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Published Version:
Mazzoni E., Benvenuti M. (2015). A Robot-Partner for Preschool Children Learning English Using Socio-Cognitive Conflict. EDUCATIONAL TECHNOLOGY & SOCIETY, 18(4), 474-485.

Availability:
This version is available at: https://hdl.handle.net/11585/413973 since: 2016-11-22

Published:

DOI: http://doi.org/

(Article begins on next page)

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A Robot-Partner for Preschool Children Learning English using Socio-Cognitive Conflict

Authors

Elvis Mazzoni – Phd Researcher
Department of Psychology – ALMA MATER STUDIORUM – University of Bologna, Piazza Aldo Moro N° 90 - 47521 Cesena (FC)
elvis.mazzoni@unibo.it – Tel: +39 0547/339840 – Fax: +39 0547/9345054

Martina Benvenuti – Doctoral student
Department of Psychology – ALMA MATER STUDIORUM – University of Bologna - University of Bologna, Piazza Aldo Moro N° 90 - 47521 Cesena (FC)
martina.benvenuti2@unibo.it – Tel: +39 0547/339840 – Fax: +39 0547/9345054

Abstract

This paper presents an exploratory study in which a humanoid robot (MecWilly) acted as a partner to preschool children, helping them to learn English words. In order to use the Socio-Cognitive Conflict paradigm to induce the knowledge acquisition process, we designed a playful activity in which children worked in pairs with another child or with the humanoid robot on a word-picture association task involving fruit and vegetables. The analysis of the two experimental conditions (child-child and child-robot) demonstrates the effectiveness of Socio-Cognitive Conflict in improving the children's learning of English. Furthermore, the analysis of children's performances as reported in this study appears to highlight the potential use of humanoid robots in the acquisition of English by young children.

Keywords

Humanoid robot, Children, Socio-cognitive conflict, English learning.

Introduction

This research project deals with a robot (MecWilly) designed to help preschool children (4-6 years) in their learning of a second language (English). The main innovation is the experimental setting chosen in order to obtain an improvement in the children's English language skills. In previous studies of educational contexts, robots have typically been used as "teachers" to "structure" the learning process (Fridin, 2014). This also means that children viewed the robot-teacher as "other" (in the case of humanoid robots) or as an "artifact" like a computer or a book (in the case of robots with non-human features).
The link between Robotics and Psychology has presented a very interesting challenge for many scholars over the last fifty years (Kelley & Cassenti, 2011). Starting from the development of the first types of computer (the first Turing-complete machine, ENIAC, created by John Von Neumann in the middle of the 20th century), the simulation of human mental processes, and, later, of human decisions and actions, has lead robotics to become one of the most exciting fields for the evolution of human behavioral models. Throughout this process, many of the most important models and theories of Psychology have been examined, in particular Piaget's Constructivism and the related processes of

assimilation and accommodation, Skinner's operant conditioning, the Vygotskian Zone of Proximal Development, Cognitivism's Human-Information Processing (HIP) model, as well as the latest models of artificial intelligence, Connectionism and Neural Networks (Dautenhahn & Billard, 1999a; 1999b; Ziemke, 2001). Even though all these models have been looked at as part of the broad field of Human-Robot Interactions (HRI) or in Robot Development/Evolution, each model has also been analyzed in more specific and well-defined scopes of application. We can briefly summarize five areas of application for psychological models in robotics:

a) The evolution of robot prototypes which simulate human mental and physical behavior;
b) Robot-robot interaction in complex environments for simulating human social behavior;
c) Human→robot and robot→robot interaction in which the human or one of the robots acts as the tutor|teacher|expert and the (other) robot is a learner;
d) Human←robot interaction in which the robot acts as a mechanical "partner" which allows the human to try out (and/or train) certain abilities or social skills so that he/she may make progress;
e) And finally a situation in which the human-robot interaction is characterized by a human who acts as a "tutor|teacher" for the robot and a robot acting as a counterpart in the learning process which, in the end, sees the convergence of improvement and knowledge acquisition influencing the human's cognitive development.

