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Robotics Construction Kits: From "Objects to Think with" to "Objects to Think and to Emote with"

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Abstract: This paper discusses new ideas about the use of educational robotics in social-emotional learning. In particular, educational robotics could be a tool intended to allow children to acquire some of the basic aspects of human emotions and emotional functioning, and to understand how these relate to the mind and body. More specifically, by using robots such as the LEGO Mindstorm construction kits—which allow users to both construct the body of the robot and to provide it with a behavioural repertory—children have the opportunity to visualize (and manipulate) the relationship between the robot's body and mind. This allows them to simulate "embodied emotional minds" and to reflect on new neuroscientific concepts regarding body-mind and cognition-emotion relationships.

Keywords: emotional intelligence; somatic markers; educational robotics

1. Introduction

During the last fifteen years, our research team has been involved in studying the impact of robotics on the improvement of cognitive skills. In our 2004 perspective paper [1], we described robotics as a new frontier in applied cognitive psychology and mentioned some emerging studies, performed in a constructivist framework, which showed important implications of the physical interaction between children and robots. In particular, we focused on four areas: (1) the social and cooperative dimensions of intelligence involved in hands-on robotic activities; (2) the reasoning strategies implied in building and programming robots; (3) the influences of robotics on mathematical and scientific education; (4) the impact of robotics on the social skills of autistic children.

In the last few years, several scientists have contributed greatly to the development of each of these research areas. Consequently, today we usually use the term "educational robotics" to refer to all applications of robotics in the cognitive-educational field. As for the social and cooperative dimensions of intelligence, many studies have demonstrated that educational robotics is a positive way to improve cooperative learning as well as individual and collective self-efficacy [2]. Robots have also been used with the goal of improving children's cognitive skills in different situations [3–6]. In one of our studies, scholastic achievement and cognitive-motivational aspects of learning in a student with intellectual disability improved significantly through the effect of robotics activities [3]. Moreover, Fridin and Yaakobi demonstrated that robotics may help to improve memory and attention in children with ADHD [4]. Robots may be used in order to improve cognitive abilities in mainstream classes as well [5,6]. These results basically show that "cold" cognitive abilities, such as logical reasoning, are important prerequisites for anticipating and planning the sequence of actions that are necessary to adapt the robot to its environment. From this perspective, working with programmable robots allows children to test both the robots' actions in the environment and their own reasoning strategies [1].

Similarly, educational robotics has been used in didactic contexts in order to support mathematical and scientific education [7,8]. Simultaneously, several scientists have started to connect the "cold" world of robotics to the "hot" world of emotions and emotional processing, in a series of studies that are usually included in the field of Affective Computing [9].

This interesting field of research has given rise to two types of studies: the first is based on a more engineeristic approach, and is devoted to finding ways to give emotion to robots, i.e., to simulate robots that can be said to have emotions [10], to develop robots that express and/or recognize emotions, and so on [11,12], as well as to improve human-computer trust or interaction [13]. The second type of studies are more concerned with the rehabilitative use of robots, and have been widely used for people with Autism Spectrum Disorders (ASD). In this research field, zoomorphic or anthropomorphic robots are generally used as social mediators in communication: the interaction with robots seems to help children with autism increase their level of attention given to the others and their range of imitative actions [14]. Paradoxically in the field of ASD, robots are useful for rehabilitation, since they express fewer emotions than humans. In fact, one of the problems of people with ASD, is the difficulty in processing the complexity of human emotional expressions [15].

In our view, the field of Affective Computing needs to be improved and enriched with studies and experiences of emotional-educational robotics [16].

We have already carried out some experiments in this direction in robotics labs aiming to enhance creativity and narrative thinking in children who were average 11 years old [17]. During the activities, children were requested to freely choose the robots' actions and to create a scenario and a story for their robots. In these contexts, we observed that children created human-like stories for their robots, such as "the robot is drunk and it is looking for another bottle of beer" or "the robot is enjoying dancing in the disco", and so on. In a further study, we replicated this methodology by also using virtual agents in Kodu Game Lab [5]. Thus, by contextualizing the robots' behaviours in a narrative context, children started to attribute emotions and motivations to robots or agents.

However, to our knowledge, so far, no research has studied the effect that the use of educational robotics kits could have in social-emotional learning, and in particular in simulating embodied emotional minds.

