The Pennsylvania State University

The Graduate School

Department of Psychology

TESTING EXPRESSION EFFECTS OF LANGUAGE AND INHIBITION WITHIN A SERIES OF FALSE BELIEF TASKS

A Thesis in

Psychology

by

Patrick L. Craven

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

May 2005

The thesis of Patrick L. Craven was reviewed and approved[1] by the following:

Keith E. Nelson
Professor of Psychology
Thesis Advisor
Chair of Committee

David Rosenbaum
Distinguished Professor of Psychology

Ulrich Müller
Assistant Professor of Psychology

Carol Miller
Assistant Professor of Communication Disorders

Kevin Murphy
Professor of Psychology
Head of the Department of Psychology

[1] Signatures are on file in the Graduate School

ABSTRACT

The extent to which theory of mind task success depends on children's language and executive function skills is tested in this study. Specifically, the hypothesis that the requirements of the false belief task mask successful expression of an underlying theory of mind is examined. To test this hypothesis, four versions of a false belief task are used in which each version has a high or low language and executive function component. The language component is modified by altering the phrasing of the theory of mind question such that a more simple language version is included in addition to the standard syntactically complex version. The executive function component is modified by allowing children to respond using either the standard finger-pointing version, or through the use of a game-board arrow. Additionally, the hypothesis that any resulting changes according to task manipulation would be related to an underlying cognitive ability in either language or inhibition is examined. Results from 28 children are reported, and main effects for the manipulation in both language and executive function were observed. Observed differences were in a direction opposite of what was expected, and these differences appeared unrelated to underlying cognitive skills. The results are interpreted in a context in which language plays a strong role in theory of mind success, possibly through working memory, and that subtle differences in theory of mind tasks can yield significantly different performances.

Table of Contents

List of Tables

List of Figures

ACKNOWLEDGEMENTS

I am grateful to Jake Feldman, Kelly Mendez, and Ned Fitzpatrick for their assistance with data collection and their role in creating theory of mind video clips. In addition, I want to thank Jake Feldman for his development of the visual working memory measure. Its inclusion in this study yielded some very interesting results. Without their contributions, this project would not have run as efficiently. I am also grateful for the guidance and feedback provided by my advisor, Dr. Nelson, throughout the course of this project. His open-minded attitude and thoughtful responses were appreciated throughout this project. Additionally, the insight offered by Dr. Miller, Dr. Müller, and Dr. Rosenbaum were invaluable in making this project a success.

Background and Significance

Introduction

Research on children's development of theory of mind (ToM) has grown steadily over the last 20 years, and the literature is filled with investigations of this process in both normal and clinical populations within various cultures. Much of this work has also examined the relations of theory of mind to other cognitive skills such as executive function (EF) skills and language. The research suggests that theory of mind development is an important skill acquired at roughly the age of four (Lalonde & Chandler, 1995; Wellman, Cross, & Watson, 2001), and that it marks one of the milestones that separates infants egocentric perspectives from children's ability to account for others' perspectives. Researchers from multiple domains have joined forces in investigating theory of mind in an effort to refine our understanding of this important cognitive development.

The development of a theory of mind is an important milestone in which children come to understand that other individuals have thoughts, beliefs, and desires which may differ from their own. The term "theory of mind" was first introduced by researchers who attributed a theory of mind to chimpanzees (Premack & Woodruff, 1978). The authors provided evidence that chimpanzees could attribute mental states to themselves and others, but this conclusion was subsequently criticized on the basis that only humans had evolved to the point of being capable of having theories regarding other's behaviors (Povinelli & Preuss, 1995). Following Premack and Woodruff's initial investigations, the exploration of theory of mind in young children followed a few years later (H. Wimmer & Perner, 1983). These authors introduced the change in location task, which has become the standard *false belief task* used in the developmental literature. In this task, a child witnesses another individual playing with a toy and then placing it in one location. That individual ends up leaving the room while the object's location is switched by the experimenter. When she returns to look for the toy, the child must decide where the individual will look. Thus, the false belief task tests one's ability to understand that another person can possess beliefs which may differ from what others believe, and possibly differ from reality. The task creates a situation whereby the character's belief contrasts from the child's known reality, and the child is tested on whether they can answer appropriately taking into account what is known by the character versus what they know.

Theory of mind research has expanded greatly to include investigation of the relation of theory of mind to varying aspects of cognition and social behavior, and these investigations have included participants from both clinical and normally developing populations. For example, studies have revealed that certain populations display difficulty with theory of mind tasks. These populations have included children with autism (Baron-Cohen, Leslie, & Frith, 1985), attention deficit hyperactivity disorder (ADHD) (Perner, Kain, & Barchfeld, 2002), and specific language impairment (SLI) (Miller, 2001). Additionally, research has revealed interesting relations between performance on theory of mind tasks and other developing cognitive capabilities. For instance, theory of mind has been positively correlated with varying aspects of language such as syntax (Astington & Jenkins, 1999) and semantics (Perner, 1988), as well as aspects of executive function such as inhibition (Carlson & Moses, 2001), cognitive flexibility (Hughes, 1998b), and working memory (Holmes, 2002)

Research examining children's developing theory of mind has been informative, but current methods have been limited in their approach. Although studies examining either language or executive function and theory of mind reveal important developmental links, they fail to capture the simultaneous influence of both cognitive skills. Few studies (Craven & Nelson, 2005; Hughes, 1998a) have examined the simultaneous impact of language and executive function on theory of mind performance. Since each of these cognitive skills has a rich body of literature supporting its independent link with theory of mind, a lack of consideration for one or the other fails to fully examine the complete development of theory of mind. The limitations of these uni-dimensional investigations are that they prevent investigation of the important intra-individual factors which contribute to degree of success on the theory of mind tasks.

Investigation of several cognitive skills including purposeful motor activity (Thelen & Smith, 1998) and children's language development suggest that one can view these developmental processes as a dynamic convergence, or *tricky mix*, of multiple initial conditions (K. E. Nelson, Craven, Xuan, & Arkenberg, 2004). According to a dynamic tricky mix perspective, success on a theory of mind task may result from the critical mix of converging conditions. Utilizing measures of only one type of condition fails to capture how intra-individual strengths or weaknesses in other cognitive domains impact theory of mind task success. Investigation of certain clinical populations (e.g., autism or SLI) may help reveal how varying cognitive skills influence task success, but some analyses are conducted with the assumption that all clinical subjects have the same unique deficit and suffer from no comorbidity. This possibility seems unlikely. Clearly, detailed examination of intra-individual influences is more powerful and can help answer questions regarding the nature of theory of mind success.

Shortly after theory of mind was first investigated in children, researchers noted that individuals with autism suffer from a lack of clear understanding of others' minds (Baron-Cohen et al., 1985). Autism is an early onset childhood disorder that is marked by severe difficulties in communication, development of language, and forming relations with others. Interestingly, individuals with autism have also demonstrated deficiencies in communication and executive function skills (Mitchell, 1997). Consequently, these common deficiencies have prompted researchers to investigate links between theory of mind and communication and executive function skills. Researchers began to investigate links between theory of mind and other cognitive skills such as language or executive function skills, and these investigations have helped shed light on the extent to which theory of mind is an independent process or an amalgamation of other processes. Theories describing the relation between theory of mind and other cognitive processes can be categorized as either *emergent* or *expressive* (Moses, 2001). Briefly, emergent accounts are ones that suggest that the related cognitive ability is required for the formation of a theory of mind. Conversely, expressive accounts suggest that an underlying and intact theory of mind exists but its use is limited by task difficulties. The following two main sections provide detailed descriptions of the known relations between theory of mind and the cognitive capabilities of executive function and language. At the conclusion of these sections, an experimental procedure is described that tests expressive accounts, or the extent to which language and executive function requirements of the false belief task itself interfere with a child's ability to display an underlying understanding of theory of mind.

Executive Function Explanations

Introduction

The preschool years are a time of rapid conceptual reorganization that can be linked to both neuronal maturation and the influence of direct experience. As cognitive skills develop, children can begin to rely on them to make even greater conceptual gains in their understanding of the world. Abilities such as inhibiting a prepotent response, working memory, and cognitive flexibility become more sophisticated during the preschool years. Aspects of these skills (inhibition, cognitive flexibility, and working memory) are often clustered as *executive functions*, or the command and control, portion of our minds, and traditionally they have been localized to regions within the prefrontal cortex. These skills are important for many types of higher level cognitive processes, and therefore it is challenging to design tasks that independently assess capability for each skill. As a result, there are often strong correlations among varying EF factors (Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000)

