Bee-bot robot in the use of executive functions in students with ASD: a pilot study

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***Abstract*— Currently, information and communication technologies (ICT) are configured as another pedagogical tool in the curricular development of students at different educational stages. Among these technological tools, the use of pedagogical robotics as a technology to support learning has created new academic experiences and favouring the inclusion of students with Specific Educational Support Needs (SEN), including those with autism spectrum disorder (ASD). Specifically, in the case of students with ASD, the scientific literature has confirmed the existence of difficulties in the management of executive functions. Therefore, the main objective of this research has been to apply the Bee-Bot robot to work on these functions. For this purpose, a quantitative study with a quasi-experimental design without a control group has been developed, where the sample is made up of a subject with ASD level 2. The instrument used is a system of categories designed *ad hoc* that is applied during the development of the 10 sessions that make up the intervention procedure. The results indicate how the student uses the executive functions worked on in most of the sessions where the Bee-Bot robot is used. In conclusion, it seems necessary to extend the research, as this type of robot could be efficient in improving the executive functions of these students.**

Keywords—autism spectrum disorder, executive functions, Bee-Bot, robot

I. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterised by difficulties in social-communicative skills and the presence of repetitive and restrictive behaviours and interests [1] that are related to difficulties in different areas of development, such as difficulties in maintaining the flow of conversation [2], abnormalities in eye contact [3] and body language [4], lack of facial expressions and non-verbal communication [5], insistence on monotony or excessive inflexibility in routines [6]. One of the main theories that tries to explain the origin of this great heterogeneity of difficulties is known as the Executive Dysfunction Theory [7] and considers that the low control of executive functions by students with ASD [8] is the cause of difficulties in the management of communication and social interaction skills and the presence of restrictive and repetitive behaviours [9].

A. Executive functioning of students with Autism Spectrum Disorder

According to Fatima [7], the term executive functions is used to describe several higher-order mental regulation operations that allow an individual to disengage from the immediate context in order to plan, organise, coordinate and execute actions to achieve their goals. In this sense, previous research has focused its efforts on highlighting the difficulties of students with ASD in the management and control of these functions. On the one hand, authors such as Landa & Goldberg [10] determined that these students have needs in planning, which is understood as a sequential and dynamic mental process that involves monitoring, prioritising, reducing/grouping information, rearranging and updating a sequence of planned actions [7]. On the other hand, Van Eylen et al. [11] evidenced difficulties related to cognitive flexibility, considered as the ability to alternate different thoughts or behaviours depending on changes in the environment, revising plans and transitioning attention between tasks [12]. Friedman & Sterling [13] identify working memory as an executive function in which students with ASD have needs. Working memory can be defined as the ability to retain, select and use the relevant information in mind to complete the task or achieve the goal [7]. The same authors, Friedman & Sterling [13], refer to inhibitory control, i.e., the ability to control your attention by neutralising irrelevant or distracting stimuli [14]. In this way, on the one hand, restrictive and repetitive behaviours could be related to a lack of cognitive flexibility skills [9] and, on the other hand, difficulties in social-communicative interaction would be related to deficits in inhibition, information recall, flexibility and the ability to control, update and select socially appropriate responses [15].

B. Educational interventions to improve executive functions

Executive functions are targeted in educational settings through different approaches, from school-based paper-and-pencil activities [16], information and communication technology (ICT) activities [17] to activities such as aerobics, martial arts and yoga [18]. These interventions have been designed for both typically developing students and those with specific educational support needs [19], such as students with ASD. In order for these educational interventions focused on executive functions to be effective so that students can assume and generalise these skills to other contexts, Diamond & Lee [18] determined that interventions must have certain characteristics. In this sense, they should include varied and at the same time challenging activities that allow for repetition as many times as necessary. Furthermore, these interventions should also have timetables that are adaptable to the needs of the learners and intensive. At the same time, they should allow for the emotional, physical and social involvement of all students [18].

C. Pedagogical robotics in the work of executive functions

Nowadays, pedagogical robotics is configured as one of the ICT aimed at enhancing executive functions [20]. The reason for this is that robotic programming requires students to be able to mentally plan the sequence of steps to reach a goal and to be able to verify their work, for which higher order cognitive functions are essential [19]. Therefore, it makes it an ideal tool for working on executive functions such as temporal sequencing, working memory or problem solving, among others [19]. In this line, Di Lieto et al. [21] implemented an intensive educational robotics training for 6 weeks to work on executive functions with preschool students. In this intervention they used a robot using a bee-shaped robot, called BeeBot®. Recently, the same authors Di Lieto et al. [19] developed another study with students aged between 5 and 6 years, to work on executive functions with this same robot, the results of which are the first quantitative evidence of the positive effects of this type of intervention on the executive functions of working memory and inhibition. Similarly, Di Lieto et al. [22] developed another study with the aim of verifying the effectiveness of this pedagogical robotics programme in students with special educational needs. In this study they also implemented the BeeBot® robot. The results of the studies [19, 21-22]. They showed that the programme could be an effective tool for improving executive functions in both typically developing pupils and pupils with special needs.

