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BRIEF REPORT

Brief Report: Self-Based and Mechanical-Based Future Thinking in Children with Autism Spectrum Disorder

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Abstract This brief report is a partial replication of the study by Jackson and Atance (J Dev Disabil 14:40–45, 2008) assessing nonverbal Self-based and Mechanical-based future thinking (FT) in children with Autism Spectrum Disorder (ASD). In a first step, these tasks were administered to 30 children with ASD. The two Self-based tasks were then modified as a verbal component could not be completely ruled out. Consequently, 77 children with ASD and 77 children with typical development received the modified Self-based FT tasks and the Mechanical-based FT tasks. We partially replicated the previous findings. Participants with ASD had impaired FT in both kinds of tasks and both groups performed better on tasks assessing Mechanical-based FT than Self-based FT. These results suggest that impairments of FT in ASD are not limited to Self-Projection.

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Introduction

This brief report describes an experiment originally aimed at replicating the findings from a study by Jackson and Atance (2008) that assessed future thinking (FT) skills in children with Autism Spectrum Disorder (ASD). In that investigation the authors compared the performance of two small groups of participants matched on verbal age [as measured by administering the Peabody Picture Vocabulary Test, 3rd edition (PPVT-III; Dunn and Dunn 1997)] and gender (11 males and 1 female in each group). Unfortunately, they were not controlled for chronological age, level of formal education, or IQ. The target group comprised 12 children with diagnosis of ASD (Chronological Age: Mean: 7.2; Standard Deviation: 2.4; Range: 4.8–13.1/Verbal Mental Age: Mean: 5.11; Standard Deviation: 1.4; Range: 4.1–8.4). The comparison group included 12 children with typical development (Chronological Age: Mean: 4.9; Standard Deviation: .9; Range: 3.6–5.10/ Verbal Mental Age: Mean: 5.11; Standard Deviation: 1.4; Range: 4.3–8.5). The authors devised two Self-based tasks for the assessment of FT requiring children to project themselves into a near future (i.e., *Ernie's doggies* and *Ant costume*) and two Mechanical-based tasks designed to assess the children's ability to predict the outcome of a physical transformation which did not imply any projection of the Self (i.e., *Balls and Tubes* and *Tapioca*). Performance at both types of tasks was analyzed with four nonverbal measures. Jackson and Atance (2008) did not perform any between-group analysis, limiting their observation to within-group performance across the two conditions (Self-based vs. Mechanical-based future thinking) among children with ASD and those with typical development. A nonparametric analysis showed that children with ASD had significantly lower scores at the Self-based tasks than at the Mechanical-based tasks suggesting an impairment in the ability to project themselves into the future but not a difficulty in foreseeing the result of a physical transformation. By contrast, no such difference was found in the comparison group. According to the authors, these results suggested that children with ASD have a "specific impairment in projecting the Self into the future" (p. 44). The authors themselves acknowledged that these results needed replication as their study suffered from some relevant limitations (p. 45). The two groups were not matched for chronological age, level of formal education, or IQ. Furthermore, the participants with ASD formed an extremely heterogeneous cohort, as they ranged from preschoolers to individuals in middle and late childhood. Finally, the two groups were too small to cover such a wide age-range and this further limited the statistical power of the results. Even if these results cannot be easily interpreted or generalized within the population of children with ASD, we believe that the tasks designed by Jackson and Atance (2008), also for their minimal reliance on language skills that are usually impaired even if at different degrees in individuals with ASD (e.g., Terrett et al. 2013; Boucher 2012), might prove clinically useful in the identification of future thinking impairments in these children.

