

How Specific is the Relation between Executive Function and Theory of Mind? Contributions of Inhibitory Control and Working Memory

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The relation between executive function (EF) and theory of mind (ToM) may involve specific processes of inhibition and/or working memory capacity contributing to ToM, or it might be a reflection of general intellectual ability. To differentiate these alternatives, we administered task batteries measuring inhibitory control (IC), working memory, and ToM, as well as measures of verbal and performance intelligence, to 47 typically developing preschool children. Inhibitory control tasks in which a dominant response needed to be suppressed while a subdominant response was activated (Conflict IC) significantly predicted performance on false belief tasks over and above working memory, the intelligence measures, a simple delay task (Delay IC), and age. In contrast, working memory, Delay IC, and intelligence were not significant in this analysis. Conflict IC, but not Delay IC, was related to working memory. Together, these findings suggest that the combination of inhibition and working memory (as reflected in Conflict IC tasks) may be central to the relation between EF and false belief understanding. Copyright © 2002 John Wiley & Sons, Ltd.

Key words: executive function; inhibitory control; theory of mind

One of the most robust changes in all of cognitive development occurs in the theory of mind domain in the preschool years. At the beginning of this period, at around age 3, children typically flounder when questioned about false beliefs, misleading appearances, and divergent perspectives. Yet, by the time they are 5 or 6, questions of this kind are more often than not answered with consummate ease (Flavell, 1999; Wellman, in press). These findings have lent themselves quite naturally to a conceptual change interpretation: What younger preschoolers lack,

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but older preschoolers have acquired, are new concepts of belief, mental representation, or perhaps representation in general (Flavell, 1988; Perner, 1991; Gopnik, 1993; Wellman *et al.*, 2001).

It seems very likely that conceptual insights of one kind or another play a significant role in theory of mind (ToM) advances in the preschool period. Still, other developmental processes may also be crucially implicated. In particular, advances in executive functioning (EF) are increasingly believed to be bound up with ToM development (Frye *et al.*, 1995; Russell, 1996; Hughes, 1998a,b; Perner and Lang, 1999; Carlson and Moses, 2001). The executive functions encompass a rather heterogeneous collection of skills that, in various ways, aid in the monitoring and control of thought and action. These skills include self-regulation, inhibitory control, planning, attentional flexibility, error correction and detection, and resistance to interference (Welsh *et al.*, 1991; Zelazo *et al.*, 1997).

How might EF affect ToM development? There are two general possibilities (Russell, 1996; Carlson and Moses, 2001). On the one hand, EF might affect the *expression* of pre-existing ToM capacities. Such a possibility arises because most tasks purporting to measure ToM also impose executive demands. For example, they typically require children to inhibit a salient aspect of reality in favour of a less tangible mental representation. At the very least, then, *some* level of executive skill is necessary for successful performance. Conceivably, children's failures on ToM tasks could reflect problems channelling already present conceptual knowledge into successful task performance. On the other hand, EF might also affect the very *emergence* of ToM capacities. A certain level of executive ability may need to have developed before children could even begin to construct complex concepts of mental life. It is certainly difficult to imagine how they could acquire such concepts without some capacity to disengage themselves from salient aspects of the real world. A creature without such a capacity, for example, would be entirely unable to consider the possibility of alternative perspectives on that world.

Circumstantial evidence for a link between EF and ToM comes from several sources. First, EF and ToM share a common developmental timetable: Both develop markedly in the preschool period (Reed *et al.*, 1984; Gerstadt *et al.*, 1994; Kochanska *et al.*, 1996; Zelazo *et al.*, 1996). Second, both sets of skills appear to be subserved by a common brain region (the prefrontal cortex) in adults (Luria, 1973; Rothbart and Posner, 1985; Frith and Frith, 1999; Channon and Crawford, 2000; Sabbagh and Taylor, 2000), suggesting that similar cognitive processes may be involved.¹ Third, both EF and ToM are deficient in autistic individuals (Ozonoff *et al.*, 1991; Hughes *et al.*, 1994; Russell, 1997), again consistent with the view that these skills are cognitively bound together.

Direct tests of the EF hypothesis suggest that the existence of this circumstantial evidence is more than coincidental. For example, manipulations designed to increase or decrease the executive demands of ToM tasks affect children's performance in predictable ways (Carlson *et al.*, 1998; Leslie and Polizzi, 1998; Hala and Russell, 2001). For example, Carlson *et al.* (1998) found that children performed poorly when required to point to an empty location to deceive an opponent. However, performance was greatly improved when they were given the opportunity to use novel methods of deception (placing a pictorial cue on the empty container or indicating that container with a game board arrow). Carlson *et al.* argued that pointing to where things really are is likely to be a prepotent response for young children, and hence the inhibitory demands would be high. In contrast, the novel methods of deception would not be affected

by a prepotent response history, and so the inhibitory demands of the task would be considerably diminished.

An alternative and converging source of evidence for a relation between these domains comes from a series of recent correlational studies, all indicating that individuals with relatively strong executive abilities perform better on various ToM tasks than do those with weaker executive abilities (Frye *et al.*, 1995; Hughes, 1998a,b; Hughes *et al.*, 1998; Carlson and Moses, 2001; Perner and Lang, 2000). For example, Carlson and Moses found a very strong correlation ($r=0.66$) between preschoolers' performance on an inhibitory control battery (assessing children's ability to suppress inappropriate but prepotent responses of various kinds) and their performance on a ToM battery (assessing understanding of deception, false belief, and appearance–reality). Importantly, the batteries remained significantly related when age, gender, and verbal ability were held constant (see Perner and Lang, 2000, for similar findings). The commonly found EF–ToM relation is thus not a spurious byproduct of the fact that, for example, developments in both domains just happen to co-occur in the same age range or that successful task performance in these domains requires a certain amount of verbal ability. Moreover, the relation persisted when additional factors, which are, or could well be, related to both EF and ToM, were statistically controlled. These factors included number of siblings, symbolic play ability, motor sequencing, and performance on control tasks designed to be similar to ToM tasks but not requiring attribution of mental states.

