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ORIGINAL ARTICLE

# The Role of Theory of Mind, Executive Functions, and Central Coherence in Reading Comprehension for Children with ASD and Typical Development

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**Abstract**

Many children with autism spectrum disorders (ASD) have challenges in reading comprehension, especially when implicit information in narrative texts is involved. Three interrelated factors influencing reading comprehension have been proposed to explain these challenges: Theory of Mind – ToM; executive functions – EF; and central coherence – CC. This study investigated the differential contribution of these cognitive abilities to reading comprehension among cognitively able children with ASD compared to matched peers with typical development (TD). 28 third-grade children with ASD and 28 third-grade children with TD participated in the study. Four measures were administered: ToM, CC, EF (working memory, planning, inhibitory control, cognitive flexibility), and reading comprehension. One-way ANOVAs were computed to examine group differences in cognitive characteristics (ToM, CC, EF) and reading comprehension. Regressions were performed to examine the contribution of cognitive characteristics (ToM, CC, EF) to reading comprehension abilities (explicit, implicit, and general score) in ASD and TD. The TD group outperformed the ASD group in ToM and various EF measures but not in CC or reading comprehension. Positive main effects were found for ToM, and EF measures (planning – 3rd level, inhibition, and cognitive flexibility), demonstrating their contribution to reading comprehension abilities in both groups. Interactions revealed positive main effects for EF planning and CC for the ASD group only, showing the contribution of EF planning and CC for better reading comprehension. Our findings suggest different processing mechanisms regarding reading comprehension in each group.

**Keywords** Autism spectrum disorder · Reading comprehension · Cognitive abilities · Narrative text

## Introduction

Reading comprehension is understanding, interpreting, and making meaning from written text. It is a multifaceted, complex cognitive skill that involves processing and comprehending the words, sentences, and paragraphs in written material and grasping the text's broader meaning, ideas, and concepts. Efficient reading involves cognitive and linguistic processes such as phonological awareness, decoding, fluency, and text comprehension. Vocabulary, oral language, and personal experiences also contribute to reading comprehension (Sorenson Duncan et al., 2021). Reports indicate that most children diagnosed with autism spectrum disorder (ASD) face more academic challenges with reading comprehension than those with typical development (TD) (e.g., Bailey & Arciuli, 2022). However, it is unclear how specific cognitive components contribute to reading comprehension abilities and challenges in children with ASD (Wang et al., 2022). Amongst other explanations, three theoretical factors regarding cognitive processes have been suggested to explain these challenges in children with ASD (Zhang et al., 2023): Theory of Mind (ToM - the ability to infer others' mental states), central coherence (CC – the ability to recognize the overall global picture), and executive functions

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(EF - goal-directed behaviors such as planning, cognitive shifting, inhibition, and working memory) (Zhang et al., 2023). These cognitive processes are generally interrelated and can influence how individuals understand and interpret written texts (Bailey & Arciuli, 2022). Research regarding these elements' complex interactions is crucial to a deeper understanding of reading comprehension processes in TD and ASD.

The purpose of the current study was twofold. The first was to expand the research and employ a novel, multi-component, in-depth examination of the cognitive characteristics (ToM, EF, and CC) and narrative reading comprehension abilities (explicit and implicit understanding of narrative texts) of cognitively able children with ASD[1] compared to those of children with TD. The second was to explore the contribution and the role of the multi-component cognitive characteristics in narrative text reading comprehension abilities beyond and between groups (ASD/TD). As far as we know, this is the first study that extensively examined all three cognitive characteristics (ToM, EF, and CC) in relation to reading comprehension within a single study.

## Reading Comprehension in ASD

ASD is a neurobiological disorder significantly affecting children's social interactions, verbal and nonverbal communication, and behavior (*DSM-5*, American Psychiatric Association, 2013). In many cases, even cognitively able children with ASD (IQ > 70) present difficulties with reading comprehension (Bailey & Arciuli, 2022). When confronted with a cognitive task, such as reading comprehension, the reader allocates cognitive resources to achieve the task's goal (Stanovich, 1984). During the first and second grades, children mostly allocate these resources to mastering the decoding process. They learn the alphabetic principle, which leads to phonological decoding, which enables accurate real-word reading and automatic word reading, which ultimately enables fluent text reading and reading comprehension (Berninger et al., 2006). Then, in third grade, the demands shift from concrete tasks of explicit message comprehension to abstract tasks that include the comprehension of implicit messages (Bauminger-Zviely & Kimhi, 2013). How individuals allocate their cognitive resources when processing information can be explained by the theoretical framework provided by the Interactive Compensatory Model (ICM) (Stanovich, 1984). According to this model, readers can integrate their cognitive resources, such as EF, CC, and ToM abilities, to comprehend a text. However, significant individual and developmental differences exist in executing these processes and, hence, can result in varying reading comprehension abilities (van der Broek & Espin, 2012), including cognitively able children with ASD.

Children with ASD, including those who are cognitively able, often exhibit lower ToM false belief abilities (Kimhi et al., 2014), difficulty in EF (Demetriou et al., 2018; Kenny et al., 2022; Kimhi et al., 2014), and weaker CC (Happe & Frith, 2006) in comparison to their typically developing peers. Furthermore, they often have varied language challenges (Norbury & Nation, 2011). (These will not be presented here as they are outside the scope of the current study.) This cognitive profile, which characterizes many children with ASD, often leads to lower reading comprehension abilities compared to children with typical development (Bailey & Arciuli, 2022). It is important to note that the research has also identified a small number of cognitively able children with ASD who have no reading comprehension difficulties (Åsberg Johnels et al., 2019; Davidson, 2021; McIntyre et al., 2017; Solari et al., 2019). Thus, it seems that children with ASD have varying degrees of reading comprehension abilities rather than a simple "can or cannot comprehend" classification. Understanding the contribution and processes of EF, CC, and ToM will enhance our knowledge and understanding of reading comprehension abilities in children with ASD and typical development.

## The Contribution of Cognitive Measures (ToM, EF, and CC) to Reading Comprehension

ToM involves the ability to understand and infer the mental states, intentions, and emotions of others, including characters in a story or narrative. ToM makes a direct contribution to reading comprehension in typical development (Atkinson et al., 2017; Dore et al., 2018). ToM also uniquely predicted reading comprehension over and above word reading ability and oral language skills among cognitively able children with ASD (Ricketts et al., 2013). The relationship between reading comprehension, word recognition, oral language, and advanced ToM measures was examined for 70 cognitively able children and adolescents with ASD in comparison to 40 children with typical development (McIntyre et al., 2018). The regression analyses in that study showed that the ToM measures predicted unique variance in reading comprehension for the ASD group only and not for the TD group (when controlling for IQ, word recognition, and oral language).

There is a well-established connection between EF and reading comprehension. Executive functions are a set of cognitive processes responsible for planning, working memory, cognitive flexibility, and inhibitory control. These processes play a critical role in various aspects of reading comprehension. A meta-analysis that examined the role of EF and its sub-components in reading comprehension for children with

[1] Cognitively able children with ASD is used as an interchangeable term for children diagnosed with ASD without intellectual disability.

typical development established that EF is a crucial component of reading comprehension (Follmer, 2018). Working memory, planning, and shifting were found to have higher, more robust links to reading comprehension than inhibition, especially in the school-age years. However, it is important to note that the author stressed that one of the limitations of the meta-analysis was that many studies measured only one measure of executive function. Therefore, the weight of each sub-component still needs to be teased out. To our knowledge, only a few studies examined the contribution of EF and reading in ASD (e.g., Micai et al., 2021). A study that examined the ability of children with ASD to adapt reading strategies to different reading goals found that planning ability predicted individual differences in text reading time, showing that children with better planning ability were better at adapting their reading behavior to different reading instructions (Micai et al., 2021).

