values from the rest of the sets. The training methods are used to obtain the parameters of the learning model. The data values will have to be modified until an adequate learning model is achieved. Once achieved, the evaluation is performed with the validation data set. Finally, test data is used when the algorithm and model are fully accomplished. Therefore, the first step is to create the database.

Table 1. Acquired information by the algorithm to process new knowledge.

Information	Value or range
Identifier	Unique for each child
Date of the session	Between May to June 2020
Sex	Woman (M) and Male (H)
Age	Between 6 and 8 years old
Academic course	2019/2020
Language subject score	Between 0 to 10 score
Math subject score	Between 0 to 10 score
English subject score	Between 0 to 10 score
Mood	Sick, Unmotivated, Tired, Happy, Excited
Total session time (sum of start time and total time to perform homework)	Between 20 and 93 min
Start time (introduction and adaptation to the robot)	Between 5 and 10 min
Total time to perform homework (is the sum of total task time, total organization time, rest time, the time it takes to go to the bathroom before starting, water time, distracted time)	Between 15 and 83 min
Total task time (sum of task 1 and task 2 times)	Between 10 and 50 min
Total organization time (sum of task 1 and task 2 organizational times)	Between 5 and 15 min
Time to perform task 1 (considering bathroom distractions 1)	Between 5 and 25 min
Time to do only task 1 (without distractions)	Between 5 and 20 min
Time to organize task 1	Between 4 and 10 min
Time to perform task 2 (considering bathroom distractions 2)	Between 5 and 25 min

(*continued*)

Table 1. (*continued*)

Time to do only task 2 (without distractions)	Between 5 and 20 min
Time to organize task 2	Between 1 and 5 min
Rest	Between 0 and 5 min
Total bath time throughout the session	Between 0 and 15 min
Total bath time before starting tasks	Between 0 and 5 min
Bath time during the first task	Between 0 and 5 min
Bath time during the second task	Between 0 and 5 min
Time to go for water	Between 0 and 3 min
Total distracted time (sum of time distracted, time to go for water, bath time 1 and bath time 2)	Between 0 and 15 min
Distracted time	Between 0 and 5 min
Strong movements detected	True or False
Number of times that the child got up from the chair	Between 0 and 10 times
Number of clicks of the help button	Between 0 and 3 times.
ADHD diagnosis	True or False

All these features are subject to those that have been established in the Firebase application. In these characteristics, the values detected by the application are stored, as well as the ones detected by the sensors from the robot and intelligent objects. From Firebase only the characteristics that are most useful to predict the ML model are being selected, followed by defining the most important characteristics. As shown in Table 1, a child can take between 20 and 93 min to carry out the session with the robot assistant. This time depends on factors such as mood and whether it has been diagnosed with ADHD or not. Starting with this basis, a database with a dimension of 32 characteristics is created, of which some will be more decisive than others when making the diagnosis prediction. Table 2 shows the characteristics that are going to be most important as well as how they are being weighted. The established value has been agreed upon in knowledge acquisition meetings held with an occupational therapist. This database analysis process is called Characteristics Engineering. The characteristics that will be decisive in observing if the child exhibits a behavior similar to that which it would have if it had ADHD are, above all, the number of times it would rise from the chair and if sudden movements were detected during the session.

A theoretical database has been created, where information has been selected for 526 boys and girls with ADHD and 520 boys and girls with typical development.

Another set of data has also been made in which four cases are compared:

– Evolution of a girl with ADHD using the robot for two weeks.
– Evolution of a girl without ADHD using the robot for two weeks.

Table 2. Information weighting.

Data	Weighting	Order of importance
Number of times that he has got up from the chair	17%	1
Strong movements detected	16%	1
Total organization time	15%	2
Time while being distracted time	15%	2
Total bath time throughout the session	10%	3
Time to go for water	10%	3
Number of clicks of the help button	10%	3
Rest time	7%	4

– Evolution of a boy with ADHD using the robot for two weeks.
– Evolution of a boy without ADHD using the robot for two weeks.

The training is carried out in a first step with the first set of data, which is a total of 1046 boys and girls who carry out the session for one day. This first step will serve to classify the values between children with ADHD or children with typical development. In this first database, the "ADHD Diagnosis" feature is present. This data is stored in the Google Cloud Platform (GCP) BigQuery. From here the data exploration is carried out. This test is done with synthetic data. In a second phase, it will be using the data from the Firebase real-time database, using the information collected by the Atent@ project in real-time.

