INCLUSIVE SCIENCE EDUCATION AND ROBOTICS

STUDIES AND EXPERIENCES

Edited by
Luisa Zecca and Edoardo Datteri

MEDIA E TECNOLOGIE PER LA DIDATTICA

FrancoAngeli

Media e tecnologie per la didattica
Collana diretta da Pier Cesare Rivoltella, Pier Giuseppe Rossi

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Robots for the study of false belief attribution in autistic children: An exploratory study

by *Serena Sabrina Vadalà*, *Carmela Esposito*, *Laura Zampini*, *Eleonora Farina* and *Edoardo Datteri*

Introduction

Robots are generally thought of as mechanical systems which can help people carry out "practical" activities. This is the case of industrial robots, robots used to perform complicated surgical operations in medical contexts, robots used to assist elderly or disabled people (see Siciliano & Khatib, 2008 for a comprehensive illustration). In a particular sense of the term, robots can also help teachers and educators by serving as didactic mediators for the acquisition of a variety of disciplinary and cross-disciplinary competencies: this is what is typically called *educational robotics* (Anwar et al., 2019).

This chapter will explore a particular use of robots, which has received little attention by the educational robotics community, despite having been extensively discussed in the social robotics and cognitive science literature: the role of robots as tools to *acquire knowledge* on human behaviour and cognition. This *epistemic* use of robots radically differs from the way robots are typically used in educational robotics. One thing is to use a robot to *intervene* on an individual's cognitive abilities (e.g., to improve their executive functions, as in Di Lieto et al., 2017). Another thing is to use a robot to *study* their cognitive abilities – for example, to assess whether an individual possesses a particular cognitive ability or not, or to study the cognitive or neural mechanism underpinning it. The epistemic value of robots will be discussed here with reference to a robot-supported empirical investigation on the "mentalization" of robots by children with autistic spectrum disorder (ASD from now on) and typically developing (TD) children. As such, this chapter does not cover the use of robots to support rehabilitation and therapies destined to

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ASD people (for reviews, see Alabdulkareem et al., 2022; Cabibihan et al., 2013; Pennisi et al., 2016).

More specifically, this chapter has two goals. First, we will report on an exploratory study whose aim is to assess whether five ASD and five TD children attribute false beliefs to a non-humanoid robot in what will be called a "robotic helping task" inspired by the "helping paradigm" exploited by Buttelmann and colleagues (2009). In particular, we wanted to probe whether five ASD children attributed false belief to the robot, to assess whether our ASD and TD participants responded differentially to the robotic helping task and to a standard "Sally and Anne" task, and – in the latter case – to identify the main differences. Studying whether children attribute false beliefs to robots is functional to the understanding of how children explain robot behaviours in educational contexts and in everyday life. As such, it may offer insights for the design of educational robotic activities and of (social) robots destined for interaction with children.

The second goal of this chapter is to reflect on whether the results of this study – more generally, children's performance in the robotic helping task – can offer insights on their theory of mind (ToM) abilities. Indeed, note that, *prima facie*, the results of the study can be brought to bear on their tendency to attribute false beliefs to *robots*. Can the same results be used to shed light on children's attribution of false beliefs to *people*, generally? One possible reason for scepticism comes from the consideration that robots are patently different from human beings at many levels of analysis – and on the assumption (by no means obvious) that robots cannot be said to "genuinely" possess a mind. Thus, the objection runs, one might not tend to attribute false beliefs to robots and yet be perfectly able to attribute false beliefs to human beings. In this work we will dismantle this objection and others, by providing reasons to believe that in some circumstances, and with some methodological provisos, robots may be used to investigate people's "general" false belief attribution abilities.

The study presented here offers some elements of novelty. Few studies have been published on (ASD and TD) children's attribution of false beliefs to robots, and they typically involve *humanoid* robots. This study complements this literature by showing evidence that children with ASD can attribute false beliefs to non-humanoid robots too. And, to the best of our knowledge, no methodological reflection has been offered so far on whether robots can be sensibly used to study ToM abilities in (ASD and TD) children.

The chapter is organised as follows. The second section presents some characteristics of the autism spectrum disorder, reflects on the relationship between ASD and difficulties in having a ToM, and describes some tasks used to study ToM. The third section offers a reflection on whether robots can be used to study cognitive abilities. The fourth section presents the exploratory study on the attribution of false beliefs to a non-humanoid robot anticipated before, and the fifth offers some concluding remarks. This study has received authorization by the Ethical Committee of the University of Milano-Bicocca.

Theory of mind and autism

Autism is a pervasive developmental disorder, characterised by a symptom dyad that can be traced to two macro areas of difficulty: social communication and imagination (Diagnostic and Statistical Manual of Mental Disorders - DSM-5, American Psychiatric Association - APA, 2013).

Deficits in the area of social communication include a more purely communicative difficulty and a social-relational one. Within the autistic spectrum disorder, in fact, some children are characterised by a total absence of language, others instead show a purely echolalic (Frith, 1989; Jordan & Powell, 1995) or – in some ways – abnormal language (Kanner, 1946), others still seem to master good verbal language. Contrary to what one might think, in the latter case children's communication is not without problems: some speak very little, while others may not be able to control the verbal flow (Cottini & Vivanti, 2013). In addition, they all have in common poor perspective taking competence – which implies a tendency to disregard and pay attention to an interlocutor's interest in a certain type of topic – and an inadequate management of conversation rules.