On the one hand, this robot Bee-Bot has sound and light effects. It can be interacted with by using the commands located on the top of the robot, each of which corresponds to an instruction ("move forward", "backward", "turn", "pause", "delete" and "ready"). In total, the maximum number of instructions that can be programmed with the robot is 40. At the end of the sequence, the robot emits sounds and lights. On the other hand, play mats divided into grids are used to work with this robot.

D. Potentialities of the use of pedagogic robots with students with ASD

Students with ASD show a great affinity for robots [23], which becomes one of their main potential to be implemented as a didactic resource. Specifically, robots arouse high levels of motivation in students with ASD due to their own characteristics [24]. In this sense, the structure of robotic toys attracts the attention of learners with ASD to a much greater extent than other types of toys [25]. Their external appearance (colours, lights, rotating mechanics...) makes them visually more attractive [26]. Thus, robots are much more predictable and simpler than humans and, therefore, it is much easier for students with ASD to learn with them [27]. Thus, the use of robotics leads to greater involvement of students with ASD in learning tasks compared to those involving only human agents [28]. Based on these potentialities, the main objective of this research study is to apply the Bee-Bot robot, to work on the executive functions of students with autism spectrum disorder. Based on this general objective, the following specific objectives are proposed

- To design an intervention to develop executive functions with the Bee-Bot robot.
- To describe the use of planning abilities with the application of Bee-Bot robot.
- To describe the use of flexibility cognitive abilities with the application of Bee-Bot robot.
- To describe the use of working memory with the application of Bee-Bot robot.
- To describe the use of inhibitory control abilities with the application of Bee-Bot robot.

II. METHOD

A. Methodological approach

The present research employs a quantitative methodology with a quasi-experimental design [29] and no control group.

B. Research context and participants

The research was conducted in a school located in the city of Alicante (Spain). Specifically, the sample was selected on an intentional non-probabilistic basis, as the researcher established the criteria to be met in relation to the objective of the study [30]. Therefore, the sample consisted of one student with ASD, 7 years old with autism level 2 and verbal communication attending school in a specific communication and language unit.

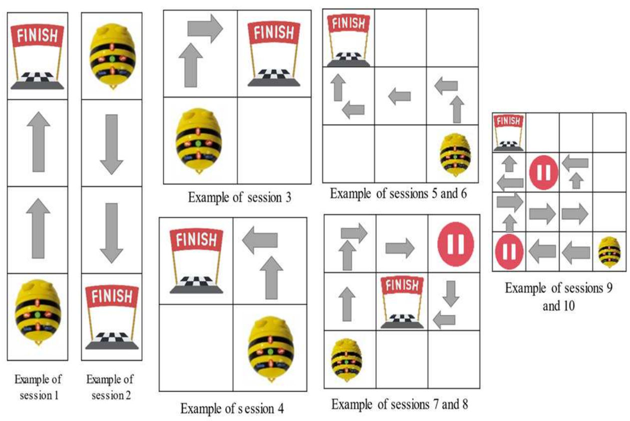
C. Instrument

The previous review of the scientific literature was conducted to determine its definition [10-14]. In this sense, to measure the competence of the participants in executive functions a system of categories composed by 12 items divided into 4 dimensions has been designed *ad hoc*: (1) planning, (2) cognitive flexibility, (3) working memory and (4) inhibitory control. In addition, a 5-point licker scale was used to measure the frequency parameter. During the sessions, data collection is conducted using the instrument described above.

D. Procedure

After approval by the Research Ethics Committee of the University of Alicante (UA-2021-09-06-1), schools were contacted to implement the intervention with their students with ASD. Ten individual sessions of 15 minutes each were developed during the months of January and February 2020. The sessions are structured with activities of different levels of difficulty. Specifically, each session is structured in 5 challenging activities. Fig. 1 shows examples of the play mats used to develop the different challenges of the sessions.

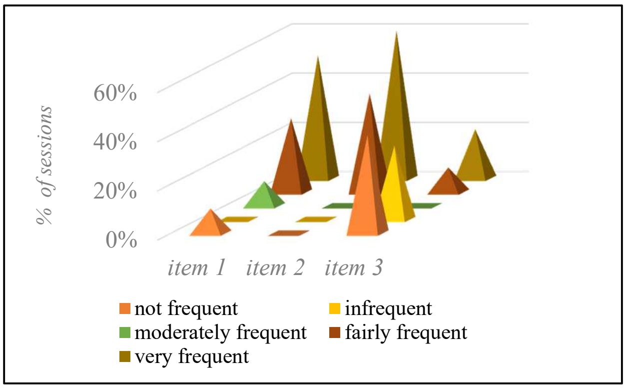
Fig. 1. Play mat for the sessions



III. RESULTS

A. *Improvements in planning with the application of the intervention with the Bee-Bot robot.*

The results in Fig. 2 indicate that in the highest percentage of sessions (80%), the student was able to use the flashcards of the commands to structure the route (item 1) quite frequently (30%) and very frequently (50%). In addition, in 100% of the sessions, he counts the squares that the robot must advance before programming (item 2) quite frequently



(40%) or very frequently (60%). On the other hand, the percentage of sessions in which the students are not able to structure an alternative route when faced with obstacles (item 3) are 40%.