Clearly, these findings constitute a *prima facie* case for the specificity of the EF–ToM relation, and suggest further that inhibitory control, in particular, may be central to the relation. Nevertheless, it remains possible that other, more general cognitive advances underlie the relation. For example, although a number of studies have attempted to control for general intellectual ability, they have typically assessed only one facet of intelligence, namely verbal ability. However, inhibitory control is believed to be central to non-verbal ('performance') intelligence, as well as to verbal intelligence (e.g. Dempster, 1991; McCall, 1994). If so, the EF–ToM relation might disappear if a broader measure of intelligence were controlled. In the one study that did include such a measure (Hughes, 1998a), results were mixed. When both verbal and performance intelligence were held constant, EF continued to predict deceptive ability but not false belief understanding. Hence, the extent to which the relation between the EF and ToM domains is independent of general intelligence is unresolved.

Moreover, working memory is a more specific cognitive ability that is believed to underpin most executive skills (Roberts and Pennington, 1996), and so could well be responsible for relations between such skills and other abilities like ToM. Working memory is a system for temporarily holding in mind and processing of information (Baddeley, 1986). Olson, Keenan, and their colleagues (Olson, 1993; Gordon and Olson, 1998; Keenan *et al.*, 1998) have proposed that advances in working memory are in part responsible for ToM development in the preschool period. They point out that the ability to hold in mind conflicting perspectives is necessary for both the acquisition and expression of much ToM knowledge. Consistent with their proposal, a number of studies have found moderate relations between ToM and working memory (Hughes, 1998a; Gordon and Olson, 1998; Keenan *et al.*, 1998), and these relations persist over and above age and verbal ability (Davis and Pratt, 1996; Keenan, 1998). It is possible then that inhibitory tasks relate to ToM only in virtue of their working memory demands, and that such relations would disappear if working memory were held constant.

An alternative possibility is that *both* inhibition and working memory are implicated in ToM development (see Russell, 1997; Carlson and Moses, 2001). In this regard, Carlson and Moses found that conflict inhibition tasks (requiring children to inhibit an inappropriate prepotent response while activating a conflicting novel response) related more strongly to ToM than did delay inhibition tasks (requiring children simply to inhibit responding). Both conflict and delay tasks require inhibition but only the conflict tasks appear to impose substantial working memory demands. In this way, the conflict tasks are like ToM tasks that require children to suppress their knowledge of reality while activating a seemingly incompatible representation of that reality. Hence, the combination of working memory and inhibition may be critical (cf. Diamond, 1991).

In sum, there is evidence suggesting a specific relation between EF and ToM that might be underpinned by inhibitory processes. However, it remains possible that the relation is not unique to inhibitory control but is instead a product of (a) general intellectual ability, or (b) working memory. The aim of the following study was to test these alternatives by examining the relative contributions to preschoolers' ToM of inhibitory control, general intelligence, and working memory. This aim was achieved by giving a sample of preschoolers short batteries of ToM, inhibitory control, and working memory tasks, as well as an assessment of both verbal and performance intelligence. The tasks in the ToM and inhibitory control batteries were subsets of those used by Carlson and Moses (2001). The ToM battery included appearance–reality and false belief tasks. The inhibitory tasks had previously been found to correlate with ToM but to tap somewhat different aspects of inhibitory control. In particular, the inhibitory battery included measures of both conflict inhibition and delay inhibition. The inclusion of both kinds of inhibitory tasks made possible a direct test of the hypothesis described earlier that conflict tasks impose greater working memory demands than do delay tasks. The working memory battery included both span tasks and a dual processing task. These tasks required children to hold in mind information while either manipulating it in a different way or processing some other information.

If inhibition is central to the EF–ToM relation, it should remain significant when working memory, as well as age, gender, and both verbal and non-verbal intelligence are controlled. Similarly, if working memory is central, it should remain significant over inhibition and the controls. If *both* inhibitory control and working memory are implicated, then they each should make unique contributions to ToM (and/or conflict inhibition tasks imposing high working memory demands should make especially strong contributions to ToM). Finally, if inhibition and working memory relate to ToM only as proxies for general intelligence, then neither should relate to ToM once intelligence is controlled.

METHOD

Participants

The participants were 47 normally developing preschool children ($M=4;6$, range = 40–66 months, 21 boys and 26 girls). Two additional children did not complete the study. The sample was predominantly European American and middle class. Children were recruited by telephoning parents listed in a database derived from birth announcements.

Procedure

Children were tested individually in a videotaped laboratory session lasting approximately 45 min. The measures consisted of two verbal and two performance sub-scales of the WPPSI-R (Wechsler, 1989), a ToM Battery, an Inhibitory Control (IC) Battery, and a Working Memory (WM) Battery. Each measure is described in detail in the following section. The fixed order of tasks was WPPSI-R—Picture Completion; Appearance–Reality; Bear/Dragon; Counting and Labeling; WPPSI-R—Vocabulary; Contents False Belief; Backward Digit Span; WPPSI-R—Block Design; Whisper; Standard Location False Belief; and WPPSI-R—Arithmetic. The same female experimenter tested all children.

Measures

Intelligence Measures

Children were given four major subscales of the WPPSI-R: Vocabulary and Arithmetic from the verbal subscale, and Block Design and Picture Completion from the performance subscale. For Vocabulary, children were orally presented with a word (e.g. 'glow,' 'nuisance') by the experimenter (E) and asked to define it. They were scored on the basis of their definition, with 0 = no understanding of the word, 1 = partial understanding, and 2 = complete understanding. For Arithmetic, children were asked a series of numerical concept questions of increasing difficulty (e.g. "Which picture shows *more* [books]?"). For Block Design, children had to replicate E's designs by placing red and white tiles in a pattern within a certain time limit (measured using a stopwatch). For Picture Completion, children had to discover the missing component for each picture in a series. Reliability coding for these and all other tasks was conducted on a randomly selected 32% of the sample ($n = 15$). Disagreements were resolved by a third coder. Coding reliability (Cohen's kappa) was: 0.85 for Vocabulary; 0.98 for Arithmetic; 0.95 for Block Design; and 0.97 for Picture Completion.

