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Associations among false belief understanding, counterfactual reasoning, and executive function

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The primary purposes of the present study were to clarify previous work on the association between counterfactual thinking and false belief performance to determine (1) whether these two variables are related and (2) if so, whether executive function skills mediate the relationship. A total of 92 3-, 4-, and 5-year-olds completed false belief, counterfactual, working memory, representational flexibility, and language measures. Counterfactual reasoning accounted for limited unique variance in false belief. Both working memory and representational flexibility partially mediated the relationship between counterfactual and false belief. Children, like adults, also generated various types of counterfactual statements to differing degrees. Results demonstrated the importance of language and executive function for both counterfactual and false belief. Implications are discussed.

Recently, researchers have explored associations between counterfactual reasoning and false belief performance (German & Nichols, 2003; Guajardo & Turley-Ames, 2004; Müller, Miller, Michalczyk, & Karapinka, 2007; Perner, Sprung, & Steinkogler, 2004; Riggs, Peterson, Robinson, & Mitchell, 1998) to understand developmental skills that might account for the consistent finding that children come to understand the representational nature of the mind around 4 years of age (Wellman, Cross, & Watson, 2000). In particular, Riggs and his colleagues (e.g. Peterson & Riggs, 1999; Riggs & Peterson, 2000; Riggs *et al.*, 1998) suggested that early difficulties with counterfactual (i.e. thinking about events inconsistent with reality) account for young children's inabilities to pass false belief tasks. Other authors have suggested that performance in these two areas might be related because each is associated with changes in executive function (German & Nichols, 2003; Guajardo & Turley-Ames, 2004; Müller *et al.*, 2007). The primary purpose of the present study was to clarify the relationship between counterfactual and false belief by examining whether executive function mediates the relationship between these two variables.

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Theory of mind and counterfactual reasoning

Preschoolers' counterfactual has been found to predict their false belief, though the amount of variance accounted for has varied. In the first study to examine an association between counterfactual and theory of mind performance, Riggs and colleagues (1998) found children's abilities to reason counterfactually accounted for approximately 25% of the variance in theory of mind performance, beyond age and language. Using a similar approach, Peterson and Bowler (2000) generalized these findings to individuals with autism. Across two studies, Guajardo and Turley-Ames (2004) found counterfactual was significantly correlated with theory of mind performance (r's ranged from .49 to .68), yet those correlations were meaningfully diminished when age and language were controlled. In Study 1 counterfactual accounted for 16% of the unique variance in theory of mind performance and only 2% in Study 2 (Guajardo & Turley-Ames, 2004).

Others have found that only complex counterfactual tasks predict false belief. German and Nichols (2003) administered a counterfactual task with variations in the length of the causal chain (one to three steps removed from the cause). Only generation of counterfactuals involving medium and long causal chains (removal of two and three steps, respectively) predicted false belief beyond variance accounted for by age (German & Nichols, 2003). Similarly, Perner and colleagues (2004) found that reasoning on a complex counterfactual task (i.e. a story involving differing means of transportation, destinations, and points of departure) was correlated with false belief (r's ranged from .43 to .53). Across two studies, however, the correlations between these variables were no longer significant when age and language were controlled.

Taken together these studies suggest that counterfactual predicts theory of mind performance, though the relationship is typically diminished and sometimes eliminated when age and/or language are controlled. Such findings inform theoretical notions as to why these two abilities are related. Riggs and colleagues (1998) suggested that children fail theory of mind tasks because they are incapable of counterfactual; they cannot consider how a current situation could differ. In order to understand that Maxi will think the chocolate is in a different location, a child must be able to consider the current and alternative situations simultaneously. Similarly, Peterson and Riggs (1999) suggested that children must be capable of modified derivation (i.e. ignoring current knowledge to consider conflicting information) to pass a variety of theory of mind tasks.

If counterfactual were a prerequisite skill for passing theory of mind tasks, then short, as well as medium and long, causal inferences should predict theory of mind performance (German & Nichols, 2003), and counterfactual, more generally, should predict theory of mind understanding when age and language are controlled (Perner *et al.*, 2004). An alternative explanation is that executive function skills mediate the relationship between both aspects of cognition (German & Nichols, 2003; Guajardo & Turley-Ames, 2004; Müller *et al.*, 2007).

Executive function and theory of mind

Multiple studies have demonstrated the association between executive function and theory of mind development. In particular, Carlson, Moses, and their colleagues (Carlson, Mandell, & Williams, 2004; Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002; Moses, 2005) have suggested that executive function could account for either the expression or the emergence of theory of mind understanding. Though support exists for both perspectives, data are more in concordance with an emergence account (Carlson *et al.*, 2004; Moses, 2005; Sabbagh, Xu, Carlson, Moses, & Lee, 2006), suggesting that executive function skills are critical for children to acquire understanding of mental representations. For example, Carlson and colleagues (2004) found that theory of mind and executive function skills were not related at 24 months of age, yet executive functioning skills at 24 months of age predicted children's theory of mind performance at 39 months. Such findings support the idea that executive function skills enable children to attend to, process, and learn about mental states.

Working memory and representational flexibility are two aspects of executive function that have been examined. Successful performance on Wimmer and Perner's (1983) Maxi task, for example, requires children to hold in mind where the chocolate really is while processing where Maxi will look first for the chocolate. Thus, children must be able to store and process information simultaneously (i.e. working memory; Baddeley, 1986). Multiple studies have demonstrated that working memory predicts theory of mind performance (Davis & Pratt, 1995; Gordon & Olson, 1998; Keenan, 1998; Müller *et al.*, 2007), though in some cases the relationship is no longer significant when age and language are controlled (Carlson *et al.*, 2002; Naito, 2003).

Representational flexibility, also known as cognitive flexibility, is another potentially important dimension of executive function. The application of theory of mind concepts requires children to think flexibly about the same situation; they must be able to consider the same event from their own as well as the character's perspective (Jacques & Zelazo, 2005). Most often, representational flexibility has been assessed with the dimensional change card sort (DCCS; Frye, Zelazo, & Palfai, 1995) in studies of theory of mind development. The DCCS requires children to sort cards according to one dimension (e.g. shape) for several trials, and then sort the same cards according to a second dimension (e.g. colour). The relationship between performance on this task and false belief is well established (e.g. Carlson & Moses, 2001; Dick, Overton, & Kovacs, 2005; Kloo & Perner, 2003; Müller, Zelazo, & Imrisek, 2005). In fact, Kloo and Perner demonstrated transfer of training effects between card sorting, based upon the DCCS, and false belief, suggesting a causal link between the two abilities.