When assessing reading abilities, it is crucial to consider Central Coherence. CC refers to interpreting information to emphasize the overall context rather than focusing solely on individual details (Happe & Frith, 2006). Individuals with weaker CC tend to process each word in isolation and may struggle to connect words and sentences with the surrounding context. A study that examined the contribution of CC, EF (working memory and inhibition), and oral language in predicting reading comprehension performance in ASD and TD found that CC, EF-working memory, and oral language significantly contributed to reading comprehension in the ASD group only (Davidson, 2016).

### Narrative Texts

Narrative texts follow a linear timeline with a beginning, middle, and end. They focus on the characters' thoughts, feelings, and actions (Dickens & Meisinger, 2017). As a result, readers who struggle with ToM may have difficulty comprehending them. Children learn from a very young age to identify the story's structure, depicted by character, setting, and plot. As the readers grow older, they accumulate knowledge regarding the topics presented in the narrative texts, developing what is referred to as schemas (familiar scripts regarding events), which are based on their everyday experiences and the ability to identify central issues. These individual schemas assist the reader in comprehending the text, even if they contain new information not encompassed in their schema (Karlsson et al., 2018). Schemas represent an overall global view of story structure, and developing schemas may, therefore, be difficult for those with challenges in EF and CC.

This study's primary purpose was to understand how these cognitive characteristics (ToM, EF, and CC) impact children's success in reading comprehension of narrative texts. The current study's contribution is twofold. First, this study is unique in its multi-component framework as it offers an in-depth examination of EF, CC, and ToM abilities and, separately, the explicit and implicit reading comprehension abilities of narrative texts in cognitively able children with ASD. We hypothesized that children with ASD would exhibit lower results in tasks that examined the cognitive abilities of advanced ToM (the ability to predict what one person thinks or feels about what another person is thinking or feeling), CC, and EF (working memory, planning, inhibitory control, and cognitive flexibility) in comparison to children with TD (Kimhi et al., 2014; Happe & Frith, 2006). We focused on the third grade since that is the stage in which most reading comprehension demands implicit and explicit comprehension (Bauminger-Zviely & Kimhi, 2013). We hypothesized that third-grade children with ASD would show lower reading comprehension skills, particularly regarding implicit information, compared to children with TD. The second novel contribution of this study was to tease out how and whether ToM, EF, and CC impact reading comprehension of narrative texts beyond and between the two groups. To the best of our knowledge, no prior research has simultaneously assessed the contribution of these three explanatory elements.

## Method

### Participants

This study was part of a larger project investigating the reading comprehension abilities of cognitively able third-grade school children with ASD and TD who had intact decoding reading abilities, as shown in the second grade. Participants were recruited randomly and consisted of 56 Hebrew-speaking third graders from different public elementary schools in central Israel: 28 children with ASD (2 girls, 26 boys) and 28 children with TD (11 girls, 17 boys). A $\chi^2$ test showed a significant link between group and gender ($X^2(1) = 8.11$, $p = .004$), as only 60.7% of the participants with TD were boys, as opposed to 92.9% of the ASD group. This reflects the uneven ratio of boys to girls in ASD (Loomes et al., 2017). Inclusion criteria were verbal receptive language scores of 75 or higher according to the PPVT-III (Dunn & Dunn, 1997), a passing score on second-grade national reading tests (see below) (see sample characteristics in Table 1), and a statement from the homeroom teacher that the participant has no decoding difficulties. As seen in Table 1, the ASD group was significantly older because, in Israel, many children with ASD remain in kindergarten for an extra year. We examined if there were correlations between age and all assessed cognitive aspects. *U* tests were undertaken for all correlations found. The results showed that age was not significant for all study measures.

**Table 1** Characteristics of the intellectually able children with autism spectrum disorder (ASD) and the children with typical development (TD)

| Characteristic | ASD ($n = 28$) | | TD ($n = 28$) | | F (1, 38) | η² |
|---|---|---|---|---|---|---|
| | M | SD | M | SD | | |
| CA (in months) | 112.57 | 5.55 | 105.68 | 4.23 | 28.38*** | 0.35 |
| Verbal receptive language score[a] | 116.79 | 6.01 | 118.32 | 6.95 | 0.78 | 0.01 |
| Mother's education[b] | 3.00 | 1.09 | 3.14 | 0.89 | 0.29 | 0.01 |

[a]Based on the PPVT-III (Dunn & Dunn, 1997)

[b]Calculated on a 6-point scale: 1 = 8th grade or less; 2 = some high school; 3 = high school with a diploma; 4 = some college; 5 = college degree (e.g., B.A.); 6 = graduate degree (e.g., master's or above)

***$p < .001$

Participants in the ASD group had received an ASD diagnosis according to *DSM-IV* (American Psychiatric Association, 2000) or *DSM-5* criteria (American Psychiatric Association, 2013) based on two previous independent professional evaluations (psychiatrist, neurologist, and/or clinical psychologist) in line with Israeli Ministry of Health and Ministry of Education guidelines. These children had no other diagnoses of disabilities. Most participants with ASD learned in regular education settings ($N = 23$, 82%), and the others ($N = 5$, 18%) learned at least five weekly hours of language class in regular education settings as part of their inclusion program from the ASD classroom. Participants with TD had no diagnosis of disabilities, according to their homeroom teacher's report. They were matched to the ASD group for verbal receptive language according to the PPVT-III (Dunn & Dunn, 1997) and the mother's level of education (see non-significant group differences in Table 1). Groups were matched on grade level, not age because the study focused on learning materials relevant to the third grade.

## Measures

### Screening Measures

Two screening measures were implemented, one for verbal and one for basic reading abilities.

#### Verbal Screening

The PPVT-III (Dunn & Dunn, 1997) was used. It is an untimed verbal test often used to assess the receptive language abilities of individuals with ASD (e.g., Kimhi et al., 2014). It can provide a quick estimate of verbal ability and verbal mental age for children at a wide range of ages from 2.6 years to adulthood. The participant receives a series of four pictures and is asked to point to or say the number of the picture that the given word describes. The PPVT-III has shown a high correlation with verbal IQ. High reliabilities (0.90 and above) were reported in Dunn and Dunn (1997) for the normed sample, with a median reliability of 0.95 (Hayward et al., 2008).

#### Basic Reading Ability Screening: GEMS

The GEMS (Growth and Effectiveness Measures for Schools) was used. It is a student achievement test (in Hebrew – the Meitzav, a Hebrew acronym for "School Growth and Efficiency Measures") developed by RAMA (the National Authority for Measurement and Evaluation in Education[2]). The native language test (including reading comprehension) corresponds with the Ministry of Education's national second-grade Hebrew curriculum (Beller, 2013), is the equivalent of exams such as the TIMSS and the PISA (Harus & Davidovich, 2019), and confirms or denies intact decoding abilities. All the children recommended for this study had passed the national test in the previous school year. The teachers affirmed that the participants had good decoding abilities.