One can imagine how these executive function skills might be linked with the development of skills which allow children to successfully view the world through another's perspective in order to succeed in false belief tasks. It seems that a child must suppress his own salient perspective in order to realize that another individual can hold a false belief. Additionally, the false belief task requires keeping several things in mind at once (e.g., the object's real location and the object's previous location). Furthermore, there may be a need for flexibility in thinking to succeed on the task. For example, a child may need to switch perspectives several times comparing one's own beliefs with another person's in order to reconcile what each individual knows. Not surprisingly, there have been correlations found between a child's developing executive function skills and success on theory of mind tasks (Tager Flusberg, Sullivan, & Boshart, 1997). As will be discussed in more detail below, these findings have been replicated in numerous studies revealing a strong correlation between executive function skills and theory of mind ability (Craven & Nelson, 2005; Fahie & Symons, 2003; Frye, Zelazo, & Palfai, 1995; Perner, Stummer, & Lang, 1999), Certain clinical populations with traditionally impaired performance on executive function skills provide a valuable contrast to normal participants. Individuals with autism have demonstrated impairments in executive performance (Hill, 2004). Studies of autistic children's performance on theory of mind tasks further justify the need to carefully examine the relation between executive function and theory of mind performance. For instance, Ozonoff, Pennington, and Rogers (1991) compared the performance of 23 individuals with autism to 20 controls matched on verbal IQ, age, and socioeconomic status on several executive function tasks including the Tower of Hanoi and Wisconsin Card Sort Task (WCST), and theory of mind tasks including both first-order and second-order false belief. First-order false belief tasks measure understanding of another's beliefs whereas second-order tasks measure embedded belief understanding (beliefs about beliefs). Results revealed that individuals with autism performed significantly worse than their matched controls on executive function and theory of mind measures. In a three-year follow-up, results suggested that individuals with autism did not show increased development of executive functioning or theory of mind with increased age (Ozonoff & McEvoy, 1994). These results suggest a strong overlap between these skills whereby deficiency in one domain is accompanied by a deficiency in the other. Similarly, other researchers investigating theory of mind in children with autism have shown a relation between theory of mind performance and a more simple version of the WCST known as the Dimensional Change Card Sort (DCCS) (Zelazo, Jacques, Burack, & Frye, 2002). The DCCS is a simpler version of the Wisconsin Card Sort Task, and measures cognitive flexibility by having two different pairs of rules which are brought into conflict. In the task, children are shown two target cards (e.g., a yellow flower and a green car) and are told that yellow cards go with the yellow flower, and green cards go with the green car. Children are given a test card then, and are asked to sort the test card into the appropriate target pile. After several successful trials, children are given the new rule that cards are to be sorted by shape. Zelazo et al. reported results which suggested that children with autism suffer from a concurrent deficit in both executive functioning and theory of mind, and that these abilities do not appear to improve over time. Thus, investigation of children with autism reveals a curious co-deficiency in theory of mind and certain executive function skills which hint at an underlying commonality.

Similarly, there is evidence to suggest that other forms of developmental delay are related to performance on theory of mind tasks. For example, Garner, Callias, and Turk (1999) studied 8 boys with fragile-X syndrome and contrasted them with eight boys ages 10-16 with intellectual disability of an unknown etiology. Children with fragile-X syndrome typically demonstrate deficiencies in executive function similar to both autistic children and children with ADHD, and approximately 15-25% of children with fragile-X are also diagnosed with mild to severe autism (MedicineNet.com, 2002). Both of these groups exhibited considerable delay, with full scale IQs ranging from 40-59. The two groups were given three measures of false belief (a) the *Smarties task* in which children are asked about a box of candy which actually holds pencils, (b) first order change in location, (c) second order change in location. Also, they were given a simpler version of the WCST, the WCST-M, which is designed to test inhibitory control (IC) and cognitive flexibility. Results show that fragile-X boys failed the unexpected contents (Smarties) task more often than the comparison group (38% compared with 0%), but there were no statistically significant differences between fragile-X and control group in the change-in-location first order (29% compared with 86%) and second order (33% compared with 50%) false belief tasks. Interestingly, there were no significant differences between the groups on the WCST-M, suggesting that both groups were similarly impaired on executive function. Garner et al. argue that delay in theory of mind and executive function acquisition may be common to all children with intellectual disability and not just ones traditionally linked with executive function difficulties such as fragile-X or autism. However, the small sample size of this study may have masked real differences between these groups as a composite score of all false belief measures reveals that 33% of fragile-X and 81% of the control group responses were correct in participants who passed the control questions. Consequently, it may be that children with fragile-X, who demonstrate a similarity with children with autism show similar deficiency on theory of mind tasks as do children with autism (Baron-Cohen et al., 1985; Leslie & Happe, 1989).

Taken together, research on clinical populations offers initial evidence that executive function performance and theory of mind performance may be linked in some fashion. However, some might question whether there are aspects other than executive function deficits in clinical populations that make it difficult for them to succeed on theory of mind tasks. For instance, a general processing limitation would negatively impact performance on both executive function and theory of mind skills without reflecting a true link between the two domains. Consequently, research on non-clinical populations is important to eliminate this concern. For some researchers, the evidence linking executive function and theory of mind across a variety of populations has been quite compelling; so compelling, in fact, that they have argued that that although theory of mind and executive function are distinct, the two are so closely related that each essentially implies the other (Frye, 1999) Others have suggested that theory of mind is a particular form of executive function (Zelazo, 2003). If these suggestions are accurate, two important questions remain: (a) What are the specific components of executive function that are related to theory of mind? (b) What are the causal links between these components and successful demonstration of a theory of mind? Below, both of these questions are considered in turn, and the current state of the literature for each is discussed.

Executive functions and related abilities linked with theory of mind

Cognitive Flexibility

Cognitive flexibility is a component of executive function which allows one to perform timely transitions between cognitive rules. A real-world example of cognitive flexibility is a typical children's game, hide-and-seek. If a child is the seeker in one round of the game, they might be the hider in the next round. To be successful in this game, the child must shift his strategy from finding to hiding. Even though the game remains the same, the roles have shifted. This ability to flexibly shift cognitive strategies has been shown to have some relation to theory of mind. An early study by Frye, Zelazo and Palfai (1995) examined the relation between children's performance on two theory of mind tasks - false belief and appearance reality - and performance on the Dimensional Change Card Sort task. Children younger than four years of age tend to have difficulty succeeding in the post-switch condition, and Frye et al. reported correlations between success on the post-switch condition of the DCCS and success on false belief ($r = .40$, $p < .001$) and appearance-reality ($r = .38$, $p <$ 01) tasks. Another study offered limited support for the idea that cognitive flexibility and theory of mind are related. Hughes

(1998a) examined 50 preschool children's theory of mind, executive function components, and language abilities. The participants had a mean age of 3 years 11 months and were measured on tasks of false-belief prediction, false-belief explanation, two deception tasks, and cognitive attentional flexibility. The latter was measured by two tasks: a simple color/shape set-shifting task and a magnets pattern-making task. Results suggest that, after removing age, verbal ability, and non-verbal ability, a child's attentional flexibility was related to his performance on the theory of mind deceit task ($r = .30$, $p < .05$) but not on his false belief explanation or prediction tasks. Although deceptive skills should imply one has at least a rudimentary understanding of others' minds, the lack of a relationship between either of the false belief tasks and attentional flexibility speaks against this idea. However, the lack of a relationship is difficult to interpret, so together these studies provide only limited support for the idea that cognitive flexibility is related to theory of mind performance.

Working Memory

Tests of theory of mind require an individual to not only flexibly shift his perspective, but he must also be able to concurrently hold multiple accurate representations in mind (Keenan, 2000). One's working memory capacity allows the temporary storage of information in connection with performing other, more complex tasks (Baddeley, 1995). According to Baddeley's model of working memory, it is comprised of three components: the visuospatial sketchpad, the phonological loop, and the central executive. The visuospatial sketchpad is responsible for holding in mind visual information, the phonological loop holds auditory information, and the central executive is the system responsible for linking the visuospatial sketchpad and phonological loop with long term memory, and is responsible for strategy selection and planning. Success on a theory of mind task seems to require a child to hold a certain scenario in mind and compare that information with an alternative scenario. In fact, certain researchers suggest that one of the most important cognitive functions for theory of mind is being able to maintain two representations of the same situation or event (Gordon & Olson, 1998; Lohmann & Tomasello, 2003a; K. Nelson et al., 2003). It is important to note that it is usually only the central executive component of Baddeley's model which is categorized as an executive function. However, discussion of all three components of working memory are included in this section as the short-term processing capacity shares closer resemblance to executive functions than to the longer-term structures of language representations.

Several studies support the idea that working memory plays a role in theory of mind task success. In a study by Hughes (1998a), working memory was significantly correlated with all three measures of theory of mind: deceit task ($r = .46$), false-belief explanation ($r = .31$), and false belief prediction ($r = .46$). Furthermore, additional evidence suggests strong correlations ($r = .61$) between 3- and 5-year-olds' scores on false-belief tasks and the Sentence Memory subtest of the Stanford Binet Intelligence Scale (Jenkins & Astington, 1996). This subtest taps into one's ability to encode and store sentences of various lengths and complexity. Additionally, Gordon and Olson (1998) examined seventy-two 3-5 year olds performance on a pair of theory of mind tasks compared with a pair of dual processing tasks incorporating Baddeley's working memory model. Strong correlations ($r = .64$) suggest that changes in capacity to hold in mind allow for the expression and possibly formation of theory of mind. Similarly, Fahie and Symons (2003) examined 26 children between 5-7 years old referred to a mental heath clinic for attentional and behavior al problems. Normally children of this age would have demonstrated success in false belief tasks, but their attentional problems allowed for enough variability in performance to relate it to measures of auditory working memory. Results suggest that after controlling for age, language, and SES, theory of mind was significantly related to an aggregate score for memory consisting of backward digit span (BDS) and forward digit span (FDS) from the Woodcock – Johnson Psycho-Educational Battery – Revised ($r = .63$, $p < .001$). Finally, Davis and Pratt (1995) looked at working memory as measured by BDS and FDS and its relations to theory of mind in fifty-four 3-5 year olds. Theory of mind was related to BDS ($r = .46$), but not FDS ($r = .26$, ns). With age and Peabody Picture Vocabulary Test (PPVT) removed, theory of mind predicted BDS ($F = 4.19$, $p < .05$). Thus, BDS was a good predictor, but FDS was not. The only difference between these tasks is that one must repeat the numbers in reverse for the BDS task. This extra step would seem to add a more complex processing requirement which taps the "central executive" component of working memory. Taken together, these results suggest that various components of working memory seem related to theory of mind task success. However, the lack of clear consistency across results suggests that both the storage and processing components of working memory may play some role in theory of mind task success.