Present study

Previous research has indicated that false belief and counterfactual abilities are related in the early preschool years, though the degree of that relationship has varied (German & Nichols, 2003; Guajardo & Turley-Ames, 2004; Perner *et al.*, 2004; Riggs *et al.*, 1998). Thus, the first major purpose of the present study was to examine this relationship further in hopes of clarifying whether or not false belief understanding and counterfactual are related when age and language are controlled.

The second major purpose of the present study was to examine the extent to which working memory and representational flexibility, two aspects of executive function, mediate the relationship between false belief and counterfactual. The connection between these aspects of executive function and theory of mind understanding, particularly false belief, is well established (e.g. Carlson & Moses, 2001; Carlson *et al.*, 2004; Dick *et al.*, 2005; Gordon & Olson, 1998; Kloo & Perner, 2003; Müller *et al.*, 2005). A link between executive function and counterfactual also is logical. counterfactual seems to involve holding knowledge of the current state of affairs in mind while generating an alternative antecedent (i.e. working memory) as well as simultaneously considering an event and how that event could differ (i.e. representational flexibility). Thus, it is possible that executive function mediates the relationship between counterfactual and false belief.

Müller and colleagues (2007), in fact, tested whether working memory, assessed with a counting and labelling task, mediated the relationship between these two variables. As suspected, working memory was related to both counterfactual ($r = .37$, $p < .01$) and false belief ($r = .32$, $p < .01$), but it did not account for unique variance in false belief beyond counterfactual and age. The present study extended this initial work in three ways: (1) three measures of working memory were included (i.e. counting and labelling, backward digit span, and backward work span); (2) representational flexibility also was examined; and (3) both age and language were entered as control variables.

There were two additional goals of the present study. A third goal was to examine whether false belief understanding would be more highly related to counterfactual tasks that focused on a character's mental state, as opposed to those focusing on physical situations. Counterfactual tasks primarily have focused upon physical situations/events (e.g. a person's location, a muddy floor), whereas false belief tasks involve a character's belief. Guajardo and Turley-Ames (2004) proposed that counterfactual thinking that involves mental references (e.g. thinking, feelings) might be more highly related to false belief than would physical tasks because false belief tasks assess children's abilities to understand mental perspectives. Thus, counterfactual tasks that focused on physical events as well as those focusing on emotion were included in the present study to test this proposition.

Fourth, the present study provided additional data about the types of counterfactual statements children generate. In the adult literature counterfactual statements have been categorized according to direction (i.e. upward and downward) and structure (i.e. additive and subtractive; Roese, 1994). Upward counterfactuals compare a current situation to a better alternative, whereas downward counterfactuals compare reality to a worse alternative (e.g. Markman, Gavanski, Sherman, & McMullen, 1993). For example, a student who receives a C on an exam could consider how he/she could have earned an A (i.e. upward counterfactual), yet he/she also could consider what might have caused him/her to earn an F (i.e. downward counterfactual). Additive counterfactuals involve adding a behaviour/event to the situation, while subtractive counterfactuals involve removing something (Roese & Olson, 1993). For example, the student could have studied more to change the outcome (additive), or he/she could not have studied at all (subtractive). Each counterfactual statement can be categorized according to direction and structure. Guajardo and Turley-Ames (2004) provided initial data suggesting that preschool aged children generate similar numbers of upward and downward counterfactuals, yet they, like adults (e.g. Roese, Hur, & Pennington, 1999), generate more additive than subtractive counterfactuals. It was hypothesized that similar patterns would emerge in the present dataset.

Method

Participants

Participants included 92 children, ranging in age from 36 to 71 months ($M = 54$ months; 56 girls, 36 boys). In total, 33 were 3 years of age; 33 were 4 years of age; and 33 were 5 years of age. Children were primarily Caucasian (74%), from middle to upper social economic status homes (M income $= 70,000–80,000$). Of the children, 29% did not have a sibling, 49% had one, and 14% had more than one sibling. Children attended one of four preschools in a small, mid-Atlantic city in the United States.

Measures

Parents completed a demographic information survey, and children completed eight measures: false belief; mental counterfactual; physical counterfactual; language comprehension; general multiple classification; backward word; backward digit; and counting and labelling.

Language

The test of auditory comprehension of language-3 (TACL-3; Carrow-Woolfolk, 1999) was used to assess language comprehension. The TACL-3 contains three subgroups of language comprehension: word comprehension; morphology; and sentence comprehension. The researcher began by reading a word, group of words, or sentence to the child and asked the child to point to the corresponding picture. The researcher recorded the responses on paper. Children received one point for each correct response, with possible scores ranging from 0 to 120.

False belief

Children completed a battery of five false belief tasks in a fixed order: unexpected change; unexpected contents (i.e. representation change and explanation); and two deception tasks. For all tasks, children received credit for the test questions only if they answered the control questions correctly; they received a score of 0 if they answered the control question(s) incorrectly regardless of how they responded to the test question. The false belief scores ranged from 0 to 5. Each task was acted out with props and the sex of each target character matched that of the child.

The first task was Wimmer and Perner's (1983) classic unexpected change task. Children were told a story about Maxi and his mother returning home from the grocery store. Maxi puts chocolate into the blue cabinet in the kitchen, and then leaves. While Maxi is outside playing, Mother moves the chocolate to the red cabinet. The experimenter then asked three comprehension questions to make sure children understood the story: 'Where did the chocolate used to be?'; 'Where is it right now?'; and 'Did Maxi see it being moved?' Next, the experimenter asked the test question: 'Where will Maxi first look for the chocolate when she comes back into the room?' Children received one point if they answered the control questions and the test question correctly.

The second task was a deception task based upon Wimmer and Perner's (1983) unexpected contents task. Children were told, 'Here is Bruce. He took the candy out of the candy box and put it in this Band-aid box so that his brother would not find it. Bruce did not want his brother to eat the candy before Bruce got any. When Bruce's brother comes into the room he asks Bruce where the candy is. Bruce decides to tell his brother something completely wrong so his brother will not find the candy'. Children then were asked the test question, 'Where will Bruce say the candy is?' Finally, the reality/control question was asked, 'Where is the candy really?' Children received one point if they answered both the control and the test question correctly.

