A longitudinal assessment of the relation between executive function and theory of mind at 3, 4, and 5 years

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Abstract:

This longitudinal study contributes to the growing literature on the predictive nature of the relation between executive function (EF) and theory of mind (ToM). A latent variable model was fit to the data acquired from 226 socioeconomically and racially diverse children (52% female) at 3, 4, and 5 years of age on a number of age-appropriate tasks designed to assess EF and ToM. After controlling for sex, income-to-needs, and receptive language ability, there was substantial stability within each construct as children aged. In addition, EF at 3 years predicted ToM at 4 years but ToM did not predict EF, replicating earlier results. This pattern also appeared from 4 to 5 years of age, suggesting that the developmental precedence of EF persists later in development. Implications of these findings are discussed in terms of contemporary cognitive development theories, as well as the relation between EF and social reasoning in general.

Keywords: Executive function | Theory of mind | Expression and emergence accounts | Social reasoning

Article:

The preschool years are characterized by a period of rapid growth in cognitive functioning. Notably, there are impressive developments from 3 to 5 years of age in executive function (EF), the set of cognitive processes (e.g., attention, inhibitory control, shifting, maintaining goals in memory) that work in concert to perform controlled goal directed behavior (see Garon, Bryson, & Smith, 2008, for a comprehensive review). For example, in the Dimensional Change Card Sort (DCCS; Frye et al., 1995 and Zelazo et al., 2003) considered a standard EF task, children initially learn to match test cards based on one of the two relevant dimensions (e.g., color such that red boats are matched with a target card of a red bunny and blue bunnies are matched with a target card of a blue boat). After several trials, which are typically performed correctly as early as 3 years of age, the rule changes such that cards must now be matched based on the other relevant dimension (e.g., shape such that red boats are now matched with a target card of a blue boat and blue bunnies are now matched with a target card of a red bunny). Successful responding after the rule change, typically seen between 4 and 5 years of age, requires shifting attention from the original dimension to the new dimension, keeping the relevant rule in mind, and inhibiting the tendency to match the card in the manner that was previously correct (see Simpson and Riggs, 2005, Simpson and Riggs, 2007 and Simpson et al., 2012, for discussion on what leads to response prepotency).

Interestingly, similar age-related improvements have been observed in tasks designed to assess children's developing theory of mind (ToM), the ability to ascribe mental states to oneself and others and to make behavioral predictions how people will act based on their mental states. For example, in the classic Smarties task (Gopnik & Astington, 1988), children observed that a familiar container contained surprising contents (e.g., a Smarties box contained pencils). When asked what another child would think is in the container, 3-year-olds incorrectly claimed that this other child would know the surprising contents of the container. In contrast, older children correctly inferred that in the absence of privileged knowledge, the other child would think that the container holds its typical contents.

ToM tasks require an understanding that one's own current knowledge is not accessible to other people, nor was it available in the past. To succeed on a ToM task, children must suppress the natural inclination to respond based on a prepotent response and instead reason from a naïve perspective, which renders the structure similar to a conflict EF task. To illustrate this commonality, consider both the DCCS and Smarties task. Correct performance on both tasks requires recognizing the prepotent response (i.e., to continue matching by the 1st dimension in the DCCS and to respond based on the current belief that the container holds pencils in the Smarties task) and then successfully inhibiting it so as to switch to the correct response (i.e., to match by the 2nd dimension in the DCCS and to respond based on the false belief that the container holds Smarties in the Smarties task). The structural similarities in both inhibition and ToM tasks prompted speculation that the characteristic errors in ToM tasks, such as responding based on the actual state of affairs and not based on the ignorance of the character, can be explained by limitations in EF. EF processes such as attentional flexibility, inhibitory control, and working memory are likely to be implicated in ToM tasks. In addition, according to Cognitive Complexity and Control theory (Frye, 1999, Frye et al., 1995 and Zelazo and Frye, 1997), both types of tasks require the coordination of “if–if–then” rule structures.

One compelling argument against the notion that EF and ToM tasks can be reduced to common architecture is from the neuropsychological study by Sabbagh, Bowman, Evraire, and Ito (2009). In this study, although EF and ToM were correlated, activity in the dorsal medial prefrontal cortex and the right temporal – parietal juncture was associated with ToM even after controlling statistically for associations with EF. This provides evidence that neural substrates of ToM reasoning are dissociable from EF reasoning (see also Sabbagh, Xu, Carlson, Moses, & Lee, 2006, for additional evidence in a cross-cultural study).

Other theorists have speculated that EF and ToM are causally related (see Moses & Tahiroglu, 2010, for a recent review; Perner & Lang, 1999). Notably, Kloo and Perner (2003) have demonstrated that training on a false belief task improved DCCS performance and training on the DCCS improved false belief performance. This finding is convincing in that advancement of skills in one domain can improve the other, but it does not directly address which domain has developmental precedence.

It is possible that ToM aptitude is necessary for development of EF. Wimmer (1989, as cited by Perner & Lang, 1999) argued that with growing sophistication of mental concepts, children become more capable of controlling mental processes. Similarly, Perner, 1991 and Perner, 1998 has claimed that metarepresentational capacities, such as the ability to represent goal states and the impediments to achieving these states, arise from developing ToM, are necessary for execution of EF tasks. Specifically, an understanding that action is mediated by internal states drives the eventual success in both false belief tasks and EF tasks.