Although studies have shown a strong relation between theory of mind and working memory, at least one has suggested that working memory plays a less important role than other contributing factors. Carlson, Moses, and Breton (2002) measured forty-seven 3-5 year-olds' IQ, inhibition, working memory, and theory of mind skills. Although working memory and theory of mind were correlated, this effect disappeared after controlling for age and IQ. Close examination of the scoring used by Carlson et al. suggests that the lack of finding a stronger relation between theory of mind and working memory might be due to the lack of an appropriate measure of working memory, limited variability, and an unconventional scoring method for the working memory measures. Since a forward digit span or similar task that could provide a pure estimate of a child's capacity to hold something in mind was not included, the results confounds the child's ability to hold something in mind with the his ability to also reverse the pattern. This resulted in a mean performance on the difficult BDS task (M = 1.58) that was close to baseline for 3-year olds and suggests a floor effect. Most importantly, the scores are difficult to interpret because Carlson et al. scored all failures on the task as a "1". In fact, a failure on this task is qualitatively different than success, and scoring a failure in this manner falsely treats the results as integer-level data. Thus, the use of a correlational analysis is inappropriate on this type of data when comparing it with results from the theory of mind measure. Judging from the BDS mean, approximately half of the children could not complete even the two-digit reversal. The correlational analysis used minimized that importance of children not comprehending or not able to comprehend the task. In conclusion, the results from Carlson et al. would not appear to diminish the importance of working memory in theory of mind skill. Taken together, the studies linking working memory with theory of mind provide support for the idea that a genuine relation exists between working memory and theory of mind. Further research needs to provide more sophisticated analyses to investigate the extent to which varying aspects of working memory relate to theory of mind development.

Inhibitory Control

In addition to cognitive flexibility and working memory, inhibitory control has been identified as having a possible link with theory of mind. Inhibitory control is the ability to prevent oneself from performing automatic actions. For example, in baseball, batters can learn to inhibit their natural reaction to move when a baseball comes towards them. Inhibiting this natural defensive move can result in greater batting performance (and a free pass to first base if they are indeed struck by the pitch). The ability to inhibit prepotent responses first emerges in infants between 8-12 months (Diamond, 1993). Although in the previous section we noted that working memory appears related to theory of mind success, there is reason to believe that inhibitory control might also play a major role.

Data to support the idea that inhibition skills are required in theory of mind tasks have been compelling. For example, Hughes (1998a) conducted a comprehensive assessment of 50 preschool children (mean age 3;11) and examined theory of mind, executive function, and language abilities. Correlations indicated a relation between inhibitory control and the theory of mind deceit task ($r = .68$, $p < .05$), explanation task ($r = .47$, $p < .05$), and prediction task ($r = .31$, $p < .05$). Furthermore, after removing age, verbal ability, and non-verbal ability, inhibitory control was related to the deceit task ($r = .45$, $p < .05$). These findings have been replicated in other laboratories. For example, Carlson and Moses assessed the relations among one hundred seven 3- and 4-year-olds' performance on a variety of measures of both executive function and theory of mind (2001). A composite of the inhibitory control measures was strongly related to theory of mind ($r = .66$) and accounted for an impressive 44% of the variance. This relation remained significant, even after controlling for age, gender, and verbal ability ($r = .41$). Also, in a previously mentioned study, Carlson, Moses, and Breton (2002) tested 47 typical preschool children on several measures of early cognitive development and their relation to inhibitory control. The two types of inhibitory control were conflict inhibitory control and delay inhibitory. One example of a conflict inhibitory control is the Day-Night Stroop task in which participants are asked to respond with "day" when shown a picture of the moon, and "night" when shown a picture of the sun (Gerstadt, Hong, & Diamond, 1994). One example for a delay inhibition task is the gift delay in which children must simply suppress a response (e.g., not looking while the experimenter is wrapping a gift). Results of the study revealed that performance tasks measuring conflict inhibitory control significantly predicted performance on false belief when working memory, intelligence, delay inhibitory control, and age were controlled for. These results suggest that inhibition, which proved to be the most powerful predictor of theory of mind performance, may be central to the relation between executive function and false belief understanding. The problems with the working memory tasks and interpretation of its results were mentioned previously, but those problems do not discount the importance of inhibition in relation to theory of mind.

The above studies offer compelling evidence that there is a fundamental link between performance on inhibitory control and theory of mind tasks. This review of the literature suggests that inhibitory control is the most influential executive function predictor of theory of mind. There are a range of inhibitory control capabilities (Nigg, 2000), so it’s important to examine which aspects might be linked with theory of mind. Additionally, there is some evidence to support the idea that both working memory and cognitive flexibility may play some role as well. Cleary, there is a need to further clarify the individual roles of particular executive function skills in the successful expression of theory of mind.

Theories of how executive function is linked to theory of mind

Many of the above studies were correlational, so the question remains as to what the causal relationship might be between executive function and theory of mind skills. Perner and Lang (1999) and Hughes (2002) discuss a variety of interpretations of the relations found between theory of mind and executive function. The proposed relations include (a) complexity theories (CCC theory), (b) executive function and theory of mind share the same brain regions, (c) executive function depends on theory of mind, (d) theory of mind depends on executive function, (e) there are executive function components in theory of mind tasks. Additionally, many of these theories describe a relation that can be termed either an *emergence* account or an *expression* accounts (Moses, 2001). Emergence accounts claim that a certain level of either executive function or language ability needs to be in place for the very construction of a belief concept, whereas expression accounts argue that young children already have a conception of belief but that they are unable to express it in standard tasks because of particular demands on aspects of executive function. Moses states that "executive impairments may occur at either the representational level (e.g., cognitive inhibition) or the behavioral level (e.g., response inhibition). Children may have false-belief difficulties because they cannot inhibit attending to reality, or because the way in which they must respond suffers from a potentially interfering response history (e.g., pointing accurately to where objects actually are)." (p. 689). Moses suggests that a proper test of the expression account would require reducing these types of executive demands, and reducing the response demands along the EF and language domains is exactly the kind of experimental design that was utilized in the present study.

Complexity theories

Two groups of theorists have emphasized that success on theory of mind and executive function tasks is related to the task complexity (Andrews, Halford, Bunch, Bowden, & Jones, 2003; Frye et al., 1995). These approaches both view theory of mind as consisting of three levels of representation" the environmental cue, the setting condition, and the individual's representation. Frye et al. (1995) describe the Cognitive Complexity and Control (CCC) theory in which they view success on executive function and theory of mind tasks as being a result of one's ability to use embedded rules (if-if-then). For example, in the DCCS task in which cards showing pictures of two dimensions (color and shape), children's strategies can be described in terms of embedded conditionals. For example, *if* we play the color game and *if* I give you a blue car *then* you place it with the blue flower target. Alternatively, *if* we play the shape game and *if* I give you a blue car *then* you place it with the red car target. The CCC theory argument states that completion of executive function and theory of mind tasks both rely upon this rule structure.

Frye et al. (1995) offered support for the CCC theory. They argued that theory of mind tasks do not require simultaneous judgments across perspectives; rather, one can succeed on the task by selecting the appropriate perspective from which to reason. Thus, they hypothesize that if correlations between theory of mind and the DCCS were observed while similar correlations between theory of mind and 1- and 2-dimensional sorting were absent, it would provide strong support for the idea that both the DCCS and theory of mind require similar types of reasoning with embedded rules. They tested sixty children ranging from 3-5 years of age on three measures of theory of mind (false belief, appearance reality and representational change) and three types of card sorting tasks (1 dimensional, 1 of 2 dimensions, and 2 dimensions). For the one dimensional sorting children were asked to sort by a single dimension, either shape or color. The one of two dimensions was similar to the DCCS task in which children are told a rule to sort by (e.g., color or shape). The two dimensional card sort is one in which cards are placed on a two by two grid in which a card must match the target on both shape and color. Results of the study provided support for the complexity theory as false belief was positively correlated with the DCCS ($r = .37$, $p < .01$), but not with 1-dimensional or 2-dimensional sorting. Similarly, appearance reality was positively correlated with the DCCS ($r = .32$, $p < .05$), but not with 1-dimensional or 2-dimensional sorting. Finally, representational change was positively correlated with the DCCS ($r = .30$, $p < .05$), but not with 1-dimensional or 2-dimensional sorting.