### Study Measures

Four measures were administered, one for ToM, one for CC, one for EF, that included four sub-tests (working memory, planning, inhibitory control, and cognitive flexibility) and one for reading comprehension.

#### Theory of Mind

*Faux Pas test* (Baron-Cohen et al., 1999). This ToM test assesses the advanced ToM abilities of children and adolescents by detecting embarrassing "faux pas" errors in stories. Five different stories were read aloud to the child. In each story, an embarrassing mistake was described in the last sentence or up to two sentences before the last to ensure that the child would not cite the last sentence heard as a response or

[2] For more information about RAMA, see: http://cms.education.gov.il/educationcms/units/rama.

use a fixed strategy to identify the response. Five questions were asked: faux pas, identification, comprehension, false belief, and a justification question. For example, a story and the five questions were as follows:

The whole class participated in a story-writing contest. Anat really wanted to win. The teacher announced the competition results when Anat was absent from school. The winner of the competition was Dana. The next day, Dana saw Anat and said, “I am sorry about your story.” “What do you mean?” Anat asked. “Oh, nothing,” Dana said. After hearing the story, the following questions were asked: (a) Did someone in the story say something that should not have been said (faux pas)? (b) What was said that should not have been said (identification); (c) Who won the competition? (comprehension); (d) Did Dana know that Anat had not heard the results of the competition (false belief); (e) How do you know? (justification). A score of 0–1 was given for questions 1 to 4. A score of 0–2 was given for question 5 (a score of 2 was given if the answer included phrases regarding feelings or thoughts). The total score for the ToM task ranged from 0 to 25. This test was administered to children and adolescents with ASD (Baron-Cohen et al., 1999).

### Central Coherence

Central coherence was assessed using the Children’s Embedded Figures Test (CEFT; Witkin, 1971). This visuospatial assessment includes 25 trials in which the children are asked to find a simple shape hidden within a more complex geometric figure within 30 s. Each trial was scored between 0 and 1 point. One point was given if the child found the shape or corrected the given response within the time framework. The total score for the task ranged from 0 to 25. The average score for ages 7–8 is 10.6, and the standard deviation is 5.6. The average score for ages 9–10 is 16.4, and the standard deviation is 5.5. Reliability ranges from 83. up to 90. and valid from 70. to 86. for older children. It was administered to children, adolescents, and adults with ASD (Dillen et al., 2015; Jolliffe & Baron-Cohen, 1999; Schlooz & Hulstijn, 2014).

### Executive Functions

Executive Functions were assessed via four sub-tests.

### Working Memory

The WISC-III (Wechsler, 1995) is an individually administered intelligence test, including 13 subtests ($M = 10$; $SD = 3$), for children between the ages of 6 and 16 that measures different intellectual abilities. The Digit Span (WISC- III; Wechsler, 1995) was used to assess the children’s working memory. In this test, digit sequences are read out aloud to the child, beginning with a length of two digits. Each participant was administered the forward and backward Digit Span. The backward digit span testing followed the forward span testing. Testing ceases when the child fails to repeat the numbers accurately or when the maximal list length is reached (7 digits maximum). Each trial was given a raw score between 0 and 1 point, and each correct trial was scored with 1 point. The raw score was translated into standard scores that ranged from 0 to 19. This test was administered to children with ASD (Gabig, 2008).

### Planning

Children’s’ planning ability was assessed using the Tower of London (ToL) procedure developed by Shallice (1982). Children were presented with a prearranged sequence of three differently colored balls (blue, green, and red) on three pegs of different lengths. They were asked to move the balls to match a goal state shown on a parallel board of pegs in a specified amount of moves and following pre-specified rules (moving more than one ball concurrently, holding the ball, or putting the ball on the table). The tasks’ complexity differed in terms of the number of moves required for solution (ranging from 2 to 5 moves) and in the moves’ complexity (a direct move in which the child just moved the balls to the correct peg or indirect moves in which the child first must move a ball off the peg to place the correct ball on that specific peg). The ToL procedure consisted of four hierarchical levels. The first level entailed the first two tasks, where the child was asked to perform each in two moves. In the second level, the child was asked to perform the following two tasks in three moves each, in which indirect moves were required. The third level entailed the next four tasks, where the child was asked to perform each task in four indirect moves. The fourth level comprised the last four tasks, in which the child was asked to perform each in five indirect moves. The children were given two attempts to solve each of the 12 tasks. After three consecutively failed tasks, the ToL procedure was halted. Each task was scored between 0 and 2 points: 2 = solved on the first attempt; 1 = solved on the second attempt; 0 = failed to solve the task. A score was given for each of the four levels according to the number of correct tasks in each level. The general planning ability scores were computed by summing the correct tasks out of the 12 given. Thus, the total score for the ToL task ranged from 0 to 24. This test was administered to children with ASD (Joseph & Tager-Flusberg, 2004).

### Cognitive Inhibition and Cognitive Flexibility

(set shifting) were assessed with the Delis–Kaplan Executive Function System (D-KEFS; Delis et al., 2001). The D-KEF has internal validity and reliability (Delis et al., 2001; Latzman et al., 2010).

**Inhibitory Control** *The color-Word Interference Test* is a modified version of the inhibition task developed by Stroop (1935). It involves two conditions requiring inhibition, with a primary score of time-to-completion: Inhibition and Inhibition/ Switching.

In the Inhibition trial, the children are shown written names of colors written in different ink colors (for example, the word blue is written in green). They are required to name the color of the ink as quickly as possible while inhibiting the initial tendency to read the word (for example, say green according to the color of the ink and not read the word blue).

The Inhibition/Switching trial requires children to read the ink color or the word written, depending on whether the word is displayed inside a box. The given time frame for each sub-test is 180 s. The score consists of the time to complete each sub-test, the number of incorrect responses that were corrected, and the number of incorrect responses that were not corrected. This test was administered to children, adolescents, and adults with ASD (Corbett et al., 2009).

**Cognitive Flexibility** The Delis-Kaplan Executive Functions System (Delis et al., 2001) sorting subtest has two testing conditions: free sorting to assess the ability to sort spontaneously and sort recognition to identify sort strategies utilized by the examiner. In the free sorting condition, the child receives two sets of six shuffled cards that display both perceptual stimuli and printed words. Participants sort the cards based on verbal and/or visual-spatial characteristics without being told how to sort the cards, thus shifting from previous sorting rules to new rules to attain more accurate sets. The child is asked to sort the cards into two groups, three cards per group, according to as many different sorting rules as possible, and then to describe the concepts or strategies used to generate each sort. In the sort recognition condition, the examiner sorted the same two sets of cards separately, each sorted into two groups with three cards per group. After each sort made by the examiner, the child was asked to identify the correct categorization strategy, rule, or concept used to generate the sort. Each trial was scored between 0 and 2 points: 2 = complete recognition of the category; 1 = partial recognition of the category; 0 = mistaken response or no response. This test was administered to children with ASD (Bauminger, 2007).