In contrast, Russell, 1996 and Carlson and Moses, 2001) argued that limitations in ToM concepts, such as deception and false belief, stem from shortcomings in executive performance, specifically ability to perform the correct action in the face of luring distractors. He further argued that agency, the endogenous change in cognitive control, is necessary for a theory of mind to develop. In other words, EF is needed for *expression* of ToM concepts (Carlson et al., 1998 and Moses and Carlson, 2004). In a more extreme line of reasoning, Moses and Carlson, 2004 and Moses, 2001) suggested that the very *emergence* of ToM might only occur after sufficient maturation of certain executive skills, such as inhibition and working memory (Moses & Tahiroglu, 2010). This is similar to Russell's (1996) claim that errors in executive competence, the ability to regulate attention appropriately, hinder the ability to “think explicitly and at will about certain mental or abstract properties and processes – such as beliefs, properties of objects (e.g., ‘amount’), and logical relations” (p. 210). Additional support for the developmental primacy of EF comes from research with children with autism. In 4–7-year olds with autism, Pellicano (2007) revealed a dissociation with ToM impaired but EF intact, suggesting that “EF is an important factor for the development of ToM” (p. 986). This unidirectional hypothesis was later supported in a longitudinal study with children with autism (Pellicano, 2010).

One way to discriminate among these theoretical alternatives is to examine relations between EF and ToM longitudinally. Five studies have converged in showing that EF skills are necessary for later ToM development. Carlson, Mandell, and Williams (2004) examined 81 children at 24 and 39 months of age on a variety of ToM and EF tasks and found that EF at 24 months predicted ToM at 39 months. Importantly, the converse relation that early ToM abilities predict later EF abilities was not shown, even when all controls were included. However, the ToM tasks used were thought to be precursors, but not actually assessments, of what is typically measured in false belief and representational change tasks, since 39-month-olds most often fail the standard versions of these tasks.

Hughes (1998) found a very similar pattern of results, despite the fact that the children were older and different EF and ToM tasks were used. In her study, 50 children were initially tested between 39 and 55 months of age and reassessed 13 months later. Early EF did predict later ToM abilities, but ToM did not predict EF. The relatively wide age range in this study suggests that this unidirectional relation holds well into the 6th year of life (the oldest children were 68 months at the time of reassessment). However, it does make it difficult to specify critical periods of development involved in these processes.

Hughes and Ensor (2007) assessed children longitudinally at 2, 3, and 4 years of age. One hundred and twenty-two children were initially tested between 24 and 36 months of age and then again at each of the following two years. Early EF predicted later ToM from 2 to 3 years and from 3 to 4 years, although the latter relation was eliminated when regressions controlled for age, verbal ability, initial scores, and social disadvantage. ToM did not predict EF from 2 to 3 or from 3 to 4 years of age, although the prediction did emerge when using ToM at age 2 to predict EF at age 4.

In a microgenetic study with 3-year-olds spanning 6 time points over 5 months, Flynn, O'Malley, and Wood (2004) found that executive inhibition tasks were performed successfully well before emergence of false belief understanding. This finding is in direct contrast to Perner's (1998) claim that ToM is necessary for the emergence of executive skills. However, it is unclear from these data whether executive inhibition is necessary for later ToM or whether the executive inhibition tasks simply are easier to complete.

Finally, Schneider, Lockl, and Fernandez (2005) reported on the first 3 time points in the Würzburg longitudinal study, where 176 children were tested at 3, 3.5, and 4 years of age. EF did predict ToM from 3.5 to 4 years of age above and beyond the effect of ToM ability at an earlier time point, but notably not from 3 to 3.5 years and not from 3 to 4 years of age. Importantly, ToM did not predict EF above and beyond the effect of earlier EF across any of the three time points.

The present study examined the relation between EF and ToM across three time points in an economically diverse sample of children. Incorporating multiple measures of each construct at each time point and a large sample size (*N* = 226), we were able to fit a latent variable model for our primary analysis. The latent variables represent the constructs EF and ToM and are formed using various indicators of the constructs at each age. Because indicators of the constructs must necessarily change with age, there are some differences in the indicator variables across ages; yet many of the tasks were administered at each time point and all of the measures serve as indicators of the associated underlying construct. Two advantages of using latent variable modeling are, first, that the underlying latent variable is free of measurement error even though the indicators are not. Second, we can test hypotheses about relationships between hypothetical constructs and not just observed indicators.

In selecting EF tasks, we were inspired by recent findings by Wiebe and colleagues (Wiebe, Espy, & Charak, 2008) that EF is best described as a unitary factor from 2 to 6 years of age. This is in contrast to the commonly accepted three-factor model of inhibition, updating, and set shifting used to describe EF in adults (Miyake et al., 2000) and 8- to 13-year-olds (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003). However, to ensure that we were sampling across a wide variety of EF tasks, we did consider tasks that arguably can be identified primarily (but not absolutely) by one of the three factors. To assess inhibition, we administered age appropriate tasks that required children to inhibit their prepotent tendencies to submit a dominant response. To assess updating, we administered a short-term memory span task. Finally, to assess set shifting, we administered age appropriate sorting tasks in which items had to be categorized according to one dimension and then according to a second dimension.