The first two areas have been principally influenced by Skinner's Operant Conditioning, Cognitivism, and more recently by Artificial Intelligence (AI), Connectionism and neural networks (including their recent evolutions). Behaviorism played an important role in the development of early robots, as this psychological model has simple rules which can be easily fed into a machine. Thanks to these characteristics, Skinner's teaching machines were very successful in learning environments and demonstrated the importance of feedback (reinforcement) and also of coherence and repeated reinforcement over time in maximizing the learning process. Applying behavioral rules to robotics (and informatics), i.e. determining the behavior of a machine on the basis of the effects of a particular type of behavior and its related reinforcement, helped to produce a set of "mechanical" machines that were able to react to their environment by simulating certain types of human behavior. Robots capable of more sophisticated actions (and quasi-decisions) have been developed using behavioral models derived from AI connected to Behaviorism, the so-called Behavior-Based Robotics (Arkin, 1998; Brooks, 1986a). Robots like Allen (Brooks, 1986b), Herbert (Connell, 1989) or Genghis (Brooks, 2002) were considered revolutionary with respect to the previous ones, although some authors (Sharkey & Ziemke, 2000) highlighted something of a return to the past (Behaviorism) rather than a move towards the bases of AI and Cognitivism. Even more highly evolved behavior can be found in robots based on models derived from Connectionism, neural networks, and evolutionary swarm robotics (Trianni, 2008), in which the latter represents a good example of studies devoted to the simulation of human social behavior by using robots interacting in complex systems or environments. Despite the sophistication and the evolution of the robots' behavior, these first two fields of application of psychological models and theories to robotics are primarily focused on the evolution of the robots to replicate human mental functions and only secondarily to enhance human cognitive development and knowledge acquisition by means of robots, i.e. the focus of attention of the final two fields of application.
A field of application which represents a bridge between simulation and human-robot interaction is the third field of application (c) in which the interest is not only in the simulation of human behavior, but also in the interaction between a robot and a human to develop the robot's behavior as a consequence. The psychological models involved in this field are those derived from the Social Learning Theory (Bandura, 1971), the adaptation processes of assimilation and accommodation (Piaget, 1985; Piaget & Inhelder, 1969), and signs mediation (Vygotskij, 1978). Experiments conducted by Bandura unequivocally demonstrate that children exposed to a video in which an adult

performs certain actions with certain tools, when left alone with the same tools, are highly likely to perform the same actions. These results show two important processes influencing human learning:
1) The importance of reinforcement and punishment in learning is not always directly connected to the human experience. There are three types of reinforcement|punishment: past (those explained by Behaviorism), promised (those that are not carried out but could be should certain actions be performed), and vicarious (by looking at the consequences of an action performed by another human, we can learn what to do to receive positive reinforcement).
2) Humans learn not only by direct experience but also by observational learning or modeling, i.e. by observing the positive or negative consequences of an action performed by another human considered to be significant.

At a computational level, and in defining a robot's behavior, we can imagine that it is relatively simple to program imitative behavior in a robot. Thanks to sensors that detect inputs deriving from the environment and a computational algorithm which takes these inputs and transforms them into actions, a robot can perfectly imitate a wide variety of human behavior and emotions. For example, Saunders and colleagues (Saunders et al., 2007, p. 109; Saunders, Nehaniv & Dautenhahn, 2007), used a Pioneer P3-DX robot and a Kephera robot to investigate how a robotic control and teaching system using self-imitation can be constructed with reference to psychological models of motor control and ideas from social scaffolding seen in animals.

It is, however, more difficult to replicate the modeling process in a robot since it involves not a simple imitation, but also a prediction and decision about which type of behavior will have more positive consequences (or avoid negative ones) based on previous "observations" of others' behavior (Nehaniv & Dautenhahn, 2007). The difficulties arise when we depart from behavioral logic and we consider the logic of actions and activities. From an activity theoretical point of view (Engeström, 1987; Nardi, 1996b), we can separate behavior from activity (Nikiforov, 1990) and define the latter as being organized in three elements: activity, actions and operations (Leont'ev, 1978; Mazzoni & Gaffuri, 2009). Unlike activity, behavior is neither directed nor subordinate to a predefined aim or set of objectives, and it therefore does not involve the forms of reasoning which typically precede human activity. At the same time, human behavior is situational since it is effectively a reaction to a situation. Although an activity can at times depend on the situation, the activity can also control and restructure the situation in order to achieve an objective (Nikiforov, 1990). On the hand, since behavior has no objective, it is motivated only by situational factors, that is to say, stimuli provided by the environment. We can better understand this differentiation by following the reasoning of Leont'ev (1978) which suggests that human activity is motivated by an objective which can be realized by goal-directed actions, which, in turn, are accomplished by operations which may not be conscious, and which respond to situational conditions (Mazzoni & Gaffuri, 2009).

