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The relationship of theory of mind and executive functions to symptom type and severity in children with autism

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Abstract

Although neurocognitive impairments in theory of mind and in executive functions have both been hypothesized to play a causal role in autism, there has been little research investigating the explanatory power of these impairments with regard to autistic symptomatology. The present study examined the degree to which individual differences in theory of mind and executive functions could explain variations in the severity of autism symptoms. Participants included 31 verbal, school-aged children with autism who were administered a battery of tests assessing the understanding of mental states (knowledge and false belief) and executive control skills (working memory, combined working memory and inhibitory control, and planning) and who were behaviorally evaluated for autism severity in the three core symptom domains. Whereas theory of mind and executive control abilities explained the significant variance beyond that accounted for by language level in communication symptoms, neither explained the significant variance in reciprocal social interaction or repetitive behaviors symptoms. These findings are discussed in terms of a proposed distinction between higher level, cognitive–linguistic aspects of theory of mind and related executive control skills, and more fundamental social–perceptual processes involved in the apprehension of mental state information conveyed through eyes, faces, and voices, which may be more closely linked to autistic deficits in social reciprocity.

Impairments in theory of mind and in executive functions have both been hypothesized to underlie the core, defining symptoms of autism. The theory of mind hypothesis (Baron–Cohen, Tager–Flusberg, & Cohen, 2000) posits that autism involves an impairment in the ability to conceive of mental states and to use mental state concepts to interpret and predict one's own and other people's behavior. Although efforts to specify the nature of the "mentalizing" impairment in autism have increasingly taken a developmental rather than a static, all or nothing approach (Tager–Flusberg, 2001), the bulk of the research on theory of mind in autism has nonetheless focused on the attainment of one key social–cognitive milestone, false belief understanding, in which individuals with autism have been found to be significantly impaired (Baron–Cohen, Leslie, & Frith, 1985; also see Baron–Cohen, 2000, for a review). The ability to impute false beliefs to oneself and others, which is normally acquired at around age 4, is considered a particularly important development in theory of mind in that it marks the emergence of a representational concept of mind, whereby children

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implicitly understand that mental states are *subjective representations* of the world that are independent of and not necessarily congruent with reality (Astington & Gopnik, 1991; Perner, 1991; Wellman, 1990). From the vantage point of the theory of mind hypothesis, an impaired ability to represent mental states, and the limited awareness of oneself and other people that this implies, provides a compelling explanation for the failures in communication and reciprocal social interaction that characterize autism (Baron–Cohen, 1988; Happé, 1994; Tager–Flusberg, 1999).

In contrast to the theory of mind hypothesis, the executive functions account of autism (Pennington, Rogers, Bennetto, Griffith, Reed, & Shyu, 1997; Russell, 1997) attributes autistic symptomatology to deficits in broader, domain-general, executive control processes that are not specific to social cognition (see Joseph, 1999, for a review). Executive functions have been described as consisting of those "mental operations which enable an individual to disengage from the immediate context in order to guide behavior by reference to mental models or future goals" (Hughes, Russell, & Robbins, 1994). More specifically, executive functions are thought to involve several interacting but potentially dissociable mental operations, including working memory, inhibition, mental flexibility, and planning (Dennis, 1991; Ozonoff, 1997; Ozonoff, Strayer, McMahon, & Filloux, 1994; Robbins, 1996). Deficits in executive control processes have been proposed as a cause of not only the rigid and repetitive behavior patterns that characterize autism (Damasio & Maurer, 1978) but also of the core impairments in communication and reciprocal social interaction. In executive terms, social–communicative competence requires on-line updating, evaluation, and selection of appropriate responses to a constant stream of multifaceted (verbal, nonverbal, contextual) information (Bennetto, Pennington, & Rogers, 1996; Hughes & Russell, 1993). The executive dysfunction account of autism has been formulated largely as an alternative to the theory of mind hypothesis. Its proponents have argued that executive deficits are potentially more primary and may possibly account for the theory of mind impairment in autism (Pennington et al., 1997; Russell, 1997), based on evidence that executive functions tasks are better at discriminating individuals with autism than are theory of mind tasks (Ozonoff, Pennington, & Rogers, 1991) and that performance on measures of executive functions and false belief understanding are correlated in autism (Ozonoff et al., 1991; Russell, Mauthner, Sharpe, & Tidswell, 1991).

Most research on theory of mind and executive functions deficits in autism has followed a classic group comparison design, with the goal of demonstrating autism-specific deficits in these domains. However, an alternative and potentially powerful approach has been to assess the degree to which individual differences in theory of mind or executive functions can account for variations in autistic symptoms (see Hughes, 2001; Travis, Sigman, & Ruskin, 2001). This individual differences approach has the obvious value of assessing whether impairments in theory of mind or executive functions are directly associated with the actual behaviors that define autism, but efforts to link theory of mind or executive functions deficits to levels of symptomatology in autism have thus far produced mixed results.

Thus, for example, a lack of false belief understanding has been linked to deficits in conversational ability (Capps, Kehres, & Sigman, 1998) and adaptive social functioning (Frith, Happé, & Siddons, 1994) in individuals with autism. However, one important consideration in assessing such links is whether they are independent of language ability, which is related to both the false belief test performance (Happé, 1995) and symptom severity (Bailey, Phillips, & Rutter, 1996) in autism. In fact, the associations that were found between false belief understanding and symptom severity were not statistically significant when the variation in language ability was taken into account (Capps et al., 1998; Fombonne, Siddons, Achard, Frith, & Happé, 1994). In another study, Travis et al. (2001) reported no relationship between false belief test performance and two observational measures of social interaction skills in school-age children with autism. Two additional studies showed that training on mental state attribution resulted in enhanced performance on theory of mind tasks in children with autism, but these effects were not accompanied by improvements in social competence (Ozonoff & Miller, 1995) or communicative competence (Hadwin, Baron–Cohen, Howlin, & Hill, 1997). Across all these studies, it is notable that the measures of severity in social and communicative functioning were limited either to single symptoms or to indirect measures that did not correspond to conventional diagnostic criteria for autism (American Psychiatric Association [APA], 1994; World Health Organization [WHO], 1993).