### Reading Comprehension: GEMS

The reading comprehension GEMS test (RAMA - the National Authority for Measurement and Evaluation) was comprised of a 287-word narrative text named “Dror and the Terrible Creature” (see Basic Reading Ability Screening section for details regarding the GEMS assessment). The text assessed the children’s explicit and implicit narrative reading comprehension abilities. The story describes a chance encounter between the boy Eran and the giant that pretends to be frightening and ends with a friendship that develops between the two. The dimensions of comprehension examined included understanding the explicit meaning (e.g., locating and identifying information) and implicit meaning of the text (e.g., interpretation, understanding of cause and effect, understanding relationships between the characters, and inference). The text was accompanied by seven questions taken from a wide array of questions in the national pool, measuring readers’ comprehension: 3 open-ended questions tapping explicit knowledge and 4 close-ended ones tapping implicit knowledge. The questions were organized in a logical order, with a clear flow from one to the other, and were both open and close-ended to maintain consistency. The questions were assessed by an experienced speech-language pathologist who examined the question consistency and confirmed that all the questions aligned with the text’s reading level. A score of 0 was given for an incorrect answer, and a score of 1 for a correct answer. The total score for the reading comprehension task ranged from 0 to 7. See Table 2 for the analysis of the questions and guidelines for scoring. The national average for the second-grade test is 77 ($SD = 17$) on a scale from 0 to 100 (Beller, 2013). All children in Israel, including those with disabilities, complete the national GEMS exams (Harus & Davidovich, 2019).

## Procedure

After obtaining permission for the study from the university’s Ethics Committee and the Chief Scientist’s Office in the Ministry of Education, we implemented a short pilot test on a small group of children – two with TD and two with ASD – to ensure the instructions and questions were clear. We then approached the schools’ principals and the teachers, who assisted in identifying the third-grade children who had passed the GEMS test the previous year. Letters explaining the study’s aims were sent to the parents, who signed the informed consent form. The children participated in two counter-balanced meetings held individually in a quiet room. All the measures were administered by the researcher (second author and ASD specialist and a research assistant (graduate student and ASD specialist). There was no set time limit, although each meeting was planned for 50 min, as per the Chief Scientist’s Office instructions. The researchers did not provide positive or negative feedback on the tasks.

**Table 2** Analysis of the narrative text questions

| Question | Score | Answer analysis | Question type |
|---|---|---|---|
| 1 | 0,1 | Complete the sentence: Dror wanted to pick strawberries to____<br>*Analysis of answers*:<br>1 = Completion indicating Dror's wish to bring his grandmother flowers / surprise his grandmother, such as:<br>… make Grandma happy.<br>…give grandmother a bouquet of flowers.<br>0 = any other answer, such as:<br>I am a terrible creature | Open question<br>Explicit |
| 2 | 0,1 | Dror asked the creature: "Who are you?" The creature shouted: "I am a terrible creature!" What did Dror answer?<br>*Analysis of answers*:<br>1 = An answer that includes Dror's answer to the creature, in whole or in part, such as:<br>"Nice to meet you," or "My name is Dror," or "Nice to meet you, my name is Dror".<br>0 = any other answer | Open question<br>Explicit |
| 3 | 0,1 | In the story, the creature shouts, "Look what scary teeth I have." What did Dror do in response to this?<br>*Analysis of answers*:<br>1 = An answer relating to Dror's statements or actions in response to the creature's shout, such as:<br>Dror said to the creature, "Great".<br>Dror opened his mouth and showed his teeth.<br>Dror showed the creature his teeth and told him that four teeth had fallen out.<br>Dror said that four teeth had fallen out and that new ones would grow in their place.<br>Dror told the creature that his grandmother had told him that new teeth would grow in their place.<br>Note: A relevant quote preceded by a verb describing Dror saying something, such as Dror said, will be considered a correct answer.<br>0 = any other answer, such as:<br>Dror is happy. | Open question<br>Explicit |
| 4 | 0,1 | The story describes the creature's face. It says that it reddened, and he breathed and blew like a train.<br>From this sentence, one can understand that:<br>*Analysis of answers*:<br>1= (d) The creature is angry.<br>0 = any other answer | Multiple choice<br>Implicit |
| 5 | 0,1 | Why did Dror ask the creature if he could reach the edge of the mountain with his hand?<br>*Analysis of answers*:<br>1= (a) Because he wanted to use the creature's long hand.<br>0 = any other answer | Multiple choice<br>Implicit |
| 6 | 0,1 | Why did the creature say it was the most miserable creature in the world?<br>*Analysis of answers*:<br>1= (c) Because he could not scare Dror.<br>0 = any other answer | Multiple choice<br>Implicit |
| 7 | 0,1 | The story says that the creature *handed* Dror some red strawberries. What does the word "*handed*" mean in this sentence?<br>*Analysis of answers*:<br>1= (a) Gave<br>0 = any other answer | Multiple choice<br>Implicit |

Translated from Hebrew

## Results

### Group Differences Regarding Cognitive Characteristics

One-way ANOVAs were computed to examine group differences (ASD/TD) regarding cognitive characteristics (ToM, CC, and EF). The ANOVAs revealed a significant group difference in ToM abilities both in false belief $F(1,54) = 6.41$, $p = .01$, $\eta^2 = 0.11$ and justification $F(1,54) = 32.29$, $p < .001$, $\eta^2 = 0.37$, showing that the ASD group's false belief and justification abilities were significantly lower than those of their peers in the TD group. Significant group differences were also found in the following EF indices: working memory $F(1,54) = 4.24$, $p = .05$, $\eta^2 = 0.07$, cognitive flexibility – free sorting $F(1,54) = 5.33$, $p = .03$, $\eta^2 = 0.09$, and mistakes in inhibition and cognitive flexibility $F(1,54) = 5.16$, $p = .03$, $\eta^2 = 0.09$, showing that these abilities were significantly lower for the children in the ASD group in comparison to those in the TD group. No significant differences were found between the groups for EF planning or CC (see Table 3. for means, standard deviations, and F values).

**Table 3.** Means, standard deviations, and F values of cognitive abilities according to group (ASD/TD)

| Cognitive measures | | TD | | ASD | | F (1, 52) | η² |
|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | | |
| ToM 2nd order | False belief | 4.61 | 0.69 | 3.82 | 1.49 | 6.41* | 0.11 |
| | Justification | 7.96 | 2.24 | 4.07 | 2.85 | 32.29*** | 0.37 |
| Central Coherence | | 17.29 | 3.41 | 18.86 | 3.42 | 2.97 | 0.05 |
| EF | Working memory | 14.46 | 3.41 | 12.71 | 2.94 | 4.24* | 0.07 |
| | Planning (general) | 18.46 | 3.20 | 17.29 | 3.74 | 1.60 | 0.03 |
| | Inhibition - time | 12.71 | 2.94 | 12.82 | 2.75 | 0.02 | 0.00 |
| | Inhibition - mistakes | 9.96 | 3.76 | 8.57 | 3.61 | 2.00 | 0.04 |
| | Inhibition + cognitive flexibility - time | 10.86 | 2.35 | 11.93 | 3.62 | 1.72 | 0.03 |
| | Inhibition + cognitive flexibility - mistakes | 10.39 | 3.00 | 8.14 | 4.30 | 5.16* | 0.09 |
| | Cognitive flexibility - time | 8.61 | 2.69 | 9.36 | 3.79 | 0.73 | 0.01 |
| | Cognitive flexibility free sorting | 11.00 | 2.49 | 9.14 | 3.45 | 5.33* | 0.09 |
| | Cognitive flexibility sort recognition | 7.14 | 3.44 | 7.21 | 4.37 | 0.01 | 0.00 |

*$p < .05$

**Table 4** Means, standard deviations, and F values of reading comprehension abilities according to group (ASD/TD)

| Reading comprehension measures | TD | | ASD | | F (1, 52) | η² |
|---|---|---|---|---|---|---|
| | M | SD | M | SD | | |
| Explicit | 2.64 | 0.62 | 2.54 | 0.69 | 0.37 | 0.01 |
| Implicit | 2.93 | 0.93 | 2.71 | 1.05 | 0.63 | 0.01 |
| General score | 5.57 | 1.07 | 5.25 | 1.46 | 0.89 | 0.02 |

## Group Differences Regarding Reading Comprehension

One-way ANOVAs were computed to examine group differences (ASD/TD) regarding reading comprehension measures (explicit, implicit, and general score). As seen in Table 4, no statistically significant differences were found between the groups regarding reading comprehension (see Table 4 for means, standard deviations, and F values).