The following two tasks were the representational change and explanation versions of the unexpected contents tasks (Bartsch & Wellman, 1989; Lewis & Osborn, 1990). First, children were presented with a crayon box and asked, 'What do you think is inside the box?' The correct response was crayons; however, other responses also were recorded. The researcher then asked, 'Let's look inside. Look, there is a toy car in here.

Imagine that, a crayon box with a toy car inside'. Children were asked the test question, 'What did you think was in the box?' Children who answered this question incorrectly were asked a second question, 'What did you think was in the box before I opened it?' Finally, children answered the control question, 'Can you remember what's really inside the box?' Children received points if the answer to either test question matched their initial response; in most cases that response was crayons. Children earned one point for answering the first test question correctly and half a point for answering the second test question correctly.

For the explanation task the experimenter presented children with a crayon box and a solid coloured box containing crayons. The researchers said, 'Let's see what is inside of here (looking at the solid box). Look, there are crayons in this box! There are crayons in this box, and a toy car in the crayon box'. The researcher then presented a toy doll and said, 'Look, here is John. John has a piece of paper. And he wants a crayon'. The doll approached the crayon box and children were asked, 'Why is he looking in there?' In order to answer this test question correctly, children had to make a reference to John's thoughts or beliefs. Children who did not make this reference were prompted with, 'What does John think?' All children were asked the control question, 'Are the crayons there really?' Children who answered the first test question and the control question correctly earned a score of 1; those who answered the prompted test question and the control question accurately earned a score of .5.

The last task was the active deception task (see Lalonde & Chandler, 1995). Children were introduced to Bill. Next, children were told that Bill knows there is candy in the green cabinet, but that he has to leave the room for a while. While Bill is 'gone' the experimenter tells the children, 'Let's play a trick on Bill. Let's move the candy to the orange cabinet'. The child then moved the candy to the orange cabinet. As with the unexpected change task, children were asked three comprehension questions to ensure that they understood the story: (1) 'Where did the candy used to be?'; (2) 'Where is the candy now?'; and (3) 'Did Bill see the candy being moved?' Next, they were asked the test question, 'When Bill comes back into the room, where will he first look for the candy?' Children received 1 point for a correct response to the control and test questions.

Counterfactual reasoning

Two sets of counterfactual tasks, specifically a physical counterfactual task and a mental counterfactual task, were administered. The physical counterfactual task, based upon Guajardo and Turley-Ames (2004), contained 4 scenarios that described events occurring in the physical environment; for example, 'Imagine that you are playing outside in the muddy yard. You are thirsty so you go inside to the kitchen to get a drink of juice. Because your shoes are muddy, you get dirt all over the floor'. Each of the scenarios was followed by a test question pertaining to the story (e.g. 'What could you have done so that the kitchen floor would not have gotten dirty?').

The mental counterfactual task was identical to the structure and instructions of the physical counterfactual task; however, the mental task contained an emotional rather than environmental component. Children were presented with 4 scenarios; for example, 'Imagine that you are playing with your friend. You both want to play with the drum. You grab it first and start playing with it. Your friend is sad'. The researcher then asked the children, 'What could you have done so that your friend would have been happy?' Both the physical and social counterfactual tasks contained two scenarios that prompted children to generate upward counterfactuals (i.e. those that make the situation better) and two scenarios that prompted downward counterfactuals (i.e. how the situation could have been worse). After each response, the experimenter prompted each child to think of additional possibilities until he/she stopped providing answers. Physical and mental counterfactual scenarios were comparable in length.

Coding of counterfactuals occurred in three steps. First, two independent raters determined whether or not each response was a counterfactual (i.e. a statement indicating an antecedent that would have changed the outcome; 97% agreement). Second, the number of upward and downward counterfactuals was totalled. Two physical and two mental counterfactual scenarios prompted upward counterfactuals and two of each prompted downward counterfactuals. Third, the same two raters coded each counterfactual statement according to structure (i.e. additive and subtractive). Statements that added antecedents to reconstruct reality were coded as 'additive', while statements that removed antecedents to reconstruct reality were coded as 'subtractive'. Thus, each counterfactual statement was identified as either an upward or downward counterfactual, based upon the scenario, and then coded as either additive or subtractive. All disagreements between the two coders were settled by a third individual ($\kappa = .88$). Children received a score reflecting the number of upward, downward, additive, and subtractive counterfactuals they generated.

Representational flexibility

Representational flexibility was measured using a general multiple classification task adapted from Cartwright (2002). The experimenter placed two wooden sticks on the table to form a 2 × 2 matrix. Each trial involved a set of 12 cards that could be sorted by two dimensions: colour and type of object. For example, one set of cards included six tools and six instruments; six of the cards were red and six were blue. To be correct children had to sort the 12 cards in piles of 3 according to both the object type and colour simultaneously. The experimenter demonstrated the procedure once; children were given a practice trial; and then children completed four trials. Given the young age of the children, the experimenter repeated part of the directions at the beginning of each trial (i.e. 'Remember, the cards need to be sorted according to both colour and type of object').

After completing each sort, participants were asked to justify the arrangements of the sort. If the sort were incorrect, the researcher corrected the sort and asked why the correct sort was right. Children received three points for a correct sort and a correct justification, two points for an incorrect sort but a correct justification, one point for a correct sort and an incorrect justification, and 0 points for an incorrect sort and justification. Children's scores could range from 0 to 12 (following Bigler & Liben, 1992; Cartwright, 2002).

Working memory

Three tasks were used to assess working memory: backward word (Carlson *et al.*, 2002); backward digit (Davis & Pratt, 1995); and counting and labelling (Gordon & Olson, 1998). For the backward word span task children were presented with a puppet and were told, 'Freddie is being silly. Everything I say, he says backward. Like this, if I say the words book, cup, Freddie says cup, book. Now I want you to do exactly what Freddie did and say everything I say backward'. Before the test trials, children were presented with five practice examples. In order to continue the task, children had to answer one practice example correctly. The task continued with individual test trials each containing three sets of words. As the test level increased, the number of words in each set increased (i.e. the first-level had two words, second level had three words, etc.). Children who answered two of the three trials within a level correctly continued to the next level. The task ended when children responded incorrectly to two of the three trials. Children's scores reflected the highest level at which they answered two of the three sets correctly. Children who answered all five practice items incorrectly received a score of 1. The procedure and scoring for the backward digit span task matched that of the backward word span task except that children were presented with numbers instead of words.

