Annual Review of Cybertherapy and Telemedicine 2010
B.K. Wiederhold et al. (Eds.)
IOS Press, 2010

doi:10.3233/978-1-60750-561-7-110

Using Robotics Construction Kits as Metacognitive Tools: a Research in an Italian Primary School

Filippo LA PAGLIA[a,1] Barbara CACI [b], Daniele LA BARBERA [a] and Maurizio CARDACI[b,c]

[a] *Dipartimento di Neuroscienze Cliniche, Università degli Studi di Palermo, Italy*
[b] *Dipartimento di Psicologia, Università degli Studi di Palermo, Italy* [c] *Centro Interdipartimentale di Tecnologie della Conoscenza, Università degli Studi di Palermo, Italy*

Abstract. The present paper is aimed at analyzing the process of building and programming robots as a metacognitive tool. Quantitative data and qualitative observations from a research performed in a sample of children attending an Italian primary school are described in this work. Results showed that robotics activities may be intended as a new metacognitive environment that allows children to monitor themselves and control their learning actions in an autonomous and self-centered way.

Keywords. Educational Robotics, Metacognition, Learning.

Introduction

Robotics kits are *high tech* toys that allow users to build and to program small mobile autonomous robots into the physical environment [1]. During the game with such kits, children first build the robot body and then create a program in order to assign it an artificial intelligence (e.g., create a robot able to move into a maze). Finally, children test the robot performance into the physical environment in order to verify its success/failure. The final test is quite important because users can instantaneously see what they have planned for the robot and verify if they behave the way they were planned to.

A large amount of theoretical studies and empirical researches have showed that playing with robots allows students of different ages to improve their planning, reasoning and problem-solving abilities [2, 3, 4] as well as social skills related to peer conflict resolution, group decision-making and so on [5]. Moreover, children with mental retardation and autism seem to have benefits from rehabilitative activities based on robotics [6, 7]. However, there are no studies, according to our knowledge, which have analyzed the possibility to use robotics kits as metacognitive tools. In general, metacognition consists of two basic processes occurring simultaneously; the first is monitoring the progress of learning; the second is making changes or adapting learning

[1] Corresponding Author: Dipartimento di Neuroscienze Cliniche, Università di Palermo, 85, Francesco Ingrao, Grotte, Italy 92020; E-mail: filippolapaglia@gmail.com; laban@unipa.it

strategies when subjects perceive that they are not successful [8]. Specifically, metacognitive skills include monitoring the progress of learning, correcting errors and changing strategies when it's needed [9]. From this perspective, the whole experience of playing with robots may be intended as a metacognitive process that leads users to becoming more aware and conscious of the way they think, learn and organize the game itself. With the aim to analyze the metacognitive strategies related to the error analysis and retrieving, we performed a research in a sample of children attending a primary school participating in a robotics laboratory.

1. Method

1.1 Participants

Twelve children (6 Male and 6 Female; mean age: 9 *yrs*; range: 8-10 *yrs*) were randomly selected from all the third, fourth and fifth forms of the primary School of Palermo. The whole group was then divided in three subgroups (four children each, 2 Male; 2 Female) according to forms and ages.

1.2 Materials and procedure

In line with our previous researches [2, 3, 4], each group was provided with a robotic kit and was involved in an extra-curricular hands-on laboratory based on robotics activities (10 meetings; two hours each, once a week). After the familiarization with the hardware and software elements of the kit, all the children were given four construction and programming tasks with an increasing level of difficulty, as measured by the number of bricks, which had to be manipulated for constructing the robot body and by the number of drives, which had to be linked to create a specific robot behavioral repertory.

Specifically, children were first assigned with the following construction tasks aimed to build a small mobile robotic vehicle:

- Build the light sensor (it requires 12 LEGO bricks and 5 assembling sequences);
- Built the single bumper (it requires 32 LEGO bricks and 8 assembling sequences);
- Built the double bumper (it requires 37 LEGO bricks and 12 assembling sequences);
- Built the chassis and the wheels (it requires 100 LEGO bricks and 21 assembling sequences).

Once the robot was built, participants were then involved in programming it by using the software interface. Each group was provided with a desktop computer and a USB infrared tower to download the software program into the robot, and assigned with the following four programming tasks, having an increasing level of difficulty measured by the number of commands necessary for programming the robot:

- Program the motors – Create a robot able to move along a linear route (1 command);

- Program the motors and the light sensor - *Create a robot able to move and change trajectory if there is a black stain along its route* (4 commands);
- Program the motors and the single bumper: - *Create a robot able to move and change trajectory if there is an obstacle along its route* (5 commands);
- Program the motors and the double bumper - *Create a robot able to move and change trajectory if there is an obstacle along its route* (9 commands).

During all the construction and programming sessions children metacognitive strategies were registered using two observational grids that provided quantitative and qualitative indicators.
The first grid, named *Searching and Assembling Grid* [10] measured metacognitive abilities employed during the construction of the robot using the following indicators:

- Number of searching errors related to search and select a wrong brick;
- Number of visual-spatial assembling errors related to difficulties in orienting the robot in the space;
- Number of eye-hand coordination errors related to difficulties in motor coordination;
- Frequency of checks made by subjects to verify if the correct bricks were taken and assembled.
- Frequency of spontaneous self-corrections
- Frequency of trough-other corrections made by the experimenters.

