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Exploring links between language and cognition in autism spectrum disorders: Complement sentences, false belief, and executive functioning

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ABSTRACT

A growing body of work indicates a close relation between complement clause sentences and Theory of Mind (ToM) in children with autism (e.g., Tager-Flusberg, & Joseph (2005). In Astington, & Baird (Eds.), *Why language matters for theory of mind* (pp. 298–318). New York, NY, US: Oxford University Press, Lind, & Bowler (2009). *Journal of Autism and Developmental Disorders*, *39*(6), 929). However, this link is based primarily on success at a specific complement clause task and a verbal false-belief (FB) task. One cannot exclude that the link found between these tasks may be a by-product of their both presupposing similar levels of language skills. It is also an open question if the role of complementation in ToM success is a privileged one as compared to that of other abilities which have been claimed to be an important factor for ToM understanding in autism, namely executive functioning (EF) (Pellicano (2007). *Developmental Psychology* 43, 974). Indeed the role played by complementation may be conceived of as an indirect one, mediated by some more general cognitive function related to EF. This study is the first to examine the relation between theory of mind assessed both verbally and non-verbally and various types of complement clause sentences as well as executive functions in children with autism spectrum disorder (ASD). Our participants included 17 children and adolescents with ASD (aged 6 to 16) and a younger TD control group matched on non-verbal IQ (aged 4 to 9 years). Three tasks assessing complements of verbs of cognition, verbs of communication and verbs of perception were conducted. ToM tasks involved a verbal ToM task (Sally-Anne, Baron-Cohen et al. (1985). *Cognition*, *21*(1), 37) as well as a non-verbal one (Colle et al. (2007). *Journal of Autism and Developmental Disorders*, *37*(4), 716). Indexes of executive functions were collected via a computerized version of the Dimensional Change Card-Sorting task (Frye et al., 1995). Standardized measures of vocabulary, morphosyntax and non-verbal IQ were also administered. Results show similar performance by children with ASD and TD controls for the understanding of complement sentences, for non-verbal ToM and for executive functions. However, children with ASD were significantly impaired for false belief when this was measured verbally. For both ASD and TD, correlations controlling for IQ were found between the verbal FB task and complement sentences of verbs of communication and cognition, but not with verbs of perception. EF indexes did not significantly correlate with either of the

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ToM tasks, nor did any of the general language scores. These findings provide support for the view that knowledge of certain specific types of complement clause may serve as a privileged means of 'hacking out' solutions to verbal false belief tasks for individuals on the autistic spectrum. More specifically, complements with a truth-value that is independent of that of the matrix clause (i.e. those occurring with verbs of cognition and of communication, but not of perception) may describe a false event while the whole sentence remains true, making these linguistic structures particularly well suited for representing the minds of others (de Villiers, 2007).

Learning outcomes: Readers will be able to (1) describe and evaluate the hypothesis that complement sentences play a privileged role in false belief task success in autism; (2) describe performance on complement sentences, executive functioning and false belief tasks by children with autism as compared to IQ-matched peers; (3) explain which types of complements specifically relate to false belief task performance and why; and (4) understand that differences in performance by children with autism at different types of false-belief tasks may be related to the nature of the task conducted and the underlying mechanisms involved.

1. Introduction

1.1. Theory of mind in autism

The term 'theory of mind' (ToM) refers to the ability to understand mental states and to reason on the basis of this information in order to interpret and predict others' behaviors (Premack & Woodruff, 1978). It is considered to be a core deficit in autism (Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 1989). One way of measuring ToM is with false belief tasks (Wimmer & Perner, 1983), the most famous version being the Sally and Anne (Baron-Cohen et al., 1985). The Sally-Anne task involves telling children a story enacted with two dolls, Sally and Anne, and then asking them a series of questions, as illustrated below:

This is Sally and this is Anne. Sally has a basket and Anne has a box. Sally has a marble and she puts it into her basket. She then goes out. Anne takes out Sally's marble and puts it into her box while Sally is away. Now Sally comes back and wants to play with her marble.

The critical 'belief question' which follows the story is: "Where will Sally look for her marble". In order to answer accurately, children must have a concept of mind which allows them to dissociate belief from reality and as such to understand that Sally has a false belief which will make her look inside the empty basket rather than where the marble really is, i.e. within the box (Dennett, 1978). The task also includes two control questions so as to ensure that children are keeping track of the story, namely a 'reality question': "Where is the marble really?" and a 'memory question': "Where was the marble in the beginning?". This task was initially used by Baron-Cohen et al. (1985) in their seminal work assessing ToM abilities in 20 children with autism, 14 children with Down's Syndrome and 27 typically developing (TD) preschool children matched to the clinical groups on mental age. These authors showed that while children with autism all successfully passed the control questions, only 20% of the group answered the belief question correctly, a significantly lesser amount than the comparison groups, with 86% accuracy being reported for those with Down's and 85% for the TD group. Those children with autism who failed the FB task pointed systematically to the actual location of the marble, leading the authors to conclude that their errors were not due to random pointing but rather to an inability to appreciate the difference between their own and the doll's knowledge, thus supporting the hypothesis that children with autism fail to employ a theory of mind.

Crucially, however, not all children failed at the task, as subsequent studies also confirm (Happé, 1995a,b; Yirmiya, Erel, Shaked, & Solomonica-Levi, 1998; Naito & Nagayama, 2004). Given this state of affairs, a valid question is: What allows a subset of children with autism to pass FB tasks, in particular if ToM is a core deficit of this condition?

1.2. Language and the role of complement sentences in ToM tasks

One proposal is that certain individuals on the autistic spectrum, despite their defective ToM, are able to apply compensatory strategies to 'hack out' correct responses for false belief (FB) tasks, with one such strategy being language (Bowler, 1992; Happé, 1995a,b; Fisher, Happé, & Dunn, 2005). This proposal finds support in the observation that language abilities and success at basic ToM tasks have been shown to be linked both in TD children (e.g., Astington & Jenkins, 1999) as well as in autism, with the latter group apparently requiring an even higher level of language ability than the former in order to pass (Happé, 1995a,b). The notion that children with autism may rely more heavily on verbalizing for ToM representation has given rise to a growing body of work exploring which particular area of language may impact FB task success the most, and certain researchers have highlighted the privileged role of grammar (Fisher et al., 2005) and, more specifically,

complement clause sentences (Tager-Flusberg, 2000; Tager-Flusberg & Joseph, 2005; Lind & Bowler, 2009[1]). Indeed complement clauses have specific semantic and syntactic properties that seem to make them particularly well suited to the purpose of mental representation (de Villiers, 1995, 2000; de Villiers & de Villiers, 2000; de Villiers & Pyers, 1997). To illustrate, consider the examples below where the complement clause is indicated by means of brackets:
(1) Certain researchers *think/believe* [that children with autism have difficulties with theory of mind].
(2) The children *said/replied* [that the marble was in the box].

These clauses often occur after verbs of cognition (1) or verbs of communication (2), i.e. verbs which precisely evoke the attitude or belief of the individual communicating or holding the mental state. The truth-value of the complement clause crucially does not affect the truth-value of the matrix. Put differently, whether or not children with autism actually do have difficulties with theory of mind is not necessary for the entire sentence in (1) to be true, it suffices that certain researchers think or believe it to be the case. Similarly, whether or not the marble was indeed in the box is not what determines the veracity of (2), but simply that children provided this response. The capacity to embed a (potentially) false proposition is what renders complement sentences an ideal tool for representing false beliefs. As de Villiers (2000: 90) explains "These sentence forms (...) invite us to entertain the possible worlds of other minds, by a means that is unavailable without embedded propositions." The central notion is thus that complementation is a cognitive tool which is crucial for reasoning about others' minds, and "without (it), the child cannot hold in mind the structures necessary for judging the truth and falsity of the content of beliefs" (de Villiers, 2007). This view of linguistic determinism further accounts for the observation that deaf children who have language delays in the absence of other cognitive deficits are nevertheless found to be delayed in the development of theory of mind (Gale, de Villiers, de Villiers, & Pyers, 1996; Peterson & Siegal, 1995; Schick, de Villiers, de Villiers, & Hoffmeister, 2007).