In Fig. 3, we see these differences. Figure 3a shows children diagnosed with ADHD rise more times from the seat during the session, with an average of approximately 8 times. In contrast, children with typical development get up an average of 3.2 times. Figure 3b shows information about the time it takes to organize both the desktop and the tasks during the session. Times are measured in minutes. ADHD children take an average of 12.6 min while normally developed children take approximately 6.9 min. In Fig. 3c, we see the relationship between the time spent distracted during the session and the number of sudden movements that have been detected. As expected, the more movements detected, the greater the distraction time.

Furthermore, Fig. 3d shows that children with ADHD are more likely to spend more time distracted, with an average of approximately 12.1 min. On the other hand, children with typical development are distracted an average of 5 min during the session. Therefore, we see that the more time a child spends distracted, the more likely it is that they have ADHD. It can be seen that the more time distracted is spent, the more likely it is to observe sudden movements, indicating it is more likely to have ADHD.

This theoretical data has been modified to obtain a curve that shows the possible improvement in the total time to carry out the session, which these children can have while using the assistant robot. In Fig. 4, the images corresponding to identifiers a and c refer to a boy with ADHD and a girl with ADHD, respectively. In contrast, b and d refer to a boy and a girl with typical development, respectively. All four children are the same

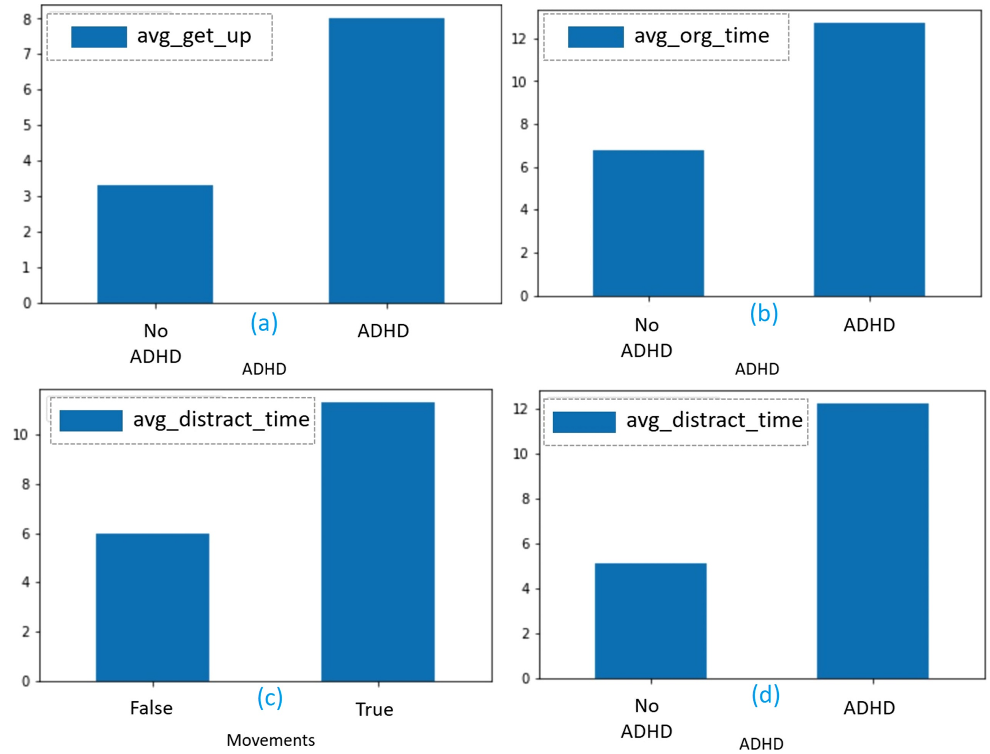

Fig. 3. Training results with theoretical data.

age, and all graphs collect data from sessions conducted over 10 business days. As we can see, children who have a typical development, Fig. 4b and d, present an evolution curve with more abrupt decreases and whose maximum does not exceed 66 min, which refers to the total time that the session lasted. This indicates that the longer they are working with the robot, the better their results will be, and the better (shorter) the duration of homework.

In contrast, children with ADHD, Figs. 4a and c, show graphs whose time difference between days is not relevant. In the case of the child with ADHD, Fig. 4a, the total time difference is not very high and varies between 60 and 72 min, maintaining an almost constant line during the last five sessions. In the case of the girl with ADHD, Fig. 4c, the times vary between 56 and 70 min, with the shortest times occurring on the last days of working with the robot. All these times may depend on other factors such as the child's mood.

