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Assessment of a Robotic Assistant for supporting homework activities of children with ADHD

Jonnathan Berrezueta-Guzman[1,2], Iván Pau[1], María-Luisa Martín-Ruiz[1],and Nuria Máximo-Bocanegra[3]

[1]Departamento de Ingeniería Telemática y Electrónica, Universidad Politécnica de Madrid, 28031 Madrid, Spain
[2]Department of Research and Project Management, CEDIA, Cuenca 010203, Ecuador
[3]Department of Physiotherapy, Occupational Therapy, Rehabilitation, and Physical Medicine, Faculty of Health Sciences Rey Juan Carlos University, 28922 Madrid, Spain

Corresponding author: Iván Pau (ivan.pau@upm.es)

ABSTRACT Robotics, Artificial Intelligence (AI), and the Internet of Things (IoT) support various processes in many scenarios of modern life such as e-health and psychological treatments. This article presents the design, development, implementation, and assessment of a Robotic Assistant (RA), named "Atent@", as a support tool in the homework activities of children with Attention Deficit Hyperactivity Disorder (ADHD). Interacting with the children the RA helps them correct their bad habits and misbehavior caused by the disorder. Its features and functionalities were designed by therapists, implementing AI algorithms to process information and make decisions in real-time to help children to be focused on their homework. This RA interacts with smart objects deployed at home, which are associated with the activity under observation (desk and chair). This solution allows therapists to receive more accurate information about the homework sessions inside the home. At the same time, remote interaction with the child is made possible (through the RA) to provide new instructions and support him/her along with the sessions. This RA is a significant evolution of an earlier version. All the improvements brought to the project by the modifications in technical and qualitative features are explained. Furthermore, the experiment and its results are presented to illustrate the clinical potential. This project shows that the RA can not only make observations with a high degree of precision like an expert (teacher/therapist) but also positively influences the homework performance of children with and without ADHD.

INDEX TERMS ADHD, Ambient assisted living, Ambient intelligence, Human-robot interaction, Internet of things, Intelligent robots, Programming environments, Robotic Assistants, Smart-home, Therapeutic robot.

I. INTRODUCTION

Robotic assistance, aimed at performing complicated tasks in different fields, has taken off exponentially in the last five years. In healthcare, RAs contribute to support complicated surgical procedures which require precision at challenging levels [1-3]. The use of RAs to support people with dementia is discussed, focusing on potential hazards, and outline related factors that influence positive outcomes [4]. In the same field, nurses' experiences with existing robotic assistance systems were analyzed in hospitals in Germany [5]. This study describes a single use case to show perspectives for the use of robots in nursing care. Additionally, IoT developments have been implemented to support e-Health

processes to vulnerable people and persons with physical disabilities [6, 7].

In the educational field, RAs can achieve objectives that a regular teaching methodology cannot [8]. Using a RA within a classroom shows that the children receive and hold relevant information for a longer time with less effort. Their attention is captured and held by the RA during the teaching session (a challenging task for several teachers nowadays). A robotic assistant is a useful tool to teach children how to prevent or deal with trauma accidents in several scenarios. This issue is of great importance, as statistics showing a high rate of deaths due to trauma are associated with school-aged children [9].

Other RAs focus their functionality on supporting extreme risk tasks in unexpected places [10].

It becomes clear that Robotic Assistance has generated a radical change, showing unimagined possibilities in its application in various fields throughout the past years. However, every robotic development creates challenges, leaving it to the user's utilization which benefits should be received from its application [11].

A. OBJECTIVE

This paper presents the assessment of a robotic assistant aimed at providing therapeutic support in the performance of homework by children with ADHD. The RA is an evolution of an earlier version that entails improving the overall functional and mechanical features, the interaction subsystem, and acquired information. All the improvements have been made according to the knowledge acquired in the previous version of the RA and the provided feedback by therapists, parents, and children. The assessment consists of an experiment aimed at demonstrating its viability in clinical settings, comparing its monitoring performance to that of an expert in the field.

B. STRUCTURE OF THIS ARTICLE

The continued development of the project [12] is shown as the background of this study. This project includes the implementation of a Smart-home environment, combining robotic assistance and IoT to support ADHD therapy processes inside the patient's home. We provide a state of the art according to ADHD to help readers understand the relevance of this project. Several related works will be included, focusing on how this project has developed and how it differs from similar ones in this field. Additionally, the development process of the robotic assistant, the experiment in which the RA works with children and the obtained results are explained. Finally, future work, discussion, and conclusions are presented.

II. STATE OF THE ART

A. ADHD DEFINITION

Attention is a quality of the human being that functions as a selector of environmental stimuli as the human mind cannot process all the information coming from its environment at once. This selection can be consciously or unconsciously. When some of the attention processes are affected and the selection function does not develop properly, a disorder can be associated [13, 14]. ADHD is considered a developmental disorder of self-control, manifested by problems around attention span, impulse control, and hyperactivity at a high level. This disorder represents a real problem for children as well as a real obstacle in the development of daily activities at home or in school. In the long term, ADHD could be heartbreaking and nerve-wracking for both, the parents and the affected children, when not treated properly [15]. ADHD is a

persistent behavioral pattern of inattention, hyperactivity and/or impulsivity.
1) Inattention refers to the inability to voluntarily maintain attention throughout the development of a task. The focus of attention is constantly changing which prevents completion of tasks, requiring great mental effort.
2) Hyperactivity refers to the inability to hold still in situations where it is appropriate to do so. They are restless, move hands and feet constantly and find it difficult to sit.
3) Impulsivity refers to the impossibility of waiting and responding to stimuli at the right time. It leads to disorder and distractions in academic tasks.

ADHD is a well-known and at the same time controversial disorder due to the overdiagnosis of which several authors have spoken in recent years. In fact, in recent years cases, several have been identified which do not present ADHD [16]. Most authors find a prevalence of ADHD between 3-7%, although there appears to be significant variability depending on age, sociocultural level, and subtypes. Some authors suggest that there are no significant differences in prevalence concerning gender. There is greater variation in the prevalence of the different ADHD types, with the inattentive subtype being the most common in the general population [16]. These subtypes are:
1) ADHD combined type. Presenting both attention deficits and hyperactivity.
2) ADHD type with predominance of attention deficit.
3) ADHD predominantly hyperactive-impulsive type

B. ASSOCIATED DISORDERS

A high percentage of ADHD cases are usually associated simultaneously with other disorders [17-19].
1) Oppositional Defiant Disorder (ODD). The prevalence of comorbidity of ADHD with ODD is estimated between 40 - 50 %.
2) Conduct Disorder. Approximately 40 - 50 % of people with ADHD may show a conduct disorder.
3) Anxiety disorder. Anxiety, phobia, obsessive-compulsive, generalized anxiety and separation anxiety have been presented in 25 - 35 % of ADHD cases.
4) Learning disorder. Children with ADHD who have a higher level of attention deficit have more problems associated with learning disorders than those who are hyper-active-impulsive. Between 8 % and 39 % have a reading disorder and 12 - 30 % have a calculation disorder.
5) Autism spectrum disorder (ASD). The 33 % of children with ASD present inattentive ADHD symptoms, 26 % of combined type (attention deficit and hyperactivity/impulsivity), the other 41 % do not present comorbidity.
6) Tic Disorder. 10 % of children with ADHD have a tic disorder or called Tourette syndrome.

ADHD is commonly a chronic, often lifelong condition that

is considered a disorder in the behavior of human beings. The impact of ADHD can change with time and its consequences can get worse if it is not treated in time [20]. In most cases, lifelong monitoring and treatment are required [21]. For these reasons, it is considered one of the neurodevelopmental disorders most commonly diagnosed in childhood [22].

C. POSSIBLE CAUSES AND DIAGNOSES

It is difficult to define the exact causes which trigger ADHD. The diagnosis is complex as there is no single cause and its origin is usually multifactorial. However, most authors agree that it is a neurological disorder for several different types of reasons [22, 23].

1) Genetic factors: It is one of the factors that have the most influence on the appearance of ADHD. Research shows the high probabilities of developing ADHD when family members have it too.

2) Environmental factors: There are environmental factors that become risk factors such as premature birth, hypoxic-ischemic encephalopathy, low birth weight, as well as tobacco use and drinking during pregnancy.

3) Psychosocial factors: They are not believed to be determining factors, although they do play an important role in the disorder and, above all, provide an opportunity for intervention.

D. ADHD TREATMENTS

The treatment of ADHD in children includes:

1) A pharmacological treatment prescribed by a psychiatrist, medical specialist, or neurologist with its objective to reduce the symptoms derived from ADHD while increasing the quality of life of the patient. These treatments decrease the risks for a wide range of ADHD-associated functional outcomes [24].

2) Psychological treatment is based on cognitive-behavioral therapy whose purpose is psychoeducation, which stands for, training and knowledge of the disorder, both by the patient and their family, to know how to cope with the symptoms and their impact on life every day [25].

3) Psychopedagogical treatment seeks to respond to the educational needs of students and propose alternative forms of learning that help them overcome the difficulties which arise [25].