Children with autism have been reported to produce few complements in their spontaneous speech (Durrleman & Zufferey, 2013) and to have an impaired comprehension of complement clauses with verbs of cognition, although not with verbs of communication (Tager-Flusberg, 2000; Lind & Bowler, 2009). Other types of complements such as those occurring with verbs of perception (e.g. *John sees that the marble is in the box*) have not been assessed in this population to date. Performance with complements of verbs of communication (and not verbs of cognition) has been seen to correlate with increased scores at FB tasks in ASD, leading certain authors to hypothesize that children with ASD are able to represent false beliefs through speaking about what people say rather than about what they think (Tager-Flusberg & Joseph, 2005:312).

However certain aspects of the complement clause task which have been used by researchers reporting a correlation between this task and FB success appear themselves to rely on ToM skills; indeed various of the anecdotes used involved lying or misreporting events such as: "*She told her husband she saw a ghost but it was really a blanket. What did she tell her husband?*". Stimuli such as this arguably require the child not only to accurately recall the complement of the verb *tell*, but also to describe a state of affairs that is not reflective of reality, and as such there is a possible overlapping cognitive function with FB tasks. The intermingling of notions such as deceit in the complement clause task may prove problematic for children with ASD independently of their linguistic abilities. This may explain why success at this complement clause task correlates with success at theory of mind abilities assessed via a verbal false-belief task in children with ASD (Tager-Flusberg, 2000; Tager-Flusberg & Joseph, 2005; Lind & Bowler, 2009). It is therefore unclear that this correlation shows that the population with ASD relies on the linguistic/syntactic specificity of complement structures to hack out accurate responses to FB tasks[2].

Aside from these issues regarding the complement clause task, there are also some properties of the FB task which may need to be considered more carefully. For one, those used to date required a certain level of linguistic sophistication themselves, independently of ToM reasoning; indeed much like the complement task, the FB task also involved anecdotes using the past tense as well as interrogative structures. Recent studies have indicated that children with autism have some difficulty both with past tense (Roberts, Mabel, Rice, & Tager-Flusberg, 2004) and with interrogatives (Zebib, Tuller, Prévost, & Morin, 2013; Franck & Durrleman, 2013). The relationship between tasks may then arguably stem from a similar level of language ability being presupposed by both the task assessing complement clauses and the one assessing ToM.

In sum, the linguistic tasks administered to assess complement sentences in ASD included a ToM component whereas the ToM tasks involved a linguistic component, hence no surprise a link has been found. What is needed so as to verify that there is a functional link between ToM and complementation in ASD are tasks that tease these factors apart. One goal of the present study is thus to assess whether correlations can be established between measures of tapping into the syntactic/semantic specificities involved in sentential complements that do not involve lying/deceit and measures of false belief which are not only verbal but also non-verbal.

[1] It is worth noting that there is considerable debate regarding which component of language most impacts ToM in typical development, i.e. whether it is more general language abilities or more specifically the competency with complementation (see Farrar et al., 2013 for a review).

[2] In one study, that conducted by Tager-Flusberg (2000), another type of complement clause was used, inspired by de Villiers, Roeper, & Vainikka (1990). Here, the stories did not necessarily involve misrepresenting the truth, but crucially they always tested complementation via the use of a wh-question, which as we will see, is also used to assess false-belief. As such, the parsing of wh-questions is presupposed by both tasks, once again introducing a possible confound, here at the linguistic level.

1.3. Executive functioning in ToM tasks

Another cognitive component other than language that has been suggested to impact ToM is executive functioning (Russell, Mauthner, Sharpe, & Tidswell, 1991; Hughes, 1998). Executive functioning (EF) is an umbrella term covering abilities implied in the control of actions, including planning, decision making, working memory, cognitive flexibility, impulse control and inhibition (Rabbitt, 1997; Roberts, Robbins, & Weiskrantz, 1998; Stuss & Knight, 2002). Various reports assessing EF in ASD report deficits (Prior & Hoffmann, 1990; Ozonoff & Jensen, 1999; Booth, Charlton, Hughes, & Happé, 2003). Certain EF skills may also play a role in succeeding at ToM tasks, because in order to reply accurately during an FB task, the child would need not only to remember the sequence of events accurately but also to suppress a natural tendency to point to where s/he knows that the object really is located so as to point instead to where s/he knows the object is not, thus inhibiting his/her own knowledge. This explains why individuals with autism have difficulty with tasks requiring them to point to an empty box rather than a box where a desired object is, independently of the need to comprehend or engage in any form of social deception (Hughes & Russell, 1993). The ability to use internal rules to guide behavior such as inhibition would thus come into play in order to reply correctly. This perspective could arguably account for the reported links between EF and ToM tasks in both TD (Perner & Lang, 1999; Sabbagh, Moses, & Shiverick, 2006) and ASD (Ozonoff & Jensen, 1999; Pellicano, 2007). Interestingly, significant correlations between success at ToM tests and EF tasks in young children with autism were found to be independent of age and verbal as well as non-verbal ability (Pellicano, 2007), with dissociations being found in one direction only, namely impaired ToM with intact EF, suggesting that EF may indeed be an important factor in ToM development in autism. Moreover neurological considerations have been evoked to substantiate the idea of a potential link between ToM and EF and to explain why children with ASD may suffer from deficits in both of these cognitive realms (Ozonoff, Pennington, & Rogers, 1991), namely that the same regions of the brain that have been claimed to be implicated in EF have also been implicated in ToM, i.e. the prefrontal cortex and the right hemisphere (McDonald, 1993; Alexander, Benson, & Stuss, 1989; Brownell, 2000). In this study we also assess EF so as to measure the potential impact of this component on FB task success in our population. Another aim of the present work is thus to determine whether the impact of complementation on FB success is potentially mediated by EF.

To recapitulate, with this work we seek to contribute to better understanding how complement clause sentences are related to ToM in ASD. More specifically, we explore if links can be found between comprehension of these sentences and both verbal and non-verbal FB tasks, which would provide further support for the hypothesis that complement clause sentences are a representational tool for ToM reasoning in autism (de Villiers, 1995, 2000; de Villiers & de Villiers, 2000; de Villiers & Pyers, 1997). As the link in ASD has been established primarily with complements of verbs of communication, we aim here to more finely screen the role of complement sentences by including those occurring with other types of verbs such as verbs of cognition and verbs of perception, with the third category having never been tested before in this population. Verbs of perception may also take tensed complements, such as complements of verbs of cognition and communication, however they show a different semantics in that the truth-value of their complement is not independent of that of the matrix clause. If these sentences are seen to be unrelated to ToM, then it is not the structural properties of complement clause sentences per se that underlies ToM success, as has been suggested, but rather the semantic properties associated with a subset of these sentences, namely those containing verbs of communication and verbs of cognition. By including a control group of normally developing peers also tested for both complements and ToM, this study further contributes to determining if the complement clause-ToM connection in ASD is similar to that in TD. Under the hypothesis that individuals with ASD rely on language for ToM task success, a stronger link may be found between performance at complements and ToM in this population than in the TD population. Finally, we aim to assess whether or not the role played by language on ToM is mediated by other cognitive abilities that have been thought to impact ToM in ASD, in particular executive functioning, or if the language of complementation has a privileged status in ToM performance.

2. Method

2.1. Participants

Seventeen native French speakers with ASD aged 6 to 16 (mean age 9;2) were recruited through parent associations and psychologists in Geneva and the suburbs. All had been previously diagnosed by a specialist as meeting DSM-IV criteria for an autism spectrum disorder (American Psychiatric Association, 1994). Parents of participants provided informed, written consent for their children to participate in the research. Children were tested in a quiet room in the comfort of their own homes.

Seventeen native French TD children aged 4 to 9 (mean age 7;6) paired to the participants with ASD on non-verbal IQ (Raven's Progressive Matrices; Raven, Court, & Raven, 1986) were recruited from a primary school in Geneva, Switzerland. They were tested in a quiet classroom of their school. Approval for this study was obtained from the Ethics Committee of the Psychology Department of the University of Geneva.