Actions and cognitive development were the focus of attention of one of the most important psychological scientists, Jean Piaget. Piagetian Constructivism emphasizes the active (and adaptive) role of a child interacting with the environment, guided by previous mental schemas for interpreting the environment, and open to the assimilation of new types of behavior|knowledge and/or to the accommodation of those previously held. Piaget clearly recognized the importance of reflexes (and positive and negative reinforcement) in his concept of an action scheme (composed of three elements: recognition of the situation → specific action related to the interpretation of the situation, expectation of a positive result), though he did so without limiting it to an overly simplistic mechanism of stimulus-response (Ziemke, 2001). Piaget's view has been, and is, very important for robotics since it proposes a number of schemas for interpreting the environment which guides interaction *with* that

environment as opposed to a simple reaction *to* it. We can summarize Piaget's idea using Von Glasersfeld's Radical Constructivism (1995):
- Knowledge is not a passive process of reception by means of the senses or communication but it is an active process of construction played out by cognition.
- Cognition has an adaptive function which enables a human's organization of the experiential world.
As underlined by Ziemke (2001, p. 164), this notion is, at least at a first glance, largely compatible with a lot of recent research into cognitive science, artificial intelligence (AI) and artificial life which is concerned with adaptive robots or autonomous agents and their formation of internal structures in the course of agent-environment interaction.
The fourth area of application refers to the same types of psychological models described above, but in this case knowledge acquisition (and cognitive development) is linked to the child, while the robot acts as a mechanical partner, sometimes serving as a teaching assistant (Fridin, 2014), and at other times proposing creative programming activities which "provoke" some types of enrichment (Bers *et al.*, 2014). This field of application has been very important for the majority of studies interested in enhancing the social skills of children with autism. Here the behavioral principles of reinforcement, repetitiveness and coherence are particularly important as autistic children tend to avoid complex and uncontrollable situations typical of many social contexts (Werry & Dautenhahn, 1999). Having a partner who always reacts to our actions in the same way brings the situation under our control and permits us to be more confident in social interaction (Dautenhahn & Werry, 2000). At the same time, imitation and some types of behavioral modeling are important, as the robot begins by reacting consistently but, as soon as the child shows more confidence, the robot's behavior, though remaining similar, begins to change (e.g. the robot mirrors the child's behavior) (Robins et al., 2004; Dautenhahn & Billard, 2002). Furthermore, these studies are based on basic constructivist principles that allow children to interpret the situation and interact with the robot so that, in the end, there may be an improvement in their behavior (in particular regarding the confidence they have in their social skills).
So far we have been very careful to divide behavior from actions in order to underline, on the one hand, the importance of feedback and reinforcement for human learning and, on the other hand, the essential and active role played by action schemes in organizing human experiences for cognitive development and knowledge construction. This theoretical background makes sense if we begin with the assumption that human knowledge construction (and cognitive development) is based on interaction with the environment and, logically, with its tools. At the beginning of the 20th century, Lev Semenovich Vygotskij, the father of the present Cultural Historical Activity Theory (CHAT), contested the simplistic idea of human learning (and cognitive development) based on stimulus-response mechanisms, arguing that:
- human cognitive development begins in social interactions with others and only later is what we construct during social interaction interiorized in an individual's cognition (e.g. thanks to Piagetian processes of assimilation and accommodation);
- the role of mediating artifacts, i.e. tools (e.g. a machine or a robot) and signs (e.g. language or action schemes), is fundamental as they allow humans to interact with each other or with their environment, interpreting it and constructing their experience and knowledge (Vygotksij, 1978).
One of Vygotskij's fundamental concepts is that of the Zone of Proximal Development, i.e. the potential for improvement in individual performances determined by social interactions or, in other words, the difference between the results achieved by a child acting individually and those that he/she can achieve by interacting with an adult or another, more expert, child (Mazzoni, 2014). This idea is the basis for the fifth type of application of psychological models to robotics and is also the main inspiration for our experiment. Here we focus on the social interaction (dialogue) between two or more humans and between humans and agents (like robots) as a precursor to cognitive development, as opposed to the interaction between a human and the context. As Dautenhahn, and Billard (1999b) have demonstrated in their studies using the Robotic Doll "Robota", focusing on social context and

the dynamics of interaction can lead to interesting experiments which can contribute to socially intelligent robotic agents.