The main communication difficulties, therefore, regard the possibility of establishing social relationships (with particular reference to the group of peers) and of correctly interpreting others' behaviour (Cottini & Vivanti, 2013). According to Surian (2005), in fact, children with autism seem to present a level of social interaction that is not appropriate either to their chronological age or to their mental age at two levels: the child's actual implementation of a behaviour (or lack thereof), or his/her understanding of the behaviour of others (Vertè, Roeyers & Buysse, 2003).

One of the hypotheses that some authors have developed to justify the social-relational difficulties coincides with a deficit in Theory of Mind (ToM) (Baron-Cohen, Leslie & Frith, 1985). Sometimes, in fact, children with autism are defined as suffering from "mental blindness", which does not allow them to understand what is happening in the world around them: having a theory of mind means being able to reflect on the contents of one's own and others' minds. First-order ToM develops around age 4 and involves the ability to reflect on what another person thinks or feels; to recognise that different people want different things and have different beliefs and knowledge; and to understand a false belief (Baron-Cohen, 2001). Second-order theory of mind, on the other hand, involves the ability to predict what one person might think of another and the understanding of lies, sarcasm, and figurative language. Children generally acquire this level of awareness between the ages of 6 and 10. Many individuals diagnosed with ASD generally show difficulty in attributing mental states and beliefs to others and therefore fail first-order theory of mind tests (Kimhy, 2014). Many others, although they successfully perform tasks involving the use of a first-order theory of mind, have difficulty generalising this skill to everyday life or show that they have not developed a second-order theory of mind (Kimhy, 2014; Scheeren et al., 2013). In everyday life, this difficulty manifests itself in a marked impediment in understanding the point of view and perspective of others (inferring what the other sees and feels from a different perspective); in feeling empathy (understanding the emotional state of the other); in being able to tell or to recognize lies; understanding the other's intentions, and therefore whether the behaviour of others is accidental or intentional.

The main task used to assess first order ToM is false belief task: subject A attributes a so-called first-order false belief to a subject B if they believe that B holds a false belief about certain aspects of the physical world – for example, if they believe that B mistakenly thinks that a certain object is located in a certain place. These tasks are sometimes called elicited-response tasks (Setoh et al., 2016), since the subject is explicitly asked to react to a situation presented through various modalities (e.g., through a story represented on vignettes), and verbal tasks, because the subject is asked to verbally respond to a question (for a review, see Liverta-Sempio, Marchetti, Castelli, Lecciso & Pezzotta, 2005).

A large body of research literature attests to the fact that typically developing girls and boys under the age of 4 tend to fail elicited-response verbal false belief tasks (Perner et al.,1987). The same tends to happen with people with autism spectrum disorder (ASD) over the age of four (Baron-Cohen et al., 1985; Happé, 1995; Tager-Flusberg, 2000; Grant et al., 2001). Together with these empirical results, an equally large literature of methodological research has developed on the appropriateness of the above-mentioned tasks for the study of false belief understanding. Many authors, in particular, have pointed out that the failure to pass these tests may be due to the fact that they involve a considerable amount of cognitive and verbal production skills (Bloom & German, 2000). Some authors developed non-verbal spontaneous-response tasks, in which the spontaneous behaviour of the participants to the presented situation is observed (in contrast to verbal elicited-response tasks, in which the production of a verbal reaction is explicitly stimulated (Setoh et al., 2016). Tasks of this kind have led some researchers to produce evidence of the possession of mentalizing abilities also in typically developing individuals under the age of 4.

Of particular interest for the study presented here is the task developed by Buttelmann et al. (2009). This is a study of unexpected displacement of the non-verbal spontaneous-response type. The participant is shown two boxes A and B that can be closed; an adult places an object in A; the object is then moved to the other box in the absence of the adult (in the false belief condition) or in the presence of the adult (in the true belief condition). The adult then tries to open box A in which the object was initially placed, but fails to do so because the box has been locked. In the study by Buttelmann and colleagues, the participants (aged 18 months) spontaneously helped the adult to open box B in the false belief condition and box A in the true belief condition: on the basis of various methodological considerations, the authors explained this behaviour by assuming that the participants attributed to the adult a false belief about the location of the object in the false belief condition, and wished to help the adult retrieve the object; that they attributed to the adult the intention to open box A regardless of the location of the object in the true belief condition. The study by Buttelmann et al. (2009) provided the inspiration for the development of the robotic task proposed in the study described here.

Behavioural analysts suggest that in many cases the ability to take another person's perspective is in close interaction with environmental stimuli. Spradlin and Brady explain that a necessary requirement for good performance on a false belief task is the ability to discriminate stimuli available to oneself from stimuli available to others (Spradlin & Brady, 2008). Related to this issue is the difficulty in perceptual dysregulation common to many individuals with autism. The difficulties in perception are, in fact, in many cases caused by the perception of a sensory overload that does not allow the subject to have the attentional focus on him/herself and on the other person at the same time (Bogdashina, 2003).