For the counting and labelling task (Gordon & Olson, 1998) the researcher presented three objects in front of the child (i.e. pretend bread, a crayon, and a small, plastic baby). The researcher then demonstrated how to point and label the toys by stating, 'I am going to name my toys, watch what I do. Bread, crayon, baby'. The researcher then demonstrated how to point and count the toys by stating; 'Now I am going to count each of my toys, watch what I do. 1, 2, 3'. Finally, the researcher demonstrated how to point, count, and label by stating; 'Now I am going to name and count my toys, watch what I do. One bread, two crayon, three baby'. The researcher simultaneously stated and performed the instructions.

Following the demonstration trial, the researcher put away the objects and placed three different objects in front of the child, specifically a toy chair, eye glasses, and small ball. The researcher instructed each child to point and label the objects by saying, 'Now it's your turn to name each of your toys like I named mine. What is this?' The researcher pointed to each object and waited for the child to identify the object. Both correct and incorrect answers were recorded. The researcher then asked the child to point and count the objects by saying, 'Now let's count each of your toys like I counted mine'. Once again, both correct and incorrect answers were recorded. Finally, the researcher asked the children to point, count, and label the objects. After the first test trial was completed, the researcher re-demonstrated the task using the same procedure, and children performed the task a second time. Children's scores on the counting and labelling task ranged from 0 to 2 (one point for correctly counting and labelling on each trial).

Procedure

Children completed three 10–20 minute sessions in a quiet part of their school. The same experimenter administered all tasks to each child. During one session children received the false belief and both counterfactual measures. In a second session children completed the language measure, and during a third session children received the general multiple classification, backward digit, backward word, and counting and labelling tasks. Sessions one and three were counterbalanced around session two, and measures were counterbalanced within sessions. The researchers recorded children's responses during each session. Between the completion of sessions one and three, 1–12 days elapsed.

Results

Overview of analyses

First, we report descriptive statistics and intercorrelations among variables. Second, age differences in the generation of different types of counterfactual statements are described. Third, we report a series of regressions to determine whether working memory and representational flexibility mediate the relationship between counterfactual thinking and false belief. In the final section, we describe a series of hierarchical regressions that examined the unique contributions of aspects of executive function (working memory, representational flexibility) and counterfactual (including total number, types, and domain of counterfactuals) to false belief as well as the degree to which executive function predicts counterfactual.

Preliminary analyses

All five false belief measures were intercorrelated (see Table 1), and the five-item scale had an internal consistency of .84. Thus, the scores for the tasks were totalled for a composite false belief score.[1] Similarly, the three working memory measures (i.e. backward digit span, backward word span, counting and labelling) were intercorrelated with an internal consistency of .76; accordingly, these scores also were summed for a working memory composite score. All variables were intercorrelated (see Table 2). Age and language were included in subsequent analyses as control variables. Number of siblings was not related to false belief or generation of physical or mental counterfactuals, p's $> .10$. Descriptive statistics for all variables are in Table 3. There was no effect of either sex or order; thus, these variables were not considered further.

Table 1. Intercorrelations among false belief tasks ($N = 92$)

Task	1	2	3	4	5
1. Unexpected change	–	.39*	.42**	.56**	.66**
2. Unexpected contents (self)		–	.42*	.42*	.49**
3. Unexpected contents (other)			–	.59**	.57**
4. Deception				–	.64**
5. Active deception					–

*$p < .01$; **$p < .001$.

Age comparisons

Analyses examined age differences in children's generation of physical and mental counterfactuals, as well as the different types of counterfactual statements (i.e. direction, structure; see Table 4). Additional analyses were conducted to examine age effects with language controlled to determine the importance of linguistic skills for cognitive development.

Domain and direction of counterfactual statements

A $2 \times 2 \times 2$ (age $\times$ domain $\times$ direction) mixed ANOVA was conducted to examine age differences in children's generation of different types of counterfactuals (see Figure 1). Domain (i.e. physical and mental) and direction (i.e. upward and downward) were within-subject variables, and age was a between-subjects variable. The main effect of

[1] *On the unexpected location and the active deception tasks, 21 and 22 children missed either one or two control questions, respectively. Of these children, 17 missed control questions on both of these tasks. The majority of children whom answered control questions incorrectly were 3-year-olds (71% for the unexpected change task; 82% for the active deception task). Three 3-year-olds answered the control question incorrectly on the unexpected change/explanation task.*

Table 2. Intercorrelations among children's age, language, false belief, counterfactual reasoning, working memory, and representational flexibility ($N = 92$)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Age	.67**	.68**	.59**	.59**	.46**	.55**	.28*	.47**	.59**	.67**	.52**	.57**	.59**	.43**
2. Language	–	.72**	.69**	.68**	.53**	.63**	.39**	.58**	.66**	.69**	.57**	.62**	.55**	.49**
3. False belief		–	.63**	.55**	.55**	.58**	.38**	.56**	.57**	.61**	.44**	.53**	.58**	.49**
4. Total number counterfactuals			–	.83**	.90**	.95**	.51**	.90**	.89**	.73**	.63**	.65**	.63**	.54**
5. Upward counterfactuals				–	.51**	.79**	.43**	.71**	.78**	.70**	.62**	.67**	.47**	.52**
6. Downward counterfactuals					–	.86**	.45**	.84**	.77**	.59**	.49**	.49**	.47**	.60**
7. Additive counterfactuals						–	.25*	.88**	.83**	.66**	.57**	.60**	.48**	.59**
8. Subtractive counterfactuals							–	.42**	.50**	.44**	.36**	.38**	.37**	.45**
9. Physical counterfactuals								–	.61**	.65**	.56**	.54**	.51**	.62**
10. Mental counterfactuals									–	.66**	.57**	.64**	.46**	.54**
11. Working memory										–	.88**	.87**	.74**	.55**
12. Backward digit span											–	.74**	.39**	.47**
13. Backward word span												–	.47**	.44**
14. Counting and labelling													–	.46**
15. Representational flexibility														–

*$p < .05$; **$p < .001$.