4) Occupational therapy uses a family-centered approach. This therapy helps the child develop his occupations as independently as possible. It uses metacognitive strategies, sensory integration and adaptations of the environment (home or school) [26, 27].

The last one is a process of constant monitoring in which the therapist supervises how the child performs his/her daily activities such as homework, playing games, sleep, etc. For the development of these therapies, it is necessary to transfer the child to specialized clinics which provide environments like home, school, etc. It includes the evaluation of the child to determine specific difficulties and therefore being able to propose an individualized intervention [12].

The therapist can observe the behavior of the child and will be able to provide feedback to improve his/her habits that commonly are associated with the ease of being distracted during a specific activity. The principal objectives of this treatment are:

--Creation of routines.

--Establish appropriate habits of conduct.

--Promote impulsivity control techniques.

--Encourage the development of self-control.

--Practice verbal self-instructions.

--Encourage social relationships and put social skills into practice.

--Work on emotions and promote good self-esteem

III. RELATED WORK

Several studies which support ADHD treatments have been developed in recent years. For example [28] presents an eye-contact game that uses mixed reality for the treatment of children diagnosed with ADHD. This interactive game helps to significantly reduce the omission errors carried out when the children were evaluated by an attention test, instead of children who resolved the same attentional test without using this innovative game. In [29] the researchers present N270 as a sensitive neurophysiological marker for ADHD children, helping to identify the facial expressions in this kind of child.

According to robotic assistance applications focused on supporting children with ADHD in the educational field, there are several projects such as [30] which implements a humanoid robot (KAR) as an educational robot for children with ADHD. This project uses an NAO robot as an assistive technology that employs a toy/game robotic approach. According to the authors, this RA can work on three different educational scenarios: Puzzle construction for supporting sustained attention, Story Telling for supporting constructive learning, and "Simon Say" Game for supporting selective attention. This project needs a humanoid robot NAO [31], who's functionalities require a programmer supervising during all times in the sessions.

Another example is KIP 3 as a robotic companion being an external cue to students with ADHD. This is a social robotic device for students with ADHD which provides immediate feedback for events like inattention or impulsivity. Its principal issue is that this robotic companion uses a tablet for its operation, which in turn could be an additional source for distracting the student [32].

There is a study that investigates the impact of Robot-Assisted Therapy (RAT) on nonverbal children with a severe form of ASD and ADHD. Same as KAR, this project uses a humanoid robot NAO in a Children's Rehabilitation Center located in Astana, Kazakhstan for 21 therapy days. The results show the sessions with a robot seemed to be effective as they showed an improvement in concentration. However, the RAT would need to offer appropriate robot behavior to meet the

specific needs of these children, adding that its results are preliminary [33].

The NAO robot is used in two related works such as [34] which is focused on speech therapy interventions in children with ADHD. On the other hand, [35] presents a therapy intervention scenario in which a child is asked to teach a robot (NAO) how to write via demonstration on a tablet. Combined with a series of games they developed to train specifically pressure, tilt, speed, and letter liaison controls. The principal limitation of this work was the time-consuming installation before starting a session, complex wiring, and unhandy interfaces.

According to therapies, [36] presents a socially assistive robot that allows building personalized therapeutic paths based on the profile of the patients with ADHD thanks to the support of artificial intelligence. This work uses a humanoid prefabricated robot called Pepper [37]. All these developments cannot (currently) be implemented without the programmer monitoring the therapy session.

Finally, [12] develops a RA called Atent@ which interacts with the children during the homework sessions inside their home. The human-robot interaction allows the monitoring and improvement of the behavior of these children [38]. This RA is part of a Smart-home environment system that uses the IoT paradigm to create intelligent environments within the home to contribute to the development of therapies for children with ADHD from the age of six to twelve years old.
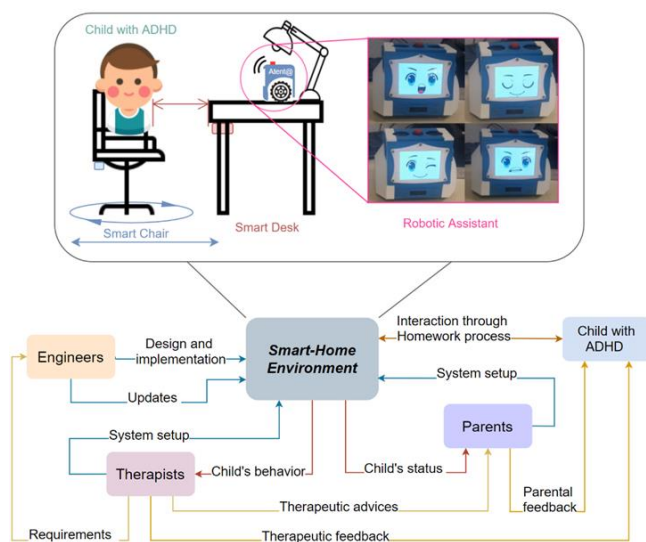
FIGURE 1. Scheme of the Smart-Home Environment functionality with the actors and their interaction during a homework session [12].

The whole Smart-home environment is composed of smart things and Atent@. These elements are connected to the Internet by Wi-Fi protocol and are placed in the homework scenario. The smart things are devices attached to the desk and chair. They are equipped with sensors (accelerometer and proximity sensors), measure the child's activity in real time and send the interpretation of actions (that the child makes during homework) to the cloud. These smart things

can detect the ADHD associated parameter such as DISTRACTIONS. This parameter is calculated by acquired data through the smart things (playing with the chair, leaving the desk, etc.) [12]. At the same time, the HYPERACTIVENESS level is calculated based on the frequency of distractions, pauses and assistance calls which the child makes during the homework session.

A. COMPARISON OF THE ORIGINALITY OF ATENT@ WITH ROBOTS IN RELATED WORKS

Atent@ has several innovative features compared to the traditional robots in related works.

1) According to the robotic functionality, [30, 33-35] involve the NAO robot as the principal tool for accomplishing the objectives. Use of a humanoid robot implies the presence of the programmer in all sessions to adapt the robot's software to the different activities and response in real-time. The same limitation presents [36] which uses Pepper and [32] using KIP3. On the contrary, Atent@ is a robot that has been programmed following the recommendation of therapists of children diagnosed with ADHD. The functionalities and the interaction process are programed to allow interaction with the children without the presence of the programmer during the session.

2) According to the collection of information, Atent@ allows therapists to monitor (remotely) the child's behavior in real-time during a homework session, providing more accurate information as the acquired data is gathered from the real homework environment (inside the home of the patient). All this information is available for therapists from a mobile application which is part of the Smart-home architecture. Additionally, the collected data is used to train a machine-learning algorithm in the cloud to predict the behavior of the child in future homework sessions [39]. This algorithm can show how the evolution of the homework in the next sessions will be, even in month terms. On the contrary, [30, 32-36] do not provide all these functionalities to collect, process and show information of the behavior of the child in a remote way.

3) Additionally, the shape and functionalities of Atent@ do not represent a source of distraction for the child. In the case of use NAO and Pepper, the use of these humanoids could represent a distraction source. On the other hand, [32, 35] present the same issue because the use of a tablet could represent a way to distract the child during the therapy session.

4) According to the replicability, Atent@ is composed of open-source elements. This RA and its application can be replied to by other researchers easily. Atent@ is composed of a microprocessor, touchscreen, speakers, and motors inside a 3D structure. All these elements allow Atent@ to speak, move within the workspace and interact with the child during the development of the

homework as an ADHD therapy process [12, 38]. Conversely, for replying to [30, 33-36] experiments, it is necessary to acquire the NAO robot or Pepper. In term of costs, there is a significant advantage of Atent@ over the humanoids without mentionig that Atent@ allows an easy way for preparing the scenario.

This RA will not replace the human therapists, it is just a useful tool for supporting the child during homework sessions.

B. FEATURES AND FUNCTIONALITIES TO BE IMPROVED IN THE SECOND VERSION OF ATENT@

The RA is the core of the Smart-home environment. Specifically in the Homework scenario as the interaction process with the child is performed with the help of and through it. However, after several months, the results show that the RA can upgrade several functionalities and features. Therapists, parents, and children have provided feedback according to the RA's features and its functionalities. The following aspects of the RA need to be improved.

1) Portability: The treatment of ADHD consists of replicating the daily activities that the child performs at home. The RA has become a very useful tool at the time of therapy during the performance of homework. Therefore, it is proposed to involve the RA in more settings at home and school, making it necessary to improve its portability.

2) Interaction process: The RA is programmed with a set of interactions that were defined by therapists. According to the data that it collects, it presents the child with feedback. After several sessions, the robot becomes boring and predictable, which makes it necessary to create a more natural interaction process.

3) Collected Information: The data collected is sent in real-time to a database in the cloud to be available for parents and therapists through a mobile application. However, it is necessary to provide exporting options.

4) Scalability: The robot is required to be tested in parallel with several children at the same time to observe the evolution of all of them during several sessions. Using several robots would speed up and ease the experiments for which the cost of production must be optimized.