Research on the relationship between executive functions and social–communicative deficits in autism (Dawson, Meltzoff, Osterling, & Rinaldi, 1998; Dawson, Munson, Estes, Osterling, McPartland, Toth, Carver, & Abbott, 2002; Griffith, Pennington, Wehner, & Rogers, 1999; McEvoy, Rogers, & Pennington, 1993) has focused mainly on younger children, for whom theory of mind tasks are not yet developmentally appropriate. Thus, the hypothesis that executive dysfunction is a primary deficit in autism with potentially greater explanatory power than theory of mind impairment has not yet been tested from an individual differences perspective. One exception is a series of studies conducted by Turner (1997) who examined the relationship of repetitive behaviors to performance on tests of executive functions and theory of mind in older children with autism. Using the Repetitive Behaviors Interview, Turner found that lower level repetitive behaviors, such as stereotyped motor behaviors, were associated with "recurrent" perseveration (i.e., simple response repetition) on the Intradimensional–Extradimensional set-shifting task, whereas higher level repetitive behaviors, such as circumscribed interests, were associated with "stuck-in-set" perseveration (i.e., inability to change set) on the set-shifting task and with impaired ability to produce novel responses on generativity tasks (see also Turner, 1999). In contrast, Turner (1997) found no association between false belief understanding and repetitive behaviors in individuals with autism.

In summary, there is as yet no compelling evidence that the social–cognitive abilities tapped by false belief tasks can explain differences in symptom severity in individuals with autism, giving some credence to arguments that success on false belief tests does not generalize to competencies in actual social–communicative functioning (Bowler, 1992; Frith, Morton, & Leslie, 1991; Happé, 1994; Klin, Schultz, & Cohen, 2000). However, the limitations of prior studies may explain these null results. For example, most studies have included samples that were either quite small or highly heterogeneous in age and ability, mitigating power to detect such a relation, particularly one that is independent of the variation in language ability. Furthermore, there has been little research comparing the explanatory power of the theory of mind and executive control abilities with regard to autistic symptomatology, especially in the domains of social and communicative functioning.

The goal of the present study was to examine the relationship of representational theory of mind ability (i.e., knowledge and false belief understanding) and executive functions to each other and to concurrent symptom severity in a reasonably large and fairly homogenous group of school-age children with autism. Our selection of a sample of verbally able children with a mean age of approximately 9 years ensured that false belief understanding served as a developmentally appropriate index of theory of mind ability because this is the verbal mental age at which roughly half of individuals with autism pass false belief tests (Happé, 1995). In addition, we administered multiple theory of mind tasks because the use of an aggregate approach has been shown to produce the most reliable measure of theory of mind abilities (Hughes, Adlam, Happe, Jackson, Taylor, & Caspi, 2000).

To assess executive functions, we selected an array of developmentally appropriate tasks designed to measure working memory, combined working memory and inhibitory control, and planning ability in children whose mental age was approximately 4–12 years. Working memory refers to the capacity to hold information "on-line" in mind while performing another mental operation or activity. Working memory deficits have been found in autism (Bennetto et al., 1996), but not consistently (Ozonoff & Strayer, 2001; Russell, Jarrold, &

Henry, 1996). Although there is no evidence of an autism-specific impairment in simple response inhibition (Hughes & Russell, 1993; Ozonoff et al., 1994; Ozonoff & Strayer, 1997), tasks that require a combination of working memory and inhibition (see Diamond, Prevor, Callender, & Druin, 1997) have reliably revealed executive function deficits in autism (Hughes, 1996; Hughes & Russell, 1993). Finally, planning ability, as measured on the Tower of Hanoi and Tower of London tasks, has consistently been found to be impaired in autism (Bennetto et al., 1996; Hughes et al., 1994; Ozonoff et al., 1991; Ozonoff & Jensen, 1999; Ozonoff & McEvoy, 1994). The Tower tasks require participants to rearrange a set of disks from their original configuration on three pegs to a prescribed goal state in as few moves as possible. In addition to measuring problem-solving and planning ability, these tasks have been conceptualized as tapping combined working memory (generating and maintaining a sequence of moves in mind) and inhibitory control (inhibiting direct placement of a disk to its final destination; Roberts & Pennington, 1996; Russell et al., 1996).

We assessed symptom severity in each of the three domains of core impairment in autism as defined by *DSM-IV* (APA, 1994) and International Classification of Diseases 10 (ICD-10; WHO, 1993) criteria and measured on the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999; see also Lord, Risi, Lambrecht, Cook, Lenventhal, DiLavore, Pickles, & Rutter, 2000). Although the ADOS includes only communication and reciprocal social interaction behaviors in its formal diagnostic algorithm, we also assessed the relationship of theory of mind and executive functions to repetitive behaviors from the ADOS for exploratory purposes, given their relevance to the executive dysfunction hypothesis of autism (Turner, 1997). In addition to providing a direct measure of the defining behavioral features of autism, an important advantage of the ADOS is that the summary score for each symptom domain is based on ratings of *several* behaviors selected to discriminate autism. The use of these summary scores would be expected to increase the reliability of our symptom measures relative to prior studies that used dependent measures based on single behaviors (Capps et al., 1998; Travis et al., 2001), and it would thereby increase the possibility of revealing the associations with theory of mind and executive functions.

An additional issue of interest was the relationship of general cognitive ability and particularly language ability to the variables under consideration. First, it is well-documented that theory of mind abilities in individuals with autism are strongly correlated with language ability (Happé, 1995; Tager–Flusberg & Sullivan, 1994; Yirmiya, Erel, Shaked, & Solomonica–Levi, 1998). Second, it has been hypothesized that formal and pragmatic language deficits contribute to executive deficits in autism (Hughes, 1996; Liss, Fein, Allen, Dunn, Feinstein, Morris, Waterhouse, & Rapin, 2001; Russell, 1997 ; Russell, Jarrold, & Hood, 1999). Third, language level and general intellectual ability are important prognostic factors with regard to symptom severity in autism (Bailey et al., 1996; Lord & Paul, 1997). Thus, an important consideration in the current study was whether associations between theory of mind ability, executive functions, and symptom severity in autism could be established independently of their shared relationships with language skills and broader cognitive abilities.