2.2. Materials and procedure

A variety of existing and novel tasks assessing complementation, ToM and EF were used for this study and will be described in detail in this section. Whenever possible we used computerized tasks since these are known to improve the

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participation of children with ASD thanks to reducing interactions with the experimenter (Ozonoff, 1995; Pascualvaca, Fantie, Papageorgiou, & Mirsky, 1998; Ozonoff & Strayer, 2001; Griffith & Pennington, 2003). As there were a series of tasks involved, we systematically present each set of experiments along with its corresponding results and an interim discussion of the findings. In addition to these tasks, ASD children were administered two general language tasks: the 'Echelle de Vocabulaire en images Peabody' or EVIP (Dunn, Thériault-Whalen, & Dunn, 1993) and the Production d'Enoncés du Bilan Informatisé de Langage Oral (Prod-E BILO, Khomsi, Khomsi, Parbeau-Guéno, & Pasquet, 2007) in order to assess the potential role of these general language abilities in our critical tasks. The EVIP, a French version of the British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton, & Burley, 1997), assesses receptive vocabulary skills. The task contains a set of 175 cards (5 examples and 170 test items). Each card displays four pictures and the child has to point to the one that corresponds to the meaning of a word pronounced by the examiner. Items are presented in order of increasing difficulty. The Prod-E section of the BILO battery is a sentence-completion task evaluating expressive grammar: The child hears a pre-recorded sentence corresponding to a picture on the computer screen and has to complete the end of the sentence to fit with the picture (e.g., Ici, le chien boit son lait; là les chiens...[boivent leur lait]/"Here the dog is drinking his milk; there, the dogs ... [are drinking their milk]"). This test contains 29 test items assessing the ability to produce a variety of grammatical morphemes, including nominal, adjectival and verbal inflexions, irregular plurals, prepositions, passive structures, and pronominal clitics.

2.3. Complement clause tasks

The tasks assessing complement sentences with verbs of communication and cognition were developed specifically for this study. The task assessing complements of verbs of perception was adapted from Poltrock (2010). With all these tasks, we aimed to abstract away from anecdotes involving deception for the reasons previously explained, and we avoided the inclusion of other linguistic structures such as interrogatives so as to tap specifically into knowledge of the syntactic dependencies involved in complementation. The tasks involved a sentence-picture matching procedure, with pre-recorded sentences being heard while corresponding pictures appeared on a computer screen. Children were instructed to listen to the sentences entirely before answering. Each task was preceded by a rich warm-up, which ensured that participants recognized characters, speech and thought bubbles and were precise at pointing. All children performed at ceiling in the recognition of the four characters: *Marie*, *Thomas*, *la soeur de Marie* (the sister of Mary) and *le frère de Thomas* (the brother of Thomas) on the basis of simple instructions (*Montre-moi le frère de Marie*, "show me the brother of Marie"). We come back to further relevance of this in the conclusion section.

2.3.1. Complements with communication verbs

In this task, the child was presented with two pictures at a time. Each picture was accompanied by two prerecorded declarative sentences, pronounced by the same voice, depicting the contents of speech bubbles, such as "The girl is playing the drum" and "The girl is playing the piano" (see Fig. 1). This initial phase established the context for the critical sentence requiring the child to point to one of these pictures. That sentence could take two forms depending on if it was the 'control'

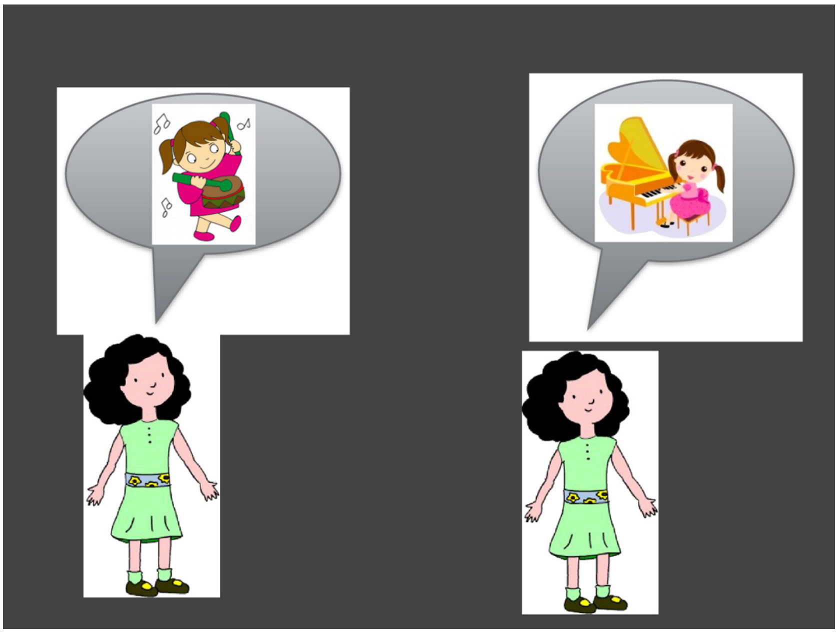

Fig. 1. Picture from the control condition for complements of communication verbs.

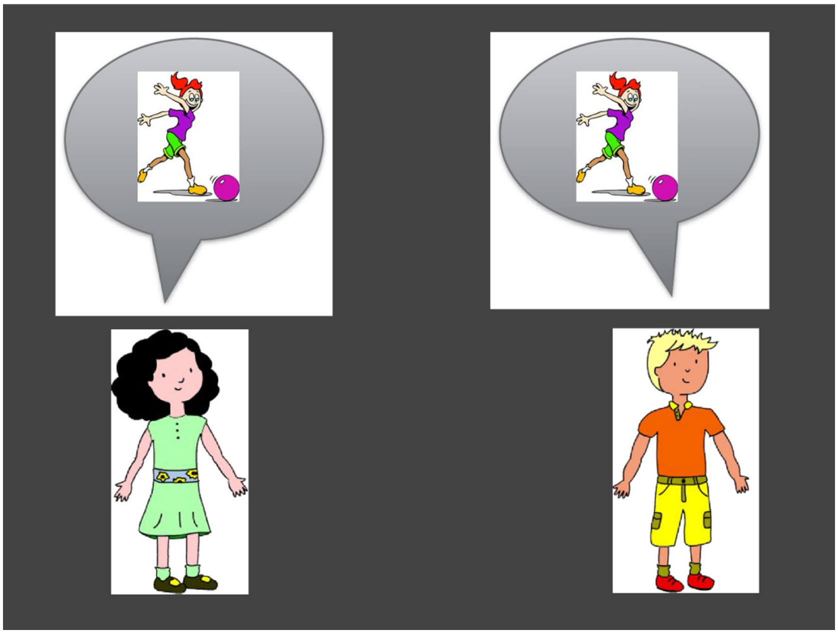

Fig. 2. Picture from the test condition for complements of communication verbs.

condition or the 'test' condition. For the control condition, the sentence contained a simple noun subject as in "Marie says that the girl is playing the piano". The child was then required to point to the left or the right of the picture on the screen as shown in Fig. 1. Success at this phase does not depend on the correct parsing of the syntactic dependencies of the sentence since it may be based on the partial parsing of the subordinate clause which is identical to one of the prerecorded sentences depicting the picture ("the girl is playing the piano"). This serves however to ensure that participants were able to focus their attention on the parsing of the subordinate clause, which in the following, critical test condition, had to be linked syntactically to the correct nominal in the matrix.

For the critical test condition, the child once again heard two prerecorded declarative sentences depicting the contents of speech bubbles (although this time there were two different voices corresponding either to a male or a female character) followed by a complement clause. The subject of the complement clause in this condition was a complex subject such as 'Mary's brother' which in French translates word for word as 'The brother of Mary' (*Le frère de Marie*), for example: "The brother of Mary **says** that the girl is playing football" and the child had to point to the relevant picture on the computer screen (Fig. 2). More precisely when hearing "le frère de Marie dit que la fille joue du piano" the child needs to know that it is 'le frère' who is the subject of the V 'dire' and not 'Marie' which is linearly closer to the V. That is, the child needs to correctly identify the 'head' of the complex NP 'le frère de Marie'. Success at this condition thus depends on the child's ability to correctly analyse the syntactic relationships involved in the sentence, because s/he had to relate the correct ('c-commanding') noun phrase subject (either "The brother of Mary" or "Mary") and the verb 'say', which selects a complement clause. Given that during the previous phase, children were primed to focus on the complement, and here they had the additional task of selecting the accurate nominal in the matrix to link it to, the two together tap into children's parsing of complementation sentences.

The familiarization phase of the test was composed of 6 items familiarizing the child with characters and speech bubbles (e.g. "Show me Mary"; "Show me Mary's brother"). This was followed by 6 test items divided amongst 2 conditions, 'simple subject' control items (e.g. "Mary says that the girl is playing football. Show me!") and 'complex subject' test items ("Mary's brother says that the girl is playing football. Show me!").