We aimed at replicating the study by Jackson and Atance (2008) with a much larger cohort of 77 participants with a diagnosis of high-functioning ASD and 77 children with typical development. The two groups shared similar age, level of formal education, and IQ. A preliminary pilot study including 30 children with ASD showed that a verbal component could not be completely removed from the two tasks assessing Self-projection. For this reason, we decided to modify the scoring procedure for the Ant costume task and the administration procedure for the Ernie's doggies task taking into account the need to consider this verbal component in both of them (please refer to the Materials and Procedures' section for a thorough description of the original tasks and their modification in the current study). Overall, we aimed at determining (1) if the introduction of verbal measures introduced a significant bias in the analyses; (2) if significant group-related differences could be found in either Self-based or Mechanical-based tasks or in both of them; (3) if children with ASD had more difficulties in Self-based than in Mechanical-based future thinking tasks. As the former issue had not been considered in the study by Jackson and Atance (2008), the second issue had been somehow left suspended in that study and the third one had received only a weak answer, we hypothesized that the inclusion of a large cohort of children would contribute to our understanding of the cognitive profile and Future Thinking skills in ASD. Indeed, different theories have been proposed to account for the ability to mentally generate potential future events (Lind et al. 2014). One such theory focuses on a mechanism of Self-projection, i.e., a self-centered prospection from the current situation to alternative points in time (e.g., Buckner and Carroll 2007). According to a different approach, episodic future thinking might require also an active process of scene construction (e.g., Hassabis et al. 2007), that is the ability to bind together multimodal non-self-relevant elements of a complex scene into a single coherent mental representation. Accordingly, we also hypothesized that if children with ASD had impaired performance in both Self-based and Mechanical-based future thinking tasks, this might support the possibility of a future thinking impairment which is not limited to the projection of the Self but affects also other skills such as scene construction.

Methods

Participants

Seventy-seven children with a diagnosis of high functioning ASD (Age: mean 8.11 years; Standard Deviation: 1.51; Range: 6–11.09; IQ level: mean: 106.08; Standard Deviation: 14.13; Range: 80–141) were recruited for this experiment. They were selected from among a larger cohort of children with ASD who came to the IRCCS Hospital "Bambino Gesù" in Rome for a yearly follow-up assessment. The IQ level was determined by administering the Leiter International Performance Scale-Revised (Roid and Miller 2002) to 26 of them, and the Wechsler Intelligence Scale for Children-III (WISC-III; Orsini and Picone 2006) and IV (Orsini et al. 2012) for the rest of the participants with ASD. Furthermore, all of them received the Raven's Coloured Progressive Matrices (Raven 1938). The gravity of their symptomatology was assessed by administering the Autism Diagnostic Observation Schedule, 2nd edition—ADOS-2 by Lord et al. (2013) which revealed that they had a mean gravity score of 6.12 with a Standard Deviation of 1.73 ranging from 2 (minimal severity) to 9 (high severity).

Their performance on tasks assessing future thinking skills was compared to that of a group of seventy-seven children with typical development (Age: mean 8.23; Standard Deviation: 1.51; Range: 6–11.11; IQ level: mean: 106.32; Standard Deviation: 11.41; Range: 90–130). All of them performed within normal range at the Raven's Coloured Progressive Matrices (Raven 1938), in the Non-Word Repetition subtest of the Prove di Memoria e Apprendimento per l'Età Evolutiva (PROMEA; Vicari

2007), and at the forward and backward digit span's subtests of the WISC-III (Orsini and Picone 2006). They had average school performance. In a preliminary interview, their teachers confirmed that they had normal cognitive and learning development. According to school records and parents' reports none of them had a known history of psychiatric or neurological disorders, learning disabilities, hearing or visual impairment. The two groups had similar age ($t_{(152)} = -.485$; $p = .628$) and IQ-Level as measured with the Raven's Progressive Matrices ($t_{(152)} = .151$; $p = .909$).

All parents released their informed consent for the participation of their children in the study and to the treatment of the data.

Materials and Procedures

All participants were tested individually and received the four tasks devised by Jackson and Atance (2008) to assess Self-based and Mechanical-based future thinking.