The second grid, named *Robot Behavioral Programming Grid* [10] measured metacognitive abilities used during the programming phase, following these indicators:

- Frequency of using the Trial command, the button that allows users to test before the robot performance as planned by children;
- Number of programming commands that users eliminated;
- Number of programming commands that users changed after the download (such indicators are quite similar to self-corrections in the Searching and Assembling Grid);
- Number of downloads;
- Frequency of trough-other errors corrections.

On the basis of previous indicators two indexes were also calculated that measure metacognitive skills based on control, named respectively: 1) *Index of construction self-correction*, which was based on the ratio between the total number of self-corrections and the total number of construction errors; and 2) *Index of programming self-correction*, which was based on the percentage rate between the total numbers of programming commands that users changed and the total number of downloads.
Other two indexes that measure of the claim for external aids, during construction and programming sessions, named respectively: 1) *Index of construction help requests*, which was based on the ratio between the total number of trough-other corrections and the total number of construction errors; and 2) *Index of programming help requests* that

was calculated on the ratio between the total number of trough-other corrections and the total number of download made by user were also calculated.

Finally, both the *Searching and Assembling Grid* and the *Robot Behavioral Programming Grid* collected qualitative indications about causal attributions and self-efficacy statements made by users during the robotics activities.

2. Results

As showed in Table 1, the third-form children made more metacognitive actions based on controlling and retrieving errors than the other two groups during the whole game action.

Table 1. Results at *Observational Grids*

	Searching and Assembling Grid			***Robot Behavioral Programming Grid***			
	Third form group	**Fourth-form group**	**Fifth-form group**		**Third form group**	**Fourth-form group**	**Fifth-form group**
Searching errors	13	0	6	Frequency of using the Trial command	2	0	0
Visual-spatial assembling errors	50	14	24	Number of eliminated commands before the download	2	2	5
Eye-hand coordination errors	10	6	5	Number of changed download after the download	116	64	63
Frequency of checks	14	6	8	Number of downloads	90	68	58
Frequency of self-corrections	15	5	14	Frequency of trough-other corrections	0	1	0
Frequency of trough-other corrections	40	10	17				
Construction self-correction index	**21%**	**25%**	**40%**	**Programming self-correction index**	**53%**	**38%**	**45%**
Construction help requests index	**55%**	**50%**	**48%**	**Programming help request index**			

However, during the construction phase they prefer to request help from experimenters rather than using self-corrections and tended to attribute their failures to external causes (e.g., “It’s very difficult!”).

On the contrary, during the programming phase, they made a higher number of self-corrections and they were more focused on their performance than on the robot, also emphasizing their own success (e.g., "I know it" or "I'm able to program the robot!").

3. Conclusions

The present study is a first attempt to investigate the possibility of using robotics activities as a metacognitive tool. From this perspective, our results allow us to describe the action of playing with robots as a kind of "thinking with robots" which creates an autonomous and self-centered learning environment and motivates children both at monitoring and at controlling their own actions. However, further researches with a large sample should be done in order to confirm these preliminary results.

References

[1] O. Miglino, H.H. Lund, & M. Cardaci, Robotics as an Educational Tool, *Journal of Interactive Learning Research*, **10 (1)**, (1999), 25-48.

[2] B. Caci, A. & D'Amico, Children's Cognitive Abilities in Construction and Programming Robots. *Proceeding of the 11th IEEE International Workshop on Robot and Human Interactive Communication, IEEE Roman 2002*, September 25-27 2002, Berlin – Germany (2002).

[3] B. Caci, A. D'Amico, & M. Cardaci, Costruire e Programmare Robots, *Tecnologie Didattiche*, **27(3)**, (2002), 36-40.

[4] B. Caci, A. D'Amico, & M. Cardaci, New frontiers for psychology and education: robotics, *Psychological Reports*, **94**, (2004), 1372-1374.

[5] M.A. Barfurth, Understanding the collaborative learning process in a technology rich environment: the case of children's disagreements. In L. Schnase & E. L. Cunnius (Eds.), *Proceedings of CSCL95: computer support for collaborative learning.* Mahwah, NJ: Erlbaum, (1995), 8-13.

[6] K. Dautenhahn, Design issues on interactive environments for children with autism. *Proceeding International Conference on Disability, Virtual Reality and Associated Technologies, ICDVRAT 2000*, 23-25 September, Alghero, Sardinia, Italy (2000), 153-161.

[7] F. Michaud, C. & Théberge-Turmel, Mobile robotic toys and autism. In K. Dautenhahn, A. Bond, L. Canamero & B. Edmonds (Eds.) *Socially Intelligent Agents - Creating Relationships with Computers and Robots.* London: Kluwer Academic (2002).

[8] W. Winn, & D. Snyder, Cognitive perspectives in pyschology. In D.H. Jonassen, ed. *Handbook of research for educational communications and technology*, New York: Simon & Schuster Macmillan (1996), 112-142.

[9] D.S Ridley, P.A. Schutz, R.S. Glanz, & C.E. Weinstein, Self-regulated learning: the interactive influence of metacognitive awareness and goal-setting, *Journal of Experimental Education,* **60 (4),** (1992), 293-306.

[10] Caci, B. (2005). Studi e ricerche su robotica e processi cognitivi. Unpublished doctoral tesis, University of Palermo,