2.3.2. Complements with cognition verb test

This task was very similar to the previous one, with the same 2 conditions ('simple subject' control condition and 'complex subject' test condition). The only difference here was that the verb in the matrix clause was a verb of cognition. As such, the familiarization phase of the test was also composed of 6 pre-test, warm up items allowing the child to identify characters and understand thought bubbles. This was followed by 6 test items which were divided amongst 2 conditions: 'simple subject' control items (e.g. "Mary thinks that the boy has lost a tooth. Show me!") and 'complex subject' test items ("Mary's brother thinks that the boy has lost a tooth. Show me!"). Fig. 3 provides a sample picture used during this task.

2.3.3. Complements with verb of perception

This task was adapted from Poltrock (2010) and aimed to test children's understanding of complement sentences with the matrix perception verb 'see' (*voir*). The test condition was composed of 12 tensed complement clauses describing a scene

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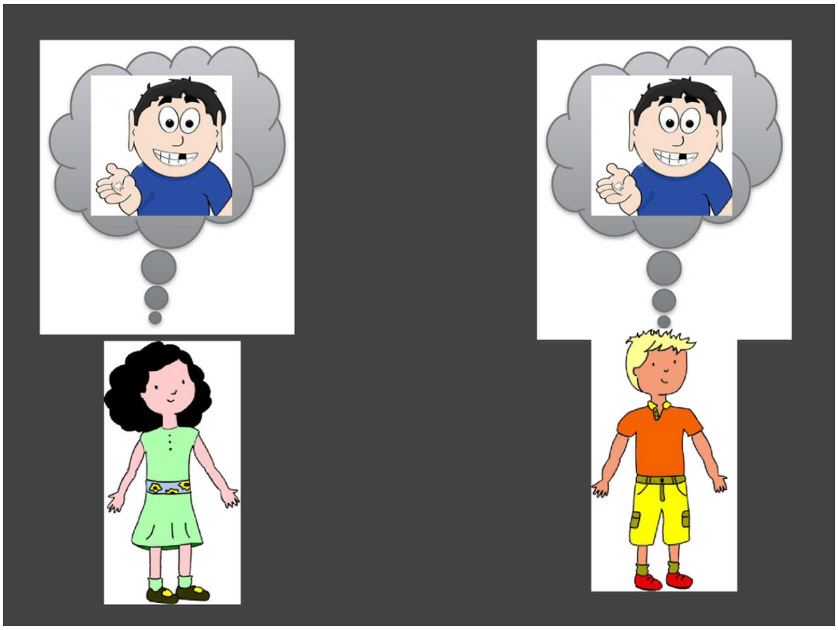

Fig. 3. Sample picture for the task assessing complements of cognition verbs.

that a given character was facing in one of two pictures, e.g. ''The duck **sees** that the mouse is playing football'' (see Fig. 4 below, with the correct picture on the left). Critically, both the target picture and the distractor picture illustrated a mouse playing football, although in the distractor the duck could not see this event and instead was clearly looking at something different (a mouse driving a car). As a result, it is necessary to correctly parse the relationship between the main clause and the embedded clause in order to select the right picture. One possible weakness of this task is that the identification of what a character can actually see may rely on ToM. Although TD 5 year-olds have already shown ceiling performance with this task (Poltrock, 2010), given that ToM delays in ASD could potentially impact performance independently of competency with complementation, we added a control condition composed of 6 items that assessed the child's ability to accurately understand what was in a character's view without any form of complementation (e.g. ''The duck **sees** the mouse''). Performance to the test condition was subsequently corrected by performance to the control condition, which was used as a baseline. Hence, we obtained a purer measure of complement sentence processing, independent of ToM ability.

Of the 12 test sentences, half accurately matched the picture to the left and the other half accurately matched the picture to the right. Children were awarded one point for every correct answer (i.e. every correct picture selected), amounting to a potential maximum of 12 points.

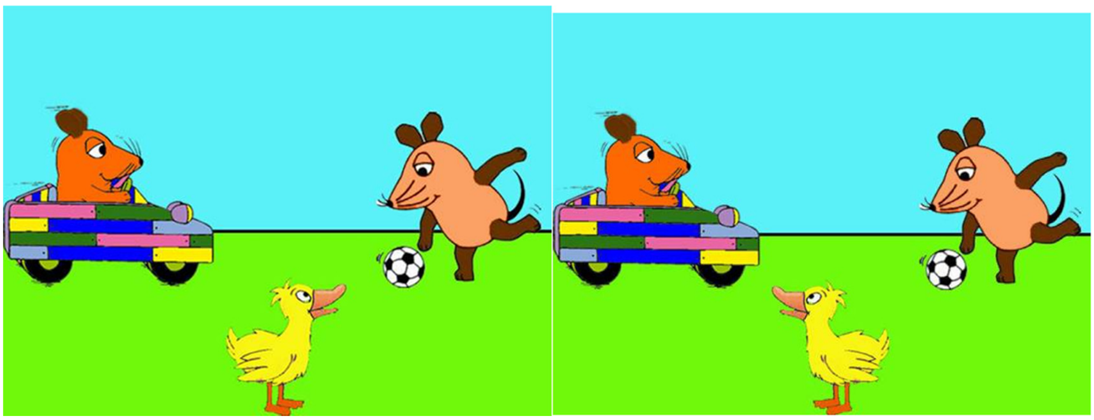

Fig. 4. Sample pictures for the task assessing complements of perception verbs.

Table 1
Percentage of correct responses in the control and test conditions of the three complement sentences tasks in ASD and TD children (standard deviations in parentheses).

		ASD	TD
Perception	Control	88.2 (17.4)	97.1 (6.5)
	Test	83.33 (21.0)	97.1 (5.1)
Communication	Control	97.8 (8.6)	97.8 (8.6)
	Test	73.3 (31.3)	84.4 (24.8)
Cognition	Control	97.8 (8.6)	97.8 (8.6)
	Test	84.4 (21.3)	77.8 (27.2)

2.3.4. Complement sentences: Results

The percentage of correct responses in the control and test conditions of the three complement tasks is illustrated in Table 1. Statistics were conducted on the proportions of correct responses, which were arcsine square root transformed in order to normalize them. For each task, pairwise comparisons within groups based on the Student t test were first conducted to assess the difference between control and test conditions. Comparisons across groups were then conducted on the control and test conditions, as well as on the score of the test condition corrected by the control condition treated as a baseline. Correction was obtained by the following formula: score test + (1 − score control). This correction allowed partialling out performance to the control condition, and therefore boosted scores from children who already had difficulties in that condition[3]. Student comparisons for independent samples were run and whenever equality of variance as assessed by the Levene test was not met adjusted values of the test are reported. Note that 2 ASD children did not comply to the two tasks of communication and cognition verbs, hence, data reported for these tasks bear on 15 ASD children and the corresponding TD-matched children.

Communication verbs. Results show a significant difference between the control and test conditions in both ASD ($t(14) = 2.80$, $p = .014$, $d = 1.07$) and TD children ($t(14) = 2.19$, $p = .046$, $d = .72$). Comparisons between groups showed no difference between them in the control condition ($t < 1$) and no difference in the test condition ($t(28) = -1.17$, $p = .251$, $d = .39$). Difference in the corrected score to the test condition also failed to reach significance level ($t(28) = -1.44$, $p = .160$).

Cognition verbs. Results show a significant difference between the control and test conditions in both ASD ($t(14) = 2.57$, $p = .022$, $d = .82$) and TD children ($t(14) = 3.24$, $p = .006$, $d = .99$). No significant difference was found between the two groups on the control, test and corrected test scores ($t < 1$).

Perception verbs. Results show no significant difference between the control and test conditions in ASD children ($t(16) = 1.90$, $p = .075$, $d = .25$) and in TD children ($t < 1$). ASD children performed marginally more poorly than TD on the control condition ($t(24.893) = -1.85$, $p = .077$, $d = .68$) but significantly more poorly on the test condition ($t(22.042) = -2.20$, $p = .039$, $d = .90$). However, once corrected for the baseline performance, no difference was found between the two groups on the test condition ($t(26.313) = -.98$, $p = .337$).

2.3.5. Complex syntax: Interim discussion

Children with ASD were found to perform similarly to non-verbal IQ-matched typically developing children in their understanding of complement sentences involving communication and cognition verbs. Both groups showed significantly better performance with sentences involving simple subjects as compared to sentences involving complex subjects. In these latter structures, syntactic dependencies need to be correctly established in order to perform the task; in particular, children need to identify the head of the main clause and correctly link it to the embedded clause. This property of complement clauses can be conceived of as the specificity of complementation syntax, and was assessed here by tools that can be assumed to abstract away from other cognitive components like memory or ToM. Our findings show that even though both groups clearly performed above chance in sentences with complex subjects, performance level was poorer than sentences with simple subjects, suggesting that the difficulty specifically lies in the linking between a complex sentential subject and a complement clause.