3.3 Data Exploration with AutoML

From the new AutoML Tables tool offered by GCP, a complete machine learning model can be prepared in which future predictions are obtained from past data. AutoML requires that there be at least 1,000 rows in the dataset and that each class has at least 100 rows. In our case it is a binary classification problem, the prediction will have to classify a set of values in a given category. As previously indicated, there will be 526 data rows from one class (ADHD) and 520 data rows from the other (not ADHD). For this project, 32

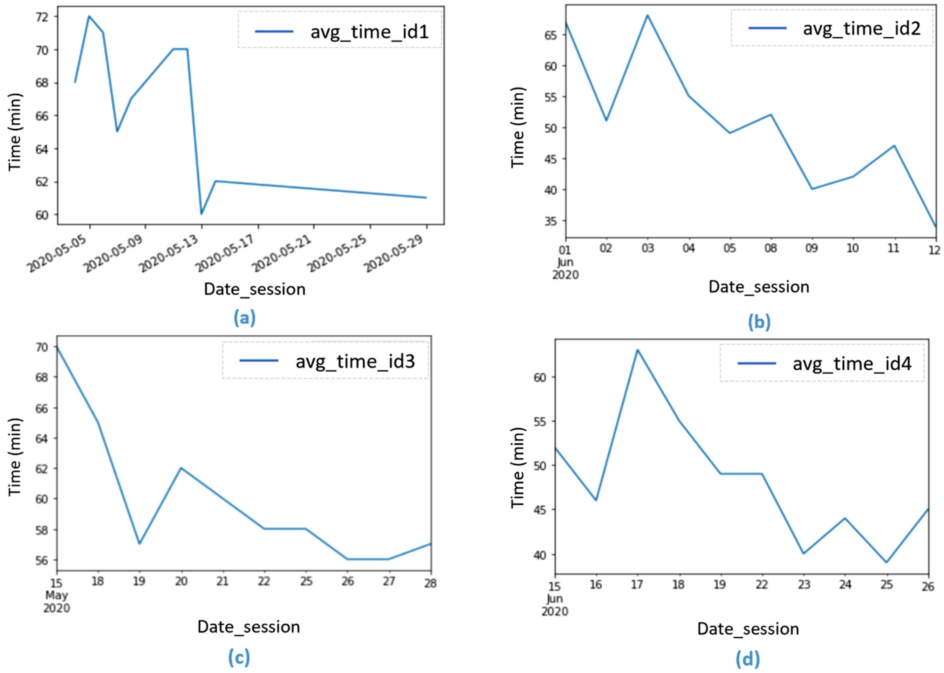

Fig. 4. Predictions about the evolution of the treatment.

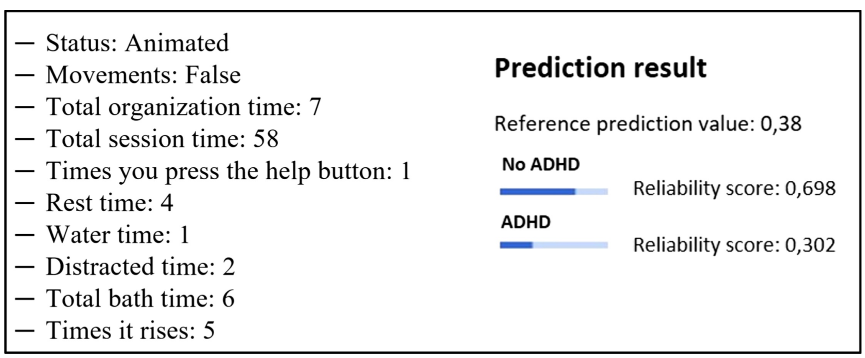

Fig. 5. The first prediction of the reliability of ADHD according to the entered data.

attributes have been considered. Therefore, enough rows are generated to guarantee a good implementation of the model.

To carry out feature engineering, the data is classified according to its typology: numerical, categorical, or timestamp. Also, the data is purged, indicating whether null values are supported. On the other hand, is a binary classification model. The column "ADHD" has been selected as the objective column so that AutoML assigns the training data with the prediction that is sought. After feature engineering is done, AutoML will segment the dataset into three partitions: a training dataset (80% of the total), a validation set (10%), and another test set (10%).