Theory of Mind Measures

Appearance–Reality. Following Flavell *et al.* (1983, 1986), each child was shown two objects with misleading appearances. One involved a discrepancy between real and apparent identity (i.e. a piece of sponge painted to look like a rock), and the other involved a discrepancy between real and apparent colour (i.e. a picture of a red castle that looked black when held behind a green filter). For each stimulus, children first were shown how the object looked and the true identity or true colour of the object. Next they were asked the appearance question, "When you look at this right now, does it look [like a sponge/red] or does it look [like a rock/black]," and the reality question, "What [colour] is this really and truly, [a sponge/red] or [a rock/black]?" Children were credited with passing each task if they answered both questions correctly. One child did not respond to the "look" question for the castle. Children received an Appearance–Reality score ranging from 0 to 1 (proportion correct) to account for this missing data point.

False Belief. Children's false belief understanding was assessed using three False Belief questions—two from a Contents False Belief task and one from a Location False Belief task. In the Contents False Belief task, following the procedure of Perner *et al.* (1987) and Gopnik and Astington (1988), children were shown a Band-Aid box and asked what they thought was inside. After discovering that the box actually contained crayons, the lid was closed, and

children were asked about their own former false belief: "When you first saw this box, before you opened it, what did you think was inside, Band-Aids or crayons?" Next, they were told that Ernie (a puppet) had never looked inside the box before and were asked, "What does he think is inside, Band-Aids or crayons?" Finally, they were asked the reality control question, "What is really inside the box?" Children were scored for their knowledge of their own former belief and the other's current false belief. All answered the control question correctly. Data from one 3-year-old and one 5-year-old were missing on this task because they refused to answer the question regarding Ernie's false belief.

In the Location False Belief task (Wimmer and Perner, 1983), two puppets (Bert and Ernie) played with a ball briefly and then Bert put the ball in a blue container and left. Ernie retrieved the ball, played briefly with it, and then put it away in a red container and left. Finally, Bert returned, wanting to play with the ball, and children were asked the False Belief question ("Where does Bert think the ball is?") followed by the reality question. One 4-year-old erred on the reality question and gave a different (but incorrect) response to the think question. She was not given credit for passing.

Children received a False Belief score ranging from 0 to 1 (proportion correct) to accommodate the small amount of missing data. There was perfect agreement between coders on all theory of mind assessments.

Inhibitory Control Measures

Bear/Dragon. The Bear/Dragon task (Reed et al., 1984; Kochanska et al., 1996) is a simplified version of "Simon Says" in which children need to selectively suppress commanded actions. To begin, E asked children to imitate the following 10 actions: stick out your tongue; touch your ears; touch your teeth; touch your eyes; clap your hands; touch your feet; touch your head; touch your tummy; touch your nose; and wave your hand. E then introduced two puppets. The first was described as a "nice Bear"; "So when he talks to us, we will do what he tells us to do." The second was described as a "naughty Dragon"; "So when he talks to us, we won't listen to him. If he tells us to do something, we won't do it." Practice trials followed, in which E moved the Bear's mouth and said (in a high-pitched voice), "Touch your nose," and then moved the Dragon's mouth and said (in a low, gruff voice), "Touch your tummy." Children passed the practice if they followed the Bear's command but ignored the Dragon's. All children but four (three 3-year-olds and one 4-year-old) succeeded on the Bear practice the first time. For the Dragon puppet, children who failed 5 practice trials in a row were told that a second E would help them on a final practice trial by holding their hands down on the table (performance on the Dragon practice is described under Results). Children then received a rule check to determine whether they remembered that they should follow the commands of the Bear but not those of the Dragon. Three children (one 3-, one 4-, and one 5-year-old) refused to respond to the rule checks and so were told the correct answers. All others answered correctly on the first try. Ten test trials followed (5 Bear trials and 5 Dragon trials, alternating order) in which children were given no assistance. They were reminded of the rules after 5 trials regardless of performance. Children received scores ranging from 0 to 3 on each Dragon trial: 0 = a full commanded movement; 1 = a partial commanded movement; 2 = a wrong movement; 3 = no movement. Coding reliability (kappa) was 1.0 on Bear trials and 0.98 on Dragon trials.

Whisper. This task called for voluntary lowering of the voice (Kochanska *et al.*, 1996). To warm-up, E gave children a practice trial in which they were asked to whisper their names. Practice trials were repeated as necessary (see Results for performance on practice trials). Then they were asked to whisper the names of 10 cartoon characters consecutively presented on laminated cards. Six of the characters were familiar (Big Bird, Pocahontas, Donald Duck, Snow White, The Beast, and Mickey Mouse) and four were unfamiliar to most children of this age (Huckle, Elmer Fudd, Petunia, and Fat Albert). The unfamiliar characters were included so that when a familiar character would appear, children might be more tempted to shout out its name. E spoke in a whisper throughout and reminded children to whisper after the first 5 trials. Scoring was as follows: 0 = a shout, 1 = a normal or mixed voice, and 2 = a whisper. Coding reliability (kappa) was 0.87.