Between 3 and 4 years of age, we expected to replicate the common finding that EF predicts ToM but not the other way around (Carlson et al., 2004, Hughes, 1998, Hughes and Ensor, 2007 and Schneider et al., 2005). However, we were less clear on what would occur between 4 and 5 years of age, as the cross longitudinal relations across this transition period have not been reported. Early EF may continue to predict later ToM but not vice versa, extending the findings of Hughes (1998), whose participants included children in this age range but whose results were combined with those for younger children. This is consistent with the notion that once critical EF skills are in place, ToM continues to arise from advances in EF (i.e., expression and emergent accounts; Moses & Carlson, 2004). Another possibility is that the longitudinal cross predictions are reciprocal (i.e., EF at 4 years predicts ToM at 5 years *and* ToM at 4 years predicts EF at 5 years), providing support for expression and emergent accounts, as well as the theory that metarepresentation skills needed for ToM tasks become the foundation of higher-order thinking (Perner, 1998). Finally, it is possible that after controlling for growth in EF and ToM from 4 to 5 years of age, no further cross predictions exist. This is broadly consistent with claims that success in both EF and ToM tasks rely on common skills, and that by 4 years of age these skills are in place.

1. Method

1.1. Participants

To be included in the final sample, children had to participate at all three time points; 38 children (14%) did not meet this criterion. Exclusion from the study was not related to sex, χ^2 (N = 264) = .002, *ns*, nor race (white vs. non-white), χ^2 (N = 263) = 2.6, *ns*. However, there was a marginal relation between exclusion and income-to-needs, derived by dividing the total family income by the poverty threshold for that family size, $t(257) = 1.9$, $p = .054$.

Thus, the final sample consisted of 226 children who were tested at 3 years (*M* age = 41.8 months, *SD* = 2.4), 4 years (*M* age = 53.4 months, *SD* = 1.8), and 5 years (*M* age = 65.5 months, *SD* = 2.3). At the time of entry to the study, mothers were 33.4 years on average (*SD* = 5.5). Approximately half of the mothers (54%) had completed a 4-year college degree and 78% were married and living with their spouse. Average income-to-needs ratio at the first visit was 2.96 (*SD* = 1.70). Approximately 34% of the sample had an income-to-needs ratio under 2 (low income); 56% between 2 and 5 (moderate income); and 10% greater than 5 (high income). The child sample was 52% female; 60% of children were European American, 34% African American, and 6% other ethnicities, including children of mixed ethnicities.

1.2. Measures

1.2.1. Demographics

A demographic questionnaire – which included information about child age, sex, ethnicity, maternal age, family income, maternal education level, and occupational status – was completed at each visit by the mother.

1.3. Peabody Picture Vocabulary Test – IIIA (PPVT-IIIA, Dunn & Dunn, 1997)

The PPVT-IIIA was administered as an assessment of receptive vocabulary. Children are asked to select one of the four pictures that best depict a word presented orally by the examiner. This test items are grouped into 12-item sets that increase in difficulty. Testing stops when children answer incorrectly 8 times within a set. The score is calculated by subtracting the total number of errors from the highest item number in the final set. Children were administered this task at all three visits.

1.4. Executive function tasks

Day/night Stroop task (Gerstadt, Hong, & Diamkond, 1994). In this age-appropriate version of the Stroop task, children were presented with cards that were either black with yellow moons and stars, to which children were to respond “day,” or white with a yellow sun, to which children were to respond “night.” Children were given two practice trials and then presented 16 cards in a fixed order. The score was the number of correct responses to the 16 test trials. Children participated in this task at the 3- and 4-year-old visits.

Animal Stroop (Wright, Waterman, Prescott, & Murdoch-Eaton, 2003). Children were shown “strange pictures” in which the animal's head was different to its body and were instructed to name only the animal's body (e.g., “duck” for a pig's head on a duck's body) as quickly as possible. Children were given two practice trials and then presented 16 cards in a fixed order. The score was the number of correct responses to the 16 test trials. Children participated in this task at the 5-year-old visit.

Number recall task (Kaufman & Kaufman, 1983). On each trial, the experimenter recited a series of numbers and children were asked immediately to repeat the numbers in the same order. Strings became progressively longer, and the task was terminated after three consecutive errors. The score was number of correct items. Children participated in this task at all three visits.

Flexible item selection task (FIST, Jacques & Zelazo, 2001). The FIST is a measure of representational flexibility. Children were administered 6 cards consisting of three pictured items such that two items share the features of one dimension (e.g., same shape) while two other items share the features of a second dimension (e.g., same color). For example, if the three pictures were of a large purple phone, a large pink phone, and a large pink fish, the first two items are both phones while the last two items are both pink. Children were first asked to point to two items that are the same in one way, and subsequently asked to point to two items that are the same in another way. The relevant score was the number of correct 2nd selection choices. If the child made an incorrect first selection, the second selection was coded as incorrect regardless of the child's answer. Children who failed both practice items received an overall score of 0. Children participated in this task at all three visits.

Head-to-toes task (Ponitz et al., 2008). The head-to-toes task was developed as a measure of behavioral regulation in children. Children were asked to play a game where they were instructed to do the “opposite” of what the experimenter said. For example, when told to “touch your toes”, children were supposed to touch their head. In the first set, the 8 trials consisted of actions on their head or their toes. In the second set, the 4 trials consisted of actions on their knees or their shoulders. In the third set, the 10 trials consisted of all of the actions practiced in sets 1 and 2. The score was accumulated by awarding 2 points for a correct response, 1 point if the child self-corrected (i.e., any discernable movement to the incorrect response, but finishing with correct response), and 0 points for an incorrect response. Children participated in this task at the 5-year-old visit only.