## Effect of Cognitive Characteristics on Reading Comprehension

To understand the contribution of group (ASD/TD) and cognitive characteristics (ToM, CC, and EF) to the understanding of reading comprehension abilities (explicit, implicit, and general score), a series of multiple regressions were performed. A regression model was allocated for each cognitive characteristic before examining the interaction between the cognitive characteristic and the group type (ASD/TD). The dependent measures were the reading comprehension measures (explicit, implicit, and general score). The group, the cognitive characteristics, and the interaction between them were the explaining independent variables.

The analysis was performed in two stages. The reading comprehension measures were analyzed in the first stage regarding the main effect (group beyond cognitive characteristics and cognitive characteristics beyond group). In the second stage, the effect of the interactions was analyzed, as was found according to the main effect.

## First Stage: Main Effect

As can be seen in Table 5, a positive main effect was found for ToM false belief and all three reading comprehension measures (explicit, implicit, and general score). A positive main effect was also found for ToM justification and explicit and general comprehension measures. A positive main effect was found for EF planning (in the third level), inhibition (general mistakes), cognitive flexibility (free sorting), and implicit and general comprehension measures.

## Second Stage: Interaction Effects

As can be seen in Table 5, interaction effects between cognitive characteristics and group were found for two cognitive characteristics – EF planning and central coherence. The meaning of these interaction effects is that the relation between the cognitive characteristic and the reading comprehension ability is different for each group. We used the Process procedure (Hayes & Andrew, 2013) to understand the source of the interaction effects. We plotted the EF planning

**Table 5** Regression Values Explaining Reading Comprehension Measures According to Group, Cognitive Characteristics, and Interaction

| Cognitive measures | | Explicitβ | Implicitβ | General scoreβ |
|---|---|---|---|---|
| ToM | Group | 0.01 | −0.02 | −0.01 |
| | False belief | 0.45** | 0.43** | 0.57*** |
| | False belief X Group | −0.21 | 0.52 | 0.30 |
| | Group | 0.24 | −0.02 | −0.001 |
| | Justification | 0.33* | 0.28 | 0.39** |
| | Justification X Group | −0.13 | 0.07 | −0.01 |
| CC | Group | −0.10 | −0.15 | −0.17 |
| | CC | 0.07 | 0.18 | 0.18 |
| | CC X Group | 0.07 | 0.48* | 0.41* |
| EF | Group | −0.09 | −0.10 | −0.13 |
| | Working memory | −0.02 | 0.02 | 0.01 |
| | Working memory X Group | −0.24 | 0.03 | −0.10 |
| | Group | −0.06 | −0.07 | −0.09 |
| | Planning (general) | 0.13 | 0.22 | 0.24 |
| | Planning (general) X Group | 0.02 | 0.37 | 0.31 |
| | Group | −0.10 | −0.11 | −0.14 |
| | Planning (level 1) | 0.09 | 0.02 | 0.07 |
| | Planning (level 1) X Group | 0.35* | 0.43** | 0.52*** |
| | Group | −0.11 | −0.10 | −0.13 |
| | Planning (level 2) | −0.12 | 0.05 | −0.02 |
| | Planning (level 2) X Group | 0.06 | 0.74** | 0.62* |
| | Group | −0.07 | −0.07 | −0.09 |
| | Planning (level 3) | 0.17 | 0.32* | 0.34* |
| | Planning (level 3) X Group | 0.10 | 0.30 | 0.29 |
| | Group | −0.07 | −0.08 | −0.10 |
| | Planning (level 4) | 0.13 | 0.21 | 0.23 |
| | Planning (level 4) X Group | −0.03 | 0.26 | 0.20 |
| | Group | −0.08 | −0.11 | −0.13 |
| | Inhibition - time | −0.14 | 0.07 | −0.02 |
| | Inhibition - time X Group | 0.01 | −0.01 | −0.004 |
| | Group | −0.07 | −0.04 | −0.06 |
| | Inhibition - mistakes | 0.09 | 0.37** | 0.34* |
| | Inhibition - mistakes X Group | 0.24 | −0.02 | 0.10 |
| | Group | −0.06 | −0.11 | −0.12 |
| | Inhibition and cognitive flexibility - time | −0.11 | −0.01 | −0.06 |
| | Inhibition and cognitive flexibility - time X Group | −0.15 | −0.26 | −0.28 |
| | Group | −0.05 | −0.05 | −0.06 |
| | Inhibition and cognitive flexibility - mistakes | 0.12 | 0.21 | 0.22 |
| | Inhibition and cognitive flexibility - mistakes X Group | 0.06 | −0.09 | −0.04 |
| | Group | −0.07 | −0.10 | −0.11 |
| | Cognitive flexibility | −0.09 | −0.11 | −0.13 |
| | Cognitive flexibility X Group | −0.11 | −0.26 | −0.26 |
| | Group | −0.001 | −0.004 | −0.004 |
| | Cognitive flexibility free sorting | 0.27~ | 0.34* | 0.41** |
| | Cognitive flexibility free sorting X Group | 0.05 | 0.32 | 0.28 |
| | Group | −0.08 | −0.11 | −0.13 |
| | Cognitive flexibility sort recognition | 0.05 | 0.23 | 0.21 |
| | Cognitive flexibility sort recognition X Group | 0.17 | 0.11 | 0.17 |