3.4 ML Model Training

When starting the training, the application asks us to enter a training budget. This refers to the number of hours it takes for training. In this project, as there are less than 100,000 rows in the database, the budget is a value between 1 and 3 h. Another piece of information to indicate is the metric with which we want the ML algorithm to optimize the model. In the case of this project, the optimization objective can be achieved with the parameter receiver operating characteristic (ROC) curve, which is why the option "Area below the receiver operating characteristic curve" has been selected, which will allow the distinguishment of the classes.

All columns except those that can filter target information have been selected. The attributes that have been considered coincide with the attributes that are related to the relevant characteristics. Those attributes are movements, total_time_organization, help_button, rest, time_water, time_distracted, total_time_ban, times_lift. Additionally, we have added status and total_session_time attributes. However, in each training, a different weight will be given to each attribute. After all these parameters have been established, training begins. The training that we have carried out did not take more than an hour. The result of the training is shown in the "Models" tab of AutoML. The first model created with the theoretical dataset, imported from BigQuery, gives a perfect result, which will be analyzed in detail in the Results chapter.

3.5 ML Model Analysis

The post-training step is evaluation. AutoML also provides functionalities to achieve this. For the evaluation, the data segment that has been created with 10% of the total base will be used. With this segment, comparing it with the training data segment, the evaluation is performed. The process will be done automatically so that when we enter the tab "Evaluate" we will see the results. The evaluation will be in charge of measuring the precision, performance, and quality of the created model [10].

- The area below the ROC curve. It is a value between 0 and 1.
- The area below the Precision-Recall (PR) curve. It is a value between 0 and 1.
- Accuracy. It measures the total number of correct predictions that have been made.
- Logarithmic loss. This refers to the entropy that has been entered into the model. It is a value between zero and infinity. The lower, the better the performance.
- True positive rate. Refers to the number of correct predictions.
- False-positive rate. This refers to the number of predictions that have been classified into a class but do not belong to it.

Other metrics offered by AutoML for model evaluation are the confusion matrix and the graph with the attributes ordered from highest to lowest importance. The more impact the attribute has on prediction, the greater is the importance. This weight changes with each workout.

3.6 Predictions

On the other hand, the AutoML tool offers the necessary functionalities to test and analyze a model. For this, it is necessary to implement the model and thus be able to perform the online prediction functionality. These online predictions consist of entering a data line with the attributes that we specify manually, obtaining the expected diagnostic result for that child with the corresponding data. Deploying a model also consumes node time and can take up to half an hour. It is important that when the appropriate predictions with the model finish, the deployment is being stopped as well to not invoice more time than used.

In the case of Fig. 6, several values have been entered for which the model has given a probability of 0.722 that the child does not have ADHD, as well as a probability of 0.278 that it has ADHD. Furthermore, for the analysis of the prediction, a percentage of importance has been generated for each characteristic. What should be attempted is that these percentages match the theoretical importance that we have established. In the Results chapter, we will evaluate and analyze the different models that we have trained and developed.

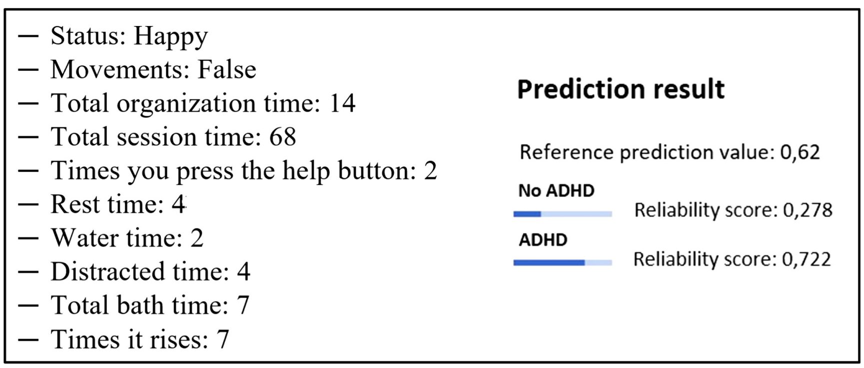

Fig. 6. A second prediction of the reliability of ADHD according to the entered data.

4 Results

This chapter describes the results obtained in the different training tests that have been carried out until obtaining the most suitable model. Based on the Google Cloud Platform, a machine learning model has been developed to detect which pattern children with ADHD meet. The results that have been obtained in the training sessions have always been in perfect alignment with the correct answers and the diagnostic correspondence to the data. This is because the database used corresponds to synthetic data. This data was obtained based on studies and averages of duration times, being agreed on by a therapist. The algorithm associates the values to a certain pattern, always showing a 100% success. When real data is available, we will only have to feed our algorithm with this data and run the model to observe the behavior obtained. The first model has been created with the ROC curve precision assessment tool. The result of the area below the curve is 1, which implies that the precision is 100%, without errors, with a perfect assignment of values by the model. The training we have carried out has a preparation cost of no more than 0.98 node hours.