Methods

Participants

The 31 children (27 males, 4 females) in the study had *DSM-IV* clinical diagnoses of autism or Pervasive Development Disorder—Not Otherwise Specified (PDD-NOS). They ranged in age from 5 years 7 months (5;7) to 14;2 (M = 8;9, SD = 2;5) and were recruited through community sources to participate in a longitudinal study on language functioning and social cognition in autism. All participants met the criteria for autism on the Autism Diagnostic Interview—Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994). All participants also met the criteria for autism (n = 27) or for a less severe diagnosis of autism spectrum disorder (n = 4) on Module 3 of the ADOS (Lord et al.,

Table 1. *Participant characteristics (N = 31)*

	M	*SD*	Range
Age (years;months)	8;9	2;5	5;7–14;2
DAS			
Verbal IQ	83	20.0	51–118
Nonverbal IQ	88	22.8	49–153
EVT standard score	78	19.6	40–114
PPVT-III standard score	83	21.1	40–134
ADI-R[a]			
Communication	17.8	3.9	9–25
Social interaction	21.6	4.8	11–29
Repetitive behaviors	6.9	2.8	3–12

[a]The diagnostic thresholds for the ADI-R communication, social interaction, and repetitive behavior domains are 8, 10, and 3, respectively.

1999). Two children from our original sample of 33, both of whom had clinical diagnoses of PDD-NOS and met criteria for autism on the ADI-R, did not meet the criteria for autism or Autism Spectrum Disorder on the ADOS and were therefore excluded from the study. Children with Rett syndrome, Childhood Disintegrative Disorder, or autism-related medical conditions (e.g., neurofibramatosis, tuberous sclerosis, fragile X syndrome) were not included in this study. Their IQs were assessed with the Differential Ability Scales (DAS; Elliott, 1990), which yield a full scale, as well as separate verbal and nonverbal, IQ scores. Language level was assessed with the Expressive Vocabulary Test (EVT; Williams, 1997) and the Peabody Picture Vocabulary Test (PPVT-III; Dunn & Dunn, 1997), which are measures of one-word expressive and receptive vocabulary, respectively. The participant characteristics are described in Table 1.

Measures

All measures were administered in two visits scheduled approximately 2 weeks apart. During the first visit, diagnostic assessments and IQ and language testing were completed. During the second visit, separate batteries of theory of mind and executive function tasks were administered in counterbalanced order. Within each battery, individual tasks were administered in randomized order. In order to reduce the Type I error associated with multiple comparisons, several composite measures were formed from the tests that were administered, each of which was justified by the intercorrelation of its component measures, as described below.

Language

Language measures included age-equivalent scores from the EVT and the PPVT-III. Because the PPVT-III and EVT were developed with the same normative sample and the two scores were strongly correlated in our sample, r (29) = .78, $p < .001$, we averaged the age-equivalent scores from these tests to generate a composite language score for each child. We used age-equivalent scores rather than age-adjusted standard scores because they were more suitable for comparison to the theory of mind and executive function measures, which were also not adjusted for age.

Nonverbal mental age (NVMA)

NVMA served as our measure of general cognitive ability. It was calculated by averaging the age-equivalent scores for all the DAS nonverbal subtests for each participant. As with the language level, an age-equivalent rather than a standardized score was used because the other measures were not adjusted for age.

Theory of mind

Three standard tasks designed to assess knowledge and false belief attribution were administered to each child.

Perception knowledge. Based on Pillow (1989) and Pratt and Bryant (1990), this task tested the ability to infer knowledge from perceptual access. On two trials, children were shown that an object was concealed in a small box. Next, they observed one (female) doll who looked in the box and another (male) doll who simply touched the box, and they were asked a *knowledge question* ("Does he/she know what's in the box?").

Location-change false belief. Based on Wimmer and Perner (1983), this task included two stories told with props in which an object is moved to a new location while the main character is absent. For each story, participants were asked a *knowledge question* ("Does X know where Y is?"), a *false belief question* ("Where will X look first for Y?"), and a *false belief justification question* ("Why?").

Unexpected-contents false belief. Based on Perner, Leekam, and Wimmer (1987) and Gopnik and Astington (1988), participants were shown two different familiar containers that contained unexpected contents. Each of two trials included a *false belief in self question* ("When you first saw this box, what did you think was inside?"), a *knowledge question* ("If I show this box to X, will X know what is inside?"), and a *false belief in other question* ("What will X think is inside?").

Two trials of each test question yielded a possible score of 0–2, for a total possible theory of mind score across the seven test questions of 0–14. Corrected item-total correlations between individual test questions and total theory of mind scores ranged from .54 (for the unexpected contents false belief in other question) to .78 (for the location change knowledge question). Chronbach's alpha for the seven test questions comprising the theory of mind measure was .90, indicating high internal consistency.

Executive functions

Five executive functions tasks were administered, providing measures of *working memory* (Word Span, Block Span) *working memory and inhibitory control* (Day–Night, NEPSY Knock–Tap), and *planning* (NEPSY Tower). Each task was preceded by a brief training procedure, consisting of a maximum of four practice trials, to ensure participants' comprehension of task instructions. No corrective feedback was given during test trials.