2. From the Double Body/Mind and Emotion/Cognition Dualism to Emotional Intelligence

During the 90s, cognitive science scholars started to discuss the necessity of revising old concepts about body/mind and emotion/cognition dualism. One major criticism of body-mind dualism comes from the studies by Damasio [18] who, in his book "Descartes' error", discussed the fundamental error in considering the existence of a mind separated from a body. In fact, Damasio proposes that "human reason depends on several brain systems, working in concert across many levels of neuronal organisation, rather than on a single brain centre. Both "high-level" and "low-level" brain regions, from the prefrontal cortices to the hypothalamus and brain stem, cooperate in the making of reason" [18]. Moreover, Damasio debunked another dogma in cognitive science, as well as in philosophy, literature and so on, regarding the emotion/cognition dualism. The author affirms that old theories need to be overcome, especially those considering "hot" emotional processes as if they were separated from "cold" emotional processes such as decision-making. He demonstrates that in decision-making, considered as one of the highest processes of human mind, all the high-level processes situated in the prefrontal cortex area work together with the low-level brain networks devoted to process emotional information and feelings that, in turn, maintain direct and mutual relationships with bodily organs. One of the most interesting concepts proposed by Damasio refers to "somatic markers" [19]; embodied feelings processed in the ventromedial prefrontal cortex and the amygdala, which are related to emotions, such as the association of rapid heartbeat with anxiety or of nausea with disgust. Damasio's opinion is that emotions and body signals strongly influence behaviour and decision-making: "the lowly orders of our organism are in the loop of high reason" [18]. When we make decisions, facing complex and conflicting choices, we need to collect information from our somatic markers. Thus, there is no separation among cognition, emotion and bodily experiences; we can say that every act of our intelligent behaviour is, at the same time, cognitively and emotionally "embodied". Damasio is definitely not a voice out of the choir; many other scientists agree with the renewed interest in the role of emotion in intelligent behaviours, and have provided evidence indicating that emotions play a fundamental role in perception, learning, attention, memory, and other abilities [18]. The idea that emotions are not obstacles but resources in decision-making is also one of the fundaments of the concept of emotional intelligence, which is described by Salovey and Mayer as the ability to perceive, facilitate, understanding and managing emotions [19]. A very vast and ever-increasing literature on Social Emotional Learning [20], has demonstrated the importance of helping students, both with typical and non-typical development, to increase emotional intelligence abilities. They are indeed of great importance for wellbeing, for achievement in different contexts and as protector factors against mental illness and maladjustment [21]. Due to its importance, the promotion of emotional intelligence is considered one of the future goals in the field of education. Children need to be guided in the world of emotions, to learn how to recognize emotional signals, how to cope with stressful situations and, more importantly, how to use emotions in reasoning. Therefore, we recently developed the program MetaEmozioni [22], to raise awareness and increase emotional intelligence in children and adolescents through a series of activities based on (1) non-verbal communication; (2) creative arts to enhance affective synaesthesia; (3) group games to develop emotional lexicon; (4) group games to improve emotional management and use of emotion to facilitate thinking. We are convinced that educational robotics could also be an excellent support for programs such as MetaEmozioni; concepts such as somatic markers and embodied-emotional cognition may be difficult to explain to children (and also to adults!); however, some of these concepts may be simpler to explain through direct and concrete experience with hands-on robots. In this way, educational robotics kits may be transformed from "objects to think with" [23] to "objects to think and to emote with".

3. Emotional Educational Robotics: Robotics Kits as Objects to Think with and to Emote with

Here, we will report some examples of how simple robotic kits—such as LEGO Mindstorms, or similar—can be used in order to carry out emotional educational robotics sessions, in which children can observe, construct and deconstruct robots' bodies and minds in order to understand the complex interactions among body, emotions and cognitions.

The examples mentioned below can be used with children from 6 to about 12 years of age. As for younger children, educators can simply use robots as attractive tools to tell and show emotional stories. Older children, on the contrary, may be involved in all the aspect of body and mind construction, under the supervision of educators.