IV. MATERIALS AND METHODS

This version of the RA seeks to optimize the functionality and physical aspects of the previous design [12]. Furthermore, it looks for increasing the efficiency of the robot compared to its predecessor in technical and functional terms. For this second version, several improvements in electronic aspects, assembly design and programming algorithms have been made.

A. ENERGY EFFICIENCY

1) The NODE MCU 8266 device has been taken off. With this modification, the robot's current energy consumption is reduced by 80mA on standby and by

110mA when it is transmitting the information [40].

2) The audio amplifier PAA-MAX9788-01 has been replaced by the model PAM – 8302 from Adafruit which only consumes 790 mA in an active state and 4 mA when it is on standby while providing a power of 2.5 Watts. This new amplifier allows subtracting one speaker, reducing the current consumption by 158 mA., increasing the gain by 12 dB [41, 42].

3) The L298N module is replaced by the TB6612FNG module reducing current consumption by 800 mA. This modification does not lead to a reduction of the mobility of the RA as the new motors are capable to adapt their current demand to the new controller current [43, 44].

4) The raspberry model 3 B+ is replaced by the Raspberry model 4. According to the official Raspberry documentation [45], the Raspberry Pi 4 model uses 600 mA in standby, and up to 1.13 A in maximum performance. These values are lower than the Raspberry Pi 3B +, which according to the same official source, requires 300 mA in standby, and up to 1.25 A at maximum performance.

5) The TFT 3.5-inch touch screen is replaced by an HDMI 4-inch touch screen. The energy consumption is being reduced by 40mA while the interaction space is 14.8% bigger than the previous version [46, 47].

6) Finally, the power supply module provides the system with 5 Volts with an amperage of 2.0, ensuring the distribution of power to the RA for a longer time.

All these modifications reduce energy consumption by around 1198mA.
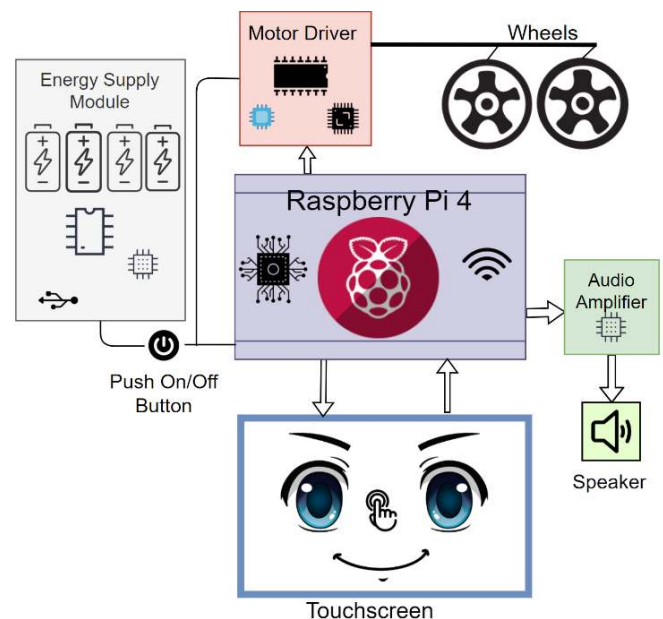
FIGURE 2. Electrical scheme of the second version of the developed RA that works in the Smart-home environment to support the homework session of children diagnosed with ADHD. This electrical scheme can be compared with figure 14 of [12].

TABLE I
ELECTRONIC COMPARISON BETWEEN RA'S VERSIONS

Electronic upgrades	1st version [a]	2nd version
Microprocessor	Raspberry pi 3 B+	Raspberry pi 4
Screen	TFT	HDMI
Microcontroller	NODE MCU 8266	-
Audio amplifier	PAA-MAX9788-01	PAM - 8302
Motor controller	L298N	TB6612FNG
Power supply	24 Wh	37 Wh
Fan	-	0.75-inch, 5V
Energy consumption	~ 3957mA	~ 2759 mA

[a] Electronic components from [12].

B. FUNCTIONAL EFFICIENCY

The raspberry pi model Pi 4 is better than the previous model. It has a higher clock frequency (model 3B+: 1400Hz, model 4: 1500Hz) as well as the capacity in RAM (model 3B+: 1Gb, model 4: 4 Gb) [45].

With these characteristics, the user interface and the interaction in it, the parallel information processing, its transmission through the Internet, the reception of commands, and the whole interaction process with the child was highly improved. Additionally, the interpretation of the acquired information from the Smart-home environment (smart objects) is more effective, adding that the new touch screen model provides a 22% higher touch-sensitive level than its predecessor [47].

TABLE II
FUNCTIONAL FEATURES COMPARISON BETWEEN RA'S VERSIONS

Functional upgrades	1st version [a]	2nd version
Thread programming	NO	YES
Stereo sound	NO	YES
Multitask performance	NO	YES
Sensibility	Resistive	Capacitive
Brightness	Fixed	Adjustable

[a] Functional features from [12].

C. ASSEMBLY EFFICIENCY

1) The RA's volume and its weight have been optimized. This version uses motors that are 63.2% smaller and 50% lighter. The wheels are 74.21% smaller and 87% lighter. The same can be observed with the motor controller which is 92.7% smaller and 55% lighter than in the previous version [43, 44].

2) The elimination of the NODE MCU 8266 device, one speaker, and the power button represents a reduction in

the volume of 7%, 2%, and 4% respectively [40].

3) The interface of the RA is 14.8% bigger than the previous one [47]. It makes the RA 6% wider.

4) Finally, the weight and volume of the power supply system are 25 % and 9% (respectively) less than the previous version.

TABLE III
COMPARISON OF DESIGN FEATURES BETWEEN RA'S VERSIONS

Design upgrades	1st version [a]	2nd version
Weight	3.1 pounds	2.1 pounds
Size	104.83 in3	81.4 in3
Start button	YES	NO
Screen size	3.5 in	4 in
Width	4.2 in	4.4 in
Height	4.8 in	3.7 in
Length	5.9 in	5 in

[a] Design features from [12].

1 Touch screen   5 Motor Driver
2 Raspberry Pi 4   6 Speaker
3 Bateries   7 Motors
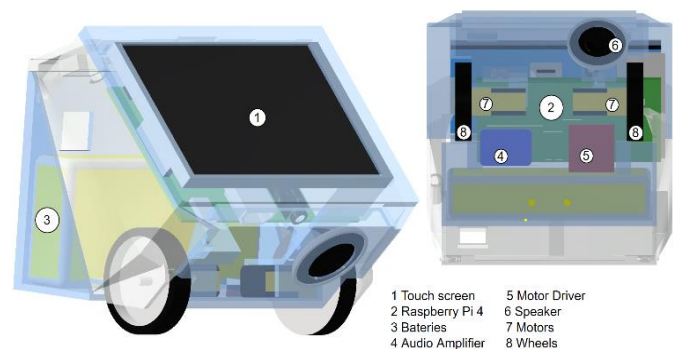4 Audio Amplifier   8 Wheels

FIGURE 3. Simulation of the assembly of the second version of the RA.

D. AI ALGORITHM FOR INTERACTION PROCESS

The first version of the RA functions via an interaction based on sequence processes. These processes depend on the interaction in real-time with the children and the collected information by the smart objects. As long as the RA is turned on, it starts to interact with the kid, while all interactions are based on following a programmed interaction plan [38]. For the second version, the RA learns the behavior of the kid, allowing the interaction process to become more natural. Atent@'s behavior is defined through a ruleset interpreted by a rule-based inference engine. The rules consider several variables such as the child's mood, the task planning, the current state of the activities or the entries via the touch-screen and the smart objects.
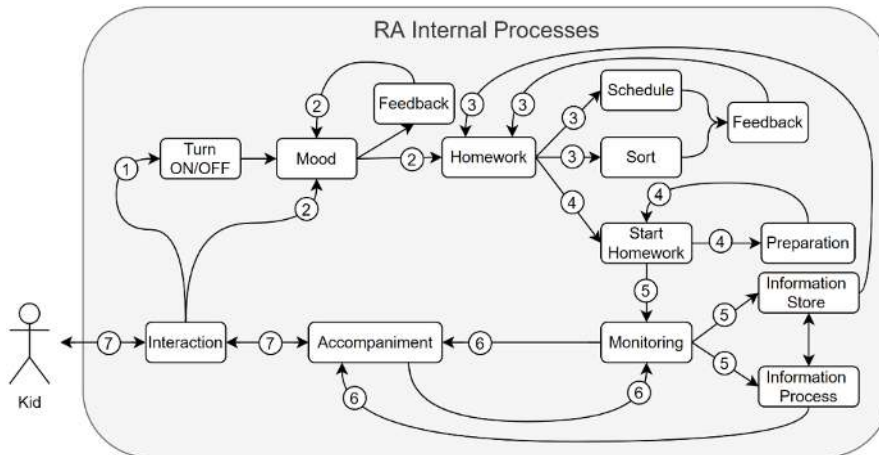
FIGURE 4. Diagram of the child-robot interaction development during a homework session in which the child develops homework.