Self-Based Tasks

In the original version of the *Ernie's doggies*' task children were presented with three closed binders and were asked to open them. Each contained a picture of an animal (i.e., puppies, kittens, and ducklings). The experimenter explained that Ernie, from "Sesame Street", was coming to visit but was afraid of puppies. So, children were asked what they would do to prepare for his visit. They received 1 point if they correctly hid the image of the puppies but scored 0 if they hid the wrong picture. According to Jackson and Atance (2008), a correct response on this task suggests that the child has anticipated him/herself in a potential future situation. In the adapted version of the task used for our experiment, the character of Ernie was replaced with a child called Marco so to avoid a cultural bias. As in the original version, also in our experiment children were instructed to hide the target image. However, some of them told the experimenter which picture they would hide instead of hiding it. In these instances, the children were asked again to hide the target picture without receiving any feedback about the correctness of their verbal answer. In order to rule out the possibility that the verbal response registered in our study might bias the results with respect to those reported in the original study by Jackson and Atance (2008), a phi correlation analysis was then run between verbal and nonverbal responses on the 31 children with ASD who produced a verbal response first. This analysis showed a perfect positive correlation ($phi = 1.000$, $p < .001$): no differences were found among these two scores as all of these children scored the same way in the two modalities.

In the *Ant's costume* test children were presented with two pieces of a carnival costume representing an ant: a black t-shirt was the "ant body", whereas a hat with two antennae was the "ant head." The experimenter asked the child to pretend that (s)he would be putting on the costume, and invited him/her to choose which part (s)he would put on first. In the original version of the task, children received 1 point if they correctly chose to put the ant body on first, as this suggested that they had anticipated a future scenario in which the ant body would not fit over the antennae on the ant head. However, during a pilot study we noticed that some children had selected the correct item first only by chance or without the correct reason. Therefore, we asked them to explain their choice to be sure that children had selected the "ant body" first for the correct reason. In order to determine whether this procedure introduced a change in the replication of the original study by Jackson and Atance (2008) for a cohort of 30 children with ASD we recorded both nonverbal (1 if they had selected the "ant body" first; 0 if they hadn't) and verbal (1 if they correctly motivated their choice; 0 if their reason was not correct) scores. Overall, these children had a mean nonverbal score of .71 (SD: .46) and a mean verbal score of .55 (SD: .51). A Wilcoxon signed-rank test showed that this difference was significant ($Z = -2.236$; $p < .025$). A qualitative inspection of the performance of these children showed that some of them ($N = 5$; 17 %) had correctly selected the "ant body" first but had provided a wrong explanation for their choice that was clearly not related to putative linguistic difficulties (e.g., "I'll put on the t-shirt otherwise I am cold"). Therefore, for the rest of the participants we recorded only the verbal score. Namely, children received 1 point if they chose to put the "ant body" on first and could show that their choice was related to a mental projection in a potential future scenario (i.e., that they had anticipated a future scenario in which the ant body would not fit over the antennae on the ant head). We are confident that this add to the original test might allow clinicians to have a better picture of the children's ability to correctly select the target item.

In the original study by Jackson and Atance (2008) the scores at the *Ernie's doggies* and at the *Ant costume* were summed up in order to obtain a composite score of Self-based future thinking. However, in that study the authors did not provide any direct evidence that could motivate this choice. Indeed, in the Ernie's doggies task, participants needed to regulate their behavior in light of their knowledge of someone else's likes and dislikes, whereas in the Ant costume task, they were required to regulate their behavior according to the physical properties of the costume. This suggests that these two tasks might be measuring different things. For this reason, a phi correlation analysis was run between these two scores in the whole sample of participants. This analysis confirmed that the two tasks assessing Self-based future thinking correlated significantly (phi = .284, $p < .001$). For this reason, a composite score of Self-based future thinking was derived for further analyses by summing up the two scores (maximum score: 2).

Mechanical-Based Tasks

In the *Balls and tubes'* test children were asked to look at two detachable tubes (one wide, one narrow) placed on a table next to a wooden ramp. The experimenter showed them that a small ball could roll down both tubes but a big ball would only fit into the wider tube as it could not roll down the narrow one. The narrow tube was placed below the wide tube and children were asked to decide which of the two balls would roll down the two tubes. Children received 1 point if they correctly chose the small ball, as the big one would get stuck once it reached the narrow tube. After their choice, they were also invited to perform the corresponding action. A correct response on this task suggests that children anticipated a mechanical relation between the two balls and the tubes.