~$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$

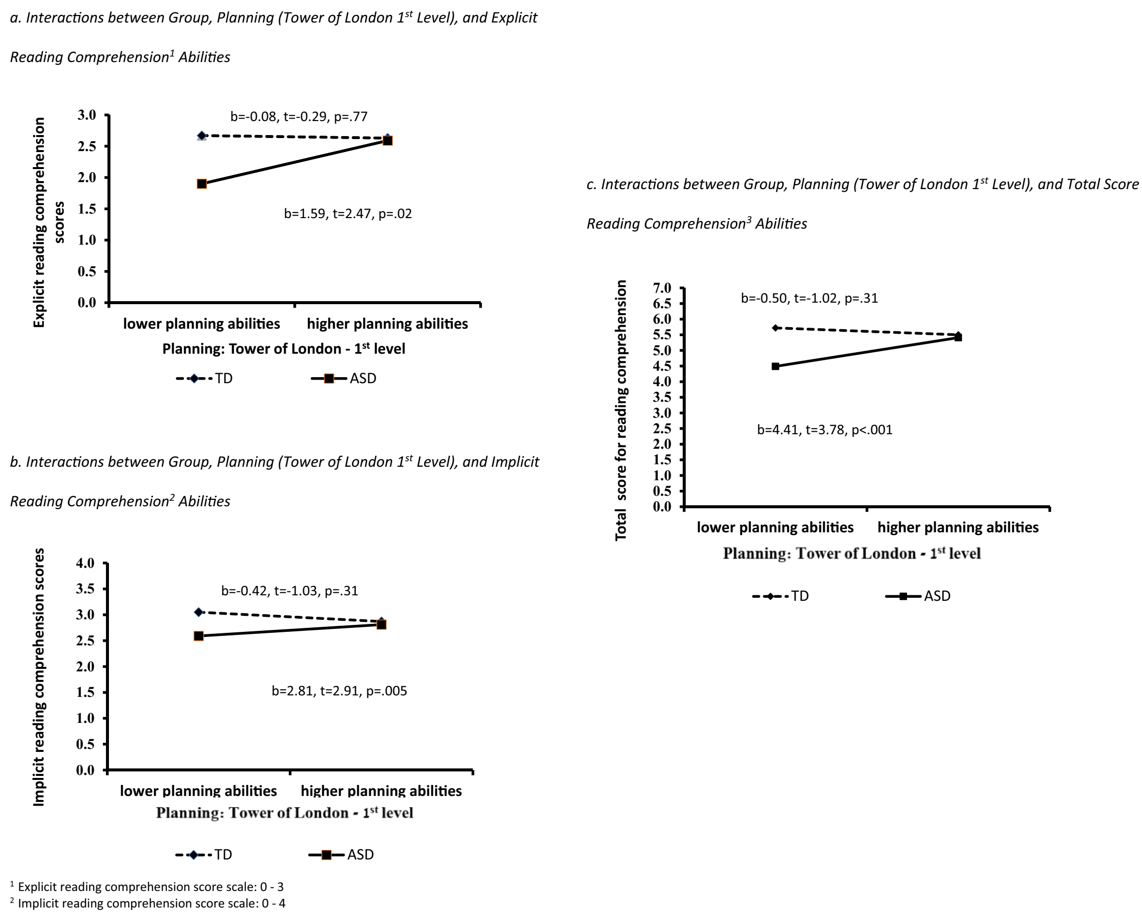



**Fig. 1** **a** Interactions between Group, Planning (Tower of London 1st Level), and Explicit Reading Comprehension Abilities. Explicit reading comprehension score scale: 0 - 3. **b** Interactions between Group, Planning (Tower of London 1st Level), and Implicit Reading Comprehension Abilities. Implicit reading comprehension score scale: 0 - 4. **c** Interactions between Group, Planning (Tower of London 1st Level), and Total Score Reading Comprehension Abilities. Total reading comprehension score scale: 0 - 7

scores and CC scores for high and low values of each cognitive characteristic. The two-way interactions are depicted in Figs. 1, 2 and 3, showing the source of the interactions between the cognitive characteristic and the reading comprehension measures for each group.

The interaction between group and EF planning (level 1) was as follows: for explicit reading comprehension ($\beta = 0.35$, $p = .02$), for implicit reading comprehension ($\beta = 0.43$, $p = .003$), and for general comprehension score ($\beta = 0.52$, $p < .001$). As is seen in Fig. 1a–c, higher planning abilities (level 1) are more beneficial for understanding explicit, implicit, and general reading comprehension score information for the ASD group only and not for those in the TD group.

The interaction between group and EF planning (level 2) was as follows: for implicit reading comprehension ($\beta = 0.74$, $p = .003$) and general comprehension score ($\beta = 0.62$, $p = .01$). As is seen in Fig. 2a, b, higher planning abilities (level 2) are more beneficial for implicit reading and general comprehension understanding for the ASD group, as opposed to those with TD.

The interaction between group and CC was as follows: for implicit reading comprehension ($\beta = 0.48$, $p = .01$) and general comprehension score ($\beta = 0.41$, $p = .03$). As is seen in Fig. 3a, b, higher CC abilities are more beneficial for implicit reading comprehension understanding for the ASD group only, and not for those in the TD group.

## Discussion

The current study expanded the research regarding the cognitive characteristics (ToM, EF, and CC) and reading comprehension (explicit and implicit understanding of narrative texts) abilities of cognitively able children with ASD by implementing a multi-component examination of the cognitive characteristics. The main findings showed that intellectually able children with ASD demonstrated difficulties