Dimensional change card sort – border version (DCCS-B, Zelazo, 2006). In this age-appropriate version of the task, children were initially required to sort 6 bivalent test cards according to one dimension (e.g., color). During a second phase, they were required to sort 6 of the same test cards according to the other dimension (e.g., shape). In the last phase, children had to sort 12 new cards using both the color and shape rules depending on whether the card had a black border surrounding it (e.g., follow color rule) or not (e.g., follow shape rule). The score wA number of correct trials across all 3 phases, ranging from 0 to 24. Children participated in this task at the 5-year-old visit only.

1.5. Theory of mind tasks

Appearance-reality distinction (Flavell, Flavell, & Green, 1983). Children were introduced, one at a time, to two realistic-looking imitation items (e.g., a candle that looks like an apple). The color of the object was modified perceptually by placing it behind a colored screen, and similarly, its size was modified perceptually by using a large magnifying lens. Children were asked “appearance” questions about what the object looked like (e.g., candle or an apple; red or blue; little or big) and “reality” questions about the true state of the object (e.g., “Is it really, really blue or is it really, really red?”). Children scored one point if they responded correctly to both the appearance and the reality questions for a specific property, yielding a total score that could range from 0 to 6. Children participated in this task at all three visits.

Unexpected contents (Gopnik & Astington, 1988). Children were shown, one at a time, two familiar containers (e.g., a band aid box) and were asked “What do you think is in here?” After responding, the experimenter opened the container to reveal the unexpected contents (e.g., blocks) and asked “Before we opened this, what do you think was in here?” and “What would your friend think was in the box if (s)he saw it?” Scores ranged from 0 to 4 correct. Children participated in this task during all three visits.

Visual perspective taking (Flavell, Everett, Croft, & Flavell, 1981). Children were given a number of Level 2 tasks followed by one Level 1 task. [1] In a Level 2 task, children need to differentiate their own viewpoint toward an object from someone else's. The experimenter presented three pictures (but only one picture during the 5-year-old visit) to the children. Each picture was presented twice, once with the orientation right side up to the child and once with the orientation right side up to the experimenter. For each presentation, children were asked a question regarding their own point of view (“When you look at the turtle do you see the turtle standing on his feet or on his back?”) and a question regarding the point of view of the experimenter (e.g., “What about me? When I look at the turtle do I see the turtle standing on his feet or on his back?”). The Level 1 task assessed whether children recognized that someone else may not see the same object that they do. Children were shown a card with a different picture on each side. The card was held up vertically so that the experimenter saw a different picture than the child, and the experimenter then asked them what picture they saw and what picture the experimenter saw. Children earned a score of 1 for correct responses to both the child-perspective and the experimenter-perspective questions for each set; otherwise they received a score of 0. The total score ranged from 0 to 7 correct (0–3 for the 5-year - old visit). Children participated in this task at all 3 visits.

Unexpected location (Baron-Cohen et al., 1985 and Hala and Chandler, 1996). Children watched as an experimenter placed a toy in one of the three boxes and then proceeded to leave the room. In the *child*version of this task, children were asked to move the object to another box to “play a trick” on the experimenter, whereas in the *puppet* version of this task, a puppet moved the object. The different versions of the tasks were necessary to ensure reasonable variability at each age; 3.5-year-old children who are not involved in the deception typically perform poorly (Chandler and Hala, 1994). Children were then asked two test questions: (a) where will the experimenter look for the toy once she re-enters the room, and (b) where does the experimenter think the toy is; and two control questions: (a) where did the child/puppet put the toy, and (b) where is the toy really. Across two trials with two different objects, children received one point for each correct test question only if they answered both control questions correctly. Number of correct responses to the test questions across both trials was summed to yield a total score from 0 to 4. Children participated in the *child* version of the task at 3 and 4 years and participated in the *puppet* version at 4 and 5 years.

Second order false belief task (Sullivan, Zaitchik, & Tager-Flusberg, 1994). Children were presented a story with two actors, Paul and Sally. Sally plays a trick on Paul by hiding his toy in the cupboard. However, Sally is not aware that Paul had seen Sally hide the toy from the window. Children were then asked a series of questions regarding Sally's and Paul's knowledge and belief: “Does Sally know that Paul knows where the puppet is?” and “Where does Sally think Paul will look for the puppet?” Each correct answer earned 1 point yielding a score from 0 to 2. Children participated in this task during the 5-year-old visit only.

1.6. Procedure

Laboratory visits lasted approximately 2 h and were scheduled about 12 months apart. During each visit, children were videotaped while performing in a variety of cognitive, social, and emotional tasks (including tasks not relevant to the present study) in a fixed order (see Table 1). Families were compensated for their time ($40 for the first session, $60 each for both the second and third sessions) and children selected a toy after each session as thanks for their participation.

Table 1. Task order at each visit.

3-Year visit	4-Year visit	5-Year visit
Appearance-reality distinction	Unexpected contents	Unexpected contents
Unexpected contents	…	…
…	PPVT	FIST
PPVT	…	Visual perspective taking
…	Unexpected location – Puppet	…
Day/night Stroop task	Unexpected location – Child	Second order false belief task
Unexpected location – Child	Number recall task	Unexpected location – Puppet
Number recall task	…	Number recall task
…	Day/night Stroop task	…
Visual perspective taking	…	Animal Stroop
FIST	FIST	…
	Visual perspective taking	Head-to-toes task
	…	Appearance-reality distinction
	Appearance-reality distinction	DCCS-B
		…

		PPVT

Note: Ellipses (…) indicate where other tasks not relevant to this report were conducted.

2. Results

Descriptive statistics of the study variables at all three ages are displayed in Table 2; the intercorrelations are displayed in Table 3a and Table 3b for the EF (Table 3a) and ToM (Table 3b) tasks. For all analyses, we set $\alpha = .05$ as significance level and further identify $\alpha = .10$ as a level for marginal significance.