In the original version of the *Tapioca* test, each child was shown a small empty container, a large container of small tapioca beads, a small box without a lid, and a large slotted spoon. Then the experimenter asked the child what (s)he would do to transfer the tapioca beads to the small container choosing either the spoon or the box. The child was then invited to perform the corresponding action. Children received 1 point if they correctly chose the small box anticipating that the tapioca beads would slip through the slotted spoon. In the adapted version of the task, we replaced the tapioca beads with white flour.

In the original study by Jackson and Atance (2008) the scores at the *Balls and Tubes* and at the *Tapioca* tasks were summed up in order to obtain a composite score of Mechanical-based future thinking. Also in this case, in order to ensure that these tasks correlated with each other, a phi correlation analysis was run between these two scores in the whole sample of participants. This analysis confirmed that the two tasks assessing Mechanical-based future thinking correlated significantly (phi = .420, $p < .001$). For this reason a composite score of Mechanical-based future thinking was derived by summing up the two scores (maximum score: 2).

Results

The present study showed that a verbal component could not be completely removed from the two tasks assessing Self-projection. Nonetheless, as we were originally interested in replicating the study by Jackson and Atance (2008), we will present two different sets of analyses. The first one focused on those 30 children with ASD who participated in the pilot study and for whom we had both "verbal" and "non-verbal" scores for the *Self-based tasks*. This allowed us to exactly replicate for these participants with ASD the study by Jackson and Atance (2008) by using non-verbal composite scores derived by both *Self-based* and *Mechanical-based tasks*. To explore within-group effects on these two non-verbal composite scores, one Wilcoxon signed-rank test was run on the means reported in Table 1. No difference was found between these two composite scores, suggesting that, when only non-verbal scores were taken into account, participants with ASD did have the same performance on both S*elf-based and Mechanical-based tasks* ($Z = -1.290$; $p = .197$; effect size $r = -.236$). However, as outlined in the Materials and Procedures' section, the non-verbal scores obtained with the *Self-based tasks* were not reliable for the Ant's costume task, as children could correctly select the ant body first but by chance or for the wrong reason. Consequently, for all the other participants in the study we recorded only the verbal score at this task. This second set of analyses focused on the "adapted" scores derived from the *Self-based tasks* and the non-verbal scores derived from the *Mechanical-based* tasks in the group of participants with ASD and that of participants with Typical Development. Before exploring the potential group-related differences between the two composite scores, preliminary analyses assessing homogeneity of variance were run. The Levene's test for equality of variances showed that the assumption of homogeneity of variance had been violated: Mechanical-based FT composite score ($p < .001$); Self-based FT composite score ($p < .017$). For this reason, non-parametric tests were used to explore both between-subject and within-subject effects (see Table 2). The group-related differences on the assessment of the children's *Self-based and Mechanical-based* future thinking skills were analyzed with two Mann–Whitney tests with group (i.e., ASD vs. TD) as fixed factor and the two composite scores (i.e., Self-based future thinking composite score and Mechanical-based future thinking composite score) as dependent variables. The level of statistical significance was set at $p < .025$ (.05/2 dependent variables) after Bonferroni correction for multiple comparisons. This analysis showed that the participants with ASD scored lower than participants with TD on both Mechanical-based future thinking ($U = 3.79$, $p < .001$; effect size $r = -.288$) and Self-based future thinking ($U = 3.88$, $p < .001$; effect size $r = -.264$) composite scores. To explore within-group effects on the two composite scores, two Wilcoxon signed-rank tests were run. The results showed that there were significantly more participants with ASD who scored better

Table 1 Performance of the 30 participants with ASD who participated to the pilot study on tasks assessing Self-based and Mechanical-based Future Thinking skills

	ASD (N = 30)
Self-based FT composite score	.80 (.61) Range: 0–2
Mechanical-based FT composite score	1.03 (.81) Range: 0–2

Data are expressed as means, standard deviations, and ranges of the non-verbal measures