The second version of the RA begins the interaction when the child turns the robot on (1). The RA connects to the internet and begins the session by determining the child's mood through specific questions (the child must indicate his/her mood touching an option on the screen).

According to the given response, the robot will be able to provide the child with motivational feedback phrases to start the homework process in a better spirit (2). Knowing the child's mood at the beginning of the task provides an estimate of how well the session will go, even before starting it. If the child's mood does not improve with the RA's feedback, the RA will notify his/her parents or therapists to intervene in the session to support the child (2).

TABLE IV
SET OF RULES FOR INTERACTION IN THE DETERMINATION OF THE CHILD'S MOOD

Mood	x1	x2	x3
Happy	Start Homework	-	-
Enthusiastic	Start Homework	-	-
Tired	Motivational msg	Motivational msg	Notify parents*
Sad	Motivational msg	Motivational msg	Notify parents*
Angry	Motivational msg	Motivational msg	Notify parents*
Sick	Notify parents*	-	-

*When the parents are notified, the session ends. The child could start it again when he/she feels better after the intervention of his/her parents.

When the child's mood is known and it is positive, the homework menu is displayed where the robot will help the child to schedule his/her tasks (new and pending tasks), ordering them according to the priority level and deadline (3). This is possible because, at this stage, the robot already has the information about the tasks which have been done, their execution time, and the pending tasks that he/she still must perform and their priority from previous sessions (3).

TABLE V
SET OF RULES FOR SORTING THE PENDING AND NEW TASKS

Tasks	Pending	Done	New
Math	Start now	Next one	Start now
Language	After math done	Next one	After math done
English	After Language done	Finish Session	After Language done

Once they have organized the work schedule, the RA recommends him/her to sort the workspace and prepare all materials to be ready for starting.

TABLE VI
SET OF RULES FOR PREPARING THE WORKSPACE

Materials	Start now	Check for the material
Notebook	Ready	Not ready
Book	Ready	Not ready
Pen/pencils	Ready	Not ready

Additionally, it will ask the child whether he/she wants to drink water or is in need to go to the bathroom before starting. If the answer is affirmative, the robot recommends doing so and will wait long enough for him/her before starting (4). The robot will recognize when the child is back in the workstation as the smart objects will detect this event. If the child does not come back, the RA starts to call for him/her. The robot becomes a supervisor for the child at this stage preparing him/her to avoid distractions as much as possible during the development of his/her school duties at home (5).

TABLE VII
SET OF RULES FOR ASSISTANCE INTERACTION

Assistance	Before	During	After
Bathroom	Atent@ detects	Atent@ waits	Atent@ continues
Drink Water	Atent@ detects	Atent@ waits	Atent@ continues
Ask parents	Atent@ detects	Atent@ waits	Atent@ continues

When the child starts the tasks, the robot begins to receive the data from the smart objects to monitor the child's behavior and help him/her regain concentration if he/she loses it at any time. It uses the data from the smart objects and determines if the child is distracted, playing with the chair, or if he/she has left the workstation. All these events are at the same time stored locally and in the cloud with a timestamp. This information helps to process the behavior patterns of the child during this therapeutic process (5).

TABLE VIII
SET OF RULES FOR DETECTING THE BEHAVIOR OF THE CHILD

	Desk	Chair	Knowledge (the child is…)
Events	In position	No motion detected	Doing the homework
	Moved Off	Motion detected	Moving away from the desk
	In position	Motion detected	Playing with the chair
	Moved Off	No motion detected	Going away

The accompaniment of the robot during the homework session is influenced according to the information processed by the smart objects and the child-robot interaction. At any time, the robot can determine a distraction and draw the child's attention back to work. Additionally, the robot can determine that the child has been working hard for a long time, advising him/her to stretch her body for a moment with exercises near the workstation.

TABLE IX
SET OF RULES FOR SORTING THE PENDING AND NEW TASKS

Tasks	Relaxing	Exercise	Stretch oneself
Math	20'	30'	40'
Language	20'	30'	40'
English	20'	30'	40'

The robot recommends several movements to the child to relax and even tries to reproduce those movements with the child (6). In the same way, the child can ask the robot for help, permission to go to the bathroom or drink water, and even ask for a short break (7). Atent@ will determine the pertinence of the request and will respond accordingly. All these events are as well stored locally and in the cloud with a timestamp (5).

Finally, the robot will keep a record of the completed and pending duties to start the next session the next day with these. At the end of the session, the robot stores all that information and sends the child a motivational message that he/she did very well (5). Parents and therapists will remotely know that the child has finished the tasks, also being able to see the number of certain events and their specific times.

Every session will be unique as the child-robot interaction is unpredictable. The RA will process new information every time because a child will present a different behavior in each session.

In this version, the collected data can be stored in a local file. These events will be stored with an identifier, a timestamp, and a description of the event (minimum required parameters for applying a data analysis technique). The CSV file will be updated at the end of each session. For downloading this file, therapists and engineers can use the mobile app. This file will be useful for therapists to analyze and evaluate the progress of the therapy, while for engineers, it will be useful to improve the model and add new functionalities.

TABLE X
COMPARISON OF THE INTERACTION FEATURES BETWEEN THE TWO VERSIONS OF THE RA

Interaction upgrades	1st version [a]	2nd version
Facial expressions	16	39
Dialogues	~12 min	~68 min
Menus	2	8
Interaction options	10	53
Mood detection	-	YES
Stress detection	-	YES
Parents and therapists' notifications	3 kinds	7 kinds
Exercises motivation	-	YES
Tasks Control	-	YES

[a] Interaction parameters from [12].

D. SCALABILITY

By removing some electronic elements from the first version, the design of the 3D structure of the robot is smaller, indicating that the printing will require less time (the price is reduced by 45 %). The cost of the materials used to build the second version of the RA is reduced by 22 %, while also reducing its production time by 37 % [40, 41, 43-45].

FIGURE 5. RA assembled and positioned in the workspace to provide support to children with ADHD during the development of homework. Left: superior isometric view. Right: superior frontal view.

With all these improvements, the new version of the RA is built and is ready to be positioned on the child's workstation. Figure 5 shows the RA with all its characteristics including its touch screen showing the graphical interface, which in this case is a face that simulates talking when it provides feedback to the child. Touching the screen displays the interactive menus, allowing the robot to begin receiving the commands provided by the child through the interactive user interface.

Table XI shows several improvements in various aspects that the second version has, and its predecessor does not. Many of these compared parameters are necessary to validate the feasibility of this RA. Besides, these parameters can help to estimate whether or not the final consumer will find this creation as a useful tool inside the home to support the homework process of children with ADHD.

TABLE XI
COMPARISON OF THE TECHNICAL FUNCTIONALITY BETWEEN THE RA VERSIONS

Technical validation	1st version [a]	2nd version
Time to connect to the internet	15 s	6 s
Time to detect an event	80ms	15ms
Time to send the event to the cloud	10ms	2ms
Reconfiguration during the tests	once	none
Volume gain	38 dB	50 dB
Autonomy	2h 20' (avg)	4h50' (avg)
Time to recharge the batteries	1h 30' (avg)	1h 48' (avg)
Time to detect a command in red button	400ms (avg)	-
Time to detect command on the touch screen	200ms (avg)	10ms (avg)
Time to receive the feedback from mobile App	300ms (avg)	52ms (avg)

[a] Results from the technical evaluation of the first version of the RA [12].

V. EXPERIMENT

The objective of this experimentation is to test the feasibility of the second version of the RA working with real children outside the lab. This is an experiment focused on the academic scenario (Homework). The experimentation process was carried out with children who, due to the COVID-19 pandemic, are receiving accompaniment from an expert educator in an improvised task support place within a company. Here the children of the company's workers can attend online classes while their parents work, doing their homework in the afternoon too. While resolving the homework, the expert educator with experience in the education of children with special abilities (special education) is offering support and help for the children if needed. To the point of the experiment, she has been working with these children for several months, knowing their routines and typical behavior. The expert selected the group of children for the experiment and developed the experimentation plan including the RA and the smart objects inside the center. The experiment focuses on testing the RA with smart objects with children who have a suspected diagnosis of ADHD as well as those who have not.

A. SAMPLE SELECTION

There are 18 girls and 12 boys in this accompaniment center., ranging in age between 4 years to 14 years. The socio-economic situation includes a wide range. For this experiment, the sample of 8 girls and 4 boys who are in the range of 6 to 12 years were selected (there are more children in this age range, but their parents did not agree to their children being part of this experiment). The expert divided this sample group between children with a suspected ADHD profile and children who do not show this disorder according to the CONNERS conduct questionnaire [48, 49] previously carried out by the expert and parents. This form consists of a series of questions that parents and teachers fill in according to what they observe in the children during an activity at home and school (task support center) respectively. The interesting thing about this questionnaire is that the threshold

that determines a suspicion of ADHD is 16.66% lower in the case of the female gender [48, 49]. As a result, it was determined that the 3 children with suspected ADHD present a profile with combined ADHD (presenting both attention deficits and hyperactivity). The sample group for the experiment includes more girls with suspected ADHD than boys.