Table 3. Task means, standard deviations, and ranges of scores ($N = 92$)

Task (possible range)	Mean	Standard deviation	Range
Age (months)	54.41	10.42	36– 71
Language (0–120)	71.93	24.40	21–122
False belief (0–5)	2.77	1.82	0– 5
Unexpected change	0.53	0.50	0– 1
Unexpected contents (self)	0.58	0.45	0– 1
Unexpected contents (other)	0.44	0.38	0– 1
Deception	0.58	0.50	0– 1
Active deception	0.64	0.48	0– 1
Total counterfactuals	6.12	3.92	0– 16
Upward counterfactuals	2.88	2.00	0– 8
Downward counterfactuals	3.24	2.50	0– 8
Additive counterfactuals	5.10	3.43	0– 13
Subtractive counterfactuals	0.97	1.18	0– 5
Physical counterfactuals	2.85	2.22	0– 8
Mental counterfactuals	3.27	2.14	0– 8
Working memory	4.68	2.46	2– 16
Backward digit span	1.76	1.18	1– 9
Backward word span	1.68	0.82	1– 5
Counting and labelling (0–2)	1.24	0.95	0– 2
Representational flexibility (0–12)	3.31	4.41	0– 12

Table 4. Mean and (standard deviation) language, false belief, and counterfactual reasoning performance

	Age			
	3-year-olds ($N = 26$)	4-year-olds ($N = 33$)	5-year-olds ($N = 33$)	Total ($N = 92$)
Language	49.31 (19.94)	74.42 (18.52)	87.27 (19.34)	71.93 (24.40)
False belief	0.89 (1.46)	3.02 (1.39)	4.02 (1.12)	2.77 (1.82)
Counterfactual reasoning				
Total counterfactuals	2.65 (2.15)	6.67 (3.32)	8.30 (3.75)	6.12 (3.91)
Upward	1.38 (1.17)	2.79 (1.71)	4.15 (1.97)	2.88 (2.00)
Downward	1.27 (1.61)	3.89 (2.32)	4.15 (2.43)	3.24 (2.50)
Additive	2.67 (2.15)	5.61 (2.91)	6.82 (3.40)	5.10 (3.43)
Subtractive	0.38 (0.70)	1.06 (1.20)	2.55 (7.03)	1.40 (4.34)

age, $F(2, 89) = 23.34$ was significant. The domain × direction, $F(1, 89) = 18.06$, $p < .001$, interaction also was significant. Three-year-olds generated fewer counterfactuals than did 4- and 5-year-olds, p's $< .001$. Irrespective of age, children generated more downward than upward counterfactuals on the physical tasks and more upward than downward counterfactuals on the mental tasks.

Domain and structure of counterfactual statements

A second 2 × 2 × 2 (age × domain × structure) mixed ANOVA examined effects of the structure of counterfactual statements (see Figure 2). Domain (i.e. physical and mental)

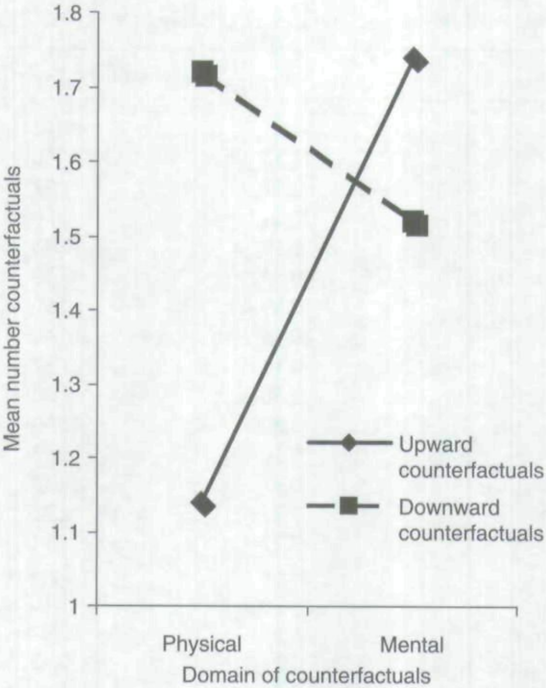

Figure 1. Mean number of upward and downward counterfactuals generated for physical and mental scenarios.

and structure (i.e. additive and subtractive) were within-subject variables and age was a between-subjects variable. The main effects of age, $F(2, 89) = 22.08$, $p < .001$, domain, $F(1, 89) = 4.81$, $p < .05$, and structure, $F(1, 89) = 156.47$, $p < .001$, were significant. These effects were qualified by age × structure, $F(2, 89) = 10.76$, $p < .001$, and domain × structure, $F(1, 89) = 4.02$, $p < .05$, interactions. *Post hoc* analyses indicated children within each age group generated more additive than subtractive counterfactuals. Three-year-olds generated fewer additive counterfactuals than did 4- and 5-year-olds, though all three age groups generated similar numbers of subtractive counterfactuals. Furthermore, children generated similar numbers of additive counterfactuals on both counterfactual tasks, but the mental tasks elicited slightly more subtractive counterfactuals than did the physical tasks.

Mediational effect of executive function

A series of regressions follows to examine whether working memory and/or representational flexibility mediate the relationship between counterfactual and false belief (see Baron & Kenny, 1986). working memory could be considered a mediator if: (1) counterfactual thinking predicts both false belief and working memory; (2) working memory predicts false belief understanding; and (3) the extent to which counterfactual thinking predicts false belief is reduced or eliminated once working memory is controlled (Baron & Kenny, 1986). Representational flexibility was considered as a potential mediator using the above criteria as well. The Sobel test (1982; as cited in Preacher & Hayes, 2004) was used to compare the meditational effect to the null

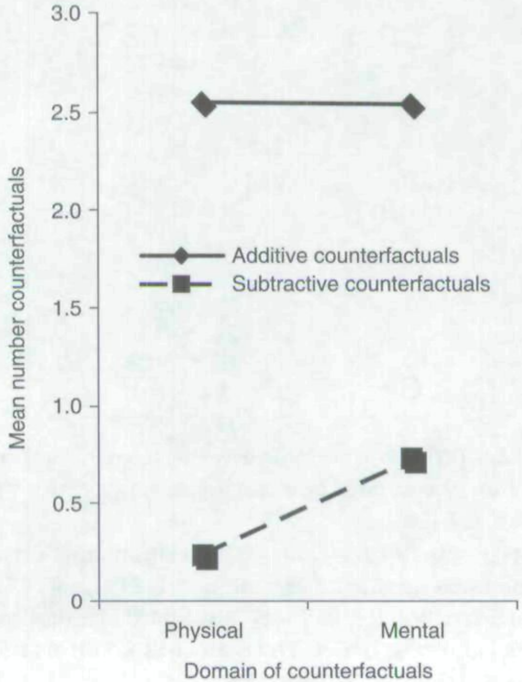

Figure 2. Mean number of additive and subtractive counterfactuals generated for physical and mental scenarios.

hypothesis (see Preacher & Hayes, 2004). For these analyses, a composite counterfactual score was calculated by totalling the number of physical and mental counterfactuals.