ASD (children with) Autism Spectrum Disorders, *FT* future thinking

on Mechanical-Based tasks than on Self-Based ones ($Z = -3.751$; $p < .001$; effect size $r = -.302$). Similarly, the analyses revealed also that there were significantly more participants with TD who scored better on Mechanical-Based tasks than on Self-Based ones ($Z = -3.979$; $p < .001$; effect size $r = -.335$). One further issue concerned the potential effect exerted by IQ level on the performance of the two groups of children. A series of Spearman's Rank Order Correlations (rho) were used to determine the relationship between IQ scores and Self-based and Mechanical-based composite scores for the whole group of participants with ASD and the one with TD. For the former, the relationship between IQ and Self-based composite score was significant (Spearman's $\rho = .259$, $p < .023$), whereas that between IQ and Mechanical-based composite score was not (Spearman's $\rho = .141$, $p = .223$). Among the control participants such a relationship was never significant (IQ and Mechanical-based composite score (Spearman's $\rho = .092$, $p = .431$); IQ and Self-based composite score (Spearman's $\rho = -.114$, $p = .327$)). Finally, we explored the potential age-related effects on both groups of participants on the four tasks. Namely, we divided the groups of participants with ASD and TD into four subgroups according to their age: children with ASD aged 6–8 years; children with ASD aged 9–11 years; children with TD aged 6–8 years; children with TD aged 9–11 years (see Table 2). Again, non-parametric tests were conducted to explore both between-subject and within-subject effects. For each age-group (children with ASD aged 6–8 years and children with TD aged 6–8 years; children with ASD aged 9–11 years and children with TD aged 9–11 years) group-related differences on the assessment of the children's *Self-based and Mechanical-based* future thinking skills were analyzed with two Mann–Whitney tests with group (i.e., ASD vs. TD) as fixed factor and the two composite scores (i.e., Self-based future thinking composite score and Mechanical-based future thinking composite score) as dependent variables. The level of statistical significance was set at $p < .025$ (.05/2 dependent variables) after Bonferroni correction for multiple comparisons. As for children aged 6–8 years, this analysis showed that the participants with ASD scored lower than participants with TD on both Mechanical-based ($U = 660.00$, $p < .012$; effect size $r = -.271$) and Self-based future thinking ($U = 674.50$, $p < .022$; effect size $r = -.247$) composite scores. Also in older children aged 9–11 years the participants with ASD scored lower than participants with TD on both Mechanical-based future thinking ($U = 431.00$, $p < .022$; effect size $r = -.277$) and Self-based future thinking ($U = 370.50$, $p < .006$; effect size $r = -.331$) composite scores. Finally, for each age-group, we also explored within-group effects on the two composite scores with two Wilcoxon signed-rank tests. The results confirmed that, for both age groups, there were significantly more participants with ASD who scored better on Mechanical-Based tasks than on Self-Based ones (6–8 years: $Z = -2.434$; $p < .015$; effect size $r = -.367$; 9–11 years: $Z = -2.874$; $p < .004$; effect size $r = -.500$). Similarly, the analyses showed that the same happened in the control groups: 6–8 years: $Z = -2.694$; $p < .007$; effect size $r = -.416$; 9–11 years: $Z = -2.977$; $p < .003$; effect size $r = -.503$). As a final analysis, we ran a series of Spearman's Rank Order Correlations (rho)

Table 2 Performance of the participants with ASD and TD on tasks assessing Self-based future thinking skills with the inclusion of a verbal component and non-verbal Mechanical-based future thinking skills

	ASD (6–8 y.o.; N = 44)	ASD (9–11 y.o.; N = 33)	ASD All (N = 77)	TD (6–8 y.o.; N = 42)	TD (9–11 y.o.; N = 35)	TD All (N = 77)
Self-based FT composite score	.80 (.85) Range: 0–2	.91 (.80) Range: 0–2	.84 (.83) Range: 0–2	1.19 (.71) Range: 0–2	1.43 (.61) Range: 0–2	1.30 (.67) Range: 0–2
Mechanical-based FT composite score	1.11 (.84) Range: 0–2	1.42 (.97) Range: 0–2	1.25 (.83) Range: 0–2	1.55 (.71) Range: 0–2	1.83 (.38) Range: 0–2	1.68 (.59) Range: 0–2

Data are expressed as means, standard deviations, and ranges for the participants with ASD and TD aged 6–8 years and 9–11 years. Furthermore, the mean values for the whole sample of participants with ASD and TD are reported