Although the CCC theory offers a novel approach to conceptualizing the potential similarity of decision-making process during theory of mind and card sorting tasks, some have argued against CCC theory (Perner et al., 1999). One argument levied by Perner et al. is that one could view the if-if-then analysis as a more simple if-then analysis. For example, “IF I am looking for the chocolate THEN look there”, and “IF Maxi is looking for the chocolate THEN look here.” Interestingly, infants display this type of reasoning as early as 18 months (Meltzoff, Gopnik, & Repacholi, 1999). Consequently, if development of this reasoning structure is responsible for gains made in both EF and theory of mind tasks, one would expect to see success on these types of tasks around 18 months rather than 48 months. In conclusion, complexity theories offer a framework for drawing similarities between theory of mind and executive function tasks, but the theory suffers from a strict specificity that weakens its explanatory power for development of a complex cognitive ability such as theory of mind. The theory presupposes a fundamentally logical form of reasoning, but there is evidence that children use a more diverse range of reasoning logic (Hickling & Wellman, 2001). Finally, the complexity theory fails to fully account for theory of mind’s relation to linguistic ability that is examined in this paper's later section. It is interesting to note that CCC theory shares similarities to linguistic explanations of the development of theory of mind that suggest theory of mind is contingent on being able to hold representations of embedded clauses. Ultimately, it seems that these approaches fail to fully account for the dynamic convergence of multiples cognitive skills which relate to theory of mind performance.

Common brain region

Another theory used to explain the relationship between theory of mind and executive function tasks suggests that commonalities in responses are observed because the two capacities both utilize similar brain regions. This theory has gained support through multiple investigations of cortical regions that have been linked to theory of mind tasks. Predominantly, the frontal cortex has been implicated in theory of mind processing. The frontal cortex can be divided into at least four major sections: primary motor cortex, premotor cortex, limbic and paralimbic cortices, and the prefrontal cortex (Arunkumar & Kotagal, 1998). Additionally, the prefrontal cortex can be further subdivided into the dorsolateral prefrontal cortex (DL-PCF) and the orbitofrontal cortex (OFC). It is the most anterior portion of the frontal cortex, the prefrontal cortex and its DL-PFC and OFC subcomponents, which have been most often implicated in both theory of mind and executive function processing.

Convergent evidence using a variety of imaging techniques suggests that the frontal lobes play a role in success on theory of mind tasks. For instance, in an evoked response potential (ERP) study, 23 college students between the ages of 18 and 42 years were assessed on tasks that required thinking about mental versus nonmental representations (i.e., beliefs versus photographs) results revealed an increased focal positivity in left frontal areas on the tasks requiring representation of mental events (Sabbagh & Taylor, 2000). Similarly, evidence from positron emission tomography (PET) scans of 9 adults in a complex theory of mind task indicated activation of the left medial frontal lobes (Goel, Grafman, Sadato, & Hallett, 1995). Finally, Gallagher et al. investigated fMRI activation in six right-handed participants with a mean age of 30 using a verbal story comprehension and visual cartoon task (2000). Results suggest that, regardless of theory of mind modality, visual or verbal, there was unique activation in the medial prefrontal cortex (the paracingulate cortex in particular).

Conclusions drawn from research on normal functioning participants have been replicated in research with clinical populations. If the prefrontal cortices are responsible for a normal-functioning participant's success on tasks, then patients who have neurological trauma in the frontal cortex should have a more difficult time with theory of mind tasks. This has been confirmed in several different studies. For instance, Channon and Crawford (2000) investigated six participants with anterior left side damage and compared them with posteriorally damaged and normal participants on a series of 12 vignettes. The participants with anterior damage showed decreased comprehension compared with both the posteriorally damaged and normal controls. Finally, Bach et al. (1998) researched the performance of a 79-year-old right-handed woman (JH) who was treated for a nonaffective psychotic illness at age 27 with a prefrontal leucotomy. This woman's performance on first and second order theory of mind tasks, strange stories (Happe, 1994), and recognition of mental state terms was observed. Happe's strange stories task is designed to test one's understanding of a series of vignettes where people say things they do not literally mean (e.g., sarcastic utterances). Although JH passed first order theory of mind questions, she did not pass the more difficult second order theory of mind tests which consisted of embedded clauses (e.g., Mary believes that John thought the car was red). Additionally, on the long and more complex strange stories she showed considerable difficulty. She did well with mental state terms, which is not surprising given that lexical access has been associated with more posterior cortical regions. Additionally, she demonstrated deficits on executive function tasks, particularly on the WCST where she failed to achieve any category. Her success on the first order theory of mind tasks is therefore puzzling. Perhaps she managed to formulate an alternate route to success during her 52 years post-surgery, but that this was not sufficient to enable an advanced understanding that would be expected for her age. Additionally, research by Stuss, Gallup, and Alexander (2001) provides further neuroscientific evidence linking theory of mind with executive function. A study of 32 adult patients with a variety of frontal lesions indicated that lesions throughout the frontal lobe and particularly in the right frontal lobe resulted in decreased performance on visual perspective taking tasks. Additionally, lesions in the medial frontal lobes resulted in decreased performance on deception tasks. Both visual perspective taking and deception tasks share strong commonalities with false belief tasks. Taken together, the above results suggest a strong link between the frontal cortex and performance on theory of mind tasks.

DL-PFC

There is limited evidence linking theory of mind with activity in the dorsolateral prefrontal cortex. Stone, Baron-Cohen, and Knight (1998) compared performance of 5 bilateral orbitofrontal patients with 5 left side dorsolateral prefrontal cortex patients on a series of theory of mind tasks. Bilateral OFC patients performed similarly to individuals with Asperger's syndrome, a mild form of autism, and performed poorly on many versions of the tasks. However, dorsolateral lesion patients had difficulty only on versions of theory of mind tasks that placed demands on working memory. This is not surprising as working memory has traditionally been associated with activity in the DL-PFC (Diamond, 2002). Thus, the DL-PFC may be related to theory of mind performance because of the recruitment of working memory in theory of mind tasks.

In contrast, the OFC has generally been linked with tasks requiring inhibition (Zelazo & Müller, 2002), but limited evidence suggests that infants may also recruit DL-PFC in tasks requiring inhibition. For instance, success on early tests of inhibition such as the *A not B* task has been linked to maturational changes in the dorsolateral prefrontal cortex in infants (Diamond, 1993). Children between 7½ and 12 months of age typically have difficulty with this task. In the A not B task, an infant is placed in front of a table with two identical-looking wells, one on the left and one on the right. In trial 1, the infant is initially successful in locating a hidden object if it is placed in location A. However, if after successfully retrieving the object from location A, the infant observes the object being hidden in location B, he will persist in searching for the object in location A. In trial 2, the infant watches as a toy is placed in the opposing well, and both wells are covered simultaneously by identical covers. A brief delay (0-10 seconds) is imposed, and children are prevented from staring or straining towards the correct well during this time. When the infant is allowed to search for the object, he will search in the location in which the object was hidden in trial 1 even though they witnessed it being hidden in the opposing location.

The evidence Diamond presents relates to infants' inhibitory skills, and these results may not be relevant to young children's recruitment of inhibition skills. Furthermore, the A not B task may not be a true measure of inhibition because the infant is only changing a recently acquired response, not a prepotent response. Also, the activation of DL-PFC areas may reflect recruitment of working memory processing. Recruitment of areas in the DL-PFC during inhibition tasks may reflect more 'cool' processes, but theory of mind inhibition may require the recruitment of more "hot" executive function areas associated with the OFC (Zelazo & Müller, 2002).

OFC

Many of the current measures of theory of mind require flexible problem representation through various viewpoints. This skill is considered to tap into the "hot" areas of executive functioning in the OFC (Zelazo & Müller, 2002). The "hot" executive function processes are those that involve affect and motivation whereas the "cool" processing is more decontextualized. It is not surprising then that there has been evidence linking the OFC with performance on theory of mind tasks (C. D. Frith & Frith, 2000). Although it is intuitive that the cortical regions associated with theory of mind are in the OFC, there are some contradictory findings that are puzzling. For instance, some researchers have used single photon emission computerized tomography (SPECT) to assess brain activation during recognition of mental state terms in a word list and found that normal adults showed increased cerebral blood flow in the right OFC (Baron-Cohen, Ring, Moriarty, Schmitz, & et al., 1994). This finding is confusing because one would expect that the mental state verbs would be localized to posterior regions typically associated with language. Furthermore, Bach, Happe, Fleminger, and Powell (2000) tested a 59-year-old right handed male (GO) with damage to the OFC whose DL-PFC was relatively intact. This sort of lesion might lead one to believe that theory of mind performance would be reduced. Happe's strange stories were used to assess theory of mind as well as a battery of executive function tests designed to test abstract reasoning, strategy formation, hypothesis-testing, self-monitoring, mental flexibility, and ability to inhibit prepotent responses. Results suggested that the patient's theory of mind was intact while executive function was reduced. Similarly, Varley, Siegal, and Want (2001) reported a case study of a 60-year-old right-handed male, MR, who performed in the bottom 5th percentile on the WCST, yet could pass both true and false belief theory of mind scenarios (5 of 5 on both). Perhaps these patients had also managed to recruit alternate cortical areas to succeed on the theory of mind tasks, or perhaps the strange stories task has less in common with the false belief task than one might assume.