The basic idea of this fifth type of application is that children interact with robots through dialogue and from this dialogue they construct their knowledge. The robot reacts or provides feedback principally based on behavioral mechanisms, while children construct knowledge by means of Piagetian assimilation and accommodation processes. This "social" interaction, however, takes place in a controlled setting (made possible thanks to the fixed patterns of behavior programmed into the robot), and is seen as having the potential to enhance the children's abilities and construction of knowledge. The main idea is that by promoting the "correct" type of dialogue (in terms of predefined interactive sequences), complete with adequate feedback from the robot, we may activate an enhancement in a child's knowledge. From this point of view, the robot is not simply a "reagent", but it must instead be designed with particular features and specific speech software in order to sustain socio-constructivist interaction with children and activate the learning and knowledge construction process. Since dialogue is essential, the implementation of adequate behavioral schemas in the robot also becomes a fundamental aspect in the activation of a Socio-Cognitive Conflict in the child (Butera & Darnon, 2010; Carugati & Gilly, 1993). From a Socio-Cognitive Conflict perspective, individual development is conceived as being the result of social interactions made possible by the simultaneous presence of different points of view, and by the consequent necessity to negotiate common meanings or objects (Mazzoni & Gaffuri, 2009).

Drawing on Vygotskian socio-constructivistic ideas (Alimisis *et al.*, 2007; Kim, 2001), this research project focuses on the use of the robot MecWilly as an outsider "friend" for playful interaction with whom children have to negotiate their ideas in what becomes a classic situation of Socio-Cognitive Conflict (Butera & Darnon, 2010). Previous experiences in the field of Robot Assisted Language Learning have already used robots (Han, 2012; Mubin, Shahid, & Bartneck, 2013) or humanoid robots as teaching assistant in language learning (Lee, Noh, Lee, Lee, Lee, Sagong, & Kim, 2011; Mubin, Shahid, & Bartneck, 2013; You, Shen, Chang, Liu & Chen, 2006), also to teach a second language in primary school (Chang, Lee, Chao, Wang & Chen, 2010). Even though this field of research is in its early stages (Lee et al., 2011) and few studies discuss the use of robots to facilitate the teaching of second languages (Chang et al., 2010), generally the results achieved are promising and suggest that robots could be effective teaching assistants to improve (Wang, Young & Jang, 2013) or learn a second language.

The aim of this research project is to demonstrate that having a technological artifact (robot) partner, can be just as effective as having a human (child) partner for a child who is learning English by acting within their Zone of Proximal Development. The experimental setting has children playing in pairs or with MecWilly to solve a task consisting of associating the fruits and vegetables with the correct English word. The two situations are constructed to induce a Socio-Cognitive Conflict in which children have to negotiate their ideas with the other child or with MecWilly to arrive at a shared solution. The basic idea is that this Socio-Cognitive Conflict will enhance the children's knowledge of English from the pre-test to the post-test, as they will have been made to consider different points of view.

Socio Cognitive Conflict

We can define Socio-Cognitive Conflict (SCC) as an interaction in which individuals reorganize and restructure their respective points of view to advance in their cognitive development by means of discussing their ideas. Cognitive improvement depends on the negotiation of points of view in order to arrive at shared understandings and agreement (Butera & Darnon, 2010). In other words, the SCC is a process in which "dissent from one or several partners over a task in which learning is concerned