Children with ASD showed slight impairment as compared to TD on the control condition of the task evaluating complements of verbs of perception, where they have to infer what the character actually sees. Thus, adding this control condition as compared to Poltrock's initial task turned out to be crucial in ensuring that what was being tested was complementation syntax and not children's ability to identify what the character was actually perceiving, which may hinge on ToM functions. Indeed, we found that when controlling for this poor baseline performance, ASD children performed similarly to TD children with complement sentences with perception verbs, replicating the finding for the two other tasks with communication and cognition verbs.

[3] Two ASD children showed better performance in the test than in the control condition, giving rise to corrected scores above 1. Since the Arcsine transformation only applies to data between 0 and 1, these two scores were replaced by 1.

Table 2
Verbal false belief task format.

1. A and B are both placed in the scenario at the beginning
2. "A puts the [object] into [location 1]"
3. "A goes out to play/shop." **The experimenter hides A from the child's view**
4. "B takes the [object] and puts it in [location 2]"
5. "A comes back." **The experimenter brings A back into the child's view**
6. "A wants the [object]"
7. Test question: "Où est-ce que A va chercher [objet] en premier?" (Where will A look for the [object] first?)
8. Reality question "Où est [objet] en réalité?" (Where is the [object] now?)
9. Memory question "Où était [objet] au début?" (Where was the [object] at the beginning?)

In summary, when complementation syntax is measured independently of other cognitive functions, ASD children perform similarly to children matched on non-verbal IQ. Performance is nevertheless equivalent to younger peers and as such is indicative of a delay in the development of the comprehension of these sentences.

2.4. False belief tasks

We used both a verbal and a non-verbal task to measure false belief. Each involved the unexpected transfer of an object from one location to another.

2.4.1. Verbal FB test

In the verbal assessment of ToM, we included 4 stories based on the classical Sally-Anne task. The first was the Sally-Anne itself, and the 3 others were created specifically for this study. The general format always involved the experimenter telling a story to the child, while illustrating it with play-mobiles and Legos. All stories involved protagonist B (Anne, Mommy, Daddy, Daniel) transferring an object (a marble, a cup, a bow, a broom) from one location to another during the absence of protagonist A (Sally, Billy, Julie, Max). When protagonist A returned, the child was asked 3 questions, 2 which were control conditions (reality and memory) and 1 which was the test question targeting false belief attribution. The general outline for these tasks is provided in Table 2 below.

Note that for the false belief condition in 7 we decided to add the term "first" ("en premier" in French) at the end of the question. This is because it has been shown to enhance TD children's performance on the task (Surian & Leslie, 1999).

This task was composed in all by 8 control questions (4 reality questions and 4 memory questions) and 4 test, FB questions.

2.4.2. Non-verbal ToM test

The non-verbal assessment of ToM was adapted from Colle, Baron-Cohen, and Hill (2007), who in turn adapted their task from Call and Tomasello (1999). Two experimenters, experimenter A and experimenter B, were present during the experiment, which was divided into three phases (1) pre-test; (2) screening; and (3) belief tests. There were three trials per phase during which the child had to find a desired object (usually a sweet), in one of two identical boxes. A child was considered to have succeeded in each of the conditions of the pre-test and screening phases when they answered correctly (i.e. pointed to the box containing the desired object) in all three trials. When one trial was failed, the experimenter administered trials of the same condition again until three consecutive correct responses were obtained, or until two consecutive incorrect responses were given. When two consecutive incorrect responses were given, the condition was considered as failed, and the testing was interrupted. This was because the subsequent phases could not be interpreted if the child did not have the prerequisite skills to understand the task.

The controlled variable was the box in which the desired object was hidden (left or right) and was semi-randomised. Following Colle et al. (2007) the object was not hidden more than twice in a row in the same box. The three experimental phases are detailed below.

The first, 'pre-test' phase, ensured that participants understood that experimenter B ('the helper') would assist them in finding the object by pointing to one of the two boxes. The desired object was placed into one of the boxes in full sight of both the participant and experimenter B. B was asked by A "Trouve le [object]" (*Find the [object]*)[4]. B pointed to the correct box, and A asked the child to find the object. After the child's answer, the experimenter opened the box in front of the child and B and showed them its contents. If the child had pointed to the box containing the object, they would immediately be given the object. If the child had pointed to the other box, they were shown the empty box, then the other box was opened and they received the object.

[4] In the initial version of the task, the child was asked "Where is the sweet?". We modified this for the instruction "Find the sweet" because the imperative involves a simple canonical syntactic structure which ensures that the children's understanding of complex, interrogative syntax does not interfere with the results.

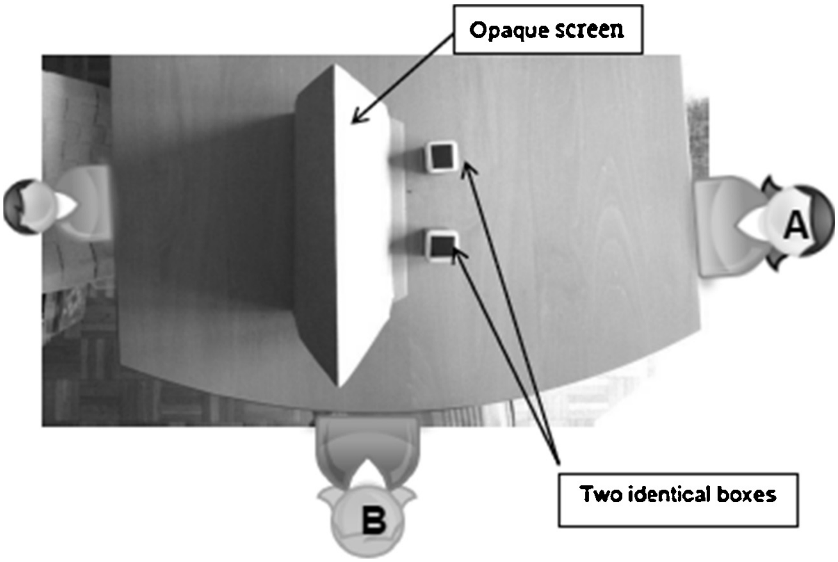

Fig. 5. The test phase set-up.

The second, 'screening' phase, ensured that participants had the necessary prerequisite skills for the test phase. There were three subparts of this screening phase, each containing three trials:

1. *Visible displacement*, i.e. the ability to follow a visible object that is transferred from one box to the other by A. In the communicator's absence, the hider opened the box with the sweet and moved the sweet to the other box so that the participant could see. Upon the communicator's return, the participant was told "Trouve le bonbon" (find the sweet). The child had to identify the box into which the sweet had been moved. The communicator's leaving the room was irrelevant in this test, however this condition was kept so as to render it comparable to the other tests.
2. *Invisible displacement*, i.e. the ability to understand that an object contained in a box can be moved with its container when A switches the two boxes. The only difference with the previous phase is that while the communicator was absent, what was moved was not only the sweet but the entire box containing it. The child had to identify the box into which the sweet was moved.
3. *Ignoring the communicator*, i.e. the ability to give a different response to experimenter B when experimenter B is clearly mistaken. In this condition, the object was hidden in one of the two boxes in view of both the experimenter and the child. B left the room and while s/he was away A switched the boxes in front of the child. When B returned, s/he was asked to find the object. B pointed to the empty box because she had not seen the switch. The participant had to take into account only what they knew about the object, i.e. that it had been placed in one box and then moved, and hence to ignore B.

The third, 'test' phase, was divided into two parts each containing three trials[5]. The first part of the test phase was the 'false belief' test condition and the second was the 'control' condition. In this phase, an opaque screen was placed between the child and experimenters A and B, so that only the two adults could see the boxes and their contents (see Fig. 5). The child was always present and thus witnessed the placement of the screen, so s/he was clearly aware that the same two boxes previously used for hiding the sweet were now behind the screen. For each trial, Experimenter A systematically showed the child the sweet above the screen and then the sweet was taken below the screen towards the boxes into which it was then hidden in front of Experimenter B. Each part of this phase is detailed below:

1. *False belief.* As soon as the sweet was hidden, B left the room, A then removed the screen so that the child could now see the boxes again. Experimenter A switched the two boxes in front of the child. B returned after the switch, and was asked to point to the box containing the desired object. As B was "unaware" of the switch, B pointed to the box with no object. The child was then asked to point to the box containing the object. If the child had realized that experimenter B held a false belief because they were not in the room at the time of the switch, then the child would point to the box containing the desired object (i.e. the opposite of the one B showed). If the child had not attributed a false belief to experimenter B, then they would point to the same box as B (i.e. the empty box).