Example 1. *Somatic markers and irrational fear.*

Children are presented with a story and a scenario: the protagonist of the story is a robot who is afraid of the dark (irrational fear). The robot, through a light sensor, runs away from dark areas (represented by the black parts of the track) and reproduces a sound that simulates heartbeats. Children observe the robot's behaviours and try to guess the emotion it is expressing. Then, with the help of educators, children are led to reflect upon the robot's behaviour by discussing the possible reasons of that fear. What has happened to this robot before? Why is his body responding to "darkness" with a reaction of fear? Are all the situations of darkness actually dangerous for him? Or is it rather an "irrational fear"? How can we help he not to feel such an irrational fear? Might this be possible by modifying the robot's body or mind? For instance, children may decide to eliminate the light sensor (modifying the body). At the beginning, it would turn out to be enough for the robot not to be scared anymore; the robot would neither see darkness nor feel fear. Nonetheless, the robot needs its sensors for adaptive life. What can we do? Perhaps the emotional experience (the somatic marker) is what should be changed—by modifying the program (the mind of the robot)—since it is associated with the perception of darkness. In this way, the robot might no longer be afraid of black zones (modifying the emotional experience). What is happening now? What has changed? Is the robot still afraid of the dark? This simulation is an opportunity to talk about somatic markers as embodied memories of emotions and body-mind constraints that influence our emotions.

Example 2. *Somatic markers and useful emotions.*

Children are presented with a story and a scenario: the protagonist of the story is a robot who is afraid of heights. Using an ultrasound sensor, it runs away from the edge of the table and reproduces a sound that simulates heartbeat. Once again children are led to reflect upon the robot's behaviour, to change robot's body (i.e., by pulling out the ultrasound sensors) or its mind (by changing its program). This time, however, the robot's behaviour is used to discuss useful emotions; those which prevent him from falling off the table. What would happen to the robot if he did not have the ultrasound sensors? What would happen to the robot if he were not afraid of heights? What do you think about the usefulness of fear in this case? When is fear useful and when is it not? Is fear of heights to be considered an innate and adaptive emotion? This simulation is another opportunity to talk with children about somatic markers of emotions that, in this case, keep us safe from dangerous situations.

Example 3. *Understanding bodily signals of emotions.*

Children are taught to construct robots capable of expressing emotions (sadness, joy, etc.) through some somatic features and through behaviour. Children are instructed to modify the robot's body by adding accessories and colours representing specific emotions (i.e., red for angry robots, yellow for happy ones, and so on). This activity may help to introduce concepts such as affective synaesthesia, thus demonstrating that some colour-emotion associations are widely shared. Children may also give facial emotional expressions to robots by adding eyes and mouths simulating the target emotions. In doing this, it is possible to introduce the use of new technologies, such as 3D printers, that may help to project and print new tiles or other accessories (i.e., eyes and mouths) for body construction and modification. Afterwards, children have to assign behaviours that represent each emotion to the robot; for instance, a sad robot will move slowly and make unpleasant and lamenting sounds, a joyous robot will move quickly and make cheerful sounds or music, an angry robot will move quickly and impulsively and make angry sounds, such as roars or grunts. Furthermore, children can also create environmental stimuli that affect the robots' mood, by using, for example, different colours on the track that some robots "don't like". This activity could be very important in order to promote emotional understanding in children. What is anger? What is joy? What are the usual bodily signals and behaviours of an angry/joyful/sad robot? When and why do people get angry/joyful/sad (i.e., the role of environmental stimuli or previous experiences), and so on?

4. Conclusions

The above-mentioned examples are only a few of the possible ways through which educational robotics may support educators in carrying out social emotional learning activities with their students. As already said, to promote emotional educational robotics, it is not necessary (but still desirable) to look for new robotic technologies, but rather to explore new possible applications of already-known technologies, such as robotics construction kits.

In our view, robotics construction kits, also associated with 3D printers or other artefacts realized in fablabs, still have a long educational life. They could allow children to manipulate and to extend both the body and the mind of robots, as well as lead them to reflect on the relationships among the body, the mind and the emotions in everyday life. In other words, Emotional educational robotics could enable children to reason with robots as an extended, emotional and embodied mind. We need to take into account body signals and emotions to maintain intelligent behaviour; it takes people almost all their life to understand it. Emotional educational robotics may help children to use robotic kits as "objects to think and to emote with", and to understand the basis for emotionally intelligent thinking and behaviour in the early stages of their lives.

We hope that, in the future, experimental studies and observational data will help to support these hypotheses and to define effective protocols for using educational robotics in social-emotional learning.

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