Working memory

The first series of regressions examined whether working memory mediated the relationship between counterfactual and false belief.

The analyses indicated that counterfactual was a significant predictor of both false belief ($\beta = 0.628$, $p < .001$) and working memory ($\beta = 0.729$, $p < .001$). working memory also predicted false belief ($\beta = 0.613$, $p < .001$); thus, the first three criteria of mediation were met. In the final equation, working memory ($\beta = 0.332$, $p < .01$) and counterfactual ($\beta = 0.386$, $p = .001$) predicted false belief, but the association between counterfactual and false belief was reduced. These analyses suggest working memory partially mediates the relationship between counterfactual and false belief. The Sobel test confirms a significant difference from zero, $z = 2.78$, $p < .01$ (see Figure 3).

Representational flexibility

The same sequence of analyses was conducted to determine whether representational flexibility was a mediator. As indicated above, counterfactual predicted false belief. counterfactual accounted for variance in representational flexibility ($\beta = 0.647$, $p < .001$), and representational flexibility predicted false belief ($\beta = 0.531$, $p < .001$). In the last equation, counterfactual and representational flexibility were entered simultaneously. The association between counterfactual and false belief was reduced, but

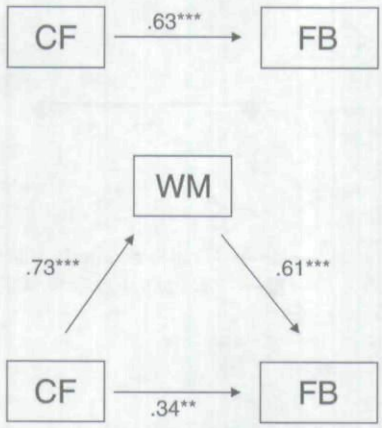

Figure 3. Working memory (WM) as a mediator between counterfactual reasoning (CF), and false belief performance (FB). *Note*. Standardized beta coefficients are reported; $^{**}p < .01$; $^{***}p < .001$.

it remained significant ($\beta = 0.490, p < .001$). The relationship between representational flexibility and false belief was significant as well ($\beta = 0.214, p < .05$; see Figure 4). These analyses suggest representational flexibility also partially mediates the relationship between counterfactual and false belief. The Sobel test confirms a significant difference from zero, $z = 2.15, p < .05$.

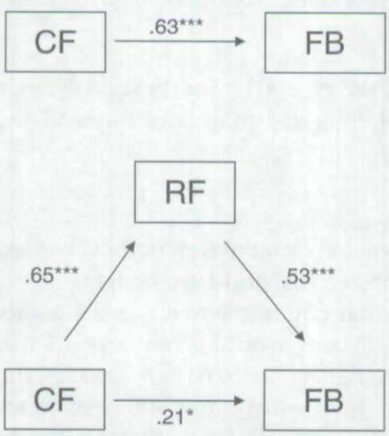

Figure 4. Representational flexibility (RF) as a mediator between counterfactual reasoning (CF), and false belief performance (FB). *Note*. Standardized beta coefficients are reported; $^{*}p < .05$; $^{***}p < .001$.

Hierarchical regressions

A series of hierarchical regressions was conducted to examine unique contributions of central variables. The first regressions examined unique contributions of age, language, counterfactual, working memory, and representational flexibility to false belief. Second, regressions explored whether executive function accounted for unique variance in counterfactual beyond age and language. Third, a set of regressions examined whether the different types of counterfactual statements predicted unique variance in false belief. A fourth, and final, regression examined the hypothesis that mental counterfactuals would better predict false belief than would physical counterfactuals.

Counterfactual thinking, executive function, and false belief

This analysis examined the unique contributions of counterfactual thinking and executive function to false belief beyond variance accounted for by age and language. In previous work, the relationship between counterfactual and false belief has been attenuated or eliminated when age and/or language have been controlled (e.g. Guajardo & Turley-Ames, 2004; Müller *et al.*, 2007; Perner *et al.*, 2004). The following two analyses allow for direct comparison between the present findings and previous work. Age and language accounted for 59% of the variance in false belief on the first step, $F(2, 89) = 63.86, p < .001$. working memory accounted for less than 1% of the variance on the second step, $p = .36$; and representational flexibility, entered on the third step, accounted for 2% of the variance in false belief, $F(1, 87) = 5.38, p < .05$.[2] The change in R^2 was not significant when counterfactual thinking was entered on the last step, $p = .45$[3] (see Table 5).

The above regression also was conducted with only age controlled to compare current findings to the previous work of Müller and colleagues (2007), in particular. Age accounted for 46% of the variance in false belief on the first step, $F(1, 90) = 77.35$, $p < .001$. On the second step, working memory accounted for a significant 5% of the variance, $F(1, 89) = 8.21$, $p < .01$, and representational flexibility accounted for an additional 4% of the variance in false belief on the third step, $F(1, 88) = 7.77, p < .01$. On the last step, counterfactual thinking accounted for 2% of the variance beyond all other variables, $p = .09$.[4] The standardized beta coefficient for age was significant in the final equation ($\beta = 0.43, p < .001$) and those for representational flexibility ($\beta = 0.17$, $p = .07$) and counterfactual thinking ($\beta = 0.20, p = .09$) approached significance (see Table 6). These analyses, taken together, suggest that language and executive function, particularly representational flexibility, are important factors in false belief.

Direction and structure of counterfactual statements as predictors of false belief performance

A hierarchical regression was conducted to determine whether different types of counterfactual statements (i.e. upward, downward, additive, and subtractive) accounted for unique variance in false belief. Age and language accounted for 59% of unique variance in false belief on the first step, $F(2, 89) = 63.86$, $p < .001$. Total number of each type of counterfactual, entered on the second step, accounted for an additional 3% of the variance in false belief, $F(4, 85) = 1.71, p > .10$.