The more attributes we introduce to train a model, the higher will be the precision and the greater the probability of success will be made by the prediction. We could consider this as a favorable and even perfect result. However, when we have real results, many of them will likely introduce errors because they are null or incorrect, causing the prediction probability to decrease. To make predictions online, this model is displayed and the data we want to carry out the tests with is entered. The following data has been entered:

With this data (Fig. 5), it is expected that the result obtained will classify the child as a child with typical development since the times are low and no sudden movements have been detected. The prediction that is obtained is the expected one. With a probability of 0.698, the child will be classified without ADHD, and with a probability of 0.302, it will be classified with ADHD. If we make another prediction, but with higher time data and without sudden movements, we should expect a result that classifies it as ADHD, since high organization and distraction times should be associated with the diagnosis of ADHD. The data that has been entered is:

With this data, a prediction is obtained that gives a higher score to the classification with ADHD. Furthermore, each of the attributes can be assigned more important when making the prediction. In this case, the important changes concerning the training and greater importance are given to the value of total organization time and the number of times the child rose. The weights refer to the loss of scores who have lost those characteristics concerning the score that was established during training. This last model is more favorable, since, with fewer characteristics to evaluate, it offers more realistic diagnostic identification results. It is always important that the other option, in which the entered data, has not been classified as a score greater than 0.099, because if not, we would not be considering the possible exceptions that occur in children. For example, a child who makes sudden movements but takes a short time to get organized does not have ADHD. The model must take this into account, even if higher scores are still associated with ADHD.

— Status: Happy
— Movements: True
— Total organization time: 5
— Total session time: 48
— Times you press the help button: 1
— Rest time: 4
— Water time: 1
— Distracted time: 5
— Total bath time: 6
— Times it rises: 8

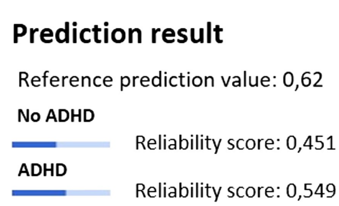

Fig. 7. Third prediction of the reliability of ADHD according to the entered data

The value with the highest weight has been the number of times it is raised, (0.158). The weighting for the attributes of detected movements and organization time was −0.001 and −0.167, respectively (Fig. 7).

5 Conclusions

The development of this project shows us an algorithm to identify characteristic patterns that children diagnosed with ADHD present at the time of carrying out their school activities. The information generated will serve the therapist as an additional normative test. The information provided indicates how the child reacts and influences the child at the same time to behave in a certain way. Also, it offers the advantage of motivating the child when studying. This way long-term positive results are being assumed since the child will acquire an order and an affinity to do homework.

To achieve this, it is necessary to deploy an intelligent architecture in the robot, allowing the therapist and the parents to observe and receive reports about the child's behavior. From GCP any model can be deployed, without limitations in storage or capacity. The machine learning mechanism has been selected using a binary classification to display the model. Therefore, from the platform, a model has been created, developed, and trained from an algorithm that is already implemented in the platform itself. It is only necessary to include the data and the weight indications of the attributes of the database. The rest oversees the platform.

The results that have been obtained differ from reality. Having used data based on theoretical studies and not on practical tests of the robot with a child, the results obtained are almost perfect, differing only in logistical loss.

However, by using fewer attributes in training and its subsequent prediction, it has been proven that results are more consistent with reality since they can consider more cases. This results from percentages of probabilities greater than 10% (0.1) to each of the classes that have been associated. Despite the results, the system meets the stated objectives.

For the development of the evolution curves of the different children, it would be advisable to use the robot for a month (20 business days), to obtain more random data and to predict behavior. Therefore, it has been verified that more amounts of data would be needed, and, above all, it must be data obtained from children while using the robot (Atent@), real-time data. Also, this project will help conduct future research in the diagnosis of ADHD.

In general, the IoT is gaining more presence in many areas of our lives. However, as the IoT evolves, it is necessary to simultaneously improve and implement security in the different devices that make up this technology. This project manages large amounts of data, which must be protected with the different existing mechanisms to avoid possible cyberattacks. Whenever the amount of data that a device manages is increased, we will increase the vulnerability to suffering a cyber-attack. The vulnerability is present before exporting data to the cloud platform.