TABLE XII
DIVISION OF THE SAMPLE GROUP BY AGE AND DIAGNOSIS OF ADHD

Gender	Age	Suspected ADHD [a]	ADHD
Male	6	1	1
	7	-	1
	9	-	1
Female	6	1	2
	7	-	1
	8	1	-
	9	-	2
	10	-	1

[a] According to the CONNERS questionnaire.

B. SAMPLE PREPARATION

Previously to the experimentation, the parents of the children involved in the experiment, signed informed consent, stating their agreement of their children participating in this study. The researchers guaranteed with specific protocols that personal or relevant information that reveals the identity of the children or their parents will not be published. Each child will have a unique identifier based on his/her order in the sample group, gender, and age.

C. EXPERIMENT PLAN

The experiment plan consists of two consecutive stages that collect data of the homework sessions for four weeks (twenty sessions). The sample group of children is split into three groups, each including four children. However, just group one is selected, carrying out three specific tasks (the most significant subjects for that school-age): math, language, and English. The distribution of the tasks throughout the week is not even, while not exceeding 70 minutes of work time per session. Presenting a series of problems aligned with the knowledge of the children, the math homework can be solved in an estimated time of 30 minutes maximum. The Language and English tasks can be resolved within 20 minutes, focusing on reading comprehension and grammar exercises. Additionally, for one day of the week, a specific task is not assigned as homework to see how the child's mood is in the absence of that subject.

TABLE XIII
DISTRIBUTION OF TASKS IN THE EXPERIMENT PLAN

Week	Subject	M	T	W	TH	F
1,2,3,4	Math	30 [a]	30 [a]	30 [a]	-	30 [a]
	Language	20 [a]	20 [a]	-	20 [a]	15 [a]
	English	20 [a]	-	20 [a]	20 [a]	15 [a]

[a] Assigned minutes for accomplishing the tasks

In week 1 and 2, the group of children will carry out the

tasks without the help of the robotic assistant but with the supervision of their expert. In week 3 and 4, the group of children will have the accompaniment of the RA and smart objects, while additionally being supervised by the expert.

The group of children for this experiment is made up of four children of the same age (6 years old). One boy and one girl have a possible ADHD result with a predominance of inattention and hyperactivity. This sample group is considered the most relevant because it is equitable in gender, age and number of children with suspected ADHD. The experimentation schedule is explained in table XIII and XIV.

TABLE XIV
EXPERIMENTATION PLAN DURING THE FOUR WEEKS

Group	Gender	Age	ADHD	ID	Week 1&2	Week 3&4
1	Male	6	✓	1M6	Teacher	Teacher & RA
		6	-	2M6		
	Female	6	-	3F6		
		6	✓	4F6		

D. EXPECTED INFORMATION

This experiment collects relevant information from the Smart-home environment and expert to validate the functionality and fulfilment of the objective.

1) In the first stage, both, the expert and the robotic assistant observe/monitor the child and obtain relevant information such as the time of completion of each task, number of distractions, pauses between tasks, calls for assistance, frequency of impulsivity, frequency of hyperactivity, number of completed tasks, change of mood, emission of sounds, and times that he/she follows the instructions (teacher/robot). The expert collected information over the four weeks to evaluate the evolution of the sessions carried out by the group of children. These results were compared to the results of involving the Smart-home environment in this therapy process. Some parameters were captured only by the expert (see table XV).

2) In the second stage of experimentation, the time evolution for the daily performance in every task was analyzed (see Table XVI).

3) Ultimately, the functionalities of the Smart-home environment have been checked during the monitoring of the child when he/she does the task. Besides, all parameters which the teacher cannot measure, but the Smart-home environment can do were checked also.

VI. RESULTS

A. FREQUENCY OF ADHD ASSOCIATED PARAMETERS

The relevant behavioral parameters of each child were identified in the four weeks of experimentation according to the schedule experiment plan in table XIV.

TABLE XV
EVOLUTION OF THE FREQUENCY OF ADHD PARAMETER ASSOCIATED

| ID	Parameter	M	T	W	Th	F	M	T	W	Th	F	M	T	W	Th	F	M	T	W	Th	F
		Week 1					Week 2					Week 3					Week 4				
1M6	Distractions	7	5	4	3	6	5	4	6	4	6	4	4	4	3	4	3	3	2	2	3
	Pauses	8	3	4	4	6	7	4	5	2	5	6	5	3	1	3	4	3	1	1	2
	Assistances	3	1	2	1	3	2	4	4	2	3	1	3	2	1	2	1	2	1	1	1
	Impulsiveness [a]	3	3	2	1	3	3	4	3	1	3	2	2	1	1	2	1	2	2	1	1
	Sounds [a]	4	2	1	1	5	3	2	2	1	2	1	1	1	1	1	1	1	1	1	1
	Hyperactiveness	4	2	3	2	3	3	2	2	1	4	2	1	1	1	2	1	2	2	1	3
	Change of mood [a]	1	1	2	-	-	2	1	1	-	2	-	-	1	-	1	-	1	1	-	2
2M6	Distractions	3	3	4	3	4	4	3	5	3	3	2	2	3	3	2	3	2	3	1	1
	Pauses	2	3	3	3	3	2	4	4	3	4	2	2	2	3	2	1	4	4	3	1
	Assistances	1	2	3	-	2	2	3	2	1	1	1	1	3	-	2	2	2	1	1	1
	Impulsiveness [a]	-	-	1	-	1	1	-	-	-	2	-	-	-	-	1	-	-	-	-	2
	Sounds [a]	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Hyperactiveness	-	-	-	-	1	-	-	-	-	1	-	-	-	-	1	-	-	-	-	1
	Change of mood [a]	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
3F6	Distractions	5	4	5	4	6	4	3	4	4	5	5	3	3	4	6	4	3	4	4	5
	Pauses	7	6	5	4	5	6	4	5	5	5	4	3	3	2	5	3	4	2	2	5
	Assistances	3	4	2	1	2	3	3	4	-	3	3	2	2	1	2	1	1	2	-	3
	Impulsiveness [a]	-	1	1	-	1	1	2	2	-	-	-	1	1	-	1	1	-	-	-	-
	Sounds [a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hyperactiveness	-	-	-	-	1	-	-	-	-	2	-	-	-	-	1	-	-	-	-	1
	Change of mood [a]	1	-	-	-	-	1	-	-	-	-	1	-	-	-	1	1	-	-	-	-
4F6	Distractions	5	5	6	4	8	5	6	4	4	6	5	4	4	4	6	5	5	3	3	6
	Pauses	5	5	4	4	6	5	5	4	4	4	4	3	4	4	6	2	2	3	2	6
	Assistances	5	3	3	2	6	5	3	4	2	4	5	2	3	2	4	3	3	2	1	6
	Impulsiveness [a]	4	1	1	-	3	2	1	1	-	2	1	1	-	-	2	2	1	1	-	2
	Sounds [a]	1	1	1	-	3	1	2	1	-	2	1	1	1	-	1	1	1	1	-	2
	Hyperactiveness	3	4	2	1	3	3	2	2	1	4	3	2	2	1	3	3	2	3	1	3
	Change of mood [a]	2	1	1	-	1	1	1	1	-	1	-	-	1	-	1	-	1	1	-	1

[a] Parameters which only the expert can detect.

The level of behavior associated with ADHD is relevant in that girl and boy who in the CONNERS conduct questionnaire turned out to have a suspicion of ADHD (1M6 and 4F6). The other two children (2M6 and 3F6) do not show those levels of behavior associated with ADHD (expected result).

Additionally, it is observed that from the third week onwards there is a reduction in the occurrence of parameters associated with ADHD in all children. Nevertheless, high levels of ADHD-associated parameters continue to prevail in children with suspected ADHD.

Analyzing the individual parameters, the distraction level of the children with suspected ADHD is higher than that of the children without suspected ADHD (this result was expected by the expert). As for the evolution of this parameter during the sessions, it can be observed that from the third week, the degree of distraction decreases linearly in the boy with suspected ADHD (1M6), but in the girl with suspected ADHD (4F6), there is only a minimal decrease.