Domain of counterfactuals as predictors of false belief performance

A hierarchical regression was conducted to test the hypothesis that counterfactual in a mental domain would better predict false belief than would such counterfactual in a physical domain. Age and language, entered on the first step, accounted for 59% of the variance in false belief, $F(2, 89) = 63.86, p < .001$. Physical and mental counterfactuals,

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[2] *The results were comparable when representational flexibility was entered on the second step and working memory on the third step.*

[3] *When counterfactual was entered on the second step it accounted for 2% of the variance in false belief,* $F(1, 88) = 3.42$, $p = .07$. *working memory did not account for unique variance on the third step,* $p = .89$, *and the 2% of variance accounted for by representational flexibility on the fourth step approached significance,* $F(1, 86) = 3.32$, $p = .07$.

[4] *counterfactual accounted for 8% of unique variance when it was entered on the second step,* $F(1, 89) = 15.34$, $p < .001$. *working memory did not account for unique variance on the third step,* $p = .35$, *and representational flexibility explained 2% of the variance on the fourth step,* $F(1, 87) = 3.32$, $p = .07$.

Table 5. Hierarchical regression analysis of executive function and counterfactual reasoning predicting false belief performance with age and language as control variables ($N = 92$)

Step	Inc. R^2	F-change	β	t value	sr^2
Step 1	.589	63.86***			
Age (months)			0.356	3.88***	.070
Language			0.482	5.25***	.127
Step 2	.004	0.845			
Age (months)			0.321	3.23**	.048
Language			0.440	4.30***	.086
Working memory			0.094	0.92	.004
Step 3	.024	5.38*			
Age (months)			0.316	3.26**	.047
Language			0.402	3.97***	.069
Working memory			0.021	0.203	.000
Representational flexibility			0.187	2.32*	.024
Step 4	.003	0.577			
Age (months)			0.311	3.20**	.045
Language			0.379	3.59**	.057
Working memory			−0.009	−0.078	.000
Representational flexibility			0.161	1.82⁺	.015
Counterfactual reasoning			0.087	0.759	.003

Note. Inc. R^2, increment in variance accounted for; β, standardized regression coefficient; sr^2, squared semi-partial correlation.
$^+p < .10$; $*p < .05$; $**p < .01$; $***p < .001$.

Table 6. Hierarchical regression analysis of executive function and counterfactual reasoning predicting false belief performance with age controlled ($N = 92$)

Step	Inc. R^2	F-change	β	t value	sr^2
Step 1	.462	77.35***			
Age (months)			0.680	8.80***	.462
Step 2	.045	8.21**			
Age (months)			0.488	4.87***	.131
Working memory			0.287	2.87**	.045
Step 3	.040	7.77**			
Age (months)			0.462	4.77***	.117
Working memory			0.172	1.64	.014
Representational flexibility			0.240	2.79**	.04
Step 4	.015	2.98⁺			
Age (months)			0.432	4.44***	.099
Working memory			0.083	0.716	.003
Representational flexibility			0.171	1.82⁺	.017
Counterfactual reasoning			0.202	1.73⁺	.015

Note. Inc. R^2, increment in variance accounted for; β, standardized regression coefficient; sr^2, squared semi-partial correlation.
$^+p < .10$; $**p < .01$; $***p < .001$.

entered together on the second step, did not account for unique variance in false belief, $F(4, 87) = 2.11, p > .10$. The standardized beta coefficients for age ($\beta = 0.33, p < .01$) and language ($\beta = 0.40$, $p < .001$) were significant; the coefficient for physical counterfactuals approached significance ($\beta = 0.16, p = .07$). Thus, these data suggest a trend towards counterfactual about physical events accounting for more variance in false belief than does counterfactual about mental situations.

Executive function and counterfactual reasoning

An additional regression examined the degree to which executive function predicted counterfactual beyond age and language because this question has not been explored in the literature to date. Age and language, entered on the first step, accounted for 50% of the variance in counterfactual scores, $F(2, 89) = 44.75$, $p < .001$. Executive function (i.e. working memory and representational flexibility) explained an additional 16% of the variance on the second step, $F(2, 87) = 20.41$, $p < .001$. The standardized beta coefficients for language ($\beta = 0.26$), working memory ($\beta = 0.35$), and representational flexibility ($\beta = 0.31$) were significant in the final equation, p's $< .01$. Children's language comprehension and executive function skills predicted their ability to generate alternative antecedents that would change an outcome.

Discussion

The primary purposes of the present study were to clarify previous findings regarding the association between counterfactual thinking and false belief and to examine whether executive function skills mediate this relationship. The present study also provided interesting information about children's abilities to generate different types of counterfactuals (i.e. upward, downward, additive, and subtractive) and the degree to which executive function accounted for developmental changes in counterfactual. Finally, this study explored whether mental counterfactuals would better predict false belief than would physical counterfactuals. Each of these goals will be addressed in turn.

Counterfactual reasoning and false belief

The present findings, consistent with previous work, suggest that the relationship between counterfactual and false belief is attenuated or eliminated when both age and language are controlled (Guajardo & Turley-Ames, 2004; Perner *et al.*, 2004). The current findings particularly correspond to those of Guajardo and Turley-Ames' (2004) Study 2; both studies indicated counterfactual accounted for 2% of the variance in false belief scores beyond age and language. counterfactual accounted for 8% of the variance in false belief when only age was controlled. These data suggest the importance of language in the association between counterfactual and false belief understanding. The role of language in these areas of thinking will be discussed later.

A primary contribution of the present study is that it supports previous suggestions (see German & Nichols, 2003; Guajardo & Turley-Ames, 2004; Müller *et al.*, 2007) that executive function mediates the relationship between counterfactual and false belief. Regressions consistent with Baron and Kenny's (1986) approach and Sobel's test suggested that both working memory and representational flexibility partially mediate this relationship. Hierarchical regressions indicated that counterfactual did not account for unique variance in false belief beyond age, language, working memory, and representational flexibility. In contrast to the work of Müller and colleagues, we found that working memory accounted for unique variance in false belief when age was controlled. When age and language were both controlled, though, it did not. Whereas Müller and colleagues assessed working memory with a counting and labelling task, the present study included this same task as well as backward digit and backward word span tasks. The discrepant findings could have been due to the use of an aggregate score in the present study, allowing for greater variability in scores, or it could have been due to different processing demands of backward span tasks and the counting and labelling task. Future research should explore these possibilities.