[5] Colle et al. (2007) added a 'true belief' condition to the original task by Call and Tomasello (1999) which we do not include in this study. Note that the verbal FB task does not contain a 'true belief' condition either, only a false belief and a control (reality) condition, like the non-verbal task.

Table 3
Percentage of correct responses in the different conditions of the verbal and non-verbal ToM tasks in ASD and TD children (standard deviations in parentheses).

		ASD	TD
Verbal ToM	False belief	54.4 (41.7)	88.2 (29.5)
	Reality	82.4 (31.6)	97.1 (12.1)
	Memory	77.9 (35.2)	94.1 (10.9)
Non-verbal ToM	False belief	69.1 (33.2)	84.4 (17.2)
	Control	82.1 (32.2)	80.0 (21.1)

2. *Control condition.* This condition ensured that the child was not simply applying the rule "when B goes away, B will always point to the wrong box". This condition was identical to the false belief condition but there was no box switch, so B still held a correct belief.

This test contained a total of 3 control items and 3 test, FB trials.

2.4.3. ToM tasks: Results

The percentage of correct responses in the different conditions of the two ToM tasks is illustrated in Table 3. Statistics were conducted on the proportions of correct responses, which were arcsine square root transformed in order to normalize them. Pairwise comparisons within groups based on the Student test were first conducted to assess the difference between the different experimental conditions within each task. Comparisons across groups were then conducted using the Student test for independent samples. Whenever equality of variance was not met, adjusted values of the test for unequal variances are reported. Note that again 2 ASD children (different from the complement tasks) did not comply to the non-verbal ToM task, hence, data reported for this task bear on 15 ASD children and the corresponding TD-matched children.

Verbal task. Results in the ASD group showed significantly poorer performance in the false belief condition as compared to the reality condition ($t(16) = 2.40$, $p = .029$, $d = .76$) and to the memory condition ($t(16) = 2.09$, $p = .053$, $d = .61$). The latter two conditions did not differ ($t < 1$). TD children showed no significant difference between the false belief condition and the reality condition ($t(16) = 1.77$, $p = .095$, $d = .39$), the false belief and the memory condition ($t < 1$), and the reality and memory conditions ($t(16) = 1.43$, $p = .172$, $d = .26$). Comparison across groups showed significantly poorer performance in ASD in the false belief condition ($t(28.848) = 2.93$, $p = .007$, $d = .94$), while the difference in the reality and memory conditions did not reach significance level (respectively, $t(20.819) = 1.83$, $p = .082$, $d = .61$ and $t(21.419) = 1.71$, $p = .102$, $d = .62$).

Nonverbal task. Results in the ASD group showed marginally poorer performance in the false belief condition than in the control condition ($t(14) = 2.08$, $p = .059$, $d = .40$), a difference that reached significance level in TD children, although with a small effect size ($t(14) = 4.84$, $p < .001$, $d = .23$). Comparisons between the groups showed no difference in the false belief condition or in the control condition ($t < 1$).

2.4.4. Interim discussion

Our group with ASD showed a significant deficit only in the false belief condition of the verbal ToM task. No impairment was found for the similar condition in the non-verbal task, suggesting that the verbal component plays a role in the difficulty they meet in the verbal false belief task. Aside from this, ASD performed similarly to the control group for the other conditions in both the verbal and non-verbal false belief, although there was a trend to worse overall scores in the verbal false belief task.

Previous studies applying these tasks report deficits for individuals with ASD, both for the verbal false belief (Baron-Cohen et al., 1985, amongst others) and the non-verbal false belief versions (Colle et al., 2007). We have replicated the weakness with the verbal task but have not done so for the non-verbal version. It is worth noting that Colle et al. (2007) had selected participants for their study with a mean non-verbal mental age of 4; 9 while our participants had a mean non-verbal mental age of 7; 6. The lower level of functioning of the participants in the study by Colle et al. (2007) as compared to ours may explain the difference in performance between the two groups, suggesting that children with ASD progressively manage to catch up their delay as they mature at the cognitive level[6].

2.5. Complements and ToM: Exploring the links

2.5.1. Results

In order to examine the relationship between knowledge of complement sentences and FB performance, we ran correlations for ASD and the TD comparison group, focussing on the scores at complements corrected for baseline and on the

[6] See also Bakhtiari et al. (2012) who show that cognitive amelioration linked to brain development continues in ASD during a later phase to that observed in TD.

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Table 4
Partial correlations (controlled for non-verbal IQ) between baseline-corrected scores to the complement tasks and scores to the false belief conditions of the two ToM tasks.

	Complements communication verbs	Complements cognition verbs	Complements perception verbs
Verbal false belief	$r(24) = .54$ $p = .005$	$r(24) = .50$ $p = .010$	$r(24) = -.05$ $p = .796$
Non-verbal false belief	$r(24) = -.04$ $p = .864$	$r(24) = .18$ $p = .375$	$r(24) = .05$ $p = .798$

scores at the false belief conditions of the two ToM tasks. Partial correlations were run with the score at the Raven's Matrix as control. Given that the same results were found for the two groups, correlations were then run on the overall group of children to increase statistical power. Results are reported in Table 4.

Significant correlations were found between the verbal false belief task and the complement tasks involving both communication and cognition verbs. In contrast, no correlations were found with the non-verbal false belief task, nor with the complement task with perception verbs.

Given the important variability in performance to the theory of mind tasks by the ASD group, we further explored through correlational analyses whether more general syntax and lexical abilities as measured by the BILO and EVIP tasks accounted for their performance in ToM. Performance to the false belief condition of the verbal task showed no correlation with EVIP ($r(15) = .004$, $p = .988$) nor with BILO ($r(15) = .27$, $p = .295$). Performance to non-verbal false belief did not significantly correlate with EVIP ($r(13) = .49$, $p = .089$) nor with BILO ($r(13) = .48$, $p = .097$).

2.5.2. Interim discussion

The correlational analyses show a selective link between success at verbal ToM and complementation sentences involving communication and cognition verbs, but not complementation sentences involving perception verbs. This suggests that it is not complementation in general which is crucial for verbal FB success but rather the subset of complement sentences that allows for the representation of two levels of reality. While correlational analyses cannot prove a causal relation between variables, these findings are nevertheless compatible with the view that specific types of complement clause knowledge may play a special role in figuring out solutions to verbal FB tasks for individuals on the autistic spectrum as well as their typically developing peers (Tager-Flusberg, 2000; Tager-Flusberg & Joseph, 2005; Lind & Bowler, 2009). However the difficulty that children with ASD meet in the verbal false belief task does not seem to be attributable to some general knowledge of syntax or lexicon as measured by the standardized BILO and EVIP: Importantly, no correlation is found between verbal ToM and more general measures of lexical and syntactic abilities, suggesting that the link found with complementation is selective.

In contrast to verbal ToM, no correlation emerges between non-verbal ToM and complementation. This finding may be surprising under the hypothesis that language serves as a support to the development of ToM as a separate cognitive function.

2.6. Executive functions

2.6.1. EF: Task

In order to assess EF, we administered an adapted, computerized version of the Dimensional Change Card-Sorting Task (Diamond & Kirkham, 2005; Zelazo, 2006). This task requires children to sort images appearing on the computer screen in one of two boxes, with the front of the box on the left showing a picture of a blue car while the box on the right showed a picture of a red teddy bear. The experimenter explained to all participants that the game involved sorting pictures by either shape or colour. The stimulus to be sorted was either identical to that on the front of the box or incongruent along one dimension, i.e. colour or shape. Our task involved three blocks, with the first two blocks containing 12 items and the last one containing 24. In Block 1 children were asked to sort object according to their colour. In Block 2 they were asked to change the sorting criterion and sort objects according to their shape. In Block 3 the sorting criterion varied across items, and was announced by a computer voice just before the object was presented ("colour!" or "shape!"). The stimuli of all three blocks were presented in a pseudo-random order. Before each one of the test blocks, a practice block of 8 items familiarized the participant with the procedure using a different set of objects to those of the test blocks, namely orange and purple balls and Legos. Feedback was provided during the familiarization trials (i.e., "correct" or "incorrect") ensuring that children understood what was expected of them before the test blocks were administered. Feedback was not given during the three subsequent test blocks tapping into the cognitive control components described below:

Perceptual inhibition was assessed in Blocks 1 and 2 by contrasting the *Conflict condition* in which the shape of the object to be sorted mismatched that of the object represented on the box to the *No conflict condition* in which both the colour and the shape of the object to be sorted matched that of the object on the box. Hence, in the conflict condition which is illustrated in Fig. 6, the child needs to inhibit perceptual information present in the stimulus, in this case its shape. A score of perceptual inhibition was obtained by subtracting performance to the Conflict condition to performance to the No conflict condition.

