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Roots and Future of Using Technologies to Foster Physical and Mental Wellbeing

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Brain and Virtual Reality: What Do They Have in Common and How to Exploit Their Potential

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Educational Robotics to develop executive functions visual spatial abilities, planning and problem solving.

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Abstract. Educational robotics is an innovative learning tool that offers students the opportunities to develop higher-order thinking skills. This research aims to verify the effectiveness of educational robotics on the mental processes of planning and problem solving. Robotics education involved in a curricular laboratory (10 meetings, two hours each, once a week) with 15 children, attending their fifth year at primary school. The proposed methodology was divided into three phases: Pre-test, Practice and Post-Test. The main finding was a significant improvement in visuo-spatial attention and a significant effect on robot programming skills. These data provide scientific support to the hypothesis that robotics activities are suitable in progressively improving abilities in planning and controlling complex tasks in children, fostering executive functions development.

Keywords. Educational Robotics, Metacognition, Learning, Problem solving, New Technology

1. Introduction

This work presents and discusses a specific didactic approach to support the development of visual spatial attention, planning and problem solving skills in activities of educational robotics. Educational robotics (ER) are being introduced in many schools as an innovative learning environment that offers students the opportunities to develop higher order thinking skills and abilities, and solve complex problems [1]. It is a powerful and flexible teaching and learning tool which engages students in activities of robot construction and control using specific programming

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tools [2]. In a typical ER activity, students work in groups to address complex problems. Through iterative design and testing, students get immediate feedback on their actions and learn how to deal with challenging situations in a real-world context.

Recent studies suggest the ER as an innovative model of empowerment of the transversal skills such as reasoning, problem solving [3-4], metacognition [5-8], programming [9-10] and collaboration [11]. Programming the actions of a robot to make it achieve an objective, requires the ability to anticipate the action mentally, select the appropriate procedure, and update it continuously. The programming of small mobile autonomous robots into the physical environment requires planning, precision in the use of language, the generation and testing of hypotheses, the ability to identify action sequences and a variety of other skills that seem to reflect what thinking is all about. Furthermore, working with programmable robots allows children to test the robots' actions in the real environment with all its variables, such as the indeterminacies and the typical uncertainties of the environment (different from the simulation in virtual contexts where everything is still predefined) and their own reasoning strategies. The feedbacks (positive and negative) provided by the robot/environment interaction require a continuous revision of the programming algorithms [12].

In order to create a successful program, children must use procedural thinking and understand the logic of instructions. When creating a program, children are thinking in terms of next, before, and until, which are all components of sequencing—in particular, temporal sequencing [9]. Given these characteristics, the robotics activities can enhance mental processes that belong to the cognitive domain of the Executive Functions: problem solving, planning, working memory, inhibition, mental flexibility, initiation and monitoring of actions. Executive functions refer to a family of adaptive, goal-directed, top-down mental processes needed when you have to focus and pay attention and when an automatic response would be insufficient [13-14]. Executive functions make "mentally playing with ideas, taking the time to think before acting, meeting novel, unanticipated challenges, resisting temptations, and staying focused" possible [15].

This research aims to verify the effectiveness of educational robotics on the executive functions and in particular on the mental process of visuo-motor planning, attention skills, and planning and problem solving.

For this purpose, we implemented a sample of students attending their fifth year at primary school involved in a robotics laboratory.

2.Methods

2.2. Participants

The sample consisted of thirty healthy children, attending their fifth year at primary school of Palermo (Italy). Participants were randomly assigned to the control and the experimental group, each composed of fifteen subjects (9 males and 6 females; 10 years).

Children of the experimental group followed the LEGO robotics laboratory described below. Children of the control group followed the regular school activities.

Table 1: Sample characteristics

	Experimental group	**Control group**
	n = 15	*n* = 15
Age (Mean ± SD)	10 ± .000	10 ± .000
Gender (M, F)	9, 6	9, 6

2.3. Instruments and procedure

The children of the experimental group were divided into small groups (three or four children per group) and each was provided with a robotic kit that involved a curricular laboratory based on robotics activities (10 meetings; two hours each, once a week). The participants had to build a robot body and subsequently plan and program different behavioral repertoire.