may stimulate task-related cognitive activity and result in progress" (Butera, Darnon & Mugny, 2010, p. 36).
Synthetically, the procedure to induce a SCC is characterized by a problem-solving task (with children this is normally a ludic task) in which a couple of children are asked to discuss and negotiate their points of view to reach a shared solution to the proposed problem (Doise & Mugny, 1984). In the classic situation created by Doise & Mugny (1984), the different points of view are caused by the two pupils faced with a plan representing a map in which pupils are asked to reproduce the same village constructed by the experimenter in another plan near the first one. Since the two plans are rotated by various degrees, and since the two pupils are seated in different positions around the plan (e.g. one in front the other), in order to correctly solve the task they have to understand that sitting in different positions means having a different perception of what is left, right, in front and behind. Only the coordination of these different points of view, by means of subsequent negotiations, allows pupils to approximate the correct solutions and, very importantly, to enhance their cognitive level. In this and further studies (Butera & Darnon, 2010; Doise & Mugny, 1984; Doise, Mugny & Perret-Clermont, 1975; Carugati & Gilly, 1993), many authors have shown the relevance of SCC in pupils' knowledge enhancement in terms of cognitive thought. Particularly relevant is the fact that results underline that enhancement occurs in all participants in the negotiations and, crucially, independently from a positive model of reference (Doise & Mugny, 1984).

Material and methods

This research is an exploratory study aiming at evaluating whether a humanoid robot can, by means of the socio-cognitive paradigm, be as effective as a human counterpart in helping Italian children who have no previous knowledge of English, in learning English words. The main actor in the study is the humanoid robot, MecWilly (fig. 1), an ecological humanoid robot (constructed entirely from recycled materials) characterized by three principal features: the replication and recognition of certain human emotions, the ability to move in a number of different ways in interactions with children in non-fixed contexts, a complex integration of software and sensors for recognizing human language, objects, and environmental changes determined by human behavior.

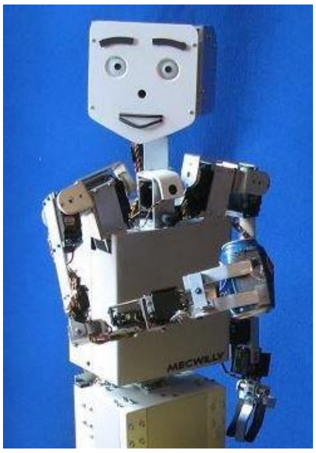

Figure 1: MecWilly

The proposed study examines and compares two experimental conditions:
1) a Socio-Cognitive Conflict between two children (child-SCC);
2) a Socio-Cognitive Conflict between a child and MecWilly (robot-SCC).
The research hypothesis is that, in learning specific English words through SCC, having a humanoid robot as a partner is just as effective as the classic situation in which two children collaborate in order to reach a shared objective.

In order to achieve our aims, the children's classroom (fig. 2) was divided into two areas: one for the experimental situation and the other in which the children who were not engaged in the test played with their educator. The desk used for the MecWilly-child experiment (the lower part of fig. 2) was near a hidden lumber room in which the computer to control the robot was placed.