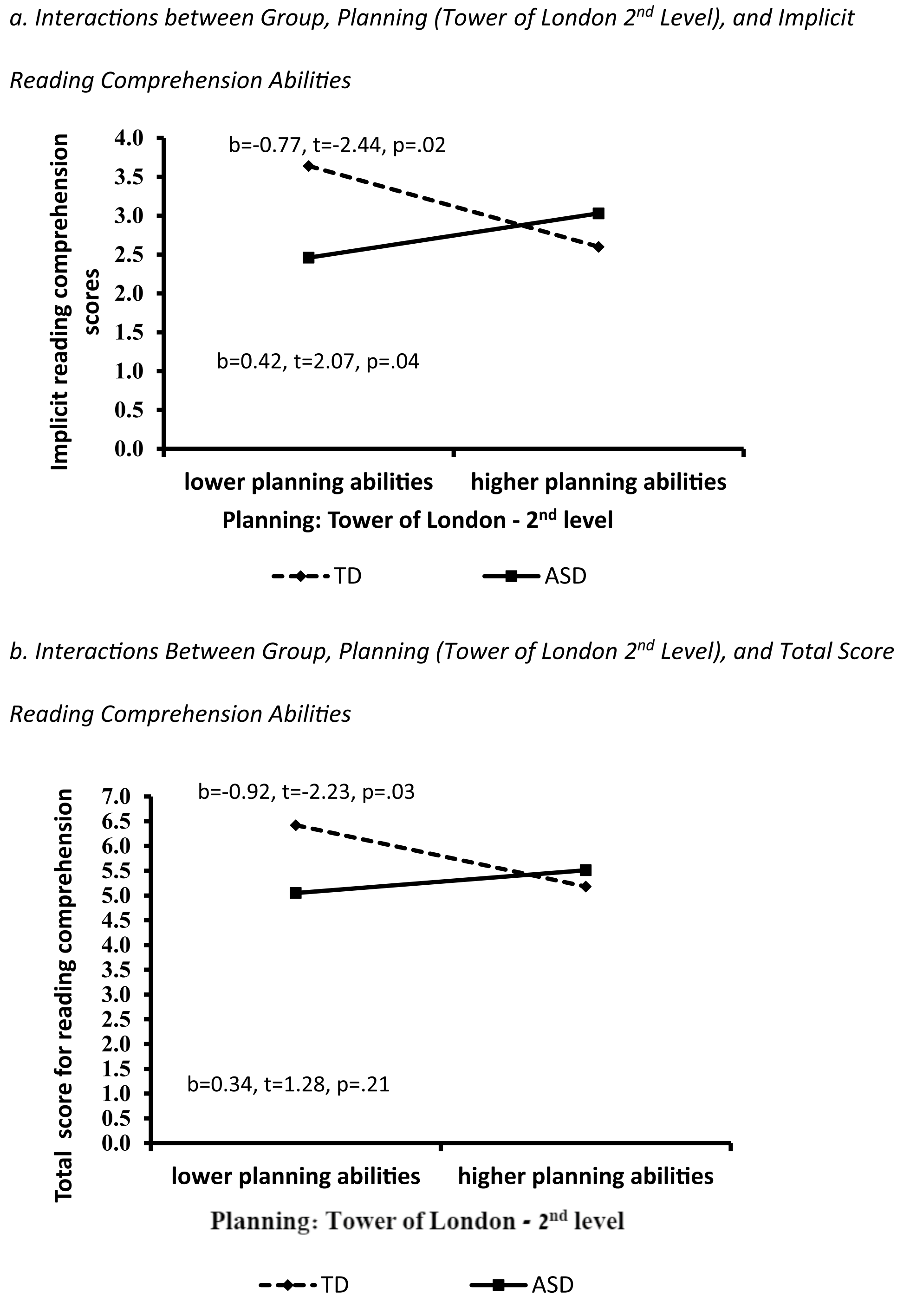



**Fig. 2** **a** Interactions between Group, Planning (Tower of London 2nd Level), and Implicit Reading Comprehension Abilities. **b** Interactions Between Group, Planning (Tower of London 2nd Level), and Total Score Reading Comprehension Abilities

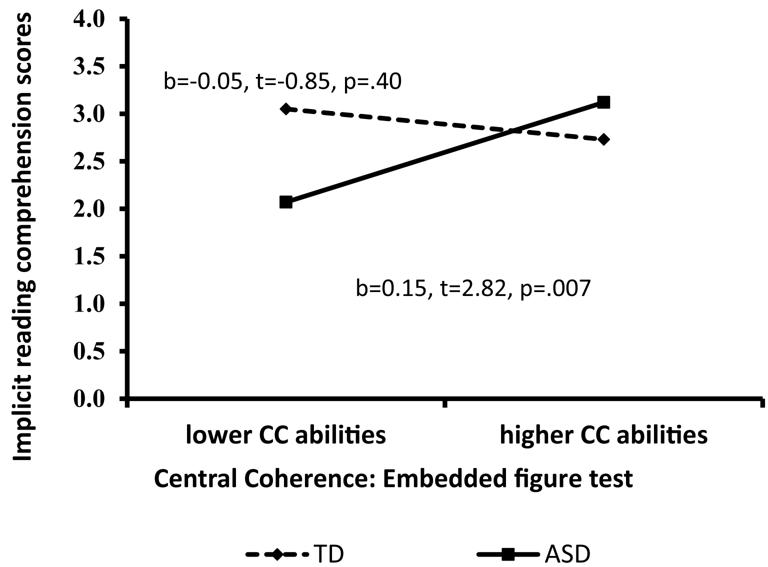
in two out of the three cognitive domains (ToM and some EF components) relative to their matched, typically developing peers. No differences were found for CC. Furthermore, no differences were found in the reading comprehension abilities of narrative texts. We also explored the contribution of the cognitive characteristics to narrative text reading comprehension abilities beyond and between groups (ASD/TD). Positive main effects were found for ToM, EF measures (planning – 3rd level, inhibition, and cognitive flexibility), and reading comprehension abilities in both groups. Interactions revealed positive main effects for EF planning (1st and 2nd level), CC, and reading comprehension for the ASD group only.

## Group Differences and Similarities

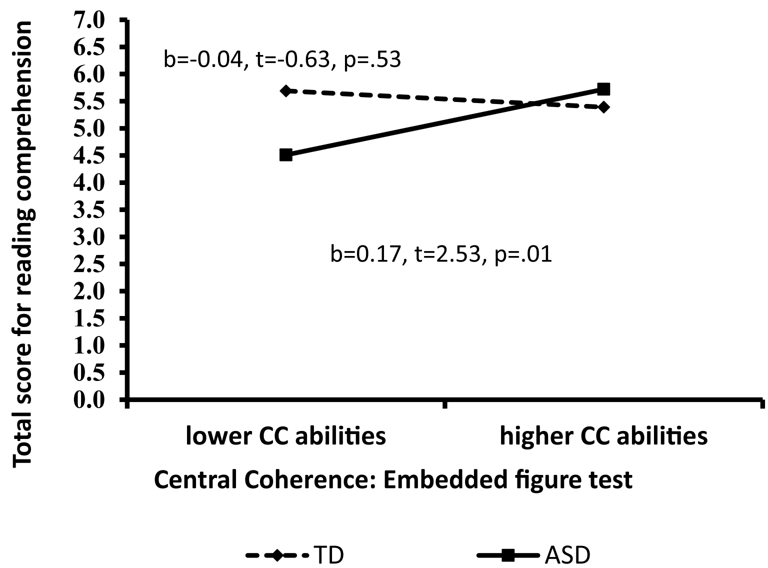
In partial support of our first hypothesis, the intellectually able children with ASD revealed significant differences

**Fig. 3** **a** Interactions between Group, CC, and Implicit Reading Comprehension Abilities. **b** Interactions between Group, CC, and Total Score Reading Comprehension Abilities

*a. Interactions between Group, CC, and Implicit Reading Comprehension Abilities*




*b. Interactions between Group, CC, and Total Score Reading Comprehension Abilities*




from TD children in advanced ToM abilities (both in false belief and justification) and EF (but only in working memory, cognitive flexibility–free sorting, and mistakes in inhibition and cognitive flexibility). Contrary to our hypothesis, no differences were found between groups in EF planning or CC. These findings indicate and support the theory that ASD places children at risk for reduced ToM and most EF capabilities.

Success on ToM false belief tasks requires the ability to consider two representations simultaneously and to go back and forth between the two. By the age of seven, children with TD understand that a character will act upon what they think that another character thinks, which can be contrary to reality (Kimhi, 2014). An even more complex aspect of ToM understanding is the pragmatic understanding of language. Most pragmatic characteristics involve sensitivity to the speaker's and the listener's mental states. A common example is one's recognition when someone says the wrong thing (faux pas) (Baron-Cohen et al., 1999), as seen in the current study. Individuals with ASD display difficulty with advanced ToM tasks relative to matched comparison groups, even when performing well on first-order ToM tasks (Rosello et al., 2020).

Our findings echo most previous findings regarding the differences in EF, showing that individuals with ASD (including children, young people, and adults) have difficulties in higher-order EF processes. In a comprehensive meta-analysis, the EF subdomains (including cognitive flexibility, inhibition, planning, and working memory) were not differentially impaired, and no significant differences in effect sizes were observed (Demetriou et al., 2018). According to the authors, this finding reflects general difficulties in EF within ASD and not a fractionated impairment, as found in the current study. A later study that examined comprehensive EF difficulties within adolescents aged 11–19 years found that the participants with ASD showed general difficulties in all EF aspects. No group differences were found for the subcomponents of EF (Kenny et al., 2022). These findings, too, challenge the theory that individuals with ASD mostly show impairment in cognitive flexibility and planning (e.g., Hill, 2004).