Robots to understand theory of mind abilities

Diagnosis and theoretical modelling

A growing body of research suggests that robots are valuable tools to support cognitive, emotional, and socio-relational therapy for children with ASD (for reviews, see Alabdulkareem et al., 2022; Cabibihan et al., 2013; Pennisi et al., 2016). As pointed out before, this chapter does not deal with the therapeutic role of robots, being distinctively concerned with their role as tools to acquire knowledge on the cognitive and socio-relational abilities of children with ASD.

What kind of knowledge on ASD children can be ideally acquired using robots? One possibility is that they can play an active role in *diagnostic* processes. The term "diagnosis" is typically used to refer to the process that leads one to state that some individual has a particular disease (for the definitions of disease and diagnosis in medicine, see Hucklenbroich, 2017). A diagnosis of ASD thus leads one to conclude that the individual under examination has ASD. Can robots be meaningfully used to support diagnostic processes? This use is explored, for example, in Petric et al. (2017), where a humanoid robot is used to perform four diagnostic tasks modelled upon the ADOS test: response to a name call, joint attention, play request, functional and symbolic imitation. The robot performs actions that, in typical diagnostic scenarios, would be performed by human beings, and is able to analyse, to some extent, children's reactions. Another study in which a robot is used for diagnostic purposes is presented in Arent et al. (2019). In these cases, it is legitimate to say that the robot is used to acquire a certain kind of knowledge on an individual human being, namely, to conclude that that person has a certain disease or not.

This epistemic use of robots raises some methodological questions. First, why should robot-supported diagnosis be preferred to diagnosis by humans? Second, is the output of robot-supported diagnosis reliable? In other terms, can one safely infer that individual X has ASD based on their reaction to the behaviour of a robot? Concerning the second question, reasons for scepticism may come from the consideration that a good diagnostic process requires one to involve X in a truly human-human relationship, and that X's responses to the robot are of no help in establishing whether X has socio-relational difficulties manifesting themselves in interaction with other people. For example, X might not establish joint attention links with a robot because X does not truly perceive the robot as genuinely attending to something, or that its eyes are too different from human eyes to be "catchy" (thus, not because they lack joint attention abilities). For these reasons, X's responses to the robot-supported test might be regarded as poorly informative of X's responses to human-administered tests.

The first question – why should robots be preferred to humans in diagnosis? – may be addressed taking into account the hypothesis, strongly supported in the literature (Cabibihan et al., 2013; Scassellati, 2007), that some robots are particularly engaging for ASD people. This consideration might be explained in light of the predictability and the paucity of morphological details characterising most robots, especially those specifically designed for interaction with ASD children, in line with Baron-Cohen's "empathising-systemizing" theory (Baron-Cohen et al., 2002). One should be careful to note, however, that robots specifically designed for engaging ASD children may be less engaging for TD children, thus biassing the diagnostic process. Another, perhaps more powerful, reason for using robots in the diagnostic process is that, as pointed out by Scassellati (2007) and others, robots can deliver standardised social stimuli ("social presses") thus improving the quality of comparison among the diagnosed individuals.

The second question – is robot-supported diagnosis reliable? – may be addressed empirically, e.g., by evaluating whether the diagnostic results converge with the results of standard diagnostic methods. In a complementary fashion, one may investigate whether (ASD and TD) children's reaction to the stimuli delivered during robot-supported diagnosis (e.g., in joint attention tasks) are similar to their reactions to the same stimuli delivered by human beings (see, for example, Pierno et al., 2008; Wiese et al., 2014).

So far, we have discussed the potential role of robots as tools to support acquisition of a certain kind of knowledge about ASD children, namely, the acquisition of a diagnosis. Let us not introduce the methodological hypothesis that robots can be meaningfully used to acquire other forms of knowledge about human beings.

1. *Possession of an ability*. By delivering standardised stimuli to individual X, and observing X's responses, one may draw conclusions

on whether X possesses or not a certain ability C. Even though assessing the possession, or absence, of a particular ability may support diagnostic statements (e.g., the absence of mentalization abilities may support diagnosis of ASD), one thing is to diagnose the presence of a disease, another thing is to assess the possession of an ability.

2. *Mechanistic (cognitive) model of an individual's ability*. By varying the characteristics of the stimuli delivered to a system, initially considered as a "black box", and observing the differences in the responses, one may obtain theoretical insights on the cognitive mechanisms that are "internal" to the black box. For example, by observing that X's mentalization performances change depending on whether the robot interacting with X has a human-like face or not, one may formulate the hypothesis that the cognitive mechanisms underpinning X's mentalization abilities are influenced by other cognitive mechanisms devoted to the recognition of human-like faces. Stimulation-based strategies for discovering mental mechanisms have been extensively discussed by William Bechtel (2008).

This chapter will examine the first methodological hypothesis. We will present an exploratory study aimed at assessing whether some ASD and TD children can attribute false beliefs to a non-humanoid and non-social robot. As such, this study illustrates and elaborates on the idea that robots can be used to assess people's possession of particular abilities – in this case, the ability of attributing false beliefs to robots. Assessing possession of this ability may be of some interest for the design of robots interacting with ASD children, and for the design of educational or therapeutic robot-supported activities destined to ASD children.