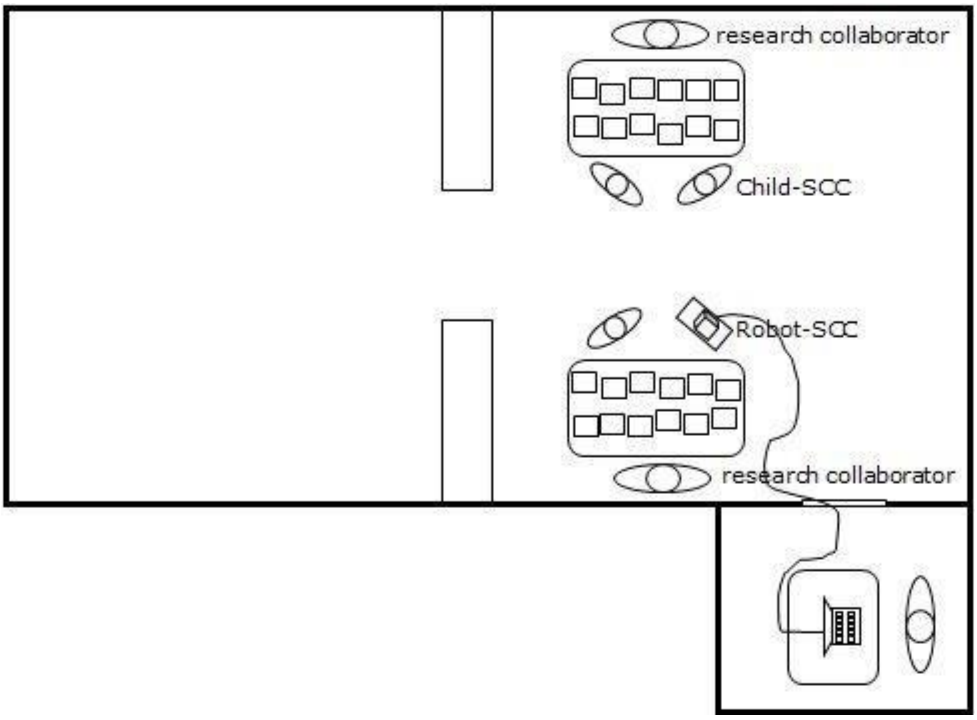

Figure 2: The room during the test phase.

Here, a research collaborator monitored the situation (by means of a webcam placed on MecWilly's nose) and controlled the robot's answers and interactions with the child during the experimental session. MecWilly's software and sensors for recognizing human language require a noiseless environment. The test phase was unable to guarantee this characteristic as it took place in the children's daily scholastic environment. Therefore we decided that a research collaborator would activate certain predefined and standardized answers (by means of push-buttons) after having heard the children's answers and comments (by means of the microphone installed in MecWilly). In this way, the same predefined answers (language + facial and corporeal expressions) were used with all the children. To induce the SCC, MecWilly's answers did not provide solutions to the problems, but they simply induced a doubt, such as in the phrase "ahh, your suggestion is interesting … but are we sure that it is correct? Could there be an alternative or do we think that this is the correct answer?" (MecWilly 1). If the child did not make any suggestions, MecWilly intervened with the following: "Hmm, it is not simple … do you have any ideas about which could be a possible match? Do you have any suggestions?" (MecWilly 2). When children suggested a match, MecWilly replied with the phrase mentioned above (MecWilly 1).

Participants

The class was composed of 13 children between the ages of 4 and 6, although only 10 children (6 girls and 4 boys) participated in the experiment, because the others were sick. The whole procedure was carried out over 3 days and took place in a kindergarten in Bellaria Igea Marina.

Experimental Procedure

After having obtained parental consent for each child, the educator told the children about the experiment a few days before it began, introducing it as a game. The educator told the children a tale in which MecWilly would come to visit from England with a list of fruit and vegetables that some English children would like to receive from Italy. However, MecWilly does not speak English very well and his list is in English, so it will ask the Italian children to help him to match the pictures of fruit and vegetables with the correct English word in order to work out which items it needs to send to the English children.
For the test phases we used 20 black and white pictures of fruits and vegetables designed by a professional sketcher (so that the sketches were similar): banana, melon, carrot, pear, onion, tomato, strawberry, apple, salad, eggplant, orange, cucumber, zucchini, apricot, peach, pepper, watermelon, cherry, lemon, and grape. The whole experimental phase, without considering the introduction made by the educator, took place over 4 days (two days of pre-testing, one day for the test, and one for the post-test) and lasted 90 minutes per day (45 to prepare the desks and the materials, and 45 for the test phases). To maintain the idea of the game, and to keep the children busy while their classmates were doing the test, at the end of each task they had the opportunity to choose two of the items, color them, and then put them in a shared basket, so we could determine the favorite fruit or vegetable of Italian children.

Pre-Test

Before starting the real pre-test, we tested the children's ability to recognize the 20 items which were placed on the two desks. The children were divided into two groups (one for each desk), each group having the same number of boys and girls. The research collaborator asked a child "what is this?" in Italian, by pointing to a specific item, and the child said the Italian name of the indicated fruit or vegetable. All children correctly recognized all the items.
After this first control test, the research collaborators (one per desk) called two children at a time, one to one desk and one to the other (fig. 2), and after reminding them of the purpose of the activity (i.e. to help MecWilly with the English names of the fruit and vegetables) they explained the task. Each child had in front of him/her the 20 items representing fruit and vegetables. The research collaborator would say the English name of a fruit or vegetable (none of the children knew any English), and the child had to choose the picture that in his opinion matched that name. The child had two chances at answering, the second only given if the child did not answer correctly the first time. However, the children were not given any feedback about whether they had answered correctly, and none of the items (not even those correctly recognized) were removed from the desk during the pre-test.
During the pre-test phase, each research collaborator made a note of whether the child was purposeful (active) in front of the task or reluctant (passive). As SCC is based on a negotiation of different points of view, we tried to balance the pairs of children in the test phase in order to control the possible acquiescence effect already described in previous literature (Mugny & Doise, 1978).