For the intervention, we used LEGO Mindstorms EV3 and assembled the robot as a small vehicle, equipped with motor, ultrasonic sensors at the front, one pointed straight ahead, and an LED color light mounted on top. LEGO Mindstorms is a programmable robotic kit released by Lego. This robot is low cost, modular, has a user-friendly interface, and also the robot configuration can gradually evolve. First, children familiarized themselves with robotics artifacts and the hardware and software elements of the kit. During these sessions, the robotics kits were introduced to the children, explaining programming characteristics and main commands. Successively, they built a small-mobile robot, following the instruction provided by the LEGO manual. After building their robot, children were trained with LEGO programming interface. Then, all the students were given programming tasks having an increasing level of difficulty measured by the number of commands necessary for programming the robot. Incrementally, more difficult activities were proposed allowing the children to gradually achieve a greater competence, with an approach based on the “error-less learning” method. Each of the tasks provided opportunities for subject to program and observe the robotic toy and to reflect on the toy’s movement. One of the most important tasks of the robot is the ability of collecting data about the environment in which it is located through different sensors. Interacting with the environment the robots can be in a position to simultaneously detect and process information coming from different sources, such as a light sensor and a contact sensor. Then, working with programmable robots allows children to test the robots’ actions in the physical environment with all its variables, such as the indeterminacies and the typical uncertainties of the environment (different from the simulation in virtual contexts where everything is still predefined) and to test their own reasoning strategies. The feedbacks (positive and negative) provided by the robot/ environment interaction require a continuous revision of the programming algorithms.

The dynamic actions of the toy created a “shared moment” which was highly visual and in turn provided opportunities for shared attention and group work. Programming robot actions requires, for each step, mental anticipation of the action, selection of the appropriate robot command and continuous updating of the programming in order to obtain the goal. The emphasis during the problem-solving exercises is the analysis of the problem, not the generation of code.

2.4. Assessing cognitive abilities

The proposed methodology was divided in three phases: Pre-test, Practice and Post-Test.

During the pre/post-test phases the cognitive and executive functions were measured using the following tests: Frontal Assessment Battery (FAB), reduced version that includes only three subtests [16], to investigate mental flexibility, motor planning and executive control. Motor planning and executive action control were explored by means of Luria's motor tasks. In the "contrast" task, exploring the ability to prevent interference effects, subjects had to perform an action opposite to that performed by the examiner, refraining from the tendency to imitate the examiner's action. Inhibition of control was evaluated by a "Go/No-Go" task. Scores ranged from 0 (no correct responses) to 3 (all correct responses) for each subtest. The overall score was the sum of the three subtest scores (range: 0-9).

The Trail Making Test (TMT, Forms A, B and B-A), version for children under 15 [17], assessed attentional skills, visuo-motor planning, sustained attention and working memory. This version has the same characteristics as that of adults, and only differs in the number of stimuli presented. The 25 numbers in part A are reduced to 15, and the 13 numbers and 12 letters in part B are replaced by 8 and 7 elements respectively.

Tower of London (ToL) [18] for the capacity of planning and problem solving. The Tower of London test is widely used for measuring planning and aspects of problem solving in neuro- psychological patients and normal populations. Participants are asked to preplan mentally a sequence of moves to match a start set of discs to a goal, and then to execute the moves one by one. The mental preplanning stage has been identified as critical to efficient performance.

All the test were administered to participants by a team of trained psychologists in a classroom setting.

2.5. Educational robot activities

In line with a consolidated methodology [6-7], each group performed different programming task having an increasing level of difficulty.

First, they were invited to create a narrative scenario for the robot behavior and to build a physical environment (i.e. the arena or city map) using pasteboard, colors and other materials. After, robot programming was proposed, asking the child to move the robot to reach a specific goal.

The steps of programming and the length of path were progressively incremented, requiring the child to display a more complex ability to plan and to visuo-spatial update.

Specifically, the subjects were requested to perform the following tasks:

- Build and program a robot able to move along a linear route;
- Program the robot able to move and describe a geometric figure as a square;
- Program the motors and the color detection sensor- Create and program a robot able to move and change trajectory if there is a red line along its route;
- Program the motors, the color detection sensor and the ultrasonic sensor- Create and program a robot able to move and shoot balls if there an object along its route.

3. Results

All participants of experimental group maintained a high level of motivation during laboratory activities period.

The effectiveness of treatment was analyzed through repeated measures ANOVA, with two levels of the between-subject factor (experimental group and control group) and two levels of the within-subject Time factor (pre-test and post-test).