Word span. The word span task was similar to the "nonverbal recall" span task used by Russell et al. (1996), except that in the present study a backward, as well as a forward, condition was included. In the forward task, children heard the examiner speak a sequence of words at the rate of one word per second. For each trial, a fixed sequence was randomly preselected from a set of nine words, all of which were single-syllable, high-frequency concrete nouns (arm, boat, brush, chair, dress, knife, mouse, ring, tree). After each sequence was spoken, participants were immediately presented with a 3×3 grid containing nine line drawings corresponding to the set of nine words, and they were instructed to touch the pictures in the same order as the words were spoken. For each trial, the arrangement of the pictures in the grid changed so as to prevent children from using a fixed visual representation of the array to help encode the word sequence and to introduce a visual search component to the task (thus requiring participants to maintain the word sequence in working memory while searching for and pointing to each successive item). Following the word span forward task, all participants were administered a word span backward task, which was exactly the same as the forward task except that children were instructed to touch the pictures in the reverse order from the spoken sequence. For both the forward and backward tasks, children were given two different trials of each sequence length, which ranged from two to seven words. One point was given for each correct trial. Testing was discontinued when a child failed both trials of any one sequence length.

Block span. In the block span test (Isaacs & Vargha–Khadem, 1989), children were asked to watch as the examiner pointed to an unstructured array of nine identical, black blocks affixed to a white board and to point to the blocks in the same sequence as the examiner in the blocks forward test and in the reverse order from the examiner in the blocks backward test. Children were administered two different trials of each sequence length, which ranged from two to eight blocks, and they earned one point for each correct trial. Testing was discontinued when a child failed both trials of any one sequence length.

The word and block span tasks were similar in that they required participants to update, rehearse, and maintain information in working memory and to use that information to carry out a response. Although the word and block span tasks differed in the modality of input (auditory vs. visual) and the backward tasks were more demanding of working memory capacities than the forward tasks in that they required mental manipulation of the response sequence, scores on all four tasks were highly intercorrelated. Therefore, a composite score was generated for each participant for a total possible span score of 0–52. Chronbach's alpha for the four component span measures was .82, indicating high internal consistency for the composite span measure.

Day–Night. Following the same procedure as Gerstadt, Hong, and Diamond (1994), children were instructed to say "day" to a picture of the moon and stars and "night" to a picture of the sun. Participants were presented with eight moon and eight sun stimuli in pseudorandom order for a total of 16 test trials.

Knock–Tap. This task was taken from the NEPSY (Korkman, Kirk, & Kemp, 1998) and was administered according to the standard procedure. Children were instructed to knock with their knuckles on the table when the examiner tapped with flat palm and vice versa. A total of 15 trials were given in pseudorandom order.

Both the Day–Night and Knock–Tap tasks required participants to hold an arbitrary response rule in working memory and to inhibit a prepotent response (to name the picture shown, to copy the hand movement of the examiner). However, the scores on these tasks were weakly correlated ($r = .27$, *ns*) and were therefore treated as separate variables.

Tower. The NEPSY Tower (Korkman et al., 1998), which was modeled after Shallice's (1982) Tower of London, was used as a measure of planning ability and administered according to the standard NEPSY procedure. Children were asked to rearrange three different colored balls situated on three vertical pegs to reach a goal state, shown on a picture board, in a prescribed number of moves without violating the rules (moving only one ball at a time directly from one peg to another). There was a total of 20 possible trials, which increased in difficulty from one to seven moves for the correct solution. Following NEPSY procedures, only trials solved in the optimum (i.e., fewest possible) number of moves were scored as correct and awarded one point, for a total possible score of 0–20. Testing was discontinued after four consecutive incorrect responses.

The executive functions tasks were chosen on the basis of their expected sensitivity to executive deficits in children within the age and ability range we studied. Given that the span tasks began with a relatively simple sequence of two and continued until the highest attainable sequence was reached, there was little likelihood of floor or ceiling effects on these measures. The NEPSY Knock–Tap and Tower tests were specifically designed for children from the ages of 5 through 12 years, which corresponded well with the age range of our sample. Although typically developing children have been found to reach near-ceiling levels of accuracy (~90% correct) by the age of 7 years on the Day–Night test (Gerstadt et al., 1994), we included this measure because of prior evidence that tasks requiring combined working memory and inhibitory control are particularly difficult for children with autism (see Joseph, 1999).

Symptom severity

The severity of autism symptoms was assessed using the ADOS (Lord et al., 1999). The ADOS involves a series of experimenter-administered social events and "presses" designed to provide quantitative ratings of communicative, reciprocal social, and repetitive behaviors. All participants in this study met the minimum language requirements (flexible sentence production, use of language to refer beyond the immediate context, ability to make logical connections within a sentence) for ADOS Module 3.

The dependent variables taken from the ADOS included the communication total score and the social interaction total score from the Module 3 diagnostic algorithm. The communication total score is derived from four items, making a possible score of 0–8, and the social interaction total score is derived from seven

Table 2. *Internal coherence of ADOS symptom domains (N = 31)*

	Item-Total Correlations	ID α
Communication items (α = .69)		
Stereotyped/idiosyncratic use of words or phrases	.50	.63
Reporting of events	.54	.59
Conversation	.66	.56
Gestures	.33	.71
Social interaction items (α = .63)		
Unusual eye contact	.33	.62
Facial expressions directed to others	.46	.56
Insight	.38	.60
Quality of social overtures	.63	.50
Quality of social response	.10	.65
Amount of reciprocal social communication	.52	.55
Overall quality of rapport	.09	.67
Repetitive behaviors items (α = .44)		
Unusual sensory interests	.10	.51
Hand and finger and other complex mannerisms	.26	.35
Excessive interest in unusual or highly specific topics	.35	.25
Compulsions or rituals	.29	.32

Note: The statistics for each of the three symptom domains were calculated separately. The item-total correlations were corrected. ID α, alpha if item deleted.

items, making a possible score of 0–14. Higher ADOS scores reflect increased symptom severity. According to test documentation (Lord et al., 1999), items included in the communication and social interaction algorithm totals were selected from all available items with the goal of operationalizing the *DSM-IV*/ICD-10 criteria for each domain. Further, items were chosen on the basis of their relatively low correlations with other items from each scale and their ability to discriminate between individuals with autism, individuals with PDD-NOS, and nonautistic individuals in the ADOS validity sample. The construction of separate communication and social interaction scales was supported by confirmatory factor analyses (Lord et al., 1999). A third dependent variable taken from the ADOS was derived from the four repetitive behavior items included in Module 3, with a possible score of 0–8. The repetitive behaviors score was not included in the final ADOS diagnostic algorithm because it did not assist in classifying individuals in the validation sample (Lord et al., 1999). However, scores on all but one of the items (*unusual sensory interests*) were significantly higher in individuals with autism than in nonautistic individuals in the validation sample.