Table 2. Descriptive statistics for study variables.

		M	SD	Range
	PPVT – 3 years	41.8	2.4	37–47
	PPVT – 4 years	53.4	1.8	49–59
	PPVT – 5 years	65.5	2.3	55–72
EF Tasks	*Age 3*			
	Day/night Stroop	6.9	5.4	0–16
	FIST	0.3	0.7	0–4
	Number recall	2.8	2.5	0–10
	Age 4			
	Day/night Stroop	10.1	4.2	0–16
	FIST	0.7	1.2	0–5
	Number recall	5.3	2.5	0–12
	Age 5			
	Animal Stroop	11.0	3.8	0–16
	FIST	1.4	1.9	0–6
	Number recall	7.0	2.1	1–12
	Head-to toes	25.6	10.4	0–39
	DCCS-B	18.1	3.3	1–24
ToM Tasks	*Age 3*			
	Appearance reality distinction	1.0	1.1	0–6
	Unexpected contents	1.1	1.3	0–4
	Visual perspective taking[a]	1.7	1.7	0–7
	Unexpected location – child	0.6	1.1	0–4
	Age 4			
	Appearance reality distinction	2.3	1.8	0–6
	Unexpected contents	1.7	1.6	0–4
	Visual perspective taking[a]	3.3	2.3	0–7
	Unexpected location – child	2.2	1.6	0–4
	Unexpected location – puppet	2.3	1.3	0–4
	Age 5			
	Appearance reality distinction	3.2	1.8	0–6
	Unexpected contents	3.1	1.3	0–4
	Visual perspective taking[a]	1.9	1.1	0–3

	Unexpected location – puppet	3.1	1.3	0–4
	Second order false belief	1.4	0.7	0–2

[a]Note that fewer trials were given to the 5-year-olds on the visual perspective task (see text).

Table 3a. Correlations among EF variables.

Variable	1	2	3	4	5	6	7	8	9	10	11
3 years											
1. Day/night Stroop	–	.19**	.40**	.38**	.06	.30**	.20**	.17*	.34**	.28**	.12^{+}
2. FIST	.19**	–	.13^{+}	.18**	.13^{+}	.25**	.13^{+}	.15*	.12^{+}	.23**	.17*
3. Number recall	.38**	.13^{+}	–	.23**	.10	.54**	.20**	.26**	.52**	.41**	.12^{+}
4 years											
4. Day/night Stroop	.37**	.18**	.24**	–	−.02	.23**	.18**	.15*	.34**	.16*	.06
5. FIST	.05	.12^{+}	.11^{+}	−.05	–	.07	.09	.11^{+}	.11^{+}	.13^{+}	.00
6. Number recall	.30**	.25**	.53**	.24**	.07	–	.15*	.22**	.60**	.47**	.23**
5 years											
7. Animal Stroop	.21**	.13*	.21**	.22**	.07	.17*	–	.12^{+}	.18**	.30**	.16*
8. FIST	.17*	.14*	.25**	.15*	.13^{+}	.22**	.12^{+}	–	.25**	.19**	.19**
9. Number recall	.32**	.12^{+}	.53**	.35**	.12^{+}	.60**	.20**	.24**	–	.33**	.14*
10. Head-to-Toes	.31**	.23**	.41**	.20**	.12^{+}	.47**	.34**	.19**	.34**	–	.31**
11. DCCS-B	.13^{+}	.17*	.14*	.09	−.01	.25**	.18**	.19**	.16*	.34**	–

Note: Partial correlations controlling for PPVT-3yr are above the diagonal. + $p < .10$ * $p < .05$ ** $p < .01$

Table 3b. Correlations among ToM Variables.