Test

The pre-test phase was very important as we used it to decide which 6 items would be used for the test phase. During the pre-test, we encountered a problem in the children's inability to stay concentrated on the task despite it taking no longer than 15 minutes. We therefore reduced the items of the test phase from 20 to 12 because there is no limit on the number of attempts the children can make in this phase: to improve their knowledge of English it was important for them to be able to negotiate their points of view and, finally, by means of answering as many times as necessary, to find the correct answer. Furthermore, in order to stay within the 45 minutes initially defined, we selected the 6 items which would be in the test. The 6 items were selected based on the amount correct answers they received in the pre-test phase (tab. 1). Items that were correctly identified between 5 and 7 times were defined "easy" (E), those which were never identified correctly, or identified correctly only once, were defined "difficult" (D), while items which were correctly identified between 2 and 4 times, were defined "medium". We had to exclude items which were always correctly identified because they would not guarantee a SCC.

Level of difficulty	Italian	English	Pre-test correct answers	Post-test correct answers
Easy (E)	insalata	salad	5/10	9/10
	limone	lemon	6/10	9/10
Medium (M)	pera	pear	3/10	8/10
	arancia	orange	3/10	7/10
Difficult (D)	albicocca	apricot	0/10	5/10
	pesca	peach	0/10	6/10

Table 1: items selected for the test phase

During the test phase two children were sitting at one desk (children-SCC → 6 children → three couples) and one child was sitting in the other desk with MecWilly (robot-SCC → 4 children). When describing the activity (the same as for the pre-test) to the children (and to MecWilly), the research collaborators, one per desk, highlighted that before giving the answer the participants (child-child or child-MecWilly) would need to collaborate and talk to each other in order to reach a shared answer. In the robot-SCC condition, before giving his suggestion, MecWilly would wait for the child's answer then make some suggestions, but would never actually give the correct answer. Based on the results of previous studies showing that a correct model is not necessary (Doise & Mughy, 1984), the idea was that MecWilly would serve as a counterpart helping the child to reflect on his or her answer and solution to a problem. MecWilly therefore normally made comments in Italian such as "Mmmhhh, your answer is interesting, but are we sure that it is correct?! Is there something else that could be the correct answer or do you think that is the correct one?!". The answer was always given by the child, by pointing to the picture on the desk corresponding to the name proposed by the research assistant. In the case of an incorrect answer, the 'wrong' item was taken off the desk and then it was put back after the correct answer was given, so that the maximum number of attempts to achieve a correct answer was 12 for each item. Unlike in the pre-test phase, in the test phase the children always had to find the correct answer.

Post test

In the post-test phase we repeated exactly the same task as that of the pre-test phase, with specific attention paid to the 6 items used in the test phase for which we expected to see an improvement both in the word-picture association task and in the children's knowledge acquisition of English words. In order to analyze their knowledge acquisition, when the word-picture association task was completed, the research collaborator asked the child in Italian to help him remember the English name of a fruit or vegetable (by pointing one of the 6 items used in the test phase): "After all these names of fruit and vegetables I've forgotten the English word for this ... do you remember it?" After having noted the child's answer (correct or incorrect), the collaborator proceeded with the other 5 items from the test phase.

Results

As this is an exploratory study with a restricted sample, we use a non-parametric test (Wilcoxon) to compare the pre- and post-tests (tab. 2).

Test				
	Easy	Medium	Difficult	Total
Z	-2.333b	-1.890b	-2.251b	-2.699b
p.	.020	.059	.024	.007

Table 2: Differences between pre- and post-tests for easy, medium and difficult items.

The results show the improvement in the word-picture association task, both for easy and difficult items, but this improvement is most clearly visible when we consider the total.
To compare the two conditions and analyze the effectiveness of a robot in Socio-Cognitive Conflict, we used the descriptive data for the different types of items and the mean of the pre- and post-tests (tab. 3).