ASD (children with) Autism Spectrum Disorders, *TD* (children with) typical development, *FT* future thinking, *y.o.* years old to explore the relationship between IQ scores and Self-based and Mechanical-based composite scores for participants with ASD and with TD included in the two age-groups. As for the participants with ASD these analyses showed that the relationship between IQ and Self-based composite score was significant for children aged 6–8 [Spearman's $\rho = .313, p < .039$], whereas that between IQ and Self-based composite score was not significant for children aged 9–11 (Spearman's $\rho = .330$, $p = .061$). The relation between IQ and Mechanical-based composite score was never significant: 6–8 years old (Spearman's $\rho = .211$, $p = .170$); 9–11 years old (Spearman's $\rho = .249$, $p = .163$). Among the control participants such relationship was never significant [6–8 years old: IQ and Mechanical-based composite score (Spearman's $\rho = .221$, $p = .160$); IQ and Self-based composite score (Spearman's $\rho = -.154$, $p = .331$); 9–11 years old: IQ and Mechanical-based composite score (Spearman's $\rho = -.154$, $p = .385$); IQ and Self-based composite score (Spearman's $\rho = -.056$, $p = .753$)].

Discussion

This brief report is a partial replication of the study by Jackson and Atance (2008). As highlighted in the Introduction and in the Methods' sections, we used the same tasks employed in that investigation but included a large cohort of children with ASD and compared their performance on Self-based and Mechanical-based future thinking tasks with that of a large cohort of children with typical development and similar age, level of formal education, and IQ. As an initial result, when considering non-verbal composite scores for Self-based and Mechanical-based tasks we failed to replicate the finding of a significant impairment in Self-based tasks in the group of children with ASD. However, we found that a verbal component cannot be ruled out in the two tasks assessing Self-based FT skills and this prompted us to modify the administration procedures for the Ernie's doggies task and the scoring procedures for the Ant's costume task. Consequently, the results from the current investigation only partially support the findings from Jackson and Atance (2008) and have both methodological and theoretical implications.

From a methodological point of view, this study suggests the need to include a verbal component in both Ernie's doggies and Ant's costume tasks. In the former children at times preferred to verbalize their answer. For this reason, during the administration of the Ernie's doggies task examiners should consider the possibility of including both a verbal and a nonverbal answer (i.e., children might either hide the target picture or just refer to that picture also by other means). As shown by our data, this methodological difference in the administration procedure does not introduce a significant bias in this task. However, we are aware that this holds true for children with ASD who, like the ones included in our study, are high-functioning and do not show significant linguistic impairments. More importantly, our experience showed that the administration of the Ant's costume task must include the request to explain the selected choice. The introduction of a verbal component in this task significantly affected the scoring procedure not because of a potential linguistic bias but because it allowed us to exclude the possibility that the child produced the correct answer with the wrong reason (i.e., it was not related to the ability of future thinking). A second methodological issue regards the suitability of the Self-based and Mechanical-based tasks developed by Jackson and Atance (2008) to assess future thinking also in children who are older than the ones originally recruited in their study. In their original study, Jackson and Atance (2008) administered these tasks to 12 children with typical development who were younger than the ones recruited for our investigation (range: 3.6–6.10 years). By contrast, the participants with diagnosis of ASD had a much wider age range (from 4.8 to 13.1 years). As we recruited a control group of children with typical development who were matched also for chronological age with those with ASD, we had the possibility of controlling for the suitability of both Self-based and Mechanical-based tasks also for older children with typical development and not only in children with ASD. Interestingly, they did not perform equally well on Self- and Mechanical-based tasks. Rather, they scored lower in Self-based than in Mechanical-based tasks suggesting that the former might posit additional difficulties still in middle childhood as this pattern of results was noted among younger and older children with ASD (and even with TD). Future studies should further explore age-related effects on performance with such tasks.