Representational flexibility also was an important factor in the relationship between counterfactual and false belief understanding. Both counterfactual and false belief understanding require children to think flexibly about the situation. On counterfactual tasks children must consider an event and then generate alternatives; on false belief tasks they need to think about their own knowledge as well as another's different perspective. Improvements in representational flexibility allow children to consider alternatives to an event and how people could have different beliefs about the same situation. Another important aspect of executive function is inhibitory control. It is still unclear whether or not changes in inhibitory control partially explain the relationship between counterfactual and false belief. Future research should examine this component of executive function as well.

Consistent with previous research, representational flexibility also proved important in predicting false belief, irrespective of counterfactual thinking, when age and language were controlled (e.g. Carlson & Moses, 2001; Dick *et al.*, 2005; Frye *et al.*, 1995; Kloo & Perner, 2003). Frye and colleagues indicated that theory of mind performance (i.e. false belief, representational change) related to children's abilities to sort cards along one of two dimensions but not their ability to sort along two dimensions simultaneously. In contrast, Perner, Stummer, Sprung, and Doherty (2002) more recently found that false belief understanding related to performance on an alternative naming task that assessed children's recognition that one object can have two names, and Andrews, Halford, Bunch, Bowden, and Jones (2003) showed that sorting cards along one dimension and doing so along two dimensions were equally predictive of theory of mind performance. Our findings are consistent with these latter studies indicating children who could simultaneously consider two dimensions of an object performed better on false belief tasks than those who could not. These findings support Andrews and colleagues' suggestion that children's abilities to integrate multiple factors into a representation enable them to pass theory of mind tasks. We now can add that such skills also allow children to reason counterfactually.

Unexpectedly, counterfactual about physical events accounted for slightly more variance in false belief than did such reasoning about mental events. We hypothesized that reasoning about mental events would be more highly related to false belief because of similarities in domain. This was not the case. The mental counterfactual scenarios focused on emotion as did those of German and Nichols (2003). Emotion understanding and false belief are consistently related, though the correlation often is eliminated when age and language are controlled (see Cutting & Dunn, 1999; Weimer & Guajardo, 2005). Thus, perhaps it is not surprising that children's generation of counterfactuals regarding emotion did not predict false belief beyond age and language. This explanation, though, does not account for the difference between the present findings and those of German and Nichols (2003) that indicated performance on an emotion counterfactual task predicted false belief. Another factor might be the fact that both the physical tasks and the false belief tasks focus on physical objects; though false belief tasks require mental representational understanding, they involve the location or contents of objects. Future work could explore these ideas further.

Counterfactual reasoning

The present study also adds to our current knowledge about preschool aged children's counterfactual thinking, irrespective of false belief understanding. First, we have additional data regarding the types of counterfactuals children generate. Consistent with Guajardo and Turley-Ames (2004), children generated relatively similar numbers of upward and downward counterfactual statements, and they generated significantly fewer subtractive than additive counterfactuals. Meaningful changes in children's abilities to generate additive counterfactuals occurred between 3 and 4 years of age, yet no age differences existed from 3 to 5 years of age for subtractive counterfactuals. All three age groups produced very few subtractive counterfactuals. Thus, there are early changes in children's skills in considering what else they could have done to change an outcome, but not in what they could *not* have done.

The pattern of results parallels research with adults (Roese *et al.*, 1999). Children and adults might be less likely to generate subtractive counterfactuals because they are more effortful. In fact, adults with more working memory capacity are more likely to generate subtractive counterfactuals than adults with less capacity (Whitfield, Turley-Ames, & Miyake, 1999). Also, adults are more likely to endorse subtractive counterfactuals when required to engage in controlled and effortful processing than in conditions that limit processing (Turley-Ames & Whitfield, 2000). In fact, the adults in Whitfield and colleagues' study only generated slightly more subtractive counterfactuals than the children in the present study. It would be interesting to compare the performance of adults and young children within the same study and to explore the role of executive function in the generation of different types of counterfactual statements. Longitudinal work could be of particular interest.

Second, the present study is the first to examine the degree to which executive function skills account for counterfactual in early childhood. Both working memory and representational flexibility predicted counterfactual, beyond age and language. counterfactual requires children to hold the outcome in mind while they generate alternative antecedents; it also requires children to think flexibly about what is and what could have been. Thus, the present study provides further evidence for the importance of executive function as a domain general skill.

Language

The present study provides additional support for the importance of language in early cognitive development. Numerous studies have demonstrated the fact that language ability relates to false belief (Milligan, Astington, & Dack, 2007) and a few have shown that it also is associated with counterfactual (Guajardo & Turley-Ames, 2004; Perner *et al.*, 2004) in early childhood. The present findings suggest that language partially accounts for the relationship between counterfactual thinking and false belief. Counterfactual thinking accounted for a larger, significant, portion of the variance in false belief beyond age, but less so when language also was controlled. Other effects, particularly of age, were eliminated when language was controlled. Undoubtedly, part of the importance of language development is that it is essential for current assessments of counterfactual thinking and false belief. Children must be able to comprehend and respond to tasks. At least equally important, though, is the fact that language provides individuals access to the thoughts and beliefs of others and alternative events; it is the means through which children become able to represent such states (e.g. Nelson, 2005; Schick, de Villiers, & de Villiers, 2007). Language acquisition also provides the basis for representational flexibility (see Jacques & Zelazo, 2005; Perner *et al.*, 2002). As children interact within a linguistic community they learn about others' viewpoints and become able to represent objects and events from multiple perspectives. These skills are important for both counterfactual thinking and false belief understanding; thus, future research examining either of these aspects of social cognitive development needs to assess linguistic development as well.

Conclusion

The present study clarifies previous research by demonstrating that counterfactual thinking about physical events accounts for only a small percentage of variance in false belief when both age and language are considered. It also adds to previous theoretical discussions by indicating that executive function skills partially mediate the relationship between these two aspects of cognitive development. Executive function may be the common underlying thread that connects a child's ability to think counterfactually with his/her ability to consider different perspectives. In line with these findings, executive function also accounted for developmental changes in counterfactual thinking irrespective of false belief. In the preschool years children are becoming better able to talk about and think about their world in a flexible manner, which allows them to consider how situations could be different, and how others' views might differ from their own.

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