Table 2 shows the internal coherence and item-total correlations for each of the ADOS symptom domains in the present sample. The Chronbach's alpha values for the ADOS communication, social interaction, and repetitive behaviors scales were .69, .63, and .44, respectively.

Results

Prior to statistical analyses, a screening was conducted to check for skewness, kurtosis, and outliers in the distribution of the data for each variable. At an alpha level of .05, the screening revealed a negative skew in the distribution of Day–Night scores. Because of the negative skewness, the Day–Night variable was reflected and a logarithmic transformation was applied, resulting in a relatively normal distribution. The transformed variable was again reflected in order to shift values in the correct direction. In addition, the ADOS repetitive behaviors scores showed positive skew, which were also corrected to normal with a logarithmic transformation. Table 3 provides the participants' (untransformed) scores on all measures.

Table 3. *Means (M), standard deviations (SD), and ranges for test scores (N = 31)*

	M	*SD*	Range
Nonverbal mental age (years;months)	7;6	2;9	3;6–16;3
Language age[a] (years;months)	6;4	2;4	3;4–12;11
Theory of mind	7.4	4.9	0–14
Executive functions			
Total span	15.7	6.8	4–26
Day–Night	12.5	4.4	0–16
Knock–Tap	10.4	4.2	2–15
Tower	7.4	4.3	2–15
ADOS symptom severity[b]			
Communication	5.2	1.8	2–8
Social interaction	9.1	2.2	5–14
Repetitive behaviors	1.9	1.74	0–8

[a]The averaged age-equivalent scores from PPVT-III and EVT.
[b]Higher scores reflect increased symptom severity. Diagnostic threshold scores for Module 3 ADOS communication and social interaction domains are 3 and 6 for an autism diagnosis, and 2 and 4 for a less severe autism spectrum disorder diagnosis, respectively. Repetitive behaviors are not included in the diagnostic algorithm.

Effects of age, NVMA, and language level

Table 4 displays the full and partial correlations among the main variables with the effects of NVMA and the effects of language level each removed separately. As can be seen in the full correlations, age was associated with NVMA, language level, and total span score only. NVMA and language level were highly correlated with each other. Further, both of these measures were significantly correlated with theory of mind ability and with performance on all of the executive functions tasks, except Day–Night. The only notable difference in the relationships of these two variables to theory of mind and executive functions measures was that language level was much more strongly associated with theory of mind ability than was NVMA; language level explained 53% of the variance in theory of mind scores, whereas NVMA explained 18%. In addition, language level explained significant variance in ADOS social interaction and particularly communication symptoms, but NVMA was not significantly correlated with any of the ADOS symptom scores.

Relationships between executive functions and theory of mind ability

As can be seen in Table 4, before the effects of NVMA or language level were removed, all executive functions scores were significantly correlated with theory of mind and with each other, with the exception that Day–Night was correlated only with total span. When NVMA and language level were partialed out, among the executive functions measures, total span and Day–Night, and Knock–Tap and Tower remained significantly correlated, possibly reflecting a shared verbal working memory component between the former two tests and a shared motor inhibition component between the latter two. Knock–Tap was the only executive functions measure to remain significantly correlated with theory of mind independently of both nonverbal ability, r (28) = .59, $p < .01$, and language level, r (28) = .48, $p < .01$. The association between these variables was moderately strong, with 23–35% of variance shared between them after NVMA and language level were partialed, suggesting that the capacity for combined working memory and inhibitory control specifically contributes to a representational understanding of mental states in this group of children.

Relationship of executive functions and theory of mind ability to symptom severity

The relationship of executive functions and theory of mind to symptom severity was examined separately for each ADOS symptom domain. When NVMA was controlled, both the Knock–Tap score, r (28) = −.48, $p < .01$, and the Tower score, r (28) = −.45, $p < .05$, were inversely related to communication symptoms, but correlations between these variables were not significant when language level rather than NVMA was partialed. Similarly, Knock–Tap was significantly correlated with repetitive behaviors symptoms, r (28) = −.50, $p < .01$, when NVMA was controlled, but not when language was controlled.

Table 4. *Full and partial correlations between measures (N = 31)*

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Age	—										
2. Nonverbal mental age	.38*	—									
3. Language age	.42*	.63***	—								
4. Total span	.56**	.73***	.55**	—							
5. Day–Night	.29	.16	.21	.44* .47** .39*	—						
6. Knock–Tap	.02	.44*	.53**	.51** .31 .31	.27 .22 .19	—					
7. Tower	.17	.61***	.49**	.51** .11 .33	.10 .00 .00	.59** .45* .44*	—				
8. Theory of mind	.22	.43*	.73***	.55** .37* .25	.39* .36 .35	.67*** .59** .48**	.42* .22 .11	—			
9. ADOS communication	−.17	−.33	−.58**	−.38* −.21 −.09	−.33 −.29 −.26	−.55** −.48** −.36	−.54** −.45* −.36	−.78*** −.75*** −.64***	—		
10. ADOS Social Interaction	−.05	.12	−.36*	.01 −.12 .26	−.06 −.09 .01	−.18 −.25 .02	−.18 −.32 −.01	−.46** −.57** −.31	.71*** .80*** .67***	—	
11. ADOS Repetitive Behaviors	.16	.08	−.34	.06 .00 .31	−.05 −.07 .02	−.41* −.50** −.30	−.05 −.13 .14	−.46** −.56** −.34	.52** .58** .42	.60*** .59** .54**	—