The between-group analysis clearly showed that the children with ASD were impaired not only in Self-based but also in Mechanical-based future thinking tasks and that their performance was only partially related to their IQ level. Indeed, IQ had a small positive correlation with the Self-based composite score which was limited to the younger group of participants with ASD. This is an important finding, as it supports the possibility that impairments in Future Thinking might rely not only on Self-projection (e.g., Buckner and Carroll 2007) but also on additional skills, such as scene construction (e.g., Hassabis et al. 2007), which reflects the ability to mentally generate a spatial representation binding together multiple elements in an imagined scene (Lind et al. 2014). In tasks assessing mechanical-based future thinking the ability of scene construction might play an important role in the generation of an adequate scenario dealing with the consequences of a mechanical transformation. Interestingly, this hypothesis is further supported by the findings of a study where we investigated episodic future thinking and narrative generation skills in the same cohort of children. There we found evidence of difficulties in generating past and future events in stories that did not involve any projection of the Self but required the generation of episodes that had to be coherently linked within a narrative discourse (Marini et al. 2016). Nonetheless, the within-group analysis showed that both children with ASD and with typical development experienced more difficulties in the two tasks assessing Self-based future thinking than in those assessing Mechanical-based future thinking. As we have seen, in the two Self-based tasks a verbal component could not be completely ruled out and was particularly important for passing the Ant's costume task. This might suggest that children simply found it more difficult to explain their actions verbally (and particularly children with ASD) than to predict the outcome of a physical transformation. However, we would like to stress that the participants with ASD selected for this experiment had good verbal skills and their explanations on the Ant's costume task were not linguistically poor as they could motivate their choice. However, in some cases their explanation showed that the reason was wrong (e.g., "I'll put on the t-shirt first otherwise I am cold"). As also children with typical development performed worse on Self-based than in Mechanical-based tasks, and the former tasks explicitly required the projection of the Self rather than the prediction of the outcome of a physical transformation, we hypothesize that both self-projection and scene construction might be impaired in children with ASD but the ability to project the Self might be more severely compromised in ASD and might posit particular difficulty to children with typical development still in middle childhood. This hypothesis should be explicitly explored in future studies.

To conclude, these results apparently suggest that Self-projection is an important aspect of future thinking but also that this is not the only function involved in such a skill. It would be fruitful in future studies to also include measures of executive functions, central coherence, or theory of mind. Further investigation is needed to address the critical issue of the relationships between these cognitive functions and future thinking skills. This would further test the possibility that their difficulties in social communication and social interaction, and their repetitive and restricted behaviors (APA 2013) along with their spatial navigation difficulties (Lind et al. 2013) and impairments affecting Theory of Mind (Baron-Cohen 2008), central coherence (Happé and Frith 2006), executive functions (Hill 2004), impaired episodic memory (Bowler et al. 2007), narrative difficulties (King et al. 2014), and difficulties of episodic future thinking (Hanson and Atance 2014) might reflect a single core impairment whose characteristics are yet to be delineated but whose comprehension will allow scholars to establish effective assessment protocols and clinicians to plan adequate rehabilitative programs to help children with ASD cope with their particular symptomatology. One limitation of this study concerns the verbal component that had to be necessarily included in the Self-based tasks. This potential bias does not allow us to completely exclude the possibility that their lower verbal composite score at the Self-based tasks was influenced also by potentially lower verbal skills. However, as noted in the Methods and Procedures' section and outlined earlier in the Discussion, a qualitative investigation of the verbal responses provided by participants with ASD and TD did not show the presence of significant linguistic difficulties that might have biased their performance. This consideration suggests the need to develop future tasks more suitable to assess Self-based FT skills without any potential verbal bias.

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Author Contributions Andrea Marini supervised the recruitment of the participants and the administration of the tasks, ran the statistics and wrote the paper. Francesco Ferretti planned the study, adapted the original tests, supervised the recruitment of the participants and contributed to the interpretation of the data. Alessandra Chiera, Rita Magni, Ines Adornetti and Serena Nicchiarelli contributed to the adaptation of the original tests, recruited the participants, administered the tasks and contributed to the interpretation of the data. Stefano Vicari and Giovanni Valeri supervised the recruitment of the participants and the administration of the tasks and contributed to the interpretation of the data.

Compliance with Ethical Standards

Conflict of Interest The authors report no conflicts of interest.

Ethical Approval All procedures were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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