The ADHD prevalence is higher for her than for the boy, leading to the assumption that she would need more sessions to see a relevant improvement in her behavior (see Figure 6).
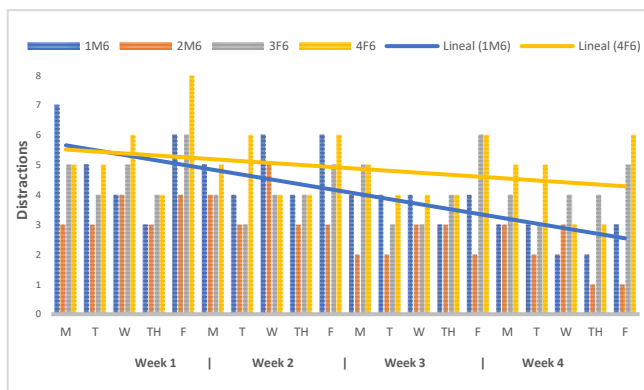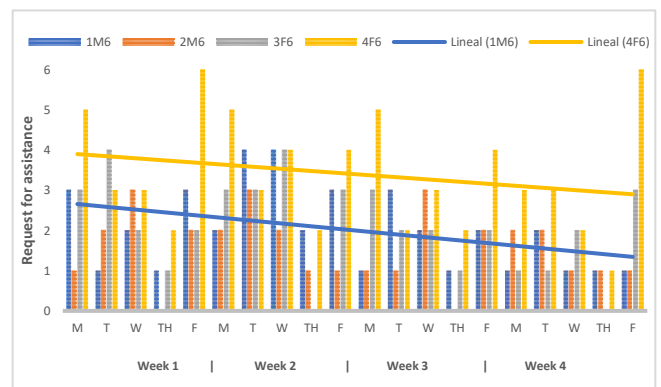

FIGURE 6. Evolution of the frequency of distraction parameter during four weeks of homework sessions. The reduction of this parameter is higher in 1M6 (according to the linear trendline) than 4F6.

About the number of breaks during the completion of homework, since the third week, a decrease in these is observed. It is also evident that the boy with suspected ADHD (1M6) prevails over the girl with the same profile (1F6) in this reduction (see Figure 7). As in the previous analysis, the expert believes that the girl needs more sessions to see an improvement in her behavior.
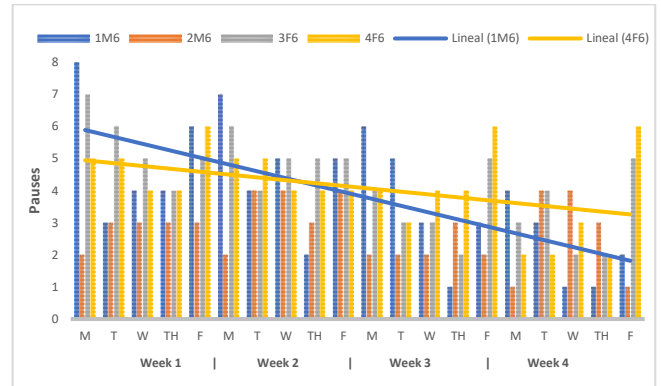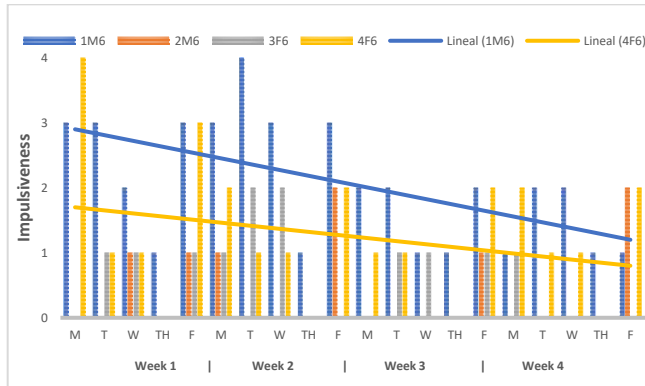

FIGURE 7. Evolution of the frequency of pause parameter during four weeks of homework sessions. The reduction of this parameter is higher in 1M6 (according to the linear trendline) than 4F6.

Regarding requests for assistance, a significant decrease is shown from the third week of experimentation. Both the girl and the boy with suspected ADHD (1M6 and 4F6) begin to require less assistance during homework. This is associated with the robot organizing the workspace, and the help to program tasks with the children before starting. Moreover, this decrease in the request for assistance is accompanied by a decrease in the request for breaks (see figure 8).
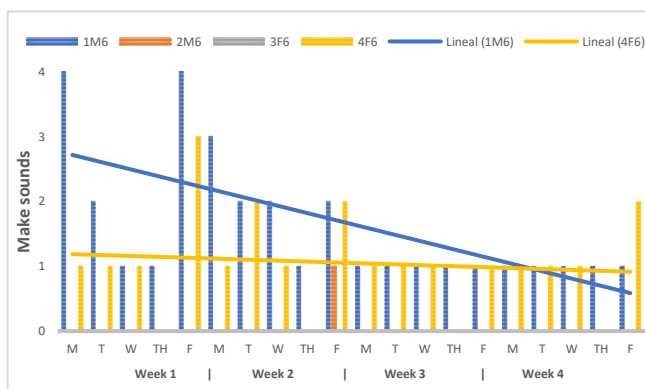

FIGURE 8. Evolution of the frequency of request assistance parameter during four weeks of homework sessions. The reduction of this parameter is similar in 1M6 and 4F6 (according to the linear trendline).

Concerning the level of impulsivity, it is observed that on Thursdays only 1M6 presents impulsivity, the rest of the children do not. This can be associated with the fact that no math homework is scheduled that day. Similarly, the evolution of the sessions shows that the boy with suspected ADHD (1M6) shows a predominant reduction compared to the girl with suspected ADHD (4F6). Working with the robotic assistant reduces the urge to be impulsive during the session. This information is provided by the expert who analyzes the behavior of the children during the sessions and records this information for this experiment (see figure 9).
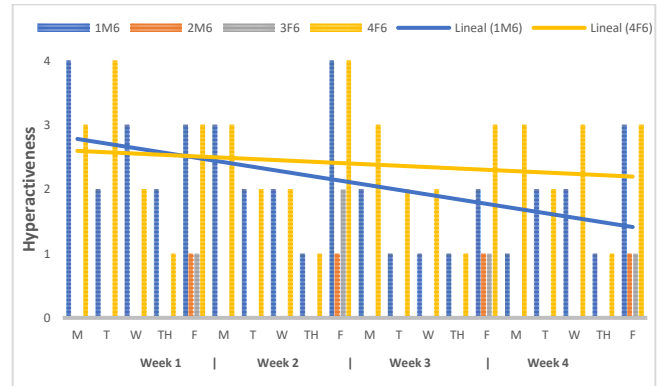
FIGURE 9. Evolution of the impulsiveness parameter level during four weeks of homework sessions. The reduction of this parameter is higher in 1M6 (according to the linear trendline) than 4F6.

FIGURE 11. Evolution of the hyperactiveness parameter level in the group of children during four weeks of homework sessions. The reduction of this parameter is higher in 1M6 (according to the linear trend-line) than 4F6.

An important parameter that is assessed by the teacher is when children start to become distracted by making noises with their mouths, noses, hands, feet, or hitting objects with the table or each other. This parameter is very susceptible to being considered a distraction when it is not because children sometimes make noises or whisper while they are thinking. However, when these noises are repetitive and not accompanied by progress on tasks, they are considered distractions. The boy with apparent ADHD (1F6) reduces his distraction level by making sounds while the girl with suspected ADHD (4F6) maintains this behavior although at a lower level, even in the sessions carried out with the robot. The interesting thing about this measurement is that this parameter is present only in children with apparent ADHD. Only on one occasion, this parameter can be observed in the second child without apparent ADHD (2M6) (see figure 10).

The last significant parameter that relates to the characteristic behavior of ADHD is the change in the child's mood while performing an activity. In this section, the boy with apparent ADHD (1M6) has significant mood changes on Fridays. This variable is determined by the teacher, who associates this behavior with the specific day (beginning of the weekend) and with the fact that the rest of the classmates have already finished their homework and he has not. However, in the case of the girl with possible ADHD (4F6), there is a significant positive change that reduces the frequency of mood changes. Another important consideration is that no child has mood swings on Thursdays, and this may be related to the fact that it is the day they do not have math homework and they complete their other homework much faster, and the entire session ends earlier.
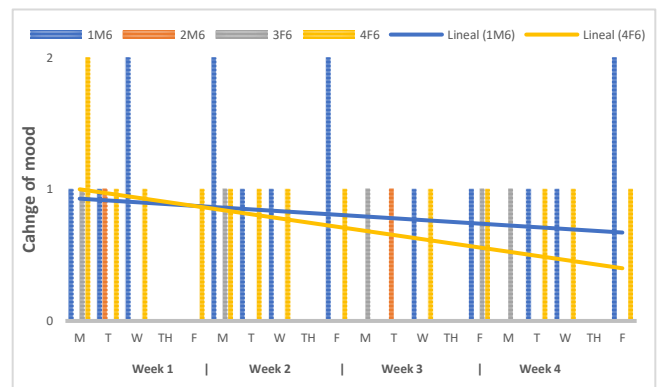

FIGURE 10. Evolution of the frequency of emission of sounds parameter during four weeks of homework sessions. The reduction of this parameter is higher in 1M6 (according to the linear trendline) than 4F6.

According to the level of hyperactivity, this parameter evolves in close relation to the evolution of the number of distractions, pauses and requests for assistance (this parameter is also calculated by the RA). It was expected that the boy with suspected ADHD (1M6) has better progress compared to the girl with possible ADHD (4F6). Additionally, children without ADHD present a low but constant level of hyperactivity on Fridays. The teacher associates this behavior with the day (the beginning of the weekend).