Note: The first correlation is full, the second is partialed for nonverbal mental age, and the third is partialed for language age.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Theory of mind was correlated with both social interaction symptoms, r (28) = −.57, $p < .01$, and repetitive behaviors symptoms, r (28) = −.56, $p < .01$, when NVMA was controlled, but these correlations were not significant when language was controlled. In contrast, theory of mind was significantly correlated with the level of communication symptoms regardless of whether NVMA, r (28) = −.75, $p < .001$, or language ability, r (28) = −.64, $p < .001$, was partialed out. Thus, independent of NVMA and language, theory of mind accounted for 41–56% of the variance in communication symptoms. The T tests for assessing nondirectional (two-tailed) differences between nonindependent correlations (Bruning & Kintz, 1987) showed that the language-partialed correlation between theory of mind and communication symptoms was of significantly larger magnitude than that between theory of mind and social interaction symptoms, t (28) = 2.88, $p < .01$, and that it was of marginally larger magnitude that that between theory of mind and repetitive behavior symptoms, t (28) = 1.96, $p < .10$.

In addition to the correlational analyses, multiple regression analyses were conducted to examine the combined contribution of executive functions and theory of mind ability to the severity of symptoms in each domain. First, language level was entered into each equation as a control variable. Language was the only control variable included because neither age nor NVMA correlated significantly with symptoms scores. Second, the theory of mind and executive function variables were entered in the order of highest statistical significance using a forward stepwise procedure. Table 5 shows the regression coefficients and the increments in variance explained at each step for each model.

Language ability accounted for 33% of the variance in the ADOS communication score, F (1, 29) = 14.4, $p < .01$. The next entered variable was theory of mind ability, which accounted for an additional 28% of variance, F_{inc} (1, 28) = 19.6, $p < .001$. Finally, the Tower score explained an additional 5% of variance in the communication symptoms, F_{inc} (1, 27) = 4.3, $p < .05$. None of the other executive functions variables contributed significantly to the model. Because of a potential overlap in the variance explained by the theory of mind and Tower scores, a second model was attempted in which Tower rather than theory of mind score was entered into the equation after language level. However, when entered independently of theory of mind ability, the Tower did not account for the significant additional variance in ADOS communication score. In addition, none of the other executive functions measures, whether entered individually or together, contributed to an increment in the variance explained. Language ability contributed relatively modestly to variance in ADOS social interaction score, $R^2 = .13$, F (1, 29) = 4.2, $p < .05$, and in ADOS repetitive behaviors score, $R^2 = .11$, F (1, 29) = 3.7, $p < .07$. Neither the theory of mind nor the executive functions measures accounted for additional variance in social interaction or repetitive behaviors symptoms.

Table 5. *Summary of regression analyses assessing contribution of theory of mind and executive functions to ADOS symptom scores*

Variable	β	R^2	ΔR^2
DV ADOS Communication Score			
Step 1			
Language	−.58**	.33	.33**
Step 2			
Language	−.02		
Theory of mind	−.76***	.61	.28***
Step 3			
Language	.08		
Theory of mind	−.72***		
Tower	−.27*	.66	.05*
DV ADOS Social Interaction Score			
Step 1			
Language	−.36*	.13	.13*
DV ADOS Repetitive Behaviors Score			
Step 1			
Language	−.34	.11	.11

Note: For each dependent variable, the language score was forced into the model on the first step. Subsequent variables were entered in the order of highest statistical significance until the threshold criterion of $p = .05$ was reached.
*$p < .05$. **$p < .01$. ***$p < .001$.

One concern is that the relatively lower internal consistency of the ADOS social interaction and repetitive behaviors scores may have made it more difficult to detect a relationship between the predictor variables and the level of symptoms in these domains. Consequently, we increased the internal coherence of these measures by removing two weakly correlated items (Quality of Social Response, Overall Quality of Rapport) from the social interaction scale, raising the alpha coefficient to .72, and removing one weakly correlated item (Unusual Sensory Interests) from the repetitive behaviors scale, raising alpha to .51. However, when similar regression analyses were repeated with these modified dependent measures, the same results were obtained.

Discussion

We now discuss our findings with regard to (a) the relationship between theory of mind and executive functions and (b) the relationship of these two variables to symptom severity in the three domains of impairment that define autism.

Executive functions and theory of mind

It has been argued that executive control deficits contribute to and are possibly the primary cause of the well-documented deficits in mental state understanding among individuals with autism (Hughes, 2001; Russell, 1997). However, evidence supporting these claims has been limited (Ozonoff et al., 1991; Russell et al., 1991). In the current study, we examined representational theory of mind abilities in a group of rigorously diagnosed, school-age children with autism for whom understanding of knowledge and false belief was developmentally within the range of their cognitive and linguistic abilities. As such, this group of children could be expected to provide a revealing picture of developmentally limiting and enabling factors affecting the understanding of representational mental states in autism. Furthermore, we included a battery of executive functions measures that tapped a range of executive control processes and that were selected to be developmentally appropriate for the children in this study. We found that children's theory of mind performance was consistently related to the components of executive control we measured, but these associations did not hold up when the shared effects of nonverbal ability and particularly language level on these two variables were controlled.

One exception was the robust relationship we found between theory of mind and Knock–Tap performance, which was independent of both NVMA and language ability. The Knock–Tap task required children to combine inhibition and working memory in order to withhold a prepotent motor response (to copy the examiner's hand movement) by maintaining an arbitrary response rule (to knock when the examiner tapped and vice versa) in active memory. The requirements of the Knock–Tap test are formally similar to other executive tasks on which autism-specific deficits have been found (Hughes, 1996; Hughes & Russell, 1993) and to at least one other executive task that has been associated with false belief performance in autism (Russell et al., 1991). It was interesting that, although the Knock–Tap task was also similar in its demands to the Day–Night test we administered, performance on the latter was not correlated with theory of mind scores. One explanation for this lack of association was that there was a ceiling effect, reflected in the negative skew on the Day–Night measure, and that this skew was not adequately corrected by the transformation that was applied.