However, as anticipated in the Introduction, one may legitimately doubt that this study (or an improved and less exploratory version of it) can be of particular interest out of the (educational or social) robotics literature, and that it can offer valuable insights on ASD children's possession of false-belief attribution abilities *generally* – i.e., on their ability to attribute false beliefs *to other people*. Indeed, one may surmise that being able to attribute false beliefs to robots is not the same as being able to attribute false beliefs to human beings. In the following sections, we will also discuss whether, and with what methodological provisos, a robot-supported false belief task can shed light on children's attribution of false beliefs to human beings.

Mentalizing robots: The literature

Some empirical studies on children's ascription of mental states to robots have been published so far. Of particular interest here are the studies specifically addressing the question whether ASD and TD children attribute false beliefs to robots.

One of such studies is reported in Zhang et al. (2019). The goal was to probe whether ASD and TD children, aged from 5 to 7, attribute false belief to a humanoid robot (NAO, SoftBanks Robotics) and predict its action accordingly, in a change-of-location and an unexpected-content task. The results show that most TD children, unlike ASD children, attribute false belief to the social robot. In another study (Banks, 2020), five ToM tasks were carried out, including a false belief task, involving various robots (presented through videos) and a human control. The main goals were to understand whether humans hold a ToM for social robots, and if ToM for robots varied according to the robots' social cues. The results suggested that the participants "mentalized" the robot, even though robot morphology influenced their ToM.

These studies explicitly focus on the question whether people with ASD have a ToM of (or more specifically attribute false beliefs to) *robots*. Can these results be brought to bear on people's ToM of *people*, generally? For example, should failure of ascribing false beliefs to NAO by ASD children, in Zhang et al. (2019), be interpreted as suggesting that (a) ASD children cannot attribute false beliefs to robots, regardless of whether they can attribute false beliefs to humans or not, or that (b) ASD children have general difficulties in ascribing false beliefs to other individuals, be they human or robotic? The second option may have interesting methodological implications, namely, that some robot-supported tasks can be employed to study ToM impairments in ASD children, enabling one to obtain results that speak to their socio-relational difficulties, extending far beyond the narrow domain of human-robot interaction. Robotic tasks might be preferred to more traditional tasks for reasons connected to the standardisation of the stimulus and to the attractiveness of robots to ASD people (see above).

Note that Zhang and colleagues (2019) seem to adopt perspective (b). Indeed, they interpret their experimental results as follows: their findings – namely, that ASD children do not pass their robotic version of the Sally-and-Anne task – «might derive from two possibilities. First, their impairments in ToM hindered the children with ASD from inferring the mental states of any agent, including the social robot». According to this interpretation, the results of the robotic test corroborate the hypothesis that ASD children have general ToM impairments. Then they add, «an alternative possibility is that children with ASD perceived the robots differently from TD children». This alternative explanation brings the experimental results to bear on their "general" ToM, too: according to this interpretation, failing the robot-supported test does not signal an impairment in children's ToM abilities, but only that their ToM mechanisms were not "activated" by the robot (because they did perceive it in a "peculiar" way).

To sum up. Some research has been published on the use of robots to assess whether ASD and TD children attribute false beliefs to robots. This literature gives rise to the question whether robots can be meaningfully used to study "general" ToM difficulties, and not only ASD children's perception of *robots*. The goal of this chapter is to introduce this methodological question and offer some insights for future reflections, also based on the exploratory study that we are now going to describe. Note that, somehow contrary to Zhang (2019), we obtained evidence that could be interpreted as suggesting that ASD children do sometimes attribute false beliefs to a robot. Moreover, our study, unlike the studies reviewed here, involves a *non-humanoid robot* and is based on a spontaneous-response task (see above) modelled after the "helping paradigm" by Buttelmann et al. (2009).

The study

The idea and the goals

The study that we are going to present is exploratory, involves a small number of participants, and should be thought of as the initial step of a longer research project that could be further developed in the future. As discussed in the previous section, the literature on false belief ascription to robots is relatively scarce, and methodological reflections on the usefulness of robots as epistemic tools to study ToM in ASD children are lacking. The task that we are going to describe was designed anew. For this reason, in this study we wanted to collect some preliminary observations that could be used to formulate clearer hypotheses to be subjected to more rigorous experimentation in the future. The importance of exploratory studies which are not guided by crystal-clear hypotheses in the first stages of discovery has been often discussed in the philosophy of science (see Franklin, 2005).

In this study, we administered a robot-supported test called "robotic helping task" (RHt) to a small group of ASD and a small group of TD children. The RHt, more thoroughly presented later, is a change-of-location task inspired by the helping paradigm reported in Buttelmann et al. (2009). Even though we made qualitative observations while the children performed the task, we represented its outcome as binary: "passed" or "failed". Under some auxiliary hypotheses, passing the test can be thought of as supporting the claim that the participant attributed a false belief to the robot. To the same participants, we administered a standard Sally-and-Anne task (STDt), whose outcome was also represented as "passed" or "failed". Passing the STDt can be thought of as supporting the claim that the participant attributed a false belief to one of the characters of the story.

The empirical goal of the study was to find out whether ASD and TD children show different performances at the STDt and the RHt. More specifically, we were guided by the following exploratory questions.