FIGURE 12. Evolution of the change mood frequency parameter during four weeks of homework sessions. The reduction of this parameter is higher in 4F6 (according to the linear trend-line) than 1M6.

B. EVOLUTION OF THE REQUIRED TIME FOR ACCOMPLISH OF HOMEWORK

For the analysis of the development times of the tasks, the values of Table 7 are taken as a base, additionally registering how much extra time each child requires or how much time is left to complete each task.

TABLE XVI
EVOLUTION OF THE REQUIRED EXTRA TIME TO ACCOMPLISH HOMEWORK

Sample		Week 1					Week 2					Week 3					Week 4				
ID	Parameter	M	T	W	TH	F	M	T	W	TH	F	M	T	W	TH	F	M	T	W	TH	F
1M6	Distractions	15	16	18	-	15	17	21	17	-	20	12	18	15	-	18	12	13	14	-	15
	Pauses	5	6	-	5	4	5	6	-	4	5	4	3	-	4	3	3	2	-	1	2
	Assistances	5	-	5	4	7	3	-	6	4	2	5	-	2	2	-1	4	-	2	2	3
	Impulsiveness [a]	4	6	4	-	10	5	5	2	-	7	5	2	3	-	4	3	3	-2	-	-2
	Sounds [a]	1	2	-	1	2	1	2	-	2	1	-	-2	-	1	-3	-3	-4	-	-2	-
	Hyperactiveness	1	-	3	2	4	2	-	3	-1	-2	-4	-	-3	-5	-7	-3	-	-2	-3	-2
	Change of mood [a]	1	3	4	-	8	2	5	4	-	5	2	-3	2	-	-4	-1	-2	-4	-	-4
2M6	Distractions	-	-1	-	-1	-3	-3	1	-	-4	-1	-3	-4	-	1	-4	-3	-2	-	-5	-5
	Pauses	-	-	-3	-5	-5	-3	-	-1	-2	-3	-5	-	-4	-5	-4	-5	-	-6	-5	-6
	Assistances	12	15	18	-	25	18	16	13	-	15	12	10	12	-	12	13	14	15	-	15
	Impulsiveness [a]	6	7	-	6	5	7	4	-	5	7	4	4	-	5	4	4	3	-	4	5
	Sounds [a]	5	-	6	4	6	5	-	6	5	7	5	-	4	3	1	3	-	3	4	4
	Hyperactiveness	15	16	18	-	15	17	21	17	-	20	12	18	15	-	18	12	13	14	-	15
	Change of mood [a]	5	6	-	5	4	5	6	-	4	5	4	3	-	4	3	3	2	-	1	2
3F6	Distractions	5	-	5	4	7	3	-	6	4	2	5	-	2	2	-1	4	-	2	2	3
	Pauses	4	6	4	-	10	5	5	2	-	7	5	2	3	-	4	3	3	-2	-	-2
	Assistances	1	2	-	1	2	1	2	-	2	1	-	-2	-	1	-3	-3	-4	-	-2	-
	Impulsiveness [a]	1	-	3	2	4	2	-	3	-1	-2	-4	-	-3	-5	-7	-3	-	-2	-3	-2
	Sounds [a]	1	3	4	-	8	2	5	4	-	5	2	-3	2	-	-4	-1	-2	-4	-	-4
	Hyperactiveness	-	-1	-	-1	-3	-3	1	-	-4	-1	-3	-4	-	1	-4	-3	-2	-	-5	-5
	Change of mood [a]	-	-	-3	-5	-5	-3	-	-1	-2	-3	-5	-	-4	-5	-4	-5	-	-6	-5	-6
4F6	Distractions	12	15	18	-	25	18	16	13	-	15	12	10	12	-	12	13	14	15	-	15
	Pauses	6	7	-	6	5	7	4	-	5	7	4	4	-	5	4	4	3	-	4	5
	Assistances	5	-	6	4	6	5	-	6	5	7	5	-	4	3	1	3	-	3	4	4
	Impulsiveness [a]	15	16	18	-	15	17	21	17	-	20	12	18	15	-	18	12	13	14	-	15
	Sounds [a]	5	6	-	5	4	5	6	-	4	5	4	3	-	4	3	3	2	-	1	2
	Hyperactiveness	5	-	5	4	7	3	-	6	4	2	5	-	2	2	-1	4	-	2	2	3
	Change of mood [a]	4	6	4	-	10	5	5	2	-	7	5	2	3	-	4	3	3	-2	-	-2

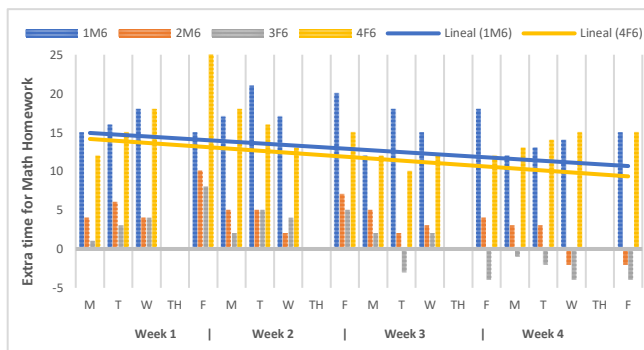[a] Parameters which just the teacher can detect.

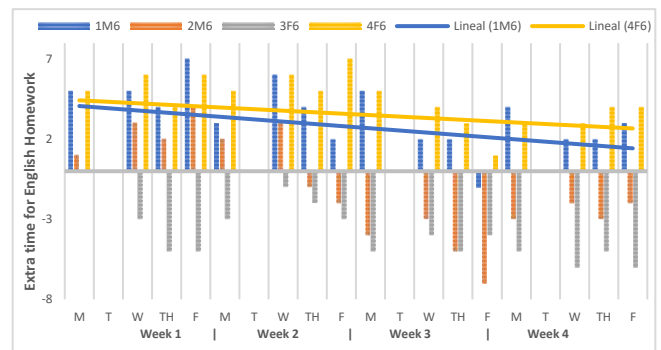FIGURE 13. Evolution of the required extra time by each child to complete the math task.

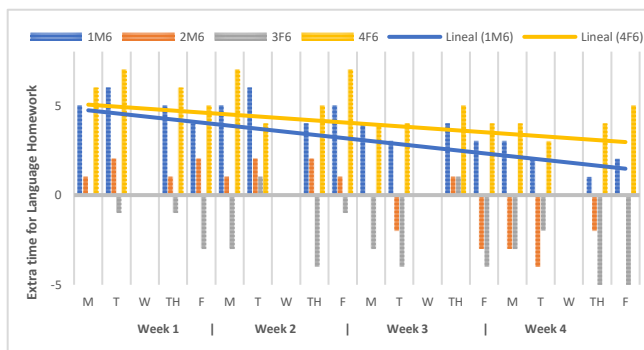FIGURE 15. Evolution of the extra time required by each child to complete the English task.

FIGURE 14. Evolution of the extra time required by each child to complete the language task.

The evolution of the required extra time to perform homework is associated with the evolution of the ADHD parameters detected in this experiment. We can see a decrease in extra time in the children with suspected ADHD diagnosis, being even more detectable in children without a suspected ADHD profile. However, we can see that in the case of math homework, all children present a considerable decrease in the required extra time even 1M6 and 4F6.

C. COMPARISON BETWEEN OBTAINED INFORMATION FROM RA AND THE EXPERT

Each recorded parameter associated with ADHD is compared by the relationship between the results obtained by the RA and smart things and the results obtained by the teacher. It is visible that the expert can measure or detect three additional parameters (noises, impulsivity, and mood changes). However, the RA is more accurate in determining the time stamp for each detected event or parameter. In addition, the RA has higher accuracy in detecting distractions related to movements and task organization is performed more attractively.

Additionally, the RA allows the information to be stored in a CSV file for future inclusion in a data analysis technique.
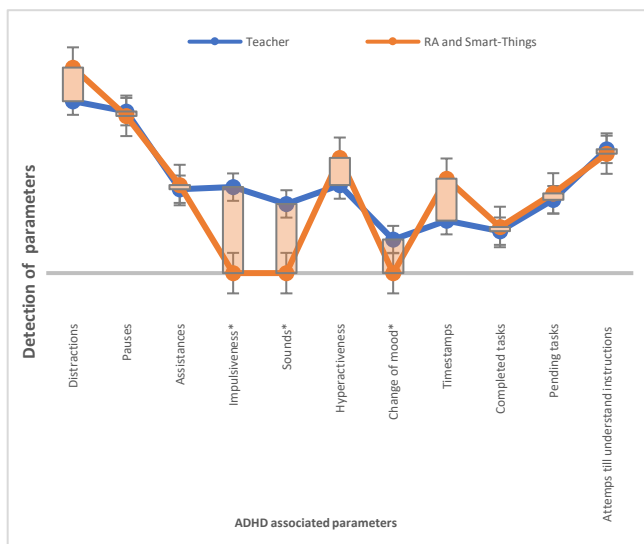
FIGURE 16. Comparison of the functionalities provided by the RA with the parameters and precision of the activities carried out by the teacher to detect parameters associated with ADHD.