Gift Delay. This measure called for delay of gratification (Kochanska *et al.*, 1996). E told children she had a present for them, but wanted it to be a "big surprise." She asked them to sit in a chair facing away and to try not to look while she wrapped the gift. She then noisily wrapped the gift over a period of 60 s. Finally, she invited children to open their present (a small toy animal). Coding included (a) a peeking score (0 = turning fully around to peek; 1 = peeking over the shoulder; 2 = no attempt to peek); (b) the total number of times children peeked; and (c) latency to peek over the shoulder (60 s for full compliance). Data from one 3-year-old were missing on this task due to camera malfunction. Coding reliability was as follows: peeking score, kappa = 0.80 (all were within a score of 1); number of peeks, kappa = 1.0; latencies were within 0.5 s on 93% and within 1 s on 100% of double-coded cases.

Working Memory Measures

Counting and Labeling. In this task designed to measure dual-task performance (Gordon and Olson, 1998), E presented three toys (a car, a hammer, and a dog). First, she named and pointed to each object in turn. Second, she counted while pointing to each object, "1, 2, 3." Finally, she enumerated and stated the name for each of the three objects, "One is a car, two is a hammer, and three is a dog." Children were then given 3 items of their own (a doll, a shoe, and a spoon) and instructed to repeat the steps E had performed (i.e. enumerate, label, and then interlace numbers and labels). They were corrected, as needed, after steps one and two but not after step three. Children received two trials for the final step in the task. Coding reliability (kappa) was 0.87.

Backward Digit Span. Following Davis and Pratt (1996) children were asked to repeat a list of single-digit numbers in reverse order. E used a puppet to demonstrate saying digits backward. For example, E said, "Ernie's being silly, so whatever I say, he says backward. Like this, if I say the numbers '1, 2,' Ernie says '2, 1.'" Children were then asked to do as Ernie had done. They were given a 2-digit practice trial, corrected if wrong, and then the test trials. List size increased with each successful trial (2, 3, and 4 digits) and we recorded the highest level achieved for each child (1–4). Children who failed the 2-digit list were given a score of 1.

Backward Word Span. In this task we adapted the Davis and Pratt (1996) method by asking children to repeat a list of single-syllable, non-semantically related words in reverse order. Again, Ernie demonstrated saying words backward (e.g. E said, "book, cup" and Ernie replied, "cup, book"), followed by a practice trial (corrected, if necessary) and then the test trials. List size increased with each successful trial (2, 3, and 4 words). This adaptation was included because we

thought that younger children's number knowledge might be limited. One 5-year-old refused to complete this task. Perfect coder agreement was obtained on both span tasks.

RESULTS

We first describe the results for the battery assessments individually, followed by the major analyses of the relations among them.

Intelligence Assessment

Scores on the four assessments of the WPPSI-R were within the normal range for children this age (Vocabulary $M=18.2$, $S.D.=8.8$, range = 3–40; Arithmetic $M=12.2$, $S.D.=4.2$, range = 2–19; Block Design $M=16.6$, $S.D.=7.5$, range = 3–32; Picture Completion $M=17.5$, $S.D.=3.4$, range = 8–25). The intelligence measures were significantly intercorrelated, $r_s > 0.42$, $p_s < 0.01$, and thus standardized scores were aggregated to form an overall IQ score for each participant (Cronbach's alpha = 0.76). IQ was significantly correlated with age, $r(47) = 0.76$, $p < 0.001$, but not gender. Because typically only verbal abilities have been examined in relation to theory of mind, we also created separate Verbal IQ (Vocabulary and Arithmetic, $r(47) = 0.59$, $p < 0.001$; controlling for age, $r(44) = 0.38$, $p = 0.01$) and Performance IQ (Block Design and Picture Completion, $r(47) = 0.52$, $p < 0.001$; controlling for age, $r(44) = 0.29$, $p < 0.06$) aggregates for further analyses.

Theory of Mind Assessment

As is clear from the top portion of Table 1, ToM performance varied as a function of age, with significant improvement occurring from 3 to 5 years. Scores on the Appearance–Reality and False Belief measures were positively but non-significantly interrelated, $r(47) = 0.26$, ns. Therefore, we examined them separately in subsequent analyses. For both Appearance–Reality and False Belief, performance was significantly related to age, $r_s(47) = 0.47$ and 0.62, respectively, $p_s < 0.001$. Both ToM measures also were significantly related to IQ (overall, Verbal, and Performance), $r_s = 0.46$, 0.46, and 0.36, respectively, for Appearance–Reality; $r_s = 0.45$, 0.46, and 0.35, respectively, for False Belief, all $p_s < 0.02$. The ToM measures were unrelated to gender.

Executive Function Assessment

Inhibitory Control. Mean scores on each of the inhibitory measures are shown in the middle portion of Table 1. As with theory of mind, older children generally outperformed younger children, although the difference was significant only for the Dragon trials on the Bear/Dragon task. The dependent measures that were significantly correlated within each inhibitory task were standardized and averaged to create a single score for each task. The number of practice trials required (reversed) for the Dragon was correlated with overall Dragon scores on Bear/Dragon, $r(47) = 0.34$, $p < 0.02$. On the Whisper task, the number of practice trials required (reversed) was related to mean scores on the test trials, $r(47) = 0.73$,

Table 1. Means and S.D. on theory of mind, inhibitory control, and working memory tasks as a function of age