Fig. 2. Results of planning abilities.

B. *Improvements in flexibility with the application of the intervention with the Bee-Bot robot.*

The Fig. 3 indicates that in most of the sessions (90%) it is not common for the student to have difficulties in finishing one activity and starting another (item 3). Furthermore, in 80% of the sessions the student did not show signs of frustration when he/she made a mistake (item 5). Finally, in 90% of the sessions the pupil did not show dissatisfaction when changing play mats (item 6).

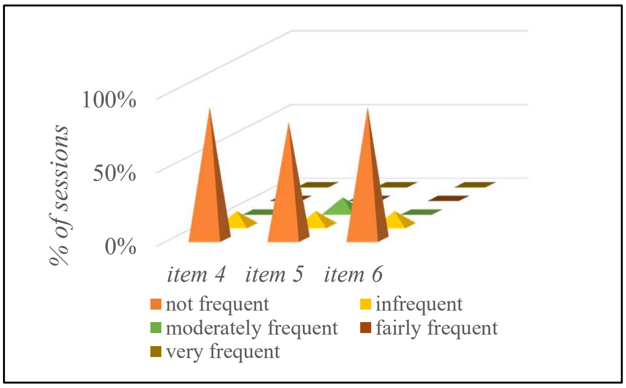
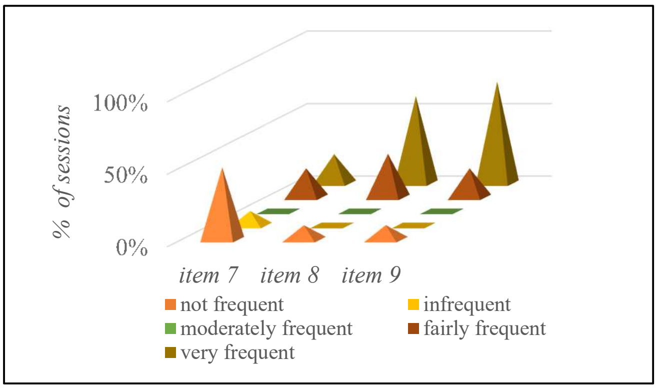


Fig. 3. Results of flexibility abilities.

C. *Improvements in working memory with the application of the intervention with the Bee-Bot robot.*

The results, showed in the Fig. 4, indicate that while in 60% of the sessions the learner does not forget some steps/stops along the route (item 7), in 40% of the sessions the learner forgets quite often (20% of the sessions) or very often (another 20%). In addition, the learner is able to retain the information provided to perform the task (item 8) quite



often in 30% of the sessions and very often in 60%. In addition, in 80% of the sessions, the learner remembers the robot's commands quite often or very often (item 9).

Fig. 4. Results of working memory abilities.

D. *Improvements in inhibitory control with the application of the intervention with the Bee-Bot robot.*

The results of the last dimension (Fig. 5) indicate that in 80% of the sessions the learner is able to maintain attention on the activity despite the stimuli (item 10) very frequently. Also, in more than half of the sessions (60%) the learner waits moderately often for his or her turn to ask questions (item 11). And, in 40% of the sessions, the student moderately frequently keeps calm when he/she makes a mistake.

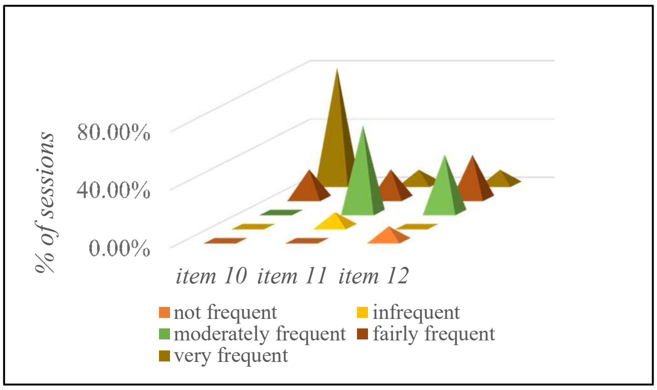


Fig. 5. Results of inhibitory control abilities.

IV. CONCLUSIONS

After the results it is possible to reach the following conclusions: (1) The student with ASD makes use of planning skills in most of the sessions when using the Bee-Bot robot very frequently. (2) Likewise, with respect to cognitive flexibility, the student shows that in most of the sessions he has difficulty in changing from one activity to another or showing frustration or dissatisfaction with changes. (3) With respect to working memory, in more than half of the sessions it is observed that he is capable of retaining previously informed or learnt information very frequently. And (4) the majority of students show inhibitory control skills moderately frequently to very frequently.

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