Rule inhibition was assessed by contrasting performance on the last two conflict items in the Block 1 to performance on the first two conflict items in the Block 2, which involved a change in the sorting criterion. The rule inhibition score was obtained by subtracting the score to the final items in Block 1 to that of the initial items in Block 2.

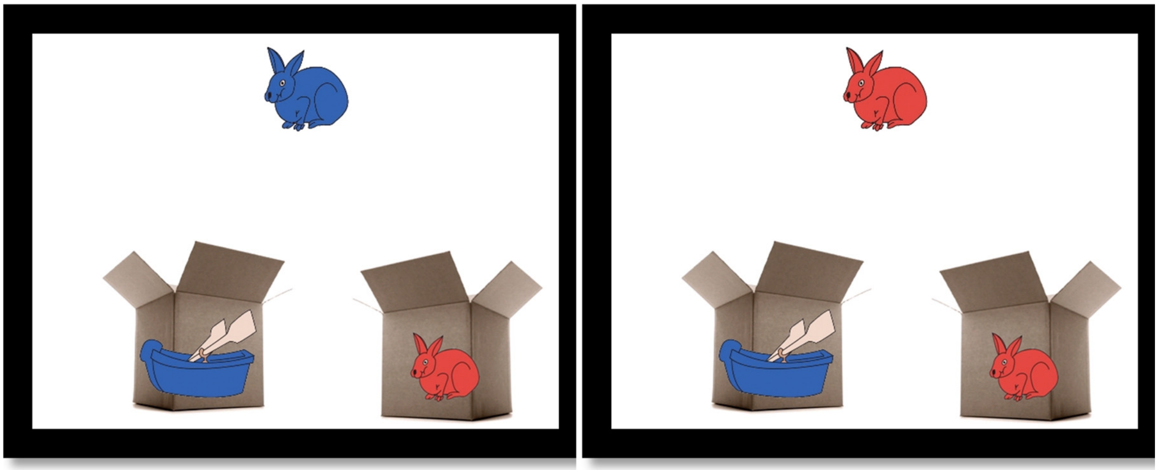

Fig. 6. Conflict versus No Conflict conditions of Perceptual Inhibition in the DCCST task.

Flexible rule switching was assessed in the third block by subtracting performance to items in the *Switch condition* involving a switch of sorting criterion as compared to the previous item to items in the *No switch condition* for which the same criterion as the one just used had to be applied.

2.6.2. EF: Results

The percentage of correct responses in the two experimental conditions of each of the three blocks is reported in Table 5. Statistical analyses were conducted on log-transformed data to ensure normalization. Within-subjects analyses were conducted on each group using the Student t pairwise comparisons test to assess the effect of conflict (contrasting conflict and no conflict conditions in Blocks 1 and 2), the effect of rule change (contrasting the last two conflict items of Block 1 to the first no conflict items of Block 2) and the effect of rule switching (contrasting the switch and no switch conditions). Comparisons between groups were then conducted on indexes of sensitivity to these three effects by subtracting the score in the relevant two conditions used to assess each of the effects (No conflict minus Conflict in Blocks 1 and 2, the last two conflict items in Block 1 minus the first two conflict items in Block 2, No switch minus Switch). Calculated as such, a small score indexes low sensitivity to perceptual conflict/rule change/flexible rule switching and therefore good EF abilities.

Perceptual inhibition. Student t tests on Block 1 showed a marginal effect of conflict in the ASD group, with worse performance in the presence of conflict ($t(16) = 1.98$, $p = .066$, $d = .42$) and a significant effect in TD children ($t(16) = 4.85$, $p < .001$, $d = 1.4$). On Block 2, no significant conflict effect was found in the ASD group ($t(16) = 1.60$, $p = .130$, $d = .47$) while a significant effect was again found in TD children ($t(16) = 4.53$, $p < .001$, $d = .1.52$). No significant difference was found between the two groups on their sensitivity to perceptual conflict either in Block 1 ($t(32) = 1.31$, $p = .200$) or in Block 2 ($t(32) = 1.48$, $p = .148$).

Rule inhibition. Pairwise comparisons in the ASD group showed no difference between the last two conflict items of Block 1 ($M = 82.4$; $SD = 30.3$) and the first two conflict items of Block 2 ($M = 82.4$; $SD = 35.1$) ($t < 1$). The TD group also showed no difference between the two conditions (Block 1: $M = 70.6$; $SD = 35.6$; Block 2: $M = 73.5$; $SD = 31.2$; $t < 1$). The two groups did not differ in their sensitivity to rule inhibition ($t < 1$).

Flexibility in rule switching. Student t tests on Block 3 showed a significant effect of switch in the ASD group, with worse performance when it involved a switch in the sorting criterion as compared to the previous item, although the effect size is

Table 5
Percentage of correct responses in the two conditions of each of the three blocks of the DCCST in ASD and TD children (standard deviation in parentheses).

		ASD	TD
Block 1	Conflict	89.2 (31.2)	80.4 (16.9)
	No conflict	99.0 (9.9)	98.0 (5.5)
Block 2	Conflict	85.3 (35.6)	72.5 (22.0)
	No conflict	98.0 (13.9)	97.1 (6.5)
Block 3	Switch	78.4 (41.2)	82.8 (13.0)
	No switch	86.3 (34.5)	93.1 (14.2)

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Table 6
Partial correlations (controlled for non-verbal IQ) between indexes of EF (perceptual inhibition in Block 1, rule inhibition and flexibility in rule switching) and scores to the false belief conditions of the two ToM tasks, in ASD and TD children.

	Perceptual inhibition	Rule inhibition	Flexible rule switching
Verbal false belief	$r(28) = .25$ $p = .182$	$r(28) = -.31$ $p = .097$	$r(28) = .20$ $p = .282$
Non-verbal false belief	$r(28) = -.18$ $p = .354$	$r(28) = -.10$ $p = .592$	**$r(28) = .39$ $p = .035$**

small ($t(16) = 4.33$, $p = .001$, $d = .21$). A significant effect was also found in the TD group ($t(16) = 2.73$, $p = .015$, $d = .76$). The difference between the two groups in their sensitivity to rule switching is non significant ($t < 1$).

2.6.3. EF and ToM: Results

Since none of the correlations between the various EF indexes and the two FB tasks were found significant on the individual ASD and TD groups, correlations were run across the two groups to increase statistical power. Partial correlations were run with the score at the Raven's Matrix as control. As illustrated in Table 6, a significant positive correlation was found between Flexible rule switching and non-verbal false belief, suggesting that the higher the score at the non-verbal FB task, the more sensitive to rule switching children were.

2.7. EF, ToM and complements: Interim discussion

Our results indicate no deficit in the group with ASD as compared to non-verbal IQ-matched children for any of the three EF abilities explored, namely the ability to inhibit perceptual information from the input, the ability to inhibit a previously used rule or the ability to constantly switch from one rule to the other upon instruction. Both groups were affected by the presence of conflicting perceptual information between the object to sort and the object represented on the sorting box, indicating that they struggled with the inhibition of the irrelevant perceptual information present on the stimulus. Both groups also showed poorer performance when having to change the sorting criterion as compared to that just used in the previous item, although a voice indicated which criterion to use. Again, this indicates some difficulty to deal with the inhibition, not of perceptual information here, but of a rule that has just been used before. It is important to note that even though ASD children were not different from their matched controls, they are on average almost two years older than them, indicating a clear delay in their maturity of EF.