Task (range of possible scores)	3-year olds (<i>n</i> = 12)	4-year olds (<i>n</i> = 19)	5-year olds (<i>n</i> = 16)	Total (<i>n</i> = 47)	Age effects (univariate <i>F</i>)
<i>Theory of mind</i>					
Appearance-Reality (0-1)	0.58(0.29)	0.84(0.34)	0.91(0.20)	0.80(0.31)	$F(2,44) = 4.81^*$
False Belief (0-1)	0.36(0.33)	0.68(0.36)	0.92(0.15)	0.68(0.36)	$F(2,44) = 12.02^{***}$
<i>Inhibitory control</i>					
Bear/dragon				1.19(0.8)	$F(2,44) = 0.71, ns$
Drag practice (1-6)	1.25(0.62)	1.32(1.16)	1.0(0.00)	13.68(3.82)	$F(2,44) = 4.43^*$
Dragon score (0-15)	11.08(6.71)	14.26(1.88)	14.94(0.25)		
Whisper				1.06(0.32)	$F(2,44) = 0.48, ns$
Practice (1-3)	1.08(0.29)	1.11(0.46)	1.0(0.00)	1.93(0.16)	$F(2,44) = 1.11, ns$
Mean score (0-2)	1.87(0.16)	1.95(0.18)	1.96(0.13)		
<i>Gift delay</i>					
Peek score (0-2)	1.09(0.83)	1.21(0.86)	1.38(0.89)	1.24(0.85)	$F(2,43) = 0.37, ns$
Total no. peeks (0-6)	1.91(2.17)	1.63(1.92)	1.07(1.71)	1.51(1.9)	$F(2,43) = 0.68, ns$
Latency (0-60)	36.33(26.22)	40.29(23.5)	41.64(250.09)	39.81(24.24)	$F(2,43) = 0.16, ns$
<i>Working memory</i>					
Count and Label (0-2)	0.75(0.97)	1.44(0.81)	1.69(0.60)	1.34(0.86)	$F(2,43) = 5.01^*$
Digit span (1-4)	1.58(0.79)	1.95(0.78)	2.88(1.02)	2.17(1.01)	$F(2,44) = 8.52^{***}$
Word span (1-4)	1.58(0.79)	2.21(0.86)	2.80(0.94)	2.24(0.97)	$F(2,43) = 6.55^{**}$

Note: *N* = 47 except on Gift Delay where *N* = 46.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

$p < 0.001$. All Gift Delay scores were highly correlated, r_s ranging from 0.87 to 0.89, $p_s < 0.001$.

Two of the three inhibitory measures—Bear/Dragon and Whisper—were significantly correlated, $r(47) = 0.31$, $p < 0.04$. However, both of these tasks were unrelated to performance on Gift Delay, $r_s(46) = 0.08$ and 0.07 for Bear/Dragon and Whisper, respectively. Based on these findings and previous research suggesting a distinction between conflict and delay facets of inhibitory control (Carlson and Moses, 2001), we aggregated the Bear/Dragon and Whisper scores into a single Conflict measure (Cronbach's $\alpha = 0.48$). As with the ToM measures, the Conflict Battery was significantly related to age, $r(47) = 0.53$, $p < 0.001$, and IQ (overall, verbal, and performance), $r_s(47) = 0.46$, 0.53 , and 0.30 , $p_s < 0.01$, 0.001 , and 0.05 , respectively, but was unrelated to gender. Performance on Gift Delay was not related to age, gender, or the intelligence measures.

Working Memory. Mean scores on each working memory measure are shown in the bottom portion of Table 1. Clear evidence emerged of age-related changes in working memory capacity on each task. Errors on Counting and Labelling were indicative of problems simultaneously performing both tasks. The most common error (48%, excluding non-responses or "I don't know") was to perseverate on one level of one dimension while processing the second dimension (e.g. "One ball, one dog, one spoon"). Other errors included stating only the numbers or only the labels, and saying all the numbers first and then all the labels (or vice versa). On Backward Digit and Backward Word Span, 80% of the errors entailed repeating the digits or words in the same order they were given. The intercorrelations among the working memory measures were highly significant: between the two span tasks, $r(47) = 0.70$; between Count and Label and Digit Span and Word Span, $r_s(47) = 0.48$ and 0.56 , respectively, all $p_s < 0.001$. Therefore, all three tasks were standardized and aggregated to form a WM Battery score for each child (Cronbach's $\alpha = 0.81$). As with ToM and Conflict IC, WM Battery scores were significantly related to both age, $r(47) = 0.61$, and IQ (overall, verbal, and performance), $r_s(47) = 0.71$, 0.64 , and 0.63 , respectively, $p_s < 0.001$, but not to gender.

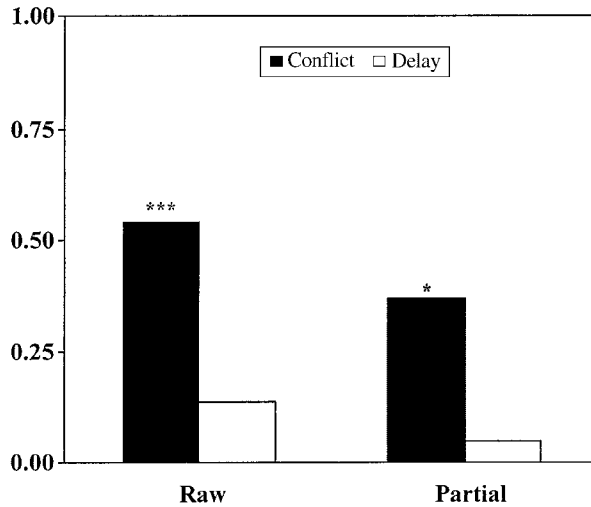
Relation between Inhibitory Control and Working Memory. As shown in Figure 1, the Conflict Battery was highly correlated with the WM Battery, and this relation remained significant controlling for age and IQ. As predicted, however, children's performance on the Delay task did not correlate with working memory. There was thus further reason for separately analysing two distinct kinds of inhibitory measures: a relatively pure measure of control over impulsive responses (delay task) and measures that appear to impose both inhibitory and working memory demands (conflict tasks).

Specifying the Relation between Executive Function and Theory of Mind

The next and most critical series of analyses were aimed at specifying the relative contributions of IC, WM, and general intelligence to ToM.

Inhibitory Control and Theory of Mind

Table 2 shows the correlations between IC and ToM. The Delay measure was positively but not significantly related to the theory of mind measures. In contrast, the Conflict Battery was significantly related to both Appearance–Reality and False Belief. When age and IQ were partialled, the Conflict Battery remained significantly related to False Belief but not to Appearance–Reality.