Our finding of an association between Knock–Tap and theory of mind performance suggests that domain-general executive processes, specifically the capacity for combined working memory and inhibitory control, may mediate or at least provide the necessary conditions for success on theory of mind tasks in children with autism, as has also been suggested for typically developing children (Carlson & Moses, 2001; Hughes, 1998a, 1998b). This makes sense given that successful attribution of false beliefs requires an individual to maintain a false representation of a given state of affairs in working memory and to resist the normal tendency to ascribe mental states on the basis of a prepotent reality. However, although these findings support the idea of a mediating role of executive functions in theory of mind in autism, it is not clear from these data, nor from prior studies, whether executive functions are mainly important for *performance* on theory of mind tasks or whether they are more deeply involved in the *conceptual* developments that are necessary for a representational understanding of mind (Moses, 2001). It is also important to note that the present data provide support for a role of executive functions in one specific aspect of theory of mind development, which normally occurs around age 4 and involves the ability to represent epistemic mental states, such as knowledge and belief. Numerous authors have proposed a broader perspective on theory of mind that would include the ability to read mental states from more immediately available perceptual information, such as body movements, eye gaze, and facial expressions (Hobson, 1989, 1991; Klin, Jones, Schultz, Volkmar, & Cohen, 2002a; Ruffman, 2000; Tager–Flusberg & Sullivan, 2000). It is likely that these more direct aspects of mentalizing are less dependent on higher order, domain-general cognitive capacities than is the ability to reason about people's beliefs, but there has been no research investigating the relationship between executive functions and these other aspects of theory of mind.

Explaining symptom severity in autism

Our main goal in this study was to examine the explanatory power of deficits in theory of mind and executive functions with respect to actual severity of symptoms in autism. This individual differences approach to testing the theory of mind and executive functions hypotheses produced an interesting and novel pattern of findings. Both theory of mind and planning abilities, as measured by the Tower task, were inversely related to ADOS communication symptoms in school-age children with autism, and these relationships were established independently of the substantial variation in communication symptoms explained by differences in language development. In contrast, neither theory of mind ability nor any of our executive functions measures accounted for statistically significant variation in the severity of reciprocal social interaction or repetitive behaviors symptoms once language level was controlled.

It has long been argued that theory of mind impairments can explain the pragmatic communication deficits that are characteristic of children and adults with autism (Baron–Cohen, 1988; Happé, 1994; Tager–Flusberg & Anderson, 1991). However, prior studies directly examining the relationship between theory of mind and communication symptoms have failed to establish a relationship between these factors that was independent of language level (Capps et al., 1998; Tager–Flusberg & Sullivan, 1995). Several factors may have contributed to the positive findings of the present study. These include the relatively larger sample size, which increased the power to detect a relationship between these factors; the use of a more reliable, aggregate measure of theory of mind with a sample of children with autism for whom it was developmentally most appropriate; and the use of a multidimensional measure of communication impairment based on a range of observed behaviors that were empirically established to discriminate between children with and without autism and consistent with standard diagnostic criteria for autism.

Although the theory of mind and executive functions hypotheses have been conceptualized largely as alternative accounts of autistic symptomatology, we found that each of these abilities explained unique variance in autistic symptoms in the domain of communication. Deficits in theory of mind have often been hypothesized to underlie the core abnormalities in autistic language use and communication (Happé, 1994; Tager–Flusberg, 2000), and the present findings provide empirical support for that hypothesis. The knowledge and belief tasks comprising our theory of mind measure in essence tested participants' awareness of and ability to monitor the subjective contents of their own and others' minds. This type of ability would have an obvious bearing on the conversational discourse and narrative skills that are characteristically impaired in autism and that are specifically tapped by the ADOS communication scale. Items from this scale assessed children's ability to report events, to converse in socially appropriate and comprehensible ways by offering new information unrelated to preoccupations and relevant to the conversational context, and to respond contingently to the examiner's comments by building on what had been said and providing needed information. Such discourse skills would presuppose some awareness of oneself as a source of knowledge unknown to the examiner, as well as an awareness of and ability to gauge the examiner's interest and need for information, all of which arguably require a representational understanding of other minds.

There has been little discussion in the literature about the contribution of executive control deficits to communication impairments in autism, and thus far no studies have found a direct relationship between executive dysfunction and communication symptoms. Our data suggest that individual components of executive control (e.g., working memory, inhibitory control) do not have much explanatory power for autism symptoms in children of the age and ability level we studied, but more complex, higher order executive abilities, such as those measured on the Tower task, do. How might the cognitive skills tapped by the Tower task contribute to effective communicative functioning? The Tower task requires the integrated functioning of multiple cognitive operations, including complex reasoning, planning, working memory, and inhibitory control. Such skills would contribute to communicative competence by allowing a person to reflect and reason on-line in order to plan contributions to the ongoing discourse. Furthermore, the integrated functioning of the executive skills tapped by the Tower task would be important for maintaining and updating the course of conversation while bringing in relevant information from working memory and inhibiting responses that are out of turn or not on topic.

In contrast to our positive findings on the relationships between theory of mind and executive functions to autism communication symptoms, we did not find any statistically significant relationships to autism social or repetitive behavior symptoms, once the effects of language were controlled. Based on a direct measure of social symptom severity, these findings add to the literature suggesting that reciprocal social interaction deficits in autism cannot be explained in terms of language-independent impairments in theory of mind. Thus, as noted in the introductory section, Fombonne et al. (1994) found that the relationship between theory of mind and everyday social adaptation, such as that reported by Frith and colleagues (Frith et al., 1994), was mediated by language ability in individuals with autism. Furthermore, Travis et al. (2001) found no relationship between false belief understanding and their measures of peer interaction and prosocial behavior, which were similar to the behaviors we rated on the ADOS social interaction scale in the present study. Taken together, these findings suggest that social interaction deficits in autism are not directly attributable to an impaired ability to represent mental states.