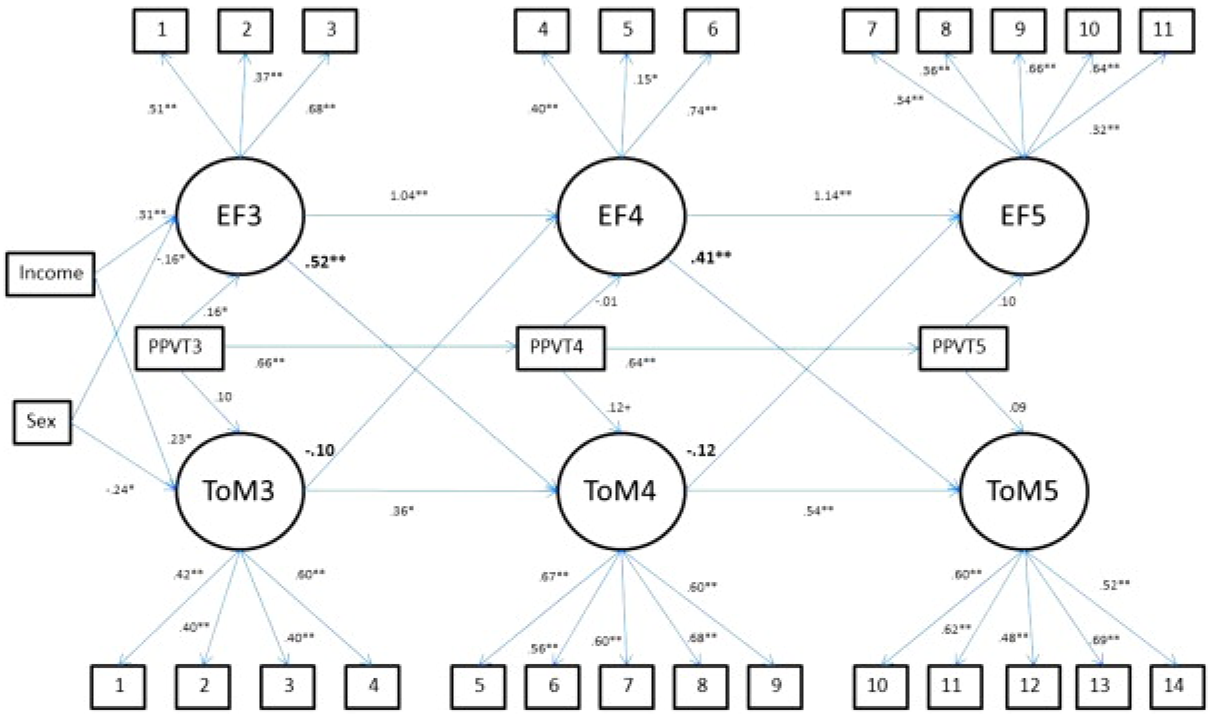
Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
3 years														
1. Appearance reality distinction	–	.24**	.23**	.20**	.27**	.09	.16*	.17**	.13*	.14*	.11^{+}	.18**	.12^{+}	.10
2. Unexpected contents	.24**	–	.18**	.31**	.12^{+}	.20**	.16*	.10	.05	.13*	.02	.10	.03	.12^{+}
3. Visual perspective taking	.23**	.18**	–	.15*	.29**	.16*	.22**	.17*	.14*	.21**	.15*	.17*	.10	.18**
4. Unexpected location – child	.20**	.30**	.15*	–	.32**	.23**	.23**	.30**	.27**	.28**	.22**	.20**	.20**	.20**
4 years														
5. Appearance reality distinction	.27**	.12^{+}	.29**	.32**	–	.40**	.38**	.40**	.42**	.44**	.35**	.28**	.34**	.23**
6.	.09	.20*	.16*	.23*	.40*	–	.39*	.34*	.37*	.20*	.28*	.34*	.20*	.25*

Unexpected contents		*		*	*		*	*	*	*	*	*	*	*
7. Visual perspective taking	.16*	.16*	.22**	.24**	.38**	.39**	–	.35**	.34**	.34**	.30**	.45**	.29**	.25**
8. Unexpected location – child	.17**	.10	.17*	.30**	.40**	.34**	.35**	–	.72**	.39**	.39**	.34**	.46**	.32**
9. Unexpected location – puppet	.13*	.05	.14*	.27**	.42**	.37**	.34**	.72**	–	.28**	.36**	.27**	.32**	.31**
5 years														
10. Appearance reality distinction	.13*	.13+	.21**	.29**	.44**	.20**	.35**	.39**	.28**	–	.32**	.24**	.39**	.28**
11. Unexpected contents	.11+	.02	.15*	.22**	.35**	.28**	.30**	.39**	.36**	.32**	–	.31**	.51**	.31**
12. Visual perspective taking	.18**	.10	.16*	.20**	.28**	.34**	.44**	.34**	.27**	.24**	.31**	–	.25**	.15*
13. Unexpected location – puppet	.12+	.03	.10	.22**	.34**	.20**	.30**	.46**	.33**	.40**	.51**	.25**	–	.41**
14. Second order false belief	.10	.12+	.18**	.21**	.23**	.25**	.26**	.32**	.31**	.28**	.32**	.14*	.42**	–

Note: Partial correlations controlling for PPVT-3yr are above the diagonal. + $p < .10$. *$p < .05$. ** $p < .01$.

2.1. Latent variable model of the development of both EF and ToM

To assess relations between early and later measures of both EF and ToM, we fit the data to a latent variable model controlling for gender (0 = female; 1 = male), income to needs at age 3, and PPVT scores at all ages. Missing data points were very rare (0.5% of all data points), which was expected given that we only included children who participated at all three time points. To account for the missing data, we employed full information maximum likelihood procedures, an algorithm that estimates the model using all available data on all cases. The resulting model, displayed in Fig. 1 using standardized coefficients, achieved a reasonably good fit as indicated by normed χ^2 = 1.493 (recommended to be <2; e.g., Bollen, 1989, Byrne, 1989 and Marsh and Hocevar, 1985) and RMSE = .047 (Hu and Bentler, 1998 and Hu and Bentler, 1999, recommended using cutoff values "close to" .06). [2]



+ $p < .10$
* $p < .05$
** $p < .01$

Fig. 1. Latent variable model with standardized coefficients. The index of the observed indicators map onto the designations in Table 3a and Table 3b. For exposition purposes, the contributions of the error terms are not displayed. Error terms were allowed to correlate for: (a) EF3 and ToM3, (b) EF4 and ToM4, (c) EF5 and ToM5, (d) ToM variables 8 and 9 (unexpected location – child and unexpected location – puppet at 4 years).

2.2. Preliminary analyses of control variables

As shown in Fig. 1, and consistent with previous research (Carlson et al., 2004, Carlson and Moses, 2001,Hughes and Ensor, 2007 and Kochanska et al., 1996), girls outperformed boys on EF at age 3 ($\beta = -.16, p = .02$). However, tests of indirect effects [3] revealed that the advantage of girls on EF was only marginally significant at age 4 ($B = -.48$, $p = .06$), and not significant at age 5 ($B = -.27$, $p = .11$). On ToM, girls outperformed boys at age 3 ($\beta = -.24$, $p = .01$), and tests of indirect effects revealed that girls continued to outperform boys in ToM at age 4 ($B = -.37$, $p = .02$) and age 5 ($B = -.29$, $p = .01$), replicating the effects reported by Walker (2005).