1. Can ASD children pass the RHt?
2. Do TD and ASD children tend to display the same performances at the two tasks?
3. If they do not, how do the two groups differ at the two tasks?

An affirmative answer to question 1 may be interpreted as suggesting that ASD children attribute false belief to the robot involved in the task. The discussion made in the section before enters stage here. Could this result be generalised as suggesting that ASD children can attribute false beliefs to other individuals, generally?

According to a possible interpretation of this result, ASD children possess a false belief attribution mechanism that underpins the ability to attribute, in some circumstances, false beliefs to an entity X (which can be human or artificial). For reasons that the task alone cannot help one clarify, this mechanism is activated in the RHt: robots activate ASD children's "general" false belief attribution mechanism. Note that more traditional tests, such as the STDt, could fail to activate, or perturb, this mechanism (which would nevertheless be "there" and potentially working) because they impose higher processing demands, potentially due to a sensory overload (Bogdashina, 2003). According to this interpretation, the RHt has the "right" characteristics to activate, in ASD children, a cognitive false-belief attribution mechanism that is idle or perturbed in other conditions. The RHt would thus provide information on ASD children's "general" false-belief attribution abilities, and not only on their ability to attribute false beliefs to robots. Regardless of whether ASD children *can* attribute false beliefs to other people in everyday contexts, the RHt would offer evidence that they do possess a general false belief attribution mechanism that can be activated in some cases.

This interpretation would clearly require support. However, one might wonder what would be needed to reject it. It is obvious that, superficially, the RHt only assesses ASD children's ability to attribute false beliefs to robots – this is how the task works. It is clear that, superficially, the RHt does not assess their ability to attribute false beliefs to people. So, to deny *in an interesting sense* that the RHt can be useful to study "general" ToM, one must claim that the results of RHt (superficially concerning robots) *cannot be used to infer* anything about children's ability to attribute false beliefs to other people. One way to interpret the claim that the RHt can only test ASD children's ability to attribute false beliefs to *robots*, but not to *other individuals* generally, would be to take it as suggesting that ASD children have *two* dedicated false belief attribution mechanisms, one activated by robots (in particular, by the RHt), another one activated by people (in particular, by the STDt, which – incidentally – does not involve "real" humans but puppets). Thus, children's performances in the RHt would speak to the working of the first mechanism only, and would say nothing about the second one. This hypothesis might well be true, even though it would imply a proliferation of separate mechanisms, each one devoted to the attribution of false beliefs to a distinct category of "third entities". We take the difficulty of defending this position as a reason to provisionally accept the claim that the RHt can provide evidence of children's possession of a false-attribution mechanism. If children attribute false beliefs to the robot in the RHt, this can be taken to support the claim that they can possess a "general" false-belief attribution mechanism which is triggered by that task (and, possibly, not activated in other contexts).

Question 2 is answered affirmatively if all children (be they ASD or TD) perform similarly at the two tasks. This is the case, for example, if ASD children fail both the STDt and the RHt, and if the TD children pass both tests. This result would indicate convergence between the two tasks and support the hypothesis that the RHt can be reliably used to assess the ability of attributing false beliefs to others, under the assumption that the STDt is a "good" false belief test. However, in that case, one may legitimately question the usefulness of the RHt, insofar as it is as "good" as the STDt, which is significantly less expensive and easier to perform.

More interesting, from a theoretical and methodological point of view, is the detection of differences in the outcomes of the two tests, in the two groups of participants (question 3). Among the many possible combinations of outcomes, it might be the case that ASD children fail the STDt and pass the RHt. This result would suggest that the ASD children possess some false-belief attribution abilities (contrary to what is suggested by the STDt). And, it may be interpreted methodologically as suggesting that the RHt can reveal possession of false-belief attribution abilities which are not revealed by the standard Sally and Anne task (perhaps due to its distinctive processing demands). Thus, that the RHt is a valid and insightful test for studying false belief attribution in ASD people.

Participants

The sample selected for this exploratory study consists of 5 ASD participants aged between 4 and 12 years, with no intellectual disability and good verbal skills, and 5 TD subjects in the same age range. These participants were selected in the framework of a collaboration with the "Meta" Cooperative, operating in the Monza-Brianza area, and the "Desio-Brianza Consortium". The exploratory nature of this study justifies the choice of such a low number of participants in such a wide age range. For all the participants, we collected informed consent declarations in accordance with the ethical guidelines imposed by the University of Milano-Bicocca Ethical Committee.

The robot

The study involved CoderBot, a small non-humanoid and non-social robot developed by the Department of Human Sciences for Education (Robot-iCSS Lab - Laboratory of Robotics for Cognitive and Social Sciences) and the Department of Computer Science of the University of Milan-Bicocca (www.coderbot.org). The robot is equipped with both front and side ultrasonic sensors and a front camera. It can be programmed using Blockly, a visual block-based programming environment. It is worth noting that the task involved no programming activity: the robot was presented to the children after being programmed by the research group so that it performed the desired behaviour during the RHt.