D. QUALITATIVE EVALUATION OF THE RA

After the experimentation, information related to qualitative aspects of the RA was gathered. This information allows validating the perspective of the final user according to the new version. As table 6 shows, the second version of the RA has been validated by the final user obtaining the same results as its previous version. That means that the RA did not lose its qualities with the upgrade while the final user nonetheless finds these updates useful in any case.

TABLE XVII
COMPARISON OF THE TECHNICAL VALIDATION BETWEEN THE RA VERSIONS

Qualitative validation	1st version [a]	2nd version
The child perceives it	YES	YES
Prevent the normal operation of the object	NO	NO
Easy positioning	YES	YES
Easy on/off	YES	YES
Easy battery charging	YES	YES

[a] Results the comparison of the technical evaluation of the first and second version of the RA [12].

All modifications made to the design of the first version of the RA represent significant improvements in energy efficiency and portability. Besides, its production cost and replicability conditions improve considerably.

For the consolidated analysis of the second version's improvements over the previous version, the measures of energy consumption, time, and production cost, as well as portability and functional performance, were adjusted because they are variables that use different units of measurement. Indicators were determined which quantified all these variables on a single scale to be able to make the graph below (see Figure 17).
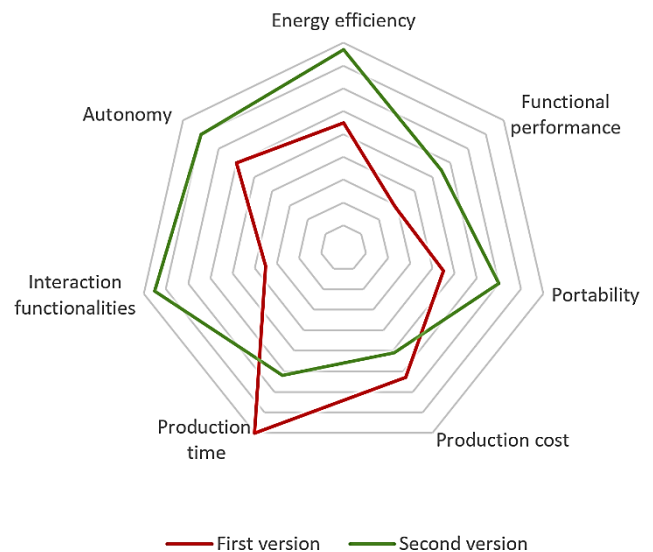
FIGURE 17. Comparison of the principal features and functionalities of the RA against its predecessor.

Figure 17 shows that energy efficiency, functional performance, portability, interaction functionalities, and autonomy are superior according to the first version. Additionally, the production cost and time are reduced compared to the first version. This graphic shows that the second version reduces the negative aspects and at the same time improves the positive characteristics (all parameters were scaled to adapt all aspects in the same graphic).

VII. DISCUSSION

The main objective of the RA is detecting when the child falls for a distraction and immediately catching the child's attention to provide him/her with instructions to keep the focus on the homework (feedback). However, this new RA is the ideal partner to work as a team when the child must fulfil his/her schoolwork avoiding distractions at home. The interaction of the robot with the child has become something more natural and spontaneous since the robot studies the child's behavior and the interaction in previous sessions to determine the best way to help him/her to perform his/her tasks every day. The interaction between the child and the robot one day varies compared to another, always. This depends on the child's

mood, the number of tasks that he/she must do, the number of tasks that were left to be done in previous sessions, and even on the day of the week. Due to the improvements, the AR no longer becomes predictable and boring over time.

This Smart-home environment offers features that are not included in related works. One of them is that this RA has multiple functions connected to the Internet, which avoids the need to take children to treatment centers to perform the treatment. The interaction with the children is more realistic than with a humanoid robot (NAO) because there is no one else controlling to atent@. Additionally, this RA can be easily replicated because it uses multiple components that are easy to find, and its programming is OPEN SOURCE.

Besides, the ability to obtain information about the child's behavior during multiple sessions can help the therapist propose new therapies (with or without the RA) and even improve traditional non-pharmacological treatments. However, there are still some parameters that this Smart-home must be able to measure. The authors are working on a proposal for future work that includes improving this scenario with more smart objects. These will then be able to capture and process the information that currently only the expert can obtain such as sounds (as a distraction) and the mood of the child.

VIII. CONCLUSIONS

This work demonstrates the evaluation of an RA as a tool to supplement the treatment process of children diagnosed with or suspected of having ADHD.

The RA was optimized from previous work, including adaptation from delivered results. The changes in the design of the electronic scheme led to improvements in the energy efficiency of the robot and its autonomy. Similarly, the interaction system was improved, allowing potentially new forms of interaction to be added. Compared to the previous work, the shape of the robot followed the same design principle: to avoid distractions at the child's workstation. For this reason, the RA has no moving parts. However, the size and weight of the RA were reduced to improve its portability. To assess the validity of the RA, an experiment was conducted with several children, with and without ADHD, and an expert. The results allow the following conclusions:

RAs together with intelligent objects in the environment are suitable for monitoring behavioral aspects of therapeutic interest during homework performance. In the experiments carried out, they did not interfere negatively with the children's performance.

As can be seen in the results, once the set of parameters to be monitored is established, the measurements of the RA and the expert are similar. Therefore, it can be concluded that the level of precision achieved by RA is sufficient to be used as a therapeutic support element.

RA monitoring allows the extension of therapeutic assessment outside specialized centers. Therapists can benefit in two specific aspects: more information about the child's performance outside the therapy setting and a deeper understanding of the child's behavior in his natural space. Measuring the child's performance in his or her natural environment is required by many therapists, so the approach presented in this study also allows for future development for robotic support of other activities, rather than focusing only on homework completion.

In addition to monitoring, a mild effective intervention can be implemented that leads to an immediate improvement in the performance of the activity at that moment. Results have shown generalized improvements in the additional time needed to complete some tasks, both in children with and without ADHD.

The experiment and its results show that the presented RA allows remote monitoring of homework with therapeutic significance and improves the routines of children with or without suspected ADHD. This research opens the possibility of conducting further experiments with a similar design (children without home monitoring) focusing on new activities such as personal hygiene, eating habits, relaxation, etc.

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JONNATHAN BERREZUETA-GUZMAN received the degree in project management from the Universidad Politécnica de Madrid, in 2016, the degree in electronic engineering with a major in industrial control and automation from the Universidad Politécnica Salesiana, in 2017, and the master's degree (Hons.) in the Internet of Things (IoT) from the Universidad Politécnica de Madrid, in 2019, where he is currently pursuing the PhD degree in systems and services engineering for the information society. He nowadays collaborating as a Researcher member of CATEDRA UNESCO Assistive Technologies for Educational Inclusion and in the Research Group on Artificial Intelligence and Assistive Technologies GIIATa. He works as a Research and Project Management Specialist at CEDIA directing R + D + i projects and competitive funds of various universities in the country. He is the Proceedings chair at the 8th and 9th Conference of Information and Communication Technologies TICEC.

MARÍA-LUISA MARTÍN-RUIZ was born in Madrid, Spain, in 1976. She received the Laurea (Graduate Diploma) degree in informatics engineering from the Universidad Carlos III de Madrid, Madrid, Spain, in 2006, and the PhD degree from the Universidad Politécnica de Madrid, Madrid, in 2014. Since 2014, she has been a Postdoctoral Fellow of telecommunications with the Universidad Politécnica de Madrid, where she is currently an Associate Professor of telecommunications. She was a research member of an innovation research group with the Universidad Politécnica de Madrid (T>SIC), from 2006 to 2015. In this research group, she was involved with research on applied research projects on AAL and home building automation supported by regional and national funds. Her current research interests include serious games, intelligent systems and developing and validating them in e-health and telemedicine scenarios).

IVAN PAU received the Ph.D. degree in accessible system and services from the Universidad Politécnica de Madrid (UPM), Spain. He is currently an Associate Professor of telematics engineering with UPM. His research background is in smart and pervasive environments (smart-home and smart schools) and user oriented security. His research activity is currently focused on the study of security and interaction issues in the conceptualization and development of sociotechnical services in the fields of health and education.

NURIA MÁXIMO-BOCANEGRA was born in Madrid, Spain, in 1973. She received the Laurea (Graduate Diploma) degree in occupational therapy from UNED, Madrid, Spain, in 1995, and the Ph.D. degree from Universidad Rey Juan Carlos, Madrid, in 2010. Since 2001, she has been working with the Physiotherapy, Occupational Therapy, Rehabilitation and Physical Medicine Department, URJC, as a Professor. She has collaborated with the Universidad Politécnica de Madrid, since 2017. Her current research interests include serious games, validating e-health and telemedicine scenarios.