Summary of neuroscientific evidence

The theory that the relation between executive functions and theory of mind is due to the involvement of common brain regions has received strong support. However, despite the evidence in its favor this explanation has two notable inadequacies. First, although evidence points to the prefrontal cortex as the common area for both executive function and theory of mind skills, there have been other cortical areas identified as playing a role in theory of mind. For example, portions of the limbic system such as the amygdala have been linked to a reduced or absent theory of mind with intact executive function processing (Fine, Lumsden, & Blair, 2001; Stone, Baron Cohen, Calder, Keane, & Young, 2003). Consequently, this dissociation suggests that there is more to understanding theory of mind than pointing to the role of the prefrontal cortex. A second inadequacy of the common brain region explanation is that there are still severe gaps in our understanding of the operation of the human brain. Identifying links between brain activity in the form of electrical activations/ bloodflow or lesions studies still only offer crude estimates of neuronal activity. Results from EEG studies are severely limited in their ability to estimate localization of activity, and bloodflow imaging has notoriously poor temporal resolution. Additionally, lesions can result in the loss of millions of neurons and billions of their associated neural connections, but neurons associated with theory of mind might compromise just a small subset of these. Therefore, although current evidence supports a link between executive function and theory of mind, our current technology and understanding is inadequate to successfully differentiate the neural functioning when performing theory of mind versus executive function tasks.

Executive function is prerequisite for theory of mind

Another possible explanation for the relationship between executive function and theory of mind is that executive function skills serve as a prerequisite for the development of a theory of mind. This relationship has been described as an emergence relationship in which executive functions serves as a prerequisite for theory of mind and aids in the development and formation of a theory of mind (Moses, 2001). Perner et al. (1999) also argued for the importance of executive functioning in developing a theory of mind (although Perner clarifies that he views theory of mind as being an integral part of executive functions). Perner distinguishes his position from others by reinforcing the idea that theory of mind is more than just executive components within the task, and says that "a review of the available data makes it unlikely that all theory of mind tasks that show a relation with executive function tasks have a strong executive function component in them" (p. 150). The authors argue that, because of the huge variety of theory of mind tasks used by various researchers, task-specific dependencies should not account for the relation between executive function and theory of mind. To support this idea, Perner, Lang, and Kloo (2002) examined fifty-six 3-6 year old children on performance of a cognitive flexibility measure (DCCS), and discovered that DCCS scores were significantly related to performance on both false belief prediction and explanation. The forced-choice explanation task required that the child explain the actions of twins in a typical change of location task, whereas the prediction task was a classical version of the change of location task. In a second study the authors replicated the findings of the first study, and tested whether inhibition as measured by a go/no-go task was related to false belief understanding. The results revealed that inhibition was related to the false belief explanation but not the prediction task. However, this relationship disappeared when age, picture vocabulary scores, and control question performance were partialed out. In this second study card sorting performance remained significant related to both false belief explanation and prediction, but only the relation between false belief explanation and card sorting remained significant after removing variance associated with age, picture vocabulary, and control question performance. According to Perner et al., there was little evidence that children's understanding of belief was masked by executive demands in the prediction task of having to inhibit the salient reality of where the desired object really was. They argued this because children's performance on the explanation task, which was designed to reduce conceptual inhibitory demands, was related to their performance on the prediction task (r = .58, p < .01). Perner et al. suggest that these results speak against the theory that observed relations between theory of mind and executive function tasks are due to problems of inhibition in the theory of mind tasks. This explanation for the relationship between theory of mind and executive function is discussed more fully in a section below.

Theory of mind is prerequisite for executive function

Perner et al. suggest that it is not inhibition which is the major problem for children in the false belief task, and they propose that another possible explanation for the relationship between executive function and theory of mind is that theory of mind serves as a prerequisite of executive function (2002). Perner has become a strong proponent of this theory in recent years, but this theory was first proposed 10 years earlier. The results of Heinz, Wimmer, and Hartl (1991) suggested that as children gain increasingly sophisticated understanding of mental concepts, they gain increased access and control of their own mental processes. Frith (1994) employed a similar concept to explain the co-occurrence of self control and theory of mind problems in schizophrenia, and Carruthers (1996) used this idea to explain the co-occurrence in autism. In order to succeed on the false belief task, a child must possess a rudimentary understanding of mental state terms and their causal powers for determining one's actions. In the previously described false belief task, the child must understand that upon the other individual's return he will look in a particular location because he thinks that it contains the desired object. Similarly, in an inhibition task such as the Day-Night Stroop task where one must say "day" when shown a picture of the moon and stars and "night" when shown a picture of the sun, it helps to understand that there is a tendency to answer with the prepotent response which matches what the picture represents. Thus, one's thoughts about the representation guide the prepotent response, and successful inhibition requires recognizing this automatic thought and performing the opposite action. Despite its merits, this theory enjoys only limited empirical support. A review of the literature reveals widespread support for the notion that executive function skills emerge prior to the age of four, which is often the earliest that children succeed on the false belief task. Consequently, empirical support for this theory has come in the form of correlations among cross sectional time slices rather than more compelling longitudinal data.

Executive function components in theory of mind tests

Another way to explain the relationship between executive function and theory of mind is by examining the tasks which measure theory of mind. Some researched have suggested that there are specific types of executive function task demands within theory of mind tasks (J. Russell, Hala, & Hill, 2003). As noted, there are two ways in which task demands can cause problems in children's responses. First, there may be aspects of understanding the task itself that make it difficult for children to inhibit salient reality. Second, the response mechanism that children use may be so automatic that it is difficult to respond correctly. Support for the first alternative comes from Moore et al. (1995) who describe a study of twenty 3-5 year-olds in a task that investigated children's understanding of desires. In this experiment, each child received two versions of a story about a little boy or girl (matched for child's gender). In the first version the child and the boy in the story have alternate preferences for a sticker reward, and in the second version the child and the boy have matching preference for a sticker reward. Thus, in the first version both child and the boy in the story can have their desired object without conflict. However, in the second situation, children must reason about a character's beliefs that conflict with one's own desire, because they both desire the same object. The conditions were analogous to holding a belief that differed from someone else's as in the false belief task. Results showed the alternate-preference condition did not differ from chance, but the matched-preference condition did ($X^2 = 11.31$, $p < .01$). The younger children were more likely to answer incorrectly in the conflicting desire condition, suggesting that they had the most difficulty when the story character wanted the same reward the child wanted. That children in the conflicting desire conditions had more difficulty than children in the no conflict condition suggests that the difficulty in the conflicting belief situation of a standard false belief task might be due to task requirements rather than a failure to represent beliefs.

Support for the second explanation of why task demand may interfere with a child's correct responding in theory of mind tasks comes from findings by Carlson, Moses, and Hix (1998) in an investigation of whether children's difficulties with false belief arise from a lack of inhibitory control rather than a conceptual theory of mind deficit. An earlier study suggested that children have deceptive capabilities, but deceptive pointing is particularly difficult (Sodian, 1991). That is, children had difficulty successfully deceiving by using a well-practiced gestural pointing response. In order to further explore this issue, Carlson et al. contrasted deceptive pointing with pointing using an external pointing device (board-game arrow). Forty-eight 3-year-olds were assigned to one of three conditions: anonymous arrow in which the experimenter was absent, public arrow in which the experimenter was present, or a standard pointing condition. Results revealed no difference between the two arrow conditions, but jointly, performance in these two conditions was significantly better than in the standard pointing condition. It may seem odd that the use of an external device aids in the inhibition of the prepotent response, but veridical pointing is a well-practiced response and a child must inhibit this tendency in order to be successful in the task. Using the pointing device helps counter the well-practiced tendency. Similarly, Hala and Russell (2001) report on a study of sixty-seven 3-year olds using a task that examines deception (Windows Task). In this task, the child is seated facing an opponent with two opaque boxes in-between, one of which contains a treat. In the first phase of the task the child was asked to point to either box, the contents of which went to the opponent as an award. In the second phase of the task the opaque boxes are replaced with transparent windows and the child is given an opportunity to deceive his opponent. Children were randomly assigned to one of four conditions: a standard one in which the child pointed to the box the opponent would open, one in which the experimenter would point to the opponent's box, one in which there was no conflict and the experimenter was an ally, and one in which a pointer was used. A main effect of condition was significant, and post hoc tests confirmed that the pointer and ally conditions were significantly better than the standard condition. This indicates that that reducing the task demands did indeed result in improved performance. Consequently, the researchers argue that executive factors play a substantial role in the development of strategic deception.

It seems clear that executive function task demands play a role in theory of mind response, and aspects of the task may make it difficult to inhibit attending to salient reality. Children may have difficulty inhibiting the fact that they saw the object move locations and they now know where the object is, and incorrect responses could be due to this fixation on reality. Specifically, they may be capable of understanding that an individual would look for an object in its original location if they did not witness the transfer, but the verbal or gestural response is so well practiced that it interferes with expressing this knowledge. Other researchers investigating theory of mind may not have clearly specified an acceptable response type and would have accepted either a gestural or linguistic response. If so, it is quite possible that the given responses were natural and well-rehearsed response type that interfered with providing an accurate answer. Therefore, there is a need to test whether using an arrow as opposed to a more natural response such as pointing aids in theory of mind tests other than deception. The study described below will in fact test whether there is an advantage gained in traditional false belief tests when an external arrow is used to indicate a response as opposed to more natural pointing.