The auxiliary tests

The study included a preliminary phase which was carried out at least one week before the robotic task, during which screening tests were administered to the participating subjects, both ASD and normotypic. Children were administered the following tests:

CPM (Colored Progressive Matrices) - Progressive colored Raven matrices (Italian standardization by Belacchi, Scalisi, Cannoni & Cornoldi, 2008). Raven's colored progressive matrices measure non-verbal intelligence in children between the ages of 3 and 11 years old. They consist of 3 series, of 12 items each; each item requires the child to complete a series of figures with the missing one, compared to a model presented, according to a criterion of growing difficulty. The model figures include graphic motifs that change from left to right and from top to bottom; the subject must understand the underlying logic to choose the right figure to complete the model. Administration takes approximately 30 minutes. The purpose of using this test is to provide important information on the ability of logical reasoning and fluid intelligence to analyse the behaviour of the participants in the "robotic task", which requires a certain level of non-verbal intelligence to understand the situation presented.

Proof of completion of stories on prosocial orientation (Grazzani & Ornaghi, 2015). The task consists of four short illustrated scenarios, concerning the following prosocial behaviours: comforting, making peace, sharing objects and helping. children are read the story and then asked to complete it with an ending. The purpose of administering this test is to check the variable of social competence involved in the non-verbal, spontaneous-response "robotic task". In particular, what is interesting to observe is the ability and predisposition of the participants to identify with the other, which in this case is a robot, and to help him achieve a goal. Furthermore, the results of this test will be useful in describing the performance of the participants in the classic Sally and Anne test.

Social Responsiveness Scale (Costantino & Gruber, 2005; Italian adaptation by Zuddas, Di Martino, Delitala, Anchisi & Melis, 2010). This scale assesses different aspects of social responsiveness: social awareness, social cognition, communication, social motivation and repetitive and stereotyped behaviors, or mannerisms. The SRS is made up of 65 items, with respect to which educators/teachers or parents express how much each behaviour refers to their child on a 4-point Likert scale (1 = not true, 2 = sometimes true, 3 = often true, 4 = almost always true). It is generally filled in by both teachers/educators and parents. In our study only parents compiled the scale. The role of this tool is to provide additional information on the social competences of the participants. This is very important information for interpreting the performance of the "robotic task".

Sally and Anne: the classic first order false belief test (Baron-Cohen, Leslie & Frith, 1985). The child listens to a short story about two puppets: Sally takes a marble and hides it in her basket. She then "leaves" the room and goes for a walk. While she is away, Anne takes the marble out of Sally's basket and puts it in her own box. Sally is then reintroduced and the child is asked the key question, the *Belief Question*: "Where will Sally look for her marble?". Other two control questions are asked. A reality question to understand if the child has really understood where the ball is after moving and a question (Where is the ball now?) and a memory question to understand if the subject remembers where the ball was before (Where was the ball before?). The answers to these questions were collected in an answer sheet indicating whether the subject passed or failed the task. These results were then compared with those of the robotic task to detect any performance difference in the two conditions.

The "robotic helping task"

A week later from the preliminary phase, the robotic task was carried out. The setting consists of two boxes (A and B) having a door that can be closed with an internal pin, and of a small box representing the object that the robot will have to reach, equipped with ARCodes that can be read by the robot. The boxes are neutral in colour to avoid possible distracting elements, especially for individuals on the autism spectrum. In the room there are several video cameras that will record the entire task and will later allow you to analyse the recorded videos.

In addition to the experimenter (S1) who followed the subject during the task, there was a second experimenter (S2) who had the task of activating the robot. The task consisted of three phases.

Familiarisation phase: the subject observes the robot as it reaches the box which is moved several times in space by the experimenter. The robot is programmed to follow the ARcode on the box and stop once reached. After various movements, S1 puts the object behind the robot which obviously does not move. This is a very important phase because, thanks to these movements, the subject must understand that the robot's goal is to reach the box. Finally, the subject is proposed to move the box himself in space. Control questions are asked to understand if the subject has understood the robot's desire:

1. Why, in your opinion, did the robot move before?
2. When I put the box behind the robots, why do you think the robot didn't move anymore?

Once the familiarisation with the robot is concluded, S1 presents the two boxes to the subject to make them understand the opening and closing mechanism of the doors. For this phase a definite time is not given but the time space necessary for the subject is left to assimilate the information about the robot's desire, that is the box.

True belief phase: the robot is placed in front of the boxes. S1 and the subject are positioned behind. The object and the two pins are located on the side of the boxes. The experimenter now takes the box and slowly places it in box A while continuing to observe the robot; then, again with a slow movement and with his gaze turned to the robot, slowly moves the object into box B. At this point the subject is asked the control question: "Do you think that the robot saw the movement?". If the answer is no, the subject is proposed to make the movements again. Once this step has been carried out, S1 asks the subject to close the doors. The robot starts and goes towards box A (empty), slamming against the door several times without being able to enter. At this point, the spontaneous attitudes of the subject are observed and the answer is awaited: if the subject helps the robot to enter box A (empty) then this phase can be considered to have been overcome since in this case he has understood that the robot's objective is that of entering the box and not reaching the object since the automaton has observed the movements.