Note. $N = 47$ for correlations involving Conflict IC, $N = 46$ for those involving Delay.
 * $p < .05$ *** $p < .001$

Figure 1. Raw and partial correlations (controlling for age and IQ) between Conflict/Delay Inhibition and Working Memory.

Table 2. Raw and partial correlations between inhibitory control and working memory and theory of mind

Measure	Theory of Mind	
	Appearance–reality	False Belief
Inhibitory control		
Delay	0.19(0.13)	0.17(0.09)
Conflict	0.30*(0.05)	0.52*** (0.30*)
Working memory battery	0.36*(0.03)	0.39**(0.03)

Note: Partial correlations controlling for age and IQ are shown in parentheses. All tests two-tailed. $N = 47$, except on correlations including Delay where $N = 46$.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

These findings go beyond those obtained previously in suggesting that the relation between inhibitory control and false belief persists when performance IQ in addition to verbal IQ is controlled.

Working Memory and Theory of Mind

The correlations between WM and ToM are also shown in Table 2. WM Battery scores were significantly related to both Appearance–Reality and False Belief. Despite these significant raw correlations, and in contrast to the findings for conflict inhibition, partial correlations between WM and the theory of mind

measures controlling for age and IQ were non-significant (and close to zero). The results were very similar when verbal IQ (instead of overall) was partialled along with age. Moreover, the WM-AR and WM-FB correlations were not significant when age alone was partialled, $r_s(44)=0.11$ and 0.01 , respectively. Unlike inhibitory control, no evidence emerged that working memory was specifically related to theory of mind independent of age or general cognitive ability.

Regression Analyses

To further assess the unique contributions of IC and WM to ToM, we carried out standard linear multiple regressions in which all variables of interest were entered simultaneously. In the first of these, conducted at the aggregate level, we entered Conflict IC, Delay IC, and the WM Battery variables, along with age and IQ, as predictors of False Belief scores. The overall equation was highly significant, $F(5, 40)=6.75$, $p<0.001$. Table 3 shows the regression weights and t values for each of the predictor variables. Conflict IC significantly predicted False Belief performance over and above Delay IC, WM, and the controls. In contrast, WM did not predict False Belief over and above Conflict IC, Delay IC, and the controls. Age was significant in this analysis, but not IQ.²

Two further regression analyses were conducted to determine whether we might have inadvertently underestimated the contribution of WM to ToM. In the first of these, we assessed whether our aggregation of the working memory variables had obscured important aspects of the WM-ToM relation. In this analysis, all three of the individual WM tasks were entered simultaneously along with Conflict IC, Delay IC, age, and IQ as predictors of False Belief. Conflict IC was again a significant predictor with Delay IC, the individual WM measures, and the controls held constant, $\beta=0.32$, $t(39)=2.17$, $p<0.04$. However, consistent with the main regression analysis, none of the individual WM tasks made unique contributions to variance in False Belief ($p_s>0.31$). Age, but not IQ, was again a significant predictor in this analysis, $\beta=0.51$, $t(39)=2.62$, $p<0.02$. In the second of these analyses we considered the possibility that false belief and working memory might in fact share substantial unique variance but that this relation was masked by the inclusion of the control variables. Hence, in this analysis Conflict IC, Delay IC, and the WM Battery were entered simultaneously as predictors of False Belief, but the control variables were excluded. Once again, however, Conflict IC was a highly significant predictor of False Belief over and above WM and Delay, $\beta=0.44$, $t(43)=2.93$, $p<0.01$, whereas WM failed to reach statistical significance over and above Conflict and Delay, $p=0.39$. These additional analyses therefore provided converging evidence that conflict inhibition shared unique variance with False Belief performance, whereas working memory did not.

Table 3. Simultaneous multiple regression for variables predicting false belief scores

Variable	<i>B</i>	S.E. <i>B</i>	Beta	<i>T</i>
Age	0.026	0.009	0.533	2.813**
IQ	-0.008	0.046	-0.037	-0.182
Conflict IC	0.043	0.021	0.299	2.073*
Delay IC	0.028	0.045	0.072	0.615
Working memory	-0.037	0.074	-0.086	-0.491

Note: $N=46$. Multiple $R=0.67$, $R^2=0.45$, Adjusted $R^2=0.38$, S.E. = 0.28.

* $p<0.05$; ** $p<0.01$.

In a series of regression analyses parallel to the above three except with Appearance–Reality as the criterion, all results were non-significant. That is, Conflict IC, Delay IC, and the WM Battery (or the individual WM tasks) did not predict unique variance in Appearance–Reality, with or without age and IQ included. Additionally, neither age nor IQ was a significant predictor in these analyses.

DISCUSSION

How does a child come to develop a theory of mind? Certainly conceptual advances must engender young children's developing awareness of their own and others' mental states and such advances may well reflect the replacement of older, inadequate theories with more adaptive ones (Gopnik, 1993; Gopnik and Meltzoff, 1997; Wellman *et al.*, 2001). That said, many other factors are likely to play critical roles in the emergence and expression of theories of mind. A number of candidates have already been identified. These include language skills (e.g. Astington and Jenkins, 1999), pretend play (e.g. Taylor and Carlson, 1997) and having an older sibling (e.g. Ruffman *et al.*, 1998), as well as parenting variables such as discipline style (Hughes *et al.*, 1999; Ruffman *et al.*, 1999; Pears and Moses, 2001) and amount of parental mental-state talk (Dunn *et al.*, 1991; Bartsch and Wellman, 1995). In the research reported here we have focused in particular on one factor—executive function—which is believed by many to be somehow bound together with ToM development (Frye *et al.*, 1995; Russell, 1996; Hughes, 1998a; Perner and Lang, 1999; Carlson and Moses, 2001). Previous studies of links between EF and theory of mind, while mounting the evidence in favour of such a relation, left unresolved the precise nature of this relation. Specifying the relations between broad constructs such as EF and ToM is critical to advancing meaningful theories of development (cf. Gopnik and Meltzoff, 1987). Without such specificity, EF accounts remain powerless to isolate the underlying mechanisms contributing to normal ToM development and, by extension, to provide insight into clinical deficits associated with its disruption. What is needed, then, is an attempt to identify the aspects of EF that are most strongly implicated in ToM development.