At the same time, there is considerable face validity to the hypothesis that social impairments in autism may be related to difficulties in interpreting mental states in other people. Elsewhere we have argued that theory of mind encompasses not only social–cognitive reasoning, as tapped by false belief and other related cognitive tasks, but also social–perceptual abilities that involve more direct and implicit judgments of mental states based on information available in faces, voices, and body gestures (Tager–Flusberg, 2001). This view, which distinguishes between the social–perceptual and social–cognitive components of theory of mind, may help to clarify the role of mentalizing deficits in autistic social impairments (see also Klin et al., 2002a; Ruffman, 2000). Everyday reciprocal social interactions crucially depend on rapid, real-time judgments of information communicated through eye gaze, facial expressions, vocal intonation, and body movements. These aspects of social information processing are integral to establishing rapport with others and to evaluating responses to ongoing interactions. Such skills are not assessed by classic social–cognitive theory of mind tasks, as were used in this study, but have been incorporated into new measures such as the eyes task (Baron–Cohen, Joliffe, Mortimer & Robertson, 1997; Baron–Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), the parallel voices task (Kleinman, Marciano, & Ault, 2001), and the social attribution task (Klin, 2000). We suggest that the social–perceptual abilities tapped by these tasks may be linked to reciprocal social functioning in autism. Lending support to this hypothesis, Klin, Jones, Schultz, Volkmar, and Cohen (2002b) recently demonstrated that ADOS social symptoms in high-ability individuals with autism were inversely related to the time they spent looking at other people's faces in a naturalistic social situation. We should clarify that we are not suggesting that social–perceptual skills are unrelated to communicative functioning and the severity of communication symptoms in autism. To the contrary, we recognize that the ability to interpret nonverbal information that is conveyed, for example, through facial expressions, shifts of gaze, and body movements is doubtlessly a vital component of effective communication between humans. What our findings suggest, however, is that in the context of impaired social perception, higher level social–cognitive theory of mind abilities, and the linguistic and executive control abilities that support them, make an important contribution to the communicative competencies that are attained by some individuals with autism.

We also failed to establish a direct relationship between theory of mind or executive functions and repetitive behaviors symptoms in our sample of children with autism. The null findings with respect to theory of mind confirm an earlier study (Turner, 1997) and suggest that links between theory of mind and this symptom domain are mediated by language skills. We did not replicate Turner's more positive findings of specific links between different aspects of executive dysfunction and repetitive behaviors symptoms. One difference between our studies was in the choice of executive functions measures. Turner (1997) used the Intradimensional–Extradimensional set-shifting task and a set of ideational and design fluency tasks for assessing the ability to generate novel responses. In contrast, we used the Tower task and other measures of working memory and inhibitory control. A second difference was that, whereas we used the ADOS, Turner developed a more comprehensive Repetitive Behaviors Interview for assessing a wide range of symptoms in this domain. It is likely that our ADOS repetitive behaviors measure provided only a limited assessment of children's symptoms because it only included behaviors that were actually observed during the ADOS assessment. Furthermore, our data suggested that this measure had relatively low reliability as indicated by the Chronbach's alphas reported in Table 2. These differences may explain our failure to link repetitive behaviors symptoms to executive dysfunction in the present study.

There are several important qualifications that should be raised with regard to our data analyses and interpretations. First, although we have examined executive functions and theory of mind as predictors of severity of autism symptoms, our data are correlational and thus do not provide any definite empirical basis for ascribing a direction of causation. This leaves open the possibility that there are reciprocal or even unidirectional causal effects of symptom severity on developments in executive functions and theory of mind. Future longitudinal studies may be useful in elucidating the causal relationships between these variables.

Second, our main finding was that theory of mind and executive functions accounted for the significant variance in communication but not in social interaction or repetitive behavior symptoms when language ability was covaried. However, it should be noted that our sample size of 31 children did not provide sufficient statistical power to reliably detect moderate or small correlations between the variables of interest. Given this limitation, it is perhaps most accurate to conclude from our data that executive skills and theory of mind abilities are more strongly associated with communicative functioning than with reciprocal social functioning or repetitive behaviors in autism, rather than to suggest that executive functions or theory of mind abilities are simply unrelated to the latter two symptom domains. This conclusion was directly supported by our finding that the correlation between the theory of mind and ADOS communication score was statistically stronger than that between the theory of mind and ADOS social interaction or repetitive behaviors scores.

Third, one final issue concerns the relationship between communication and social interaction symptoms in autism, especially given that we found a differential pattern of relations between our theory of mind and executive functions variables and these two symptom domains. Although confirmatory factor analyses were used to justify separate ADOS subscale scores for communication and social interaction symptoms corresponding to the symptom domains defined by *DSM-IV*/ICD-10 (Lord et al., 1999), it has been questioned whether these two domains are truly independent and separable (Lord, 1990; Tanguay, Robertson, & Derrick, 1998). In fact, in the current sample, there was a strong association between communication and social interactions symptoms, even when NVMA and language level were controlled. However, even if impairments in communication and reciprocal social skills are largely overlapping, this does not preclude the possibility that theory of mind and executive function abilities selectively scaffold functioning in the communication domain of autistic symptomatology. Nevertheless, an important direction for future research investigating the neurocognitive underpinnings of the autism phenotype will be to develop empirically derived and validated factors that can index its various components. Such studies will require much larger samples than in the present study.

Summary and Conclusions

Our findings indicate that there are limited relationships between representational mental state understanding, executive functions, and symptom severity in autism. Most of the significant correlations that we found among our measures were accounted for by the mediating effects of language ability, underscoring the significant role that language plays in the social and cognitive developmental outcomes of children with autism. Our data confirmed that a representational understanding of mind and higher level executive functions are directly related to the severity of communication symptoms in autism, but the data suggested that social interaction symptoms are relatively independent of these skills. These findings are consistent with a distinction between the higher level cognitive–linguistic aspects of theory of mind that are measured by classic false belief tasks and more fundamental attentional and perceptual components of theory of mind that are largely independent of language ability and may provide more direct links to social interaction deficits in autism. Future research can address this hypothesis by exploring whether more direct measures of the social–perceptual component of the theory of mind are directly related to symptom severity in autism, especially in social reciprocity.

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