		Word-picture association task										Acquisition of English words
	Experimental condition	Pre E	Pre M	Pre D	Pre sum	Pre mean	Post E	Post M	Post D	Post sum	Post mean	
1	Children-SCC	0	0	0	0	1.67	0	1	2	3	3.17	2+0+1=3
2	Children-SCC	1	0	0	1		2	0	2	4		0+0+0=0
3	Children-SCC	2	2	0	4		2	2	1	5		1+2+0=3
4	Children-SCC	1	0	0	1		2	0	0	2		2+0+0=2
5	Children-SCC	0	0	0	0		1	0	0	1		0+0+0=0
6	Children-SCC	2	2	0	4		2	2	0	4		1+1+0=2
7	Robot-SCC	1	1	0	2	1.25	2	2	1	5	4.25	2+1+1=4
8	Robot-SCC	2	1	0	3		2	1	1	4		2+2+1=5
9	Robot-SCC	0	0	0	0		1	1	0	2		0+0+0=0
10	Robot-SCC	0	0	0	0		2	2	2	6		2+2+2=6

Table 3: Pre-test and post-test results in the two experimental conditions.

The results show a clear improvement in almost all children and for all items, though the mean of the pre- and post-tests highlights a significant improvement in the robot-SCC and a less relevant improvement in the children-SCC condition.
Finally, in order to analyze the acquisition of English words, the number of items learned from the 3 categories of item (easy, medium and difficult) shows that most children improve their English knowledge and the three best performances from 3 children (10, 8, and 7) were in the robot-SCC condition.

Discussion

The obtained results show the effectiveness of Socio-Cognitive Conflict in improving the children's performance both in the word-picture association task, and in the acquisition of English words. Although these results are coherent with the literature in the field of Socio-Cognitive Conflict, they also show that a humanoid robot can be as effective as a human counterpart in the knowledge acquisition process. More specifically, all the children but one in the robot-SCC demonstrated a post-test performance which was better than that of the children-SCC (both in the association task and the acquisition of English words). This result may be explained by considering the difficulty of controlling the relations and negotiations in the children-SCC setting, particularly with children in Piaget's preoperational stage. The robot-SCC is more structured since the robot always answers in the same manner and thus makes children take the responsibility for giving an answer and reflecting on it. Furthermore, as another study (Kanda et al., 2004) making use of a robot to learn English has shown, one of the requisites for improving students' knowledge of English is a relationship with the robot. In this study, the human appearance of the humanoid robot MecWilly, together with the animism typical of preoperational children (Opfer & Gelman, 2011), guaranteed a relationship between child and robot in the robot-SCC condition which was very similar to that observed in the children-SCC condition. From this point of view, we might ask whether only a humanoid robot is so effective or whether computer software (like in the study proposed by Huang, Liu, Y. & Shiu, 2008), particularly a smartphone or tablet application, might also be able to reproduce the same improvement by means of Socio-Cognitive Conflict. A robot, particularly a humanoid robot, has the clear advantage of creating a situation which is very similar to that proposed in the classic children-SCC, while other types of technological artifacts would suggest a different type of relationship, more similar to that analyzed in classic studies of human-computer interaction.

Conclusions

We analyzed the effectiveness of a humanoid robot in improving children's knowledge of English words and we concluded that it does seem to play a relevant role in this process, and to be more effective than a human counterpart. Despite these promising results, the sample is too restricted to suggest that they may apply to other contexts in which preoperational children are involved. Further studies with larger samples are needed to confirm these results, and to analyze whether other types of technological artifacts (such as smartphones or tablet applications) might be able to activate the same process of improvement. It would be particularly worthwhile to replicate the study worldwide in order to compare cultural similarities and/or differences between young children in their interaction with robots. In these future studies, an important robot’s feature that could be improved and tested is the automatic interactive dialogue with children through Socio-Cognitive Conflict paradigm.

Acknowledgements

We would like to thank very much Roberto Masini, the creator of MecWilly, to have accepted the proposal of this research and to have prepared and managed the robot during the experimentation. We would also thank very much the teachers of the kindergarten "San Giuseppe" in Bellaria Igea Marina, in which the study took place, particularly Gloria Giovannini who was actively involved in the project.

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