That is why one of the future jobs, and which is essential for this robot, would be the implementation of a security system that encrypts the data and manages it securely before entering it on the cloud platform. It may also be interesting to create a visual web interface that shows and collects all the information from all the sessions, with graphs of the evolution of the diagnosis. This interface must be interactive and comprehensive for the therapist.

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Capítulo 5

Discusión y Conclusiones

5.1 Contribuciones presentadas en esta tesis doctoral

El acceso a procesos de terapia pervasiva en el entorno natural de niños diagnosticados de TDAH se presenta como una cuestión compleja que implica relacionar conocimientos de los síntomas del trastorno, la capacidad de observarlos adecuadamente y su extrapolación a un contexto específico. La solución presentada en esta tesis doctoral facilita a los terapeutas trasladar el proceso de terapia que realizan en entornos clínicos al hogar del niño, de una forma correctamente dirigida y sin convertirlo en un entorno tecnológico poco natural.

Esta tesis doctoral ha contado con la colaboración de profesionales en terapia ocupacional, educación e ingeniería. A nivel tecnológico, se han combinado los principios del IoT con la Robótica para desarrollar y validar una primera aproximación de un servicio que ayuda a mejorar los procesos de terapia en niños con TDAH dentro del hogar.

Desde el punto de vista técnico, la metodología iterativa aplicada en el desarrollo de este trabajo permitió la mejora continua de la solución propuesta, ya que después de analizar los resultados de las pruebas específicas y de los experimentos, se modificaba la conceptualización y formalización de la solución. Sin embargo, todas las versiones implementadas tuvieron resultados que se consideraron positivos y alineados con las hipótesis de esta tesis.

La posibilidad de obtener información sobre el comportamiento del niño durante múltiples sesiones puede ayudar al terapeuta a proponer nuevas terapias o incluso a mejorar los tratamientos tradicionales no farmacológicos. Sin embargo, todavía hay algunos parámetros que este entorno no es capaz de medir. Por ejemplo, la información que actualmente sólo puede obtener la educadora, como los sonidos (a modo de distracción) o una indicación precisa y directa de un cambio repentino del estado de ánimo del niño durante la realización de los deberes.

Las contribuciones de esta tesis doctoral están alineadas con la definición de sus objetivos y el planteamiento de las hipótesis de trabajo.

La aplicación de tecnologías a la terapia de niños con TDAH es algo común en la literatura científica. Incluso es posible encontrar trabajos específicos con asistentes robóticos y, en menor medida, con tecnologías IoT. Sin embargo, no se han encontrado aproximaciones similares a las tratadas en esta tesis doctoral y que estén relacionadas con el concepto de terapia pervasiva como una extensión de la terapia tradicional.

Esta tesis doctoral presenta las siguientes contribuciones al ámbito de conocimiento:

- La propuesta tecnológica para el complemento a la terapia tradicional en el entorno natural del niño. Los desarrollos tecnológicos están pensados para ser controlados por los terapeutas y alinearse con otro tipo de acciones terapéuticas más ortodoxas. No están diseñados para ser utilizados sin la supervisión de terapeutas, aunque el uso por parte del niño pueda ser completamente autónomo.
- El uso de actividades como elemento fundamental de diseño tecnológico. Las actividades son ampliamente usadas en varias aproximaciones terapéuticas clásicas. Esta tesis muestra el proceso de formalización de actividades para facilitar su integración con la tecnología y mantener la significancia clínica. Para ello se ha realizado un proceso de transformación de los aspectos observados por los terapeutas en medidas cuantificables.
- Propuesta de una solución tecnológicamente interdisciplinar. La propuesta tecnológica es original dentro del ámbito de la terapia en la que no es común el despliegue de distintos elementos basados en aproximaciones tecnológicas diferentes como IoT y robótica asistencial.

Esta tesis también presenta contribuciones relevantes a nivel tecnológico:

- Tras llevar a cabo un estudio del proceso tradicional de terapia al que tienen acceso estos niños, ha sido posible proporcionar un diseño que cubre con la funcionalidad requerida del asistente robótico Atent@. En su solución, se llevaron a cabo distintas versiones de Atent@ empleando en todos ellos materiales de bajo coste. Con esto se demuestra que es posible crear soluciones ergonómicas y adaptables a un entorno natural. El diseño ergonómico de Atent@ permite extender más funcionalidades y características como juegos, imágenes, secuencias de movimiento, voces, expresiones faciales, etc. Esto hace que Atent@ pueda tener diversos escenarios de aplicación, de utilidad terapéutica muy novedosa, que se puede extrapolar a otras patologías o trastornos de niños o adultos, en los que sea necesario proporcionar un sistema de acompañamiento atractivo.