For the univariate test, the Time factor was statistically significant on all the variables considered. Furthermore, the univariate tests showed that the effect of Time x Group interaction was statistically significant on the scores of TMT A ($F_{1\text{-}28}$= 9,375, p < .01, η_p^2 = .251), TMT B ($F_{1\text{-}28}$= 4,004, p= .055, η_p^2 = .125); ToL ($F_{1\text{-}28}$= 9,618, p < .01, η_p^2 = .256) and on the reduction of attempts to the Tower of London test ($F_{1\text{-}28}$= 51,746; p= < .01, η_p^2= .649).

As reported in Table 2, after robotics activities, the experimental group showed a significant reduction of execution time for TMT-A ($F_{1\text{-}28}$=12,997, p = .001, η^2 = .317), while it was not significant for TMT-B ($F_{1\text{-}28}$=6,270; p = n.s.), suggesting an improved performance in the following attentional skills: visuo-motor planning and sustained attention.

At the FAB, the performance of experimental group increased from pre-test to post-test because of treatment ($F_{1\text{-}28}$=7,646, p= .010, η^2 = .214):

Regarding the Tower of London, the difference between experimental group and control group was statistically significant ($F_{1\text{-}28}$=5,531, p= .026, η^2 = .165): the subjects of the experimental group increased their score and showed improvement on the capacity of planning and problem solving.

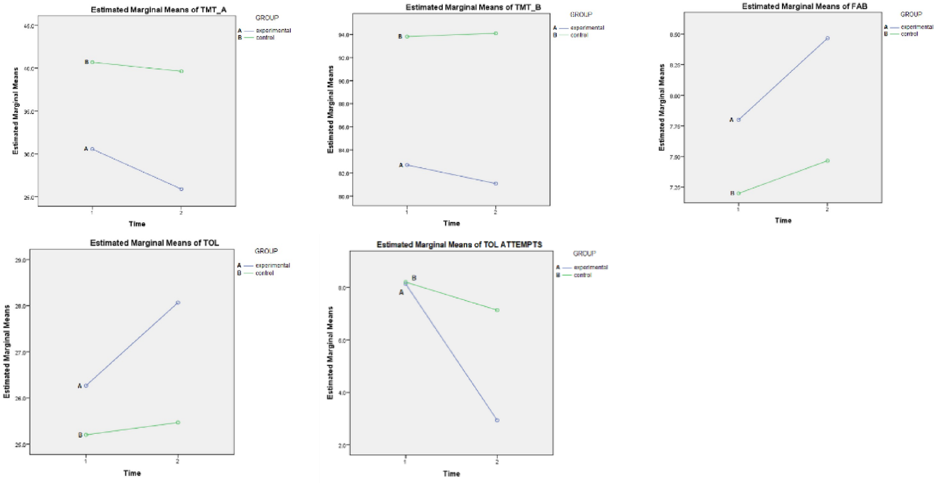
Furthermore, the experimental group showed a reduction of attempts to complete the Tower of London test ($F_{1\text{-}28}$=15,392, p= .001, η^2 = .355).

Table 2. Repeated Measures ANOVA between subject and within subject (before and after training

	Experimental group				**Control group**			
	Pre-test		**Post-test**		**Pre-test**		**Post-test**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
TMT-A	30,560	6,941	25,907	5,925	40,693	14,625	39,640	13,771
TMT- B	82,693	14,733	81,080	14,940	93,820	32,783	94,100	31,957
FAB	7,800	1,207	8,467	0,743	7,200	1,320	7,467	1,187
TOL	26,267	2,815	28,067	1,907	25,200	4,126	25,467	3,833
TOL attempts	8,133	3,888	2,933	2,404	8,200	3,967	7,133	3,737

The estimated marginal means showed a significant difference between the two groups over all measurement time (figure 1).

Fig 1. Estimated marginal means for Group*Time



4. Conclusions

The results of the present research confirm the importance of using educational systems based on robotics to encourage the use of specific cognitive and attentive abilities.

This study supports the hypothesis that activities of Educational Robotics have repercussions on executive functions because they can be a vehicle for the development of higher-level control components, such as forecasting, planning, and problem solving skills. Indeed, this research provides quantitative data for evaluating the effects of a robotics laboratory on transversal high-level cognitive functions in children.

In general, the results showed that the involvement and the improvement of the logical reasoning ability allows subjects to anticipate and to plan the sequence of the actions needed to solve a particular behavioral task.

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