Income-to-needs measured at age 3 was significantly related to both EF ($\beta = .31$, $p < .001$) and ToM ($\beta = .23, p = .02$), partially consistent with Hughes and Ensor (2007)'s findings that social disadvantage related to EF but not ToM, as well as Hughes, Ensor, Wilson, and Graham's (2010) finding that family income was related to initial levels of EF at 4 years of age, and Wiebe et al.'s (2011) finding that at-risk 3-year-olds had lower levels of EF than low-risk children.

Tests of indirect effects revealed that income-to-needs continued to predict EF at 4 ($B = .29$, $p = .01$) and 5 years ($B = .17$, $p = .01$), and also continued to predict ToM at 4 ($B = .17$, $p = .01$) and 5 years ($B = .15$, $p = .01$).

Previous reports showed verbal ability related to EF and ToM throughout the preschool years (Hughes and Ensor, 2007 and Schneider et al., 2005). We found partial evidence for this claim: PPVT at 3 years of age was predictive of EF ($\beta = .16$, $p = .04$) but not ToM ($\beta = .10$, $p = .24$), PPVT at 4 years was marginally predictive of ToM ($\beta = .12$, $p = .054$) but not predictive of EF ($\beta = -.01$, $p = .89$), and PPVT at 5 years of age did not predict either EF ($\beta = .10$, $p = .15$) or ToM ($\beta = .09$, $p = .13$).

Finally, as can be seen clearly in Fig. 1, EF, ToM, and PPVT all maintained stability from one time point to the next.

2.3. Longitudinal cross predictions of EF and ToM

After accounting for the effects of gender, income-to-needs, PPVT, and the stability within each construct, earlier EF abilities predicted later ToM abilities (from age 3 to age 4: $\beta = .52$, $p = .001$; from age 4 to age 5: $\beta = .41$, $p = .009$). In contrast, earlier ToM abilities did not uniquely predict later EF (from age 3 to age 4: $\beta = -.10$, $p = .60$; from age 4 to age 5: $\beta = -.12$, $p = .58$).

3. Discussion

Debate persists on whether executive processes are needed to understand the mental states of others, whether theory of mind competence drives the cognitive flexibility inherent in executive control, or whether EF and ToM can be considered equivalent constructs whose similarities are so prevalent that they develop in tandem.

One approach to answering these questions is to examine longitudinal relationships between EF and ToM. The present study assessed the construct across three time points and capitalized on a number of methodological advantages: (a) We tested a larger number of children than earlier studies; (b) our sample was socioeconomically diverse; (c) we controlled for PPVT, gender, and income-to-needs ratio; (d) we were able to abstract latent variables for our constructs; and (e) we assessed children at three time points, allowing for two longitudinal assessments. Our unique combination of EF and ToM tasks revealed that both constructs of EF and ToM demonstrate considerable stability over time.

In addition, EF predicts ToM from 3 to 4 years of age and from 4 to 5 years of age. However, earlier ToM does not predict later EF at either age. This asymmetrical pattern is consistent with and extends reports from Hughes and Ensor, 2007 and Schneider et al., 2005), Carlson et al. (2004) with younger children (2.5 and 3 years of age), and Hughes (1998) with preschoolers over a wide age range. It is also an empirical validation of the findings of a meta-analysis conducted by Devine and Hughes (2013), supporting the notion that EF skills develop prior to and are involved in the expression and/or the emergence of ToM understanding.

One way to distinguish expression vs. emergence accounts would be to examine longitudinal relations between EF tasks and tasks that tap ToM abilities while minimizing executive demands (Carlson et al., 1998). For example, Hala and Russell (2001) found that even 3-year-olds were adept at deception when executive demands were reduced by involving the participants in a "partnership" with the experimenter. Based on expression accounts, we would expect to see no longitudinal predictions from earlier EF abilities because mature EF skills would not be needed to succeed in the task. In contrast, based on emergence accounts, we would still expect to see a longitudinal prediction from earlier EF abilities as the ability to deceive would presumably only be possible after a certain proficiency of EF is achieved.

A contribution of the present study is the finding that the asymmetrical pattern persists over two time points. It would have been conceivable to assume that if early EF is needed for later ToM, then at some point when ToM reached a certain level of maturity, its developmental course would not continue to be influenced by previous levels of EF. In fact, a simple version of the emergence account would argue this point – basic EF skills are needed for emergence of early ToM skills, but once these basic skills are in place the two constructs develop separately (although they would be expected to correlate at any age). Our data contradict this notion, suggesting instead that as the nature of ToM changes with age, more complex EF skills must be in place prior to its emergence. In this study, the nature of ToM is likely to be different at age 5 than at age 4, and the EF skills needed to demonstrate ToM at age 5 are likely more advanced than the EF skills needed at age 4. For example, according to the scaling of Wellman and Liu (2004), the modal 4-year-old can correctly answer questions of diverse desire, diverse belief, and knowledge access, while the modal 5-year-old can also correctly answer questions of contents false belief and real-apparent emotion. Although the measures in our study were not designed to indicate where on Wellman and Liu's scale our participants are situated, the general point is that at different ages, ToM can have a very different quality and different levels of EF skills required.