It should be noted that an expression account does not necessarily preclude the idea that earlier executive function skills help in the development of a theory of mind, and that concurrent levels of executive function, specifically inhibitory control, impacts the expression of such an underlying ability. Thus, one may distinguish between a *strong* or *weak* expression account of executive function. In the strong account, the relation between executive function and theory of mind is determined entirely by the task demands. In the weak version of this account, concurrent executive function and theory of mind are somewhat related by task demands, but executive function and theory of mind may also be related in that over time gradually improving executive function skills contribute to the formation and/or conceptualization of theory of mind.

Conclusion

Task demands seem to play an important role in the expression of an underlying theory of mind capability. However, within the expression accounts there are two ways in which task demands can prevent the expression of theory of mind understanding. Namely, that children may suffer from a reality bias in which they have difficulty imagining the hidden object in a different location, or that a well practiced response type prevents successfully performing the task. The study described below will help elucidate the connection between executive function and theory of mind by examining the role that inhibitory control plays in the expression of a theory of mind in typical false belief tasks through modification of response requirements. Previous studies have used the deception task and pointing, but it is undetermined whether similar results can be obtained through the modification of false belief task requirements. Furthermore, there exists a wide range of inhibitory control capabilities, and further research needs to clarify the degree to which initial inhibitory control ability predicts changes due to a modification of inhibitory task demands in theory of mind tasks. In theory, modifying task demands for children with deficiencies in inhibitory control should result in greater gains in theory of mind success. This is a question that has not been addressed previously in the literature, but would help to clarify the relation between theory of mind and inhibitory control.

Language Explanations

Introduction

As detailed above, various aspects of executive function skills have been linked to theory of mind. However, our understanding of theory of mind would be incomplete if we focused only executive function accounts of theory of mind development without considering language development. The shared developmental timeframe between language and theory of mind is the first indicator that the development of these skills might interact in some capacity. Early communication capacities such as joint attention behaviors begin to emerge as early as two months, and older infants show a capacity to share reference and engage in complex joint attention behaviors (Trevarthen & Aitken, 2001) These early joint attention behaviors have been linked with later theory of mind development. For example, in a group of 13 children, measures of joint attention (looking to adult during ambiguous goal detection task and gaze switches between adult and active toy) were collected at 20 months of age were followed up longitudinally at 44 months with a battery of theory of mind measures. Early goal detection was longitudinally associated with theory of mind ability at 44 months ($r = .69$, $p < .05$), and after partialing out IQ and language, gaze switching ($r = .67$, $p < .05$) was also longitudinally related to theory of mind at 44 months (Charman et al., 2001). In another study investigating 18 children's social development skills, researchers report that children's social understanding as measured by preferential looking at 14 months was significantly related to scores on battery of theory of mind tasks at four years of age (Wellman, Phillips, Dunphy Lelii, & LaLonde, 2004). These early communication skills rapidly increase in complexity through the fourth year of life (Brown, 1973), and this development appears to coincide with understanding of others intentions, desires (ages 2-3) and beliefs (age 3-4) (Cadinu & Kiesner, 2000). In fact, some have even argued that theory of mind first becomes apparent in children near the end of the first year of life (Bretherton & Beeghly, 1982). It has been both the temporal proximity of the emergence of a theory of mind and complex language fluency (Gopnik, 1990; Gopnik & Wellman, 1992) and the shared commonalities between early social perspective taking and early communication skills that has prompted researchers to examine the relations between these skills.

Investigations of clinical populations reveal shared deficiency in language development, communication, and understanding of others' minds. For example, theory of mind researchers have investigated the skills of children with autism. Children with autism exhibit severe language deficits coupled with tremendous difficulty in succeeding on theory of mind tasks (Baron-Cohen et al., 1985; Happe, 1993; Tager Flusberg, 1994). One could argue that autism is a disorder that is not language specific, so difficulties with theory of mind may arise from related deficits. However, investigation of specific language impaired (SLI) and deaf children help narrow the focus on communication difficulties. In fact, studies have shown that deaf children, who traditionally exhibit delays in language development, also exhibit delayed false belief task performance (Peterson & Siegal, 1995; P. A. Russell et al., 1998). Similarly, investigation of SLI children's task performance on traditional measures of false belief suggest that they are also impaired (Miller, 2001).

Although clinical populations help highlight shared deficiencies in language and theory of mind, it is essential to investigate normally developing children to assess whether their behavior also supports a common link between theory of mind and language. The relationship between language and theory of mind appears to be quite complex, and there are several different aspects of language such as syntax, semantics, and linguistic environment that demonstrate a relation with theory of mind ability. Additionally, some researchers have argued for a framework in which theory of mind is jointly dependent on language and social experience (Garfield, Peterson, & Perry, 2001). The authors suggest that theory of mind is produced by a combination of increased language development with children's growing social understanding acquired through conversation and interaction with others. These authors suggest that adequate social skills are jointly causally sufficient and individually causally necessary for producing theory of mind. However, the boundary between pragmatics and this growing social understanding may be blurred. In short, correct usage of many complex sentence structures requires an understanding of the varying conditions in which these grammatical variations are appropriate. Likewise, sensitivity for distinctions in varying social situations creates the need for using more complex language which describes such situations. Growth and development of appropriate language usage seems strongly linked with a corresponding growth in understanding of the social world in which this language can be used. It seems that many aspects of language are potentially important for theory of mind development and deserve exploration.

Although the structure of this discussion may have implied that executive function and language are orthogonal, it is important to note that there may be a link between these skills. Vygotsky's theory of cognitive development describes the pivotal role that language plays in development, and the way in which language relates to other cognitive skills (1986). In an earlier study, a moderate correlation between executive function skill and theory of mind was reported ($r = .26$), but this correlation was not significant for the sample size used in the study (Craven & Nelson, 2005). A similar relationship size was reported by Hughes in which scores for language and inhibition were related at $r = .24$, but this relation was also not significant for the given sample size (Hughes, 1998a). Although the strength of the relationship in these studies failed to achieve a statistically significant threshold, they do hint at a possible relation. However, a detailed examination of a link between these cognitive skills is beyond the scope of this paper.

Aspects of language related to theory of mind

General Language

Although several specific aspects of language might be related to theory of mind, some researchers have adopted the approach of linking general language capacity with theory of mind. As Astington (2000) argued, "general language development is crucial because language provides a means of coding perceptual reality and holding on to it when the visual display changes" (p. 280). Thus, in her view it is not necessarily any single component of language which is related to the development of a theory of mind, but general advancement of the communication system. Consequently, researchers have utilized a variety of measures in an attempt to generate a composite reflecting generalized language ability.

Evidence for linking general language ability with theory of mind comes in several forms. In a study of 68 children with normal language capacity, composite scores on the Test of Early Language Development (TELD) were correlated with a composite of false belief tasks ($r = .64$, $p < .001$) (Jenkins & Astington, 1996). The TELD tests a range of language abilities, looking at both syntactic and semantic capacities assessed through verbal and visual forms. This effect remained significant even after removing the effects of age ($r = .35$, $p < .01$). These findings were replicated in a study using a sample of 41 older children with a mean age of 5;7 (Craven & Nelson, 2005). Using a more complex false belief task and a composite measure of language, a positive relation was found between the scores ($r = .30$, $p < .05$). The specific language measures assessed included two subtests of the Test of Language Development (TOLD), sentence imitation and grammatical understanding, mean length of utterance (MLU) generated from transcripts of children's free play sessions, and scores on the elicited one-word picture vocabulary test (EOWPVT). Although the composite measure was partially comprised of subtests measuring discrete aspects of language, the MLU and vocabulary measures serve as good estimators of general language ability. This finding was replicated in a study by Meins et al. (2002) using fifty-seven 4-year-old children in which verbal intelligence ability as measured by the BPVS accounted for 16% of the variance in false belief understanding. Also, in a study of 27 children, the 4-year verbal IQ as measured by a summary scale score of the Information, Arithmetic, and Similarities subscales of the Wechsler Preschool and Primary Scale of Intelligence – Revised (WPPSI-R) was related to 4-year false belief ($r = .54$, $p < .01$) (Watson, Painter, & Bornstein, 2001). In this study the Verbal IQ served as an estimate of general language ability. Additionally, language control tasks with low syntactic demands correlated equally well with false belief. These contradictory results may suggest that the specific language aspects related to theory of mind may differ across individuals, and that results will vary from experiment to experiment depending on the general makeup of the participants in the study. Taken together, these findings suggest a genuine link between false belief understanding and general language capabilities.

Although concurrent language and theory of mind skills appear to be related, some have argued that it is earlier general language capabilities that impact later theory of mind development. For instance, Watson, Painter, and Bornstein (2001) had mothers of 27-months-old children complete four measures from the MacArthur Communicative Development Inventory (MCDI): total number of words produced by a child, grammatical morpheme usage, sentence complexity, and mean length of child's longest utterance. Additionally, children participated in a structured language assessment, the Reynell Developmental Language Scales, from which the Comprehension and Expressive scales were used. These six measures of early language were factor analyzed, and one general factor emerged with an eigenvalue greater than 1.00 that explained 71% of the variance . This factor was used in subsequent analyses, and was related to false belief understanding at 48 months ($r = .59$, $p < .01$), and remained significant after removing the effects of 48-month verbal IQ ($\Delta R^2 =.22$, $F(1,22) = 8.80$, $p < .01$). Additionally, Farrar & Maag (2002) investigated 20 children's early language development at 2 years of age compared with theory of mind understanding at 4 years. Simple correlations between the measures revealed that a composite measure of theory of mind was significantly related to vocabulary at 24 months ($r = .57$, $p < .05$), vocabulary at 27 months ($r = .55$, $p < .05$), MLU at 27 months ($r = .66$, $p < .01$) and grammatical complexity at 27 months ($r = .73$, $p < .01$). Children's MLU remained correlated with one measure of theory of mind (representational change) after removing effects of vocabulary at 27 months ($r = .70$, $p < .05$). Also, after controlling for vocabulary at 27 months, grammatical complexity no longer predicted any of the theory of mind measures. These results suggest that grammar may play a role in theory of mind development, but a more general language ability as reflected in vocabulary may be the more critical element in predicting later theory of mind development. However, this study is limited by the fact that no 48 month measures of language were available, so it is impossible to determine the extent to which the 24-27 month measures uniquely contribute to 48 month theory of mind. Taken together these studies suggest that earlier general language ability may predict later theory of mind development.