- Los objetos inteligentes de bajo coste que se han desarrollado, como cualquier dispositivo actual conectado a internet, ofrecen funcionalidades específicas de gran valor para el escenario propuesto. Estos objetos inteligentes podrían ser equipados con más sensores en su interior, proporcionando más información sobre el comportamiento del niño con respecto al objeto. O incluso, sería posible que se desarrollasen más objetos inteligentes para unirlos a otros objetos (como bolígrafos, almohadas, etc.), que nos permitieran obtener aún más información en otros escenarios.

5.2 Validación de hipótesis

Además de las contribuciones descritas, en la tesis se han validado las hipótesis de trabajo.

Hipótesis 1: Una solución tecnológica que combine los principios de la robótica asistencial con el IoT, permite proporcionar un servicio sociosanitario capaz de mejorar el rendimiento ocupacional independiente en niños con TDAH en su entorno natural.

Esta tesis ha creado una solución tecnológica que combina los principios de la robótica con el IoT y es capaz de proporcionar un servicio que ayuda a mejorar el rendimiento ocupacional independiente en niños con TDAH en el hogar. Los resultados obtenidos en el segundo experimento plasmado en el paper [75] lo respaldan. La correlación que existe entre la disminución de distracciones por parte del niño y la reducción del tiempo que le toma en terminar sus deberes hace evidente el cumplimiento de esta hipótesis.

Hipótesis 2: Poder aplicar técnicas de terapia ocupacional convencionales al entorno del hogar de un niño, ayuda a reducir la frecuencia con la que los niños con TDAH se distraen mientras lleva a cabo actividades específicamente diseñadas.

La metodología aplicada en esta tesis permitió demostrar que es posible extender una terapia ocupacional utilizando una solución tecnológica que adapta un entorno dentro del hogar de un niño con TDAH y así reducir la frecuencia con la este se distrae mientras hace una actividad específica (deberes escolares). Los resultados de la implementación de la primera versión en el paper [36] muestran que tanto los niños como sus padres aceptan los dispositivos y el robot dentro del hogar. Además los resultados del experimento en el paper [75] muestra, en efecto, que la frecuencia en que ocurren distracciones disminuye.

Hipótesis 3: La combinación de un asistente robótico con objetos inteligentes es de utilidad para monitorear de forma clínicamente significativa el comportamiento del niño en su entorno natural, extendiendo el proceso terapéutico supervisado a otros contextos.

La combinación de un asistente robótico con objetos inteligentes permite obtener información relevante desde el punto de vista terapéutico, ya que hace posible monitorear el rendimiento del niño y su comportamiento en su entorno natural. Los resultados de los artículos [36, 75] muestran que la información es más precisa y la forma en que se presenta y se almacena, facilita su interpretación a nivel terapéutico. No existen trabajos que hagan algo parecido hasta la fecha [65]. El único trabajo que se enfoca en obtener este tipo de información es [64] pero los autores han sido claros en que su metodología resultó incomoda a los niños, mientras que esta tesis muestra resultados opuestos.

5.3 Conclusiones

Como ha quedado recogido en el planteamiento de esta investigación, el acceso a un proceso adecuado de terapia para diversos trastornos que se sufren en la infancia, permite mejorar múltiples trastornos neurológicos, psiquiátricos y fisiológicos en niños, trastornos que es importante detectar en etapas tempranas de forma que se actúe sobre ellos lo antes posible evitándose así que se instalen de forma permanente e irreversible.

Hoy en día, los terapeutas ocupacionales llevan a cabo procesos de terapia muy útiles en niños diagnosticados de TDAH, pero estas intervenciones normalmente son costosas y demandan tiempo considerable de los padres durante meses u años, lo que implica que en ocasiones su frecuencia sea inferior en relación a lo que realmente sería necesario. De aquí surge la necesidad de construir sistemas que faciliten a los profesionales que trabajan con poblaciones infantiles el acceso a procesos de terapia pervasiva de utilidad y diseñados *ad hoc* para cada patología concreta.