Although our data do not speak to it directly, the possibility exists that the necessity of earlier EF skills to achieve later ToM milestones persists throughout childhood and perhaps into adulthood. This is consistent with contemporary social development theories. For example, in DIT (Developmental Intergroup Theory), the development of stereotyping and prejudice is based on the prior existence of a flexible cognitive system (Bigler & Liben, 2007). In an example regarding adolescents, results from a study confirming the RED (Response Evaluation and Decision) model revealed that antisocial behavior was predicted by the prior ability to evaluate responses (Fontaine, Yang, Dodge, Bates, & Pettit, 2008), theorized to be a critical aspect of executive function (Zelazo, Carter, Reznick, & Frye, 1997). Notably, it was also found that response evaluation led to changes in future antisocial behavior, suggesting that the asymmetrical longitudinal predictions between EF and ToM that we found in early childhood might develop into symmetrical ones later in childhood and into adolescence.

The absence of a relation between early ToM and later EF directly counters theories that suggest that EF arises from gains in metarepresentation, or that the two constructs are equivalent. In particular, this finding is at odds with Kloo and Perner's (2003) finding that training 3- and 4-year-olds in false belief tasks improved future EF performance. However, there are a number of reasons these findings may indeed be compatible: First, Kloo and Perner tested their children less than one month after the training, while we assessed children about a year apart. It is possible that increased ToM abilities lead to short-term gains in EF, which in turn contribute to stronger EF and ToM about a year later. If so, a microgenetic analysis might be needed to capture short-term relations that are being missed by assessments that are relatively far apart. Second, roughly 25% of children in Kloo and Perner's study were excluded because of ceiling level performance on either the EF or ToM measures. The inclusion of these children might reveal the asymmetry that we and others have found. Third, exercise of training ToM (e.g., repeatedly pointing out incorrect responses and correcting them) might engage executive processes such as monitoring, inhibition, and updating so that, in essence, EF is being trained simultaneously. Thus, Kloo and Perner's result might be an indication of EF training improving EF performance.

3.1. Limitations

Results of the present study may be specific to the particular tasks we used. Yet, our criterion for task inclusion did confirm a fair amount of similarity among the tasks within each construct at each age, there was high stability of the constructs over time, and use of latent variables minimizes measurement error. In some sense, this task specificity is a positive, as earlier demonstrations of asymmetrical longitudinal patterns in early childhood were based on different EF and ToM tasks. Nonetheless, we cannot completely rule out the possibility that our findings are specific to the tasks used.

Another caveat is that we used the most common approach to ToM by focusing on understanding the perspectives and beliefs of others. A recent research perspective identifies a ToM scale that ranges from the understanding of diverse desires, to the more complex understanding of diverse beliefs, and finally to the ability to mask one's emotions purposefully (Wellman et al., 2006 and Wellman and Liu, 2004). Thus, following this scale, our construct of ToM is relatively late-evolving, and it is conceivable, and worth testing, that young children's understanding of diverse desires (and not diverse beliefs) are predictive of later EF development (although Carlson et al., 2004, did find the same asymmetrical longitudinal relation with 2.5-year-olds using ToM tasks intended for earlier abilities).

It is worth noting that “delay inhibition” tasks were not included in our EF task battery. In a delay inhibition task, the participant must inhibit responding until the appropriate time (e.g., the gift delay task, Kochanska et al., 1996). Carlson, Moses, and Breton (2002) found that delay inhibition tasks were not a significant contributor (over and above conflict tasks) to the relation between EF and ToM.

We included a forward digit span in our EF battery, arguably a measure of short term, but not working memory. Although this point has merit, there are a number of reasons why we contend that the forward digit span is appropriate to our EF construct. In our conceptualization of EF, the maintenance of items in memory over time is critical (Marcovitch, Boseovski, Knapp, & Kane, 2010). It has been argued (Carlson, 2005) that forward span is a pure measure of working memory, whereas more complex span tasks (e.g., backward digit span) involve other cognitive processes. Moreover, methods of confirmatory factor analysis (Leerkes, Paradise, Calkins, O'Brien, & Lange, 2008) have associated forward digit span with other measures of EF. An advantage of our latent variable design is that if the forward digit span is not an appropriate index of EF, this would have been reflected by a nonsignificant path in the measurement of the latent construct.

We were able to assess the effects of gender on EF and ToM from 3 to 5 years of age. Girls show an early advantage for both EF and ToM skills, but in the case of EF that advantage diminishes with age. This is consistent with Hughes and Ensor's (2007) report of sex differences in 3-year-olds' EF, but not that of 4-year-olds. The diminishing effect of gender on EF fits well with findings that gender differences were only found in speed/arousal tasks, but not other EF tasks, in 6–13-year-olds (Brocki & Bohlin, 2004). In addition, Seidman et al. (2005) failed to find any effects of gender in both ADHD and control samples of 9–17-year-olds on 8 of 9 measures of EF. In stark contrast to this finding is the constant effect of gender on ToM at all three ages, consistent with findings of Walker (2005). The differential gender effects speak to the independence of EF and ToM, further challenging accounts that claim that difficulty in ToM tasks can be explained solely by constraints in executive function.

In sum, we have provided strong evidence supporting the hypothesis that the emergence of ToM depends on earlier mastery of EF skills and that this asymmetrical longitudinal relation between EF and ToM persists throughout the preschool years and into school entry. It is becoming increasingly clear that there are many advantages to the concentrated training of EF skills in early childhood (Diamond, Barnett, Thomas, & Munro, 2007), and based on the present research, one of the most important outcomes of this training may be the development of a sophisticated theory of mind.

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