False Belief Phase (FC): the setting is the same as the previous phase. The experimenter begins by slowly placing the object in box A, always with his gaze turned towards the robot. At this point the experimenter covers the robot with a box and returns to the side of the subject, takes the object from box A and moves it to box B, closing the doors. The control question is asked: "Do you think the robot saw the movement?". If the answer is yes then it continues, otherwise the move is repeated again. Now the robot is activated and will continue to go towards box A and crash without being able to enter.

Therefore, the spontaneous attitudes of the subject are observed and the response is attentive. To overcome this phase, the subject must understand that the robot wants the object but having not seen the movement continues to go towards box A, so the possible answers that can lead the subject to overcome the task are:

- the subject takes the object and gives it to the robot;
- the subject takes the robot and puts it inside box B where the object is located;
- the subject takes the object from box B, puts it in box A and opens the door to let the robot in;
- the subject takes the robot and places it in front of box B;
- the subject takes the robot, puts it in front of box B and opens the door;
- subject opens the door of box B.

The total duration of the task varies according to the response times of the subject, during this pilot study it had a duration ranging from 30 to 40 minutes, including a ten minute break between the VC phase and the FC phase.

Results

The auxiliary tests: Results

The SRS showed that the participants of the control group on average fall into a "normal" profile (Table 1). As regards the experimental group, S02 and S04 have a "severe" profile which indicates a serious interference in daily social interactions.

Raven's CPM: the participants in the control group are within the normal range for age, while 2 subjects in the experimental group have scores that are significantly below average.

Tab. 1 - Results Social Responsiveness Scale

Subj.	*Sex*	*Age*	*Group (experimental/control)*	*SRS_social awareness*	*SRS_social cognition*	*SRS_social communication*	*SRS_social motivation*	*SRS_social motivation*	*SRS_tot*
S01	F	63	S	9	9	14	5	9	46
S02	M	82	S	13	28	36	17	22	116
S03	M	130	S	11	20	21	9	13	74
S04	M	131	S	12	20	27	19	25	103
S05	M	137	S	6	15	23	14	22	80
C01	M	111	C	11	14	23	11	11	70
C02	M	71	C	2	1	3	3	2	11
C03	M	65	C	5	3	7	5	1	21
C04	F	88	C	6	3	8	1	6	24
C05	M	64	C	3	6	9	7	2	27

Tab. 2 - Results Raven, Prosocial Behavior and Sally and Anne

Subject	*Sex*	*Age*	*Group (experimental/control)*	*Raven*	*Prosocial Behaviour*	*ToM_Sally&Anne*
S01	F	63	S	16	1,5	1
S02	M	82	S	12	0,5	0
S03	M	130	S	27	1	0
S04	M	131	S	16	4	0
S05	M	137	S	32	3	0
C01	M	111	C	24	2,5	1
C02	M	71	C	26	1	0
C03	M	65	C	23	4	1
C04	F	88	C	23	2	1
C05	M	64	C	14	0,5	1

Proof of stories completion on prosocial orientation and “classic” test of Sally and Anne: from figure 1 it is interesting to note that most of the participants who achieved good results in completing prosocial stories then succeeded to pass the classic Sally and Anne test. However, some participants, particularly S03 and S04, who gained high scores in completing the prosocial stories, then failed to pass the classic Sally and Anne test. Overall, the experimental group failed to pass the classic Sally and Anne test, except for a single subject S01. We must remark that both S01 parents and educator are working hard on social skills; therefore, this result could be attributed to the specific training that the participant undergoes both at home and at school.

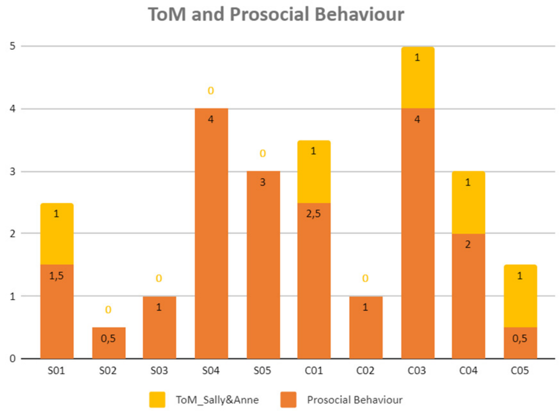

Fig. 1 - Comparison of results between the Sally and Anne test and Prosocial Behaviour test

The robotic helping task: Results

The results of the STDt and the RHt, administered to the ASD and the TD participants (labelled as Sx and Cx, respectively) are shown in Table 3. Note that the STDt is passed if the participant answers that Sally will look in the basket (i.e., where she had put it before leaving). The RHt is passed only if two conditions are met:

- in the TB condition – i.e., when the robot was not covered and "saw" the change of location of the object – the participant spontaneously helps the robot enter box A, which is empty;

- in the false belief condition – i.e., when the robot was covered – the participant displays one of the spontaneous responses listed previously, intending to help the robot reach the object in box B.

Note that the RHt can be thought of as revealing attribution of a false belief to the robot only if both conditions are met, as thoroughly discussed in Buttelmann et al. (2009).

Let now discuss how these results speak to the three empirical goals of this study, which are the following.

1. Can ASD children pass the RHt?
2. Do TD and ASD children tend to display the same performances at the two tasks?
3. If they do not, how do the two groups differ at the two tasks?