No differences were found in CC, although better local processing typifies most individuals with ASD. This inconsistency may be due to the visuospatial embedded figures task employed in the current study rather than a linguistic task (Dillen et al., 2015). A study that examined the cognitive profile of cognitively able children with ASD between the ages of 7–11 years found that the children exhibited proficient local processing with lower global processing on the linguistic tasks but not on the visuospatial task when compared to children with TD (Vanegas et al., 2015). Furthermore, a recent study that examined the global and local verbal central coherence abilities of cognitively able adults with ASD found that the accuracy of their responses was similar to that of their typically developing peers. However, their response time was slower (Walęcka et al., 2022). Together with the current study's findings, these findings strengthen the concept that individuals with ASD can process information globally, especially when the task instructions specifically demand global processing (Happe & Frith, 2006).

Contrary to our second hypothesis, no group differences were found in the reading comprehension of narrative texts – neither in the explicit nor the implicit messages. Although this is in contrast with the many studies that have shown that children with ASD who are not affected by intellectual disabilities have difficulty in developing grade-appropriate reading comprehension abilities (e.g., McIntyre et al., 2017; McIntyre et al., 2018), it does coincide with recent research regarding reading comprehension in ASD, demonstrating a range of abilities, including a small group with no reading comprehension difficulties and who are considered typical readers (Åsberg Johnels et al., 2019; Davidson, 2021; McIntyre et al., 2017; Solari et al., 2019). The participants with ASD included in this study had passed the national second-grade reading test as a screening measure and are, therefore, in the upper range of the ASD population in their reading comprehension abilities. Therefore, it is vital to understand their unique cognitive profile and its contribution to reading comprehension, as described in the following section.

### The Contribution of Cognitive Measures (ToM, EF, and CC) to Reading Comprehension

The current findings demonstrated a clear contribution of ToM and EF to reading comprehension abilities of narrative texts in both groups, showing that ToM and EF (various planning, inhibition, and cognitive shifting measures) abilities contribute to better reading comprehension abilities. As previously stated, ToM is closely linked to reading comprehension of narrative texts (Dore et al., 2018), as higher ToM abilities advance the understanding and inferencing the characters' mental states in narrative texts. A recent study that examined the role of advanced ToM regarding reading comprehension abilities in young Chinese children with ASD (ages 7–9) found that advanced ToM skills such as perspective-taking predicted the children's reading comprehension abilities (Lee et al., 2023). EF abilities such as working memory, cognitive shifting, and inhibitory control show moderate positive relations with decoding and comprehension in TD (Follmer, 2018). However, in ASD, this relation needs further examination and more evidence.

We found differences in the contribution of cognitive capabilities and reading comprehension between the two groups - we found interaction effects between the group and EF sub-component of planning and CC. These interactions showed a difference between the groups, demonstrating that EF planning and CC contributed to reading comprehension only in the ASD group. Our findings regarding planning abilities, as found by the Tower of London, echo Micai and colleagues' findings (2021). They, too, examined which cognitive functions predicted the reading abilities of children with ASD and TD. The children's planning abilities were assessed with the Tower of Hanoi, similar to the Tower of London. They found that children with good planning skills could adjust their reading habits (Micai et al., 2021), which positively impacts their reading comprehension skills.

A study that examined the relative contribution of CC, oral language, and EF (working memory and inhibition) in predicting reading comprehension performance in ASD and TD found that oral language, EF-working memory, and CC significantly contributed to reading comprehension in the ASD group only (Davidson, 2016). Interestingly, their implemented CC measure was also visuospatial rather than linguistic, as in our study. Yet, CC did not contribute to reading comprehension in the ASD group after accounting for word reading abilities in the Davidson study (2016). Therefore, further studies should tease out the contribution of both visuospatial and linguistic CC to reading comprehension in ASD, especially since the ability to focus on details can indeed benefit the academic abilities of children with ASD. The findings contribute to the ongoing debate on what enhances reading comprehension in children with ASD. The evidence suggests that a single-deficit model cannot fully account for the strengths and weaknesses in their reading comprehension abilities, but rather, an interrelated model is at work. Further research is needed to understand the abilities that are shared or interrelated or act as mediators or moderators.

In sum, the current study's findings suggest that children with ASD may have relied on different cognitive abilities and processes when reading compared to those with TD. The findings also underscore the importance of ToM and EF for all children, whether TD or ASD and EF planning and CC for ASD specifically. Indeed, especially as there were no significant group differences in the children's narrative reading comprehension abilities, these may indicate a cognitive compensatory mechanism. One could speculate that the children with ASD and impaired ToM abilities would have more difficulties in following the story as it unfolds, as they would be missing the forward-looking benefits of understanding what is in the characters' minds. However, they could still rely on their intact CC capabilities to integrate the factual elements that they absorbed while reading the text and thus reach a similar level of comprehension. They would, however, need to wait until the end of the story to have all the information available for integration, which could lead to an overall slower response time. Although these results should be addressed cautiously, they may have clinical implications that may improve the quality of life (QoL) for children with ASD, especially regarding academic aspects. Practitioners should be encouraged to develop cognitive tasks that increase all children's ToM and EF abilities in general and the EF planning and CC abilities of children with ASD, as these could enhance their reading comprehension abilities.

The current study's future implications suggest that interventions aimed at improving ToM, EF, and CC abilities may benefit children with ASD who struggle with the reading comprehension of narrative texts. This aligns with a recent meta-analysis examining reading comprehension instruction for children with ASD (Zhang et al., 2023). The authors of that meta-analysis surmised that it is important to identify which interventions are most appropriate for which subgroups of children with ASD by referring to ToM, EF, and CC measures. Thus, children with lower ToM abilities could benefit from interventions employing character maps (Zhang et al., 2023). Furthermore, a recent intervention study for young children with ASD showed how an intervention that included EF abilities (such as monitoring and organizing their understanding) and CC abilities (such as understanding ambiguous homographs) improved their understanding of narrative texts (Engel & Ehri, 2021).

## Limitations and Conclusions

Regardless of its merits, the current study has some limitations. First, the children with ASD were diagnosed according to DSM-5 criteria but not reconfirmed by other diagnostic measures. Second, although the study sample size in the current study is considered appropriate for research in clinical subgroups such as ASD, its small size may have limited the power of our analyses to detect statistically significant differences between the groups and may be specific only to this sample. Further studies with larger groups should be conducted to validate the present results. Furthermore, the choice of passing the national GEMS test as a participant selection criterion, in and of itself, produced a specific population that was situated at the very high end of the ASD reading comprehension range. In addition, since we used only one reading passage, the results should be interpreted cautiously. A further limitation was the choice of a visuospatial assessment for assessing CC, rather than a linguistic measure that may have been a better predictor of reading comprehension.

Nevertheless, the present study holds significant value in the scientific and academic fields concerning cognitively able children with ASD. It expands the scope of knowledge attained through studies that explored the academic capabilities of children with ASD regarding reading comprehension of narrative texts. Furthermore, the current study extends the body of research examining the contribution of cognitive functions to reading comprehension of narrative texts and suggests that this contribution may be different for ASDs and TDs. The findings provide multi-component information on how cognitive capabilities can contribute to the narrative text reading comprehension of children with ASD. Understanding how these variables impact reading comprehension can aid in determining the most effective approach for assessing and intervening with cognitive functions in children with ASD.

**Author contributions** YK: Conceptualization, Supervision, Analysis, Methodology, Writing - Original draft and review. YM: Conceptualization, Analysis, Investigation, Methodology. NBZ: Conceptualization, Supervision, Analysis, Methodology.

## Declarations

**Conflict of interest** There is no conflict of interest

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