Recall that a link between complementation and FB was selectively found when FB was assessed verbally. In order to verify that this link was not mediated by some more general ability to inhibit hinging on executive functions (see Hughes, 2001; Russell, 1997; Pellicano, 2007), we tested whether performance on verbal FB was linked to EF and saw that it is not the case. The finding of a significant correlation with one of the EF indexes (flexible rule switching) and non-verbal FB suggests that the lack of a correlation with verbal FB is not due to lack of power in our small sample. Moreover, correlations between complement sentences and ToM also emerged despite this limitation, which suggests that EF abilities in ASD do not impact verbal ToM performance in the same way as specific complementation skills do. It is interesting to underline that recent studies that have found a relation between verbal theory of mind performance and executive control abilities in ASD have reported that associations between these components disappeared when the effects of non-verbal ability and language level on these variables were controlled (Joseph & Tager-Flusberg, 2004).

The link found between EF and non-verbal FB is at first surprising because it suggests that in order to perform well at the non-verbal FB task, children needed some sort of rigidity. Interestingly, the subpart of the screening phase immediately preceding the crucial FB test phase of the task involved "Ignoring the communicator". In that phase, there was a switching of boxes in the communicator's absence so that pointing to the opposite box to the one indicated by the communicator was an accurate response. Pointing to the opposite box is precisely what is also needed to accurately respond during the FB phase of the task as well (the only difference being that the children actually saw themselves where the sweet was in the previous screening phase, and did not see it in the FB phase). It is conceivable that participants were thus 'primed' to select the opposite box and as such if they are rigid and don't know what to answer in the FB task they simply keep pointing at the other box. In line with that possibility, a strong correlation was found between performance at the preceding 'Ignoring the Communicator' phase and performance at the FB condition in the ASD group ($r(13) = .66$ $p < .01$). This may explain why higher scores at the nonverbal FB task were related to rigidity as measured by the EF task. If our interpretation is correct that the non-verbal FB task involves a bias from the screening phase, the good performance reported for our ASD group may simply attest of their rigidity rather than of their ability to deal with false belief. In other words, the task may not have tapped specifically into ToM but rather into some more general cognitive tendency to perseverate.

3. Conclusions

This work aimed to improve our understanding of how knowledge of complement sentences relates to ToM in ASD and TD by (a) teasing out the ToM component from the tasks assessing the linguistic component of complements as much as possible, setting aside the ToM component involved in previously used complement tasks (Tager-Flusberg, 2000; Tager-Flusberg & Joseph, 2005; Lind & Bowler, 2009), and (b) including a false belief ToM task with minimal linguistic demands in order to determine whether the link previously reported between complements and ToM extends to non-verbal ToM abilities. We further set out to determine whether or not the role played by complementation in ToM success is an indirect one, mediated by some more general cognitive function related to EF. Results indicate that the children with ASD and the TD control group matched on non-verbal IQ did not differ on the various tasks used except for verbal FB, indicating that the performance of subgroups with ASD for complementation, non-verbal FB and EF is comparable to performance by younger TD peers functioning at a similar cognitive level. The present findings confirm the weakness with verbal FB in ASD and also, crucially, highlight a privileged link between certain types of complement sentences and ToM success when ToM is assessed via verbal FB attribution. More precisely, the subset of complement clauses that may represent a false proposition, namely those involving communication or cognition verbs, appears to play a selective role in figuring out solutions to verbal FB tasks in both ASD and TD, whereas no such role seems to appear from perception verbs that fail to provide such a representational tool. Interestingly, ASD children performed similarly to TD children in the non-verbal FB task developed by Colle et al. (2007), and no relation was found between performance to this task and complementation syntax. However, our finding that performance on this task was positively correlated with cognitive rigidity made us suggest that a bias in the screening phase of the non-verbal FB task may have contributed to blur the picture.

There are various limitations to the current study: one concerns the task used to assess complements of verbs of communication and cognition. Given the highlighted shortcomings of previous tasks, we created a novel experiment. However with the current task, one cannot exclude the possibility that children adopted a strategy of either pointing to the referent of the first NP of the sentence or simply analyzing the complex subject without parsing the whole sentence. Still, the design of the experiment and the results obtained suggest that this was not the case. The content of the complement clause itself was indeed made critical in the control phase preceding the test phase. Children were thus primed here to consider the content of the complement and moreover children had no difficulty during this phase of the experiment, while they performed significantly worse in the test condition involving the linking of this complement to a complex nominal subject. Note that the lower performance observed in the test condition cannot be explained by children's difficulty with the syntax of complex NPs, since children also performed at ceiling in the warm-up phase of the experiment in which they were presented with isolated complex NPs (''Montre-moi le frère de Marie''; Show me the brother of Marie). Thus, difficulties observed in the test phase, in ASD and in TD children, appear to lie in the linking of a complex sentential subject and a complement clause. Finally, there is no theoretical reason to believe that adopting a strategy of determining accurate reference for relational expressions such as 'brother' or 'sister' would be related to FB success. The fact that results are rather in line with the prediction from a theoretically motivated hypothesis for a relation between complementation and false belief, which moreover has already received support from other empirical approaches, brings further evidence for the assumption that our task tapped into complementation. It may nevertheless be interesting to explore the relation between the complement task designed here and FB in a language where the first nominal in a complex NP does not correspond to the head, unlike French. English could be of particular relevance for this given the reverted order found with genitives, such that children would have to determine that it is the second nominal responsible for stating the complement in 'Mary's brother says that the girl is playing the piano'. If the correlation between complementation syntax and FB reported for French children here reflects an intrinsic link between these two spheres of cognitive development, the same correlation is expected in English children, despite the surface variation of linear word order in that language.

Another limitation of this work is the considerable variability of our ASD cohort. There is a need to understand this variability further in future research, in particular since clinicians work with individuals and not populations, and so their grasp of the likely limits to variation is important. Still, our study has shown that the variability in general language abilities does not account for the link we have found between performance at complement sentences and verbal FB, suggesting this link is a selective one. However, given that our study was not a longitudinal one, we cannot conclude that this link is a causal one, with complementation being a precursor of ToM, as has been suggested in previous work (e.g. Tager-Flusberg & Joseph, 2005). Our results nevertheless support the interpretation that this hypothesis may be on the right track. Indeed the performance of the group with ASD on complements was unimpaired, while their performance on verbal FB clearly showed deficits. Given these findings, it appears to be more plausible that children with ASD rely on the skill of complementation for verbal ToM performance rather than the other way around. Further research is needed to determine whether coaching of complement sentences may have benefits for false belief reasoning in individuals with ASD, along the lines of that which has been shown by training studies conducted with TD children (Hale & Tager-Flusberg, 2003; Lohmann & Tomasello, 2003).

In neither group were links shown between FB and complement sentences without the semantic particularity of representing a false proposition, namely complements of verbs of perception. Executive functions also failed to show any link with verbal FB success. This provides support for the view that knowledge of certain complement sentences impacts verbal ToM performance in a special way as compared to other language abilities or other cognitive tools such as EF.

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Appendix A. Continuing education

1. False-belief tasks are used to evaluate
(a) executive functioning
(b) theory of mind
(c) language
(d) autism
(e) complement sentences
2. The results of this study suggest that children with autism
(a) capitalize on knowledge of certain complement sentences to pass verbal false-belief tasks
(b) perform at age level on false-belief tasks
(c) cannot pass verbal or non-verbal false-belief tasks
(d) have a deficit in the comprehension of complement sentences
(e) rely on executive functioning skills for false-belief task success
3. Linguistic determinism states that
(a) mastery of sentence complements is crucial for passing executive functioning tasks
(b) the link found between false-belief tasks and complement sentence tasks is due to both involving similar levels of linguistic sophistication
(c) a rich vocabulary is necessary to develop a functional ToM
(d) ToM is necessary for the comprehension of complement sentences
(e) mastery of sentence complements is crucial for passing false-belief tasks
4. An important difference between complements of verbs of cognition and communication as compared to complements of verbs of perception is that
(a) the former are tensed while the latter are not
(b) children with autism are selectively impaired with only the former
(c) only the former have a truth-value that is independent of that of the matrix clause
(d) only the latter have a truth-value that is independent of that of the matrix clause
(e) only the former are related to executive functions
5. Performance by children with autism on verbal false-belief tasks consistently
(a) yield similar results to non-verbal false-belief tasks
(b) correlate with their performance on executive functioning tasks
(c) yield ceiling results
(d) indicate their deficits in ToM
(e) show that they can perform similarly to IQ-matched peers

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