The choice of a small sample (five ASD children, five TD children) does not enable us to formulate general answers to these questions. The following answers will concern our pool of participants, and further studies will investigate whether they can be generalised in one way or another.

Can ASD children pass the RHt (question 1)? Three out of five ASD children passed the task. Two of them, S02 and S04, did not. Participant S02 tended to play with the robot for the whole duration of the task, paying little or no attention to the task. Participant S04 displayed the "right" reaction in the FB condition and the "wrong" reaction in the TB condition, helping the robot reach box B.

Do TD and ASD children tend to display the same performances at the two tasks (question 2)? As shown in Table 1, the answer is negative for our small pool of participants. This brings us to the third question: how do the two groups differ from one another at the two tasks?

This question can be answered, first, identifying ASD/TD differences in each single task.

- The ASD and the TD participants behaved differently in the STDt: 4 out of 5 ASD children failed it, while 4 out of 5 passed it.
- They also behaved differently in the RHt: 3 out of 5 ASD children passed the test, while all the TD children failed it.
- Second, one may identify STDt/RHt differences within each single group of participants.
- As far as the ASD group is concerned, the results are variegated. One participant (S01) passed both tests. Two participants (S02, S04) failed both tests. Two participants (S03, S05) failed the STDt and passed the RHt.

- The results are more homogeneous in the TD group: 4 out of 5 children passed the STDt but failed the RHt. C02 failed both tests.
- These rather aseptic results can be profitably complemented with more qualitative observations of our participants' behaviour, that can be useful to interpret the data and obtain possible explanations.
- As far as the ASD group is concerned, S01 passed the classic false belief task, correctly answering the first-order false belief question and the memory question, showing that he remembered the story. However, he did not answer the reality question correctly, showing that he did not understand where the object really was. On the other tests (SRS, Raven, Story Completion) he obtained normal scores. He passed the RHt.
- S02 failed the classic test and gave a wrong answer to the memory question, showing that he did not understand the story. However, he correctly answered the reality question revealing that he understood the actual location of the object. With regard to the SRS test, he falled into a "severe" profile that indicates a serious interference in daily social interactions. He also failed the CPM and showed several difficulties, although passing the test, in the completion tests. He failed the RHt.
- S03 failed the classical task. However, it correctly answered both the reality question and the memory question, thus demonstrating that it remembered the story and understood the actual real location of the object. According to SRS scores, he has a normal profile. He passed the RHt.
- S04 failed the classical task. However, he correctly answered both the reality question and the memory question, thus demonstrating that he remembered the story and understood the actual location of the object. He has a severe SRS profile, indicating serious difficulties in everyday social interactions. He passed the other two tests (Raven, Story Completion). He failed the RHt.
- S05 failed the classical task. However, he correctly answered both the reality question and the memory question, thus showing that he remembered the story and understood whether the object actually was. He passed the RHt.

As previously mentioned, all the TD participants showed difficulties in the RHt. More specifically, C02 and C04 displayed the "wrong" reaction in both the TB and FB condition. C03 and C05 displayed the "right" reaction in the TB condition and the "wrong" reaction in the FB condition. C01 displayed the "wrong" reaction in the TB condition, and the "right" reaction in the FB condition.

Tab. 3 - For each participant (Sx: ASD child, Cx: TD child), the table summarises the results at the STDt and at the RHt

Participant	*STDt*	*RHt*
S01	Passed	Passed
S02	Failed	Failed
S03	Failed	Passed
S04	Failed	Failed
S05	Failed	Passed
C01	Passed	Failed
C02	Failed	Failed
C03	Passed	Failed
C04	Passed	Failed
C05	Passed	Failed

Discussion and concluding remarks

The results of this exploratory study are in line with the literature when comparing TD and ASD children using classical standard tests. In particular, a significant difference emerges, in favour of TD children, with respect to social responsiveness, prosocial behaviour and understanding of false belief using the classic paradigm of unexpected displacement (Sally and Anne, STDt).

An interesting aspect seems to emerge if we compare the two groups on the "robotic helping task". All TD children do not pass the task, which is instead better understood by ASD children. This result can be interpreted – as suggested in the section on objectives – as an indicator of the ASD children's possession of cognitive decentering and false belief attribution skills, which the classic Sally and Anne test is unable to capture. This may also be in line with the idea that the use of false belief tasks involving people or characters with human characteristics (including humanoid robots) contributes to a sensory and perceptual overload that hinders the cognitive processes of hierarchization and selection of salient elements to understand the intentionality of actions based on beliefs, whether true or false. It is therefore possible that ASD children are able to understand the objectives of the robot by observing its movements, without being "disturbed" by other sources of information that would make the situation too complex.

On the other hand, the fact that TD children fail the robotic helping task leaves room for different interpretations: it is possible that children do not recognise the robot as an agent endowed with thought and intentionality. It is also possible that, although the children understand the robot's purpose, the empathic closeness that would lead to the activation of pro-social behaviour is not activated in this case.

The results of this exploratory study offer interesting insights into cognitive perspective taking processes and false belief attribution skills in both TD and ASD children, and on the possibility of using robots to study ToM in ASD and TD children. However, the small number of subjects involved only allows for hypotheses and speculations that should be tested with studies involving a sufficiently large number of subjects.

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