La solución presentada en esta tesis doctoral está compuesta por objetos inteligentes y el asistente robótico Atent@ enmarcados en el contexto del hogar. Todos los elementos desarrollados se conectan a Internet mediante el protocolo Wi-Fi y se colocan en el escenario de la realización de deberes escolares. Los objetos inteligentes son dispositivos que se colocan en el escritorio y en la silla, están equipados con sensores que miden la actividad del niño en tiempo real, y envían la interpretación de las acciones (que el niño realiza durante los deberes) a la nube. Estos objetos inteligentes pueden detectar parámetros asociados al TDAH, como las distracciones. Al mismo tiempo, el nivel de hiperactividad se calcula en base a la frecuencia de las distracciones, pausas y llamadas de asistencia que el niño realiza durante la sesión de deberes.

El asistente robótico, junto con los objetos inteligentes en el entorno son adecuados para monitorizar aspectos conductuales de interés terapéutico durante la realización de los deberes escolares en el hogar. A partir de los experimentos realizados, se puede afirmar que estos elementos no interfieren negativamente en el desarrollo normal de sus deberes. Los resultados muestran que las mediciones del entorno del hogar y de la educadora son similares. Los terapeutas pueden beneficiarse de este entorno en dos aspectos:

1. Les permite obtener más información sobre el rendimiento del niño fuera del entorno terapéutico. Para que así puedan llegar a comprender y determinar, de forma precisa, cual es el comportamiento del niño en su espacio natural en cierta actividad.
2. La medición del rendimiento del niño en su entorno natural puede ser útil para distintos tipos de terapeutas infantiles (psicólogos, logopedas, entre otros). Esta tesis prueba que se puede adaptar los entornos sin convertirlos en laboratorios.

El asistente robótico que interactúa con los niños durante las sesiones de deberes en su casa, es un claro ejemplo de los beneficios de la interacción humano-robot, que además de permitir la monitorización de niños con TDAH, también mejora su comportamiento. El asistente robótico es el núcleo de esta solución pervasiva e inteligente.

El enfoque presentado en este estudio también permite pensar en el desarrollo futuro para el apoyo robótico de otras actividades, en lugar de centrarse sólo en la realización de tareas escolares. Ya que el entorno terapéutico generalizado que se presenta, podría aplicarse en otros escenarios a partir de la investigación que presenta en esta tesis doctoral. Los nuevos escenarios (para el uso terapéutico) requerirían nuevas cosas inteligentes que deberían ser diseñadas específicamente para estos fines. Este primer enfoque simplemente establece la base para el desarrollo de esas nuevas cosas inteligentes, ya que compartirán los mismos métodos y modelos de comunicación.

Durante la realización del trabajo presentado se ha perseguido respetar su enfoque multidisciplinar, permitiendo la discusión de todos los actores implicados durante las etapas de análisis, diseño y validación funcional.

5.4 Líneas de investigación abiertas y por explorar

En este apartado se presentarán futuros trabajos encaminados a evolucionar los sistemas presentados en esta tesis doctoral. Este trabajo ha abierto líneas de investigación sobre los entornos domésticos, y concretamente de hogar digital, en el cuidado y tratamiento de niños con TDAH. Esta investigación ha sido de interés para varios trabajos en este ámbito [76-81].

Es así que, siguiendo la misma metodología de esta tesis doctoral, nuevas investigaciones podrían surgir a partir de mejoras que se vayan implementando o nuevos entornos que se vayan desarrollando.

- Desde el punto de vista terapéutico, una opción o línea de investigación podría partir del desarrollo del asistente robótico, al que se le puede mejorar o adaptar sus funcionalidades para el soporte de terapias de algún otro tipo de trastorno de neuro-desarrollo como Autismo. En el artículo [65] muestra que muchos robots que son aplicados en el soporte del TDAH también lo son en el autismo, sin embargo, estos robots presentan serias limitaciones, como se menciona en dicho artículo.
- Conforme avanza la tecnología y el acceso a nuevos componentes de hardware cada vez más compactos, podría también surgir una nueva versión de Atent@, que incorpore nuevos elementos de hardware que inspiren a desarrollar nuevas funcionalidades. En la Universidad Técnica de Múnich (Alemania) y la Universidad Politécnica Salesiana (Ecuador) se encuentran trabajando en un modelo de visión artificial para Atent@ mediante una cámara incorporada en su estructura. Los resultados preliminares muestran un alto grado de aplicabilidad en miras de detectar aquellos parámetros que únicamente la educadora detectó en el experimento 2 de esta tesis.

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