The evidence supports a link between children's general language ability and their theory of mind performance. The previous studies employed both cross-sectional and longitudinal designs, and their results suggest that the relationship between general language and theory of mind is genuine. However, two criticisms can be levied against the approach taken in these studies. First, there is evidence to suggest that general language is not always a strong predictor of theory of mind. In a study of 41 children's theory of mind development with a mean age of 5;2, results revealed that composite scores of language were not significantly correlated with an advanced theory of mind measure recorded both at the same time as well as 5 months later (Craven & Nelson, 2005). This finding suggests that any relation between theory of mind and language most likely occurs earlier on in development. Second, measures of general language intentionally fail to examine contributions of specific aspects of language. The composite measures' relations with theory of mind performance may be driven by a strong underlying relation between specific aspects of language. It is quite possible that strong inter-individual differences exist in the specific components that play a significant role in one's theory of mind, but these differences cannot be revealed with general language measures and composites. In the following sections, the relations between theory of mind and more specific aspects of language are explored.

Linguistic Environment

One of the early influences that may impact later theory of mind development is the impact of the linguistic environment in which a child develops. Contextual information is essential to understanding the development of many cognitive skills (K. E. Nelson et al., 2004), and few developmental researchers view the development of children's cognitive capacities in isolation. As will be demonstrated below, several important contextual factors also play a role in the development of theory of mind, such as available input, number of siblings, family size, and parental occupation.

The available linguistic input in an environment seems to play an important role in theory of mind development (Meins, 2003). For example, Meins et al. (2002)

investigated 57 mother-infant pairs' mental-state language at 6 months and compared that with their children's theory of mind performance at 48 months. Mental state language was defined as: (a) comments on mental states such as knowledge, thoughts, desires, and interests; (b) comments on mental processes; (c) references to level of emotional engagement; (d) comments on attempts to manipulate people's beliefs; (e) the mother "putting words into her infant's mouth" so that the mother's discourse took on the structure of dialog between her infant and herself. Results suggest that mothers' use of mental state language that commented appropriately on infant's mental states was related to children's theory of mind performance at 48 months. Regression analysis showed that mother's use of appropriate mental state comments predicted overall theory of mind performance, accounting for 11% of the variance. Similarly, in a study by Ruffman, Slade, and Crowe (2002), mothers were asked to describe pictures to 82 children at three different time points over a 1 year period. Mothers use of mental state utterances in these descriptions at 6-months was correlated with 48-month theory of mind understanding ($r = .34$, $p < .01$). This was true even when a number of potential mediators were accounted for, including children's own use of mental state language, their earlier theory of mind understanding, their language ability, age, mother's education, and other types of mother utterances. Therefore, mothers' mental state talk, especially at early infant ages, seems to have an impact on later theory of mind development.

It would seem logical to assume that if there are more members of a household that a child would be more likely to witness mental state talk. Consequently, it is not surprising to find that exposure to mental state talk is greater in cases where there are siblings in the house. Parents with multiple children may use a broad range of language skills. This was investigated in a study in which the authors distinguished three types of increasingly sophisticated mental state talk (desire, feeling, cognitive) and investigated 37 mothers and fathers in homes interacting with 2- and 4-year-old children at two separate time points (Jenkins, Turrell, Kogushi, Lollis, & Ross, 2003). Parental mental state talk varied as a function of children's age, context, and parent's gender. Four-year-old children with an older sibling produced and heard more cognitive talk and less desire talk than children without an older sibling. In an earlier study of sixty-eight 3-5 year olds theory of mind development, Jenkins and Astington (1996) found that, after removing the effects of age, language, and birth order, that family size was a significant predictor of false belief understanding ($F(1,63) = 15.2$, $p < .001$). These results offer tentative support for the idea that the family size and composition are related to theory of mind development. However, the Jenkins and Astington's results were not replicated in a study by Cutting and Dunn (1999) who examined 128 urban preschoolers from a wide range of backgrounds. Children's false belief understanding was assessed and family background information was collected. Family background data included family structure (single or two-parent), number of adults in the home, number of language spoken in the home, and the number of other children in the home, and parental education and occupation. The results suggest that mother's education ($r = .31$, $p < .01$), mother's occupational class ($r = .37$, $p < .01$), and father's occupational class ($r = .26$, $p < .01$) significantly relate to the development of theory of mind, but the number of siblings at home was not related to false belief performance even when younger and older siblings were examined separately. Taken together, the above results offer mixed results with respect to the impact that family size plays on theory of mind development. Consequently, it is difficult to determine the extent to which parent mental state talk impacts performance on false belief tasks.

Pragmatics

Parents mental state talk may certainly provide an important early step in the later acquisition of a theory of mind (Sabbagh & Callanan, 1998). However, the child must be an active player in this, and there are those who believe that the pragmatics, or usage of language, is essential for successful demonstration of theory of mind. Evidence for the importance of the pragmatic aspect of language for the development of a theory of mind comes from research that examined the development of theory of mind in deaf children. Woolfe, Want, and Siegal (2002) compared deaf children who learned sign language either early or late to test the effect of language input on theory of mind development. Results suggest that deaf late signers showed deficits in theory of mind understanding relative to deaf native signers or hearing controls. The researchers claim that expression of theory of mind is the end result of a social understanding mediated by early conversational experience, and the data support the idea that early access to conversation aids in the development of theory of mind.

In a review of related literature, Gray, Hosie, Russell, and Ormel (2001) conclude that “available research on the topic is consistent with the view that early conversational experience plays a crucial role in helping a child gain access to other people’s mental states.” (p. 153). This notion is supported by Remmel, Bettger, and Weinberg (2001), who claimed that deaf children of hearing parents (DH) but not deaf children of deaf parents (DD) show a delay in understanding of mental state representations, but do not show a similar delay in understanding of physical representation. They support this claim by pointing out that DH children do not demonstrate as much difficulty with tests of supposedly equivalent logical and linguistic complexity such as false photographs, suggesting that delay is not due to difficulty with delayed cognitive development in general or to linguistic task demands. Consequently, they conclude that the environment of DH children may be important because there are fewer opportunities for them to discuss and learn about mental states, and develop the syntactic structures necessary for representing other people’s mental representations. A similar sentiment has been echoed in other research (Peterson, 2003). Additionally, this idea is echoed by Lohmann & Tomasello (2003a) who note that “the reason it takes so long for children to develop false belief understanding is that this understanding depends on extensive linguistic and discourse experience.” Similarly, Nelson has claimed that changes in children’s understanding of mind reflects participation in discourse about social interactions within pragmatic contexts (K. Nelson, Plesa, & Henseler, 1998; K. Nelson et al., 2003). The pragmatic experience offers opportunity for children to interact with and learn about other individuals, but the question remains whether it is this experience itself or the opportunity to acquire specific semantic and/or syntactic capabilities that leads to improved performance in theory of mind situations.

Semantics

Pragmatic conversational skills may be related to theory of mind development, but there is evidence indicating that more specific language skills, like semantic development, are necessary. This understanding has been related to pretend play, which may share certain features of false belief tasks (Leslie, 1987). For instance, Hughes and Dunn (1997) conducted a study of 50 inner-city preschoolers with a mean age of 47 months who were recruited from local inner-city nurseries to take part in a study of early friendships and the development of social understanding. Friendship pairs were filmed for 20 minutes and scored for mental state talk as well as given an assessment of theory of mind ability. Results from the study suggest a strong positive association between children's engagement in pretend play and the frequency and nature of mental-state talk.

Levels of intent can be conveyed through the use of modals, and understanding the difference between different modals requires attention to detail in order to pick up subtle cues to their meaning. Listeners can distinguish between when a speaker says “you must do this!” versus “you might do this.” This ability to discriminate intent through understanding the meaning of modals has also been linked to theory of mind task success. For example, results from a study of 3- and 4-year-olds’ understanding of modals (must, might, could, probably, possibly, and maybe) suggest that understanding of the meaning of modals was correlated with their theory of mind performance (Moore, Pure, & Furrow, 1990). A complication, however, is that an understanding of modals necessitates having a representation of the syntactic structure of the sentence in addition to the semantic content of the modal.