The present study represents such an attempt. Given prior findings (e.g. Hughes, 1998a; Hughes *et al.*, 1998; Carlson and Moses, 2001) indicating that individual differences in inhibitory control and ToM were strongly positively related, we focussed particularly on whether inhibitory functioning could be shown to be a specific contributor to theory of mind. Our aims were threefold. First, we sought to determine whether the IC–ToM relation would survive once general cognitive ability was controlled. Second, we addressed whether the relation would persist once working memory—which is believed to underpin executive abilities—was held constant. Finally, we examined which aspects of inhibition might be most strongly implicated in ToM development.

Our findings confirm earlier research suggesting that inhibitory control does indeed relate strongly to false belief performance. Moreover, the results strongly suggest that the relation is a specific one. The association persisted even when age and a broad measure of intelligence including both verbal and performance aspects was controlled. With the exception of Hughes (1998a), previous work on this topic has relied exclusively on measures of verbal ability as an index of cognitive ability. Yet we found that both IC and false belief understanding were

also related to performance intelligence. The finding that the IC–false belief relation holds up over this additional aspect of intellectual ability is therefore an important one. Our findings in this respect are broadly consistent with those of Hughes, although she had found that inhibition related over general intelligence to deception but not to false belief.

We also found that inhibition predicted false belief even when working memory (in addition to the other controls) was held constant. This finding, coupled with those of previous research demonstrating that the relation between IC and ToM survives when other controls are included (e.g. mental state control tasks, motor sequencing, pretend actions, number of siblings—see Carlson and Moses, 2001), constitutes strong evidence that inhibitory functioning is central to the relation between executive function and theory of mind. Furthermore, not only was inhibition a unique predictor of false belief performance, it also appeared to be *sufficient* to explain the EF–false belief relation. That is, working memory failed to relate to false belief over and above IC. In fact, individual differences in working memory did not predict false belief independently of age and general cognitive ability. Here our results are again consistent with those of Hughes (1998a) who found that inhibitory control predicted deception over age and intelligence whereas working memory was related only at the level of raw correlations.

Of course, the results of any study depend on the particular measures employed. Perhaps, for example, the working memory measures we chose simply did not tap variation in executive functioning in this age range as well as did the inhibitory measures. There is little support for this possibility in the data, however. The working memory tasks all showed sufficient variability to correlate highly with false belief, if working memory was indeed closely intertwined with ToM. Moreover, as noted earlier, the working memory measures cohered more tightly than did the inhibitory measures. Given this superior reliability of the working memory measures, the finding that inhibition predicts false belief over controls but WM does not is all the more compelling.

We also replicated Carlson and Moses' (2001) finding that not all IC tasks relate strongly to ToM. In particular, conflict tasks, but not a delay task, predicted false belief, and this difference persisted with age and intelligence controlled. These results were not due to the delay task simply being easier for children: The Gift Delay, Bear/Dragon, and Whisper tasks were of comparable difficulty and showed similar variability.

While conflict and delay tasks differ along a number of dimensions, that of greatest relevance to ToM, in our view, is working memory. Conflict tasks (like Bear/Dragon and Whisper) require children not only to suppress an inappropriate response, but also to activate a conflicting response, hence imposing working memory demands as well as inhibitory demands. In contrast, delay tasks (like Gift Delay) simply require children to inhibit responding (e.g. wait until the experimenter gives a signal). The working memory demands of such tasks would appear to be relatively light. False belief tasks are like conflict tasks in that they impose both working memory and inhibitory demands. That is, they require children to simultaneously hold in mind two representations (working memory), and to select the representation and corresponding behavioural response that directly conflicts with children's own salient perspective, which must be actively suppressed (inhibition). Our findings are thoroughly consistent with this analysis of why only conflict tasks relate to false belief. It was Conflict IC, and not Delay IC, that was significantly related to working memory. This was the case even when age and intelligence were held constant.

Our proposal then is that some combination of working memory and inhibition may be critical for mental state attribution. The proposal explains why tasks that draw heavily on IC but less so on WM (e.g. delay tasks) are not strongly related to false belief, why tasks that draw heavily on WM but less so on IC (e.g. span tasks) are not strongly related to false belief, and why tasks that draw heavily on *both* (e.g. conflict tasks) relate strongly to false belief. In this respect, our hypothesis shares considerable similarity with proposals that prefrontal functions involve an interaction between inhibitory processes and working memory (Bjorklund and Harnishfeger, 1990; Dempster, 1991; Diamond, 1991; Diamond and Taylor, 1996; Roberts and Pennington, 1996; Miyake *et al.*, 2000). Diamond and her colleagues have found that even 3-year olds perform well when an executive task places demands on working memory alone, but they do poorly when both working memory and inhibitory control are involved. For example, Gerstadt *et al.* (1994) showed that young preschoolers could remember the rules to say "day" when presented with one abstract design and to say "night" when presented with another. However, they had considerable difficulty when required to say "day" in response to a moon card and "night" in response to a sun card. While both tasks impose working memory demands, only the latter imposes inhibitory control demands. In another study using the day-night task (Diamond *et al.*, in press), 3-year olds readily responded with the words "pig" and "dog" when shown the sun and moon cards (working memory), yet they were again unable to perform the standard version of the task (working memory plus inhibition).

The present study thus provides strong evidence for specificity in the EF-ToM relation and for the centrality of conflict inhibition. That said, it remains possible that other aspects of executive functioning might contribute to ToM, or even subserve the relations we observed. While this possibility cannot be definitively ruled out at this point, some evidence speaks against it. For example, Carlson and Moses (2001) found that an executive motor sequencing task, in which children had to plan and execute a finger-tapping sequence, was unrelated to theory of mind after age and verbal ability were controlled. In a more thorough investigation of the role of planning employing multiple measures (e.g. Tower of Hanoi and planning how to load a truck for the most efficient delivery), Moses and Carlson (2000) reported that planning was not significantly related to ToM once age and verbal ability were partialled. In contrast, conflict inhibition was again a strong predictor, and this relation held up over the controls and planning ability. Finally, although Hughes (1998a) obtained a relation between attentional flexibility and deception, the attentional flexibility measures appeared to incorporate inhibitory components as well (e.g. shifting to a new set from an earlier and now prepotent one). Therefore, it might well be the case that these measures would no longer predict ToM with inhibitory control held constant.

While our findings of specificity were strong for false belief, this was not the case for Appearance-Reality. Both Conflict IC and WM were significantly related to Appearance-Reality in bivariate correlations. However, these correlations did not persist when age and IQ were controlled. Executive tasks with inhibitory components have been found to relate to Appearance-Reality in previous research, controlling for age and/or verbal ability (Frye *et al.*, 1995; Carlson and Moses, 2001). Perhaps, then, our inclusion of a broader measure of intelligence reduced the relations. Against this, however, the relations did not survive even when age but not intelligence was controlled. For reasons that are unclear, then, it may just be the case that the role of inhibition and working memory

is greater for false belief than for Appearance–Reality, and that relations with the latter are difficult to detect when samples are relatively small as in the present study. It is noteworthy in this respect that in Frye *et al.* (1995), correlations between their executive measure (Dimensional Change Card Sort) and Appearance–Reality were somewhat weaker than those between EF and false belief.

Several issues with respect to the EF–ToM relation remain unresolved. As noted in the introduction, executive theories come in two varieties (Moses, 2001). Emergence accounts propose that children must first have the ability to suppress salient representations of reality in order to entertain less tangible mental representations (Russell, 1996; Carlson and Moses, 2001). In this view, EF skills are necessary for a theory of mind to get off the ground, although surely not sufficient for its full development. In contrast, expression accounts focus more on the EF requirements for children to show what they might already know on ToM tasks (e.g. Carlson *et al.*, 1998; Hala and Russell, 2001; Leslie and Polizzi, 1998). These two accounts map well onto Johnson's (1998) discussion of differing views of the role of prefrontal cortex in cognitive development more generally. In the first of these views, structural developments in the frontal cortex occur at particular ages, *enabling* advances in certain cognitive skills (e.g. Diamond, 1991). On this view, EF is integrally linked to the emergence of specific cognitive abilities at specific time periods corresponding to brain maturation. In the second view regarding the role of the frontal cortex in cognitive development, EF is *recruited* any time individuals are learning novel skills (e.g. Case, 1992; Thatcher, 1992). To the extent that learning a new skill (such as attributing mental states) is taxing and effortful, general purpose frontal functions including working memory and inhibition ought to be involved. Which of these accounts more accurately captures the observed relation between executive abilities and ToM has yet to be determined.

A second unresolved issue concerns the direction of causality between EF and ToM. On the one hand, as just discussed, EF developments in the early preschool years might be important predecessors of either the ability to understand false beliefs or the ability to express that understanding; on the other hand, the emergence of a theory of mind, and the metarepresentational abilities which attend it, might enable advances in executive abilities. With respect to the latter possibility, Perner and Lang (1999, 2000) have argued that children must first have the capacity to metarepresent habitual response tendencies before they can control them. Our pattern of correlations does not definitively rule out either of these alternatives but it is certainly more consistent with an EF to ToM causal account. For example, if ToM were causally primary, it is hard to explain why false belief would relate to conflict inhibition but not to delay inhibition. As we understand it, the relations should be similar on Perner and Lang's account. Moreover, in a longitudinal investigation, Hughes (1998b) found that the relation between EF skills at age 3 and ToM at age 4 was stronger than that between ToM at 3 and EF at 4, again suggesting that some level of executive functioning may be necessary for ToM to develop.

In sum, while many theoretically important questions about the EF–ToM relation remain, our findings help to constrain the answers. The relation between these two domains is not a simple product of general advances in intellectual ability, working memory, or even inhibition. Rather, as in other areas of cognitive development (Diamond, 1991), the combination of working memory and inhibition appears to be intimately bound together with theory of mind development.

Notes

1. Of course, the existence of common neural processes does not guarantee the operation of common cognitive processes: the same brain region may be involved in quite different psychological processes (Johnson, 1998). Our point is only that a shared neural substrate is at least consistent with the possibility that EF and ToM are in some way cognitively linked.
2. The results were similar when the variables predicting False Belief were entered in blocks. The first block included age and IQ, $R^2=0.3892$. In the second block, WM was added, $R^2=0.3897$, accounting for an additional 0.05% of the variance (ns). In the third block, Delay IC was added, $R^2=0.3942$, accounting for an additional 0.5% of the variance (ns). In the final block, Conflict IC was added, $R^2=0.4516$, accounting for an additional 5.7% of the variance in False Belief scores over and above working memory, Delay IC, and the controls, $p < 0.05$. We also conducted a corresponding analysis in which age and IQ were entered at step 1, Delay IC at step 2, Conflict IC at step 3, and WM at step 4. The change in R^2 in the final step was 0.0032; that is, working memory contributed 0.3% to variance in false belief over and above inhibition and the controls (ns).

ACKNOWLEDGEMENTS

Portions of this paper were presented in L. J. Moses & S. M. Carlson (co-Chairs), *Executive function and theory of mind*. Society for Research in Child Development, Albuquerque, NM, 1999. The research was funded in part by a University of Oregon Summer Research Award. We thank Laura Claxton, Serena Word, Mary Clark, and Antoinette Wong for assistance with data collection and coding.

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