The development in understanding of mental-state terms and modals may be tied to larger vocabulary growth. For instance, in a study by Jenkins and Astington (1996) in which they examined the co-development of language and theory of mind proficiency, 68 children were given a measure of general vocabulary and a battery of theory of mind tasks. Results suggest strong correlations ($r = .61$, $p < .001$) between 3- and 5-year-olds’ scores on false-belief tasks and the measure of Vocabulary subtest of the Stanford Binet Intelligence Scale. This relation remained significant after partialing out age ($r = .33$, $p < .01$). Additionally, in a study of 40 children with either semantic-pragmatic developmental language disorder, phonological-syntactic language disorder, high-level autism, or a normal functioning control group, measures of theory of mind, social comprehension, and eye direction detection were taken (Shields, Varley, Broks, & Simpson, 1996) Results revealed that the children with autism and semantic-pragmatic developmental language disorder performed worse than the controls and phonological-syntactic language disorder on all measures. These results suggest that deficits in semantic-pragmatic ability mirror deficits suffered by individuals with autism who are notorious for having tremendous difficulty on false belief tasks (Baron-Cohen et al., 1985). Consequently, this results hint at the idea that phonologic-syntactic impairments may be less influential in performance on theory of mind measures, and semantics and pragmatics might play a larger role in theory of mind success. The latter conclusion requires further exploration, especially in normally developing children. Furthermore, the pairing of semantic/pragmatics and phonology/syntax suggests an artificially elevated commonality that is not reflected in the predominant psycholinguistic literature.

Syntax

There is mixed support for the idea that general syntax or mastery of specific syntactic components plays a role in theory of mind development. For instance, Astington and Jenkins (1999) longitudinally studied fifty-nine children with a mean age of 3 years 4 months at three time points on measures of language and theory of mind development. Language was assessed by the TELD (Test of Early Language Development) which designates items as assessing either syntax or semantics, and theory of mind was measured by appearance-reality, unexpected contents, and change-in-location false belief tasks. Results suggest that it was children's earlier syntactic ability rather than semantic ability that predicted theory of mind performance; results indicated that syntactic ability accounted for 10% of the variance in later theory of mind ability after covarying both age and earlier semantic ability (Astington & Jenkins, 1999). Scores for syntax and semantics were highly correlated at all three time points (r = .84 to .76). However, another investigation examining the contribution of both syntax and semantics offers a less clear picture of the role of general syntax (Ruffman, Slade, Rowlandson, Rumsey, & Garnham, 2003). In the first of two experiments, children's language at 3 years old was compared to theory of mind performance at 4 time points when the children ranged from 3 to 5 years. The first results indicated that semantics predicted unique variance in later belief understanding, but syntax did not explain any unique variance. However, in a similar second experiment the results indicated that it was syntax which related to false belief, but not semantics. Consequently, the authors argue for a relation between general language ability and theory of mind.

Perhaps the mixed findings for general syntactic ability are driven by underlying skills in specific aspects of syntax. For instance, it may be the acquisition of a particular syntactic skill, such as relative pronouns (Smith, Apperly, & White, 2003) or sentence complementation, which constrains performance on theory of mind tasks. Sentence complements are embedded propositions, and sentences with mental state terms require them. For example, words like *know, think,* and *forget* all take complements (e.g., I know *that the dog is tired*). Some researchers have claimed that a theory of mind is impossible without being able to demonstrate a comprehension of sentence complementation (de Villiers & de Villiers, 2000). They argue that the syntactic structure of a complement allows for the internal representation of a false belief scenario, and an inability to represent complements prohibits a conceptual understanding of a false belief scenario. This theory is clearly an emergent theory, and de Villiers and de Villiers present it as a strong deterministic account of the relation between language and theory of mind. Data to support this theory was presented in the investigation of 28 normally developing preschoolers who averaged 3-5 years at the study's start (de Villiers & Pyers, 2002). They were tested 4 times over the course of one year on three measures of theory of mind (unexpected contents, unseen displacement, explanation of action), and two measures of language (memory for complements, and spontaneous speech from which MLU scores were obtained). Correlations revealed relations between memory for complements and all the theory of mind measures. Additionally, in a hierarchical regression analysis, memory for complements was significantly related to a composite of false belief after removing the effects of MLU ($F = 4.84$, $p < .05$). Thus, the results of this regression analysis suggested that it was the mastery of specific aspects of syntax, namely sentence complements, that served as a precursor and possibly a prerequisite for successful mastery of false belief tasks. Further evidence for this idea is provided by Lohmann and Tomasello (2003b) who conducted a training study with 138 children in which different kinds of linguistic interaction were tested to determine what role they played in developing false belief understanding. Children were randomly assigned to one of four training conditions: (a) a full training condition that emphasized deception, complement structures, and mental state verbs; (b) a discourse only condition that emphasized the deceptive aspect, but did so without reference to mental state verbs or sentential complements; (c) sentential complement only condition in which deception was not highlighted, but complements and mental state verbs were used; (d) no language training in which the deception aspect was non-verbally highlighted. Children showed most improvement in the full training condition, followed by the complement only, and then the discourse only. No gains were observed in the no language condition. There was a significant difference between the full condition and the discourse only condition ($p < .001$). Because these groups differed only on use of sentential complements this finding suggests a strong effect of sentence complements on false belief understanding. However, there was also a strong effect for deceptive training as witnessed in the difference between the full training and sentential complement training groups ($p < .01$). Consequently, the above studies together present some evidence for the idea that sentence complements play a role in success on theory of mind tasks.

Having an understanding of sentence complementation may not be the only or even the best explanation of how language is related to theory of mind. In the de Villiers and Pyers study (2002), it is possible that the measure of complement memory was not representing an underlying capacity to comprehend complementation: rather it may have been a reflection of a child's phonological loop capacity. As was discussed in the section on working memory, there is a demonstrated link between theory of mind and working memory. Furthermore, it is interesting that in the Lohmann and Tomasello (2003b) study there was a strong effect for deceptive training in addition to complementation training. This seems to suggest that complementation training is helpful in success on theory of mind tasks, but is by no means critical as de Villiers and de Villiers (2000) suggest. For example, in a study of 79 German-speaking children aged 2 ½ – 4 ½, children exhibited mastery of complementation well before exhibiting theory of mind understanding (Perner, Sprung, Zauner, & Haider, 2003). Additionally, replication of de Villiers findings has been mixed (Miller, 2001). Other research has suggested that theory of mind is possible even in participants with severe grammatical deficits. For instance, Varley et al. (2001) reported the case study of a 60-year-old right-handed male who suffers from severe agrammatic aphasia. This man was unable to understand or produce language propositions in any modality of language use, but he succeeded on theory of mind tasks. This case argues against the proposal that the understanding of specific aspects of syntax are required for success on false belief tasks. These findings were replicated in a second patient (MR) who suffered from aphasia and impaired executive function, but could pass theory of mind tasks. Together, these studies suggest that an understanding of complementation is not required for passing false belief tasks in adults with brain damage. However, it is an outstanding question whether complementation may aid in developing theory of mind understanding in the first place, and whether the need for syntactic understanding may diminish once relevant neural pathways are established.

Theories of how language is linked to theory of mind

Emergence

The research on syntax and sentence complementation provided an example of a theory in which authors view aspects of language as being responsible for the formation of a theory of mind (de Villiers & de Villiers, 2000). The authors suggest that these syntactic components are essential in the conceptualization of a theory of mind, and that in order to actually mentally represent a theory of mind situation there must exist the capacity to process sentence complements. Specifically, de Villiers and de Villiers claim that a child who is able to use embedded propositions has also developed the means to internally represent a theory of mind situation. This *linguistic determinism* logic implies that the capacity to process sentence complements is a necessary condition for success on theory of mind tasks. Although the specificity of this theory is admirable, the supporting evidence has not been compelling. First, convergent evidence supports the notion that multiple cognitive capacities are linked with theory of mind development. A linguistic determinism account fails to explain the observed relation of aspects of executive function with theory of mind. Additionally, detailed analysis of the evidence supporting this theory reveals that the measures of memory of sentence complements confound an understanding of sentence complements with working memory. The relation that de Villiers and Pyers (2002) report may represent the relation between theory of mind and working memory. Certainly, there may be elements of sentence complements or other syntax which aid in the formation of theory of mind, but given the large volume of related research it seems unlikely that sentence complementation is the sole player or even the major player in the development of a theory of mind. It is possible, however, that it may play a more important role in limiting the expression of an underlying capacity.

Expression

Previous studies have compared the performance of SLI children with age and language-matched peers on performance of theory of mind tasks when the language requirements were reduced. In some instances, removing language altogether makes the task extremely difficult. However, when language is minimized, it seems to have a positive influence on task performance. In a study by Miller (2001), four conditions of false belief tasks were administered to ten children with SLI, ten age-matched controls, and nine controls who were matched for language comprehension. The four conditions varied as a function of linguistic complexity. The *think* condition was a standard change-in-location false-belief task in which the experimenter asks “Where does [puppet] think the [toy] is?” to which the child may respond verbally or nonverbally. The *look* condition was the same as the think condition, but the child is asked “Where will [puppet] look for the [toy]?” The *show* condition was one in which the experimenter asked the child to act out the role of the puppet and show what happens next. Finally, the fourth condition was the *pretend* condition in which the puppet likes to pretend that certain objects are other objects (e.g., a block is a racecar). In the puppet’s absence, the experimenter suggests changing what is being pretended. Upon the puppet’s return the child is asked “What does [puppet] think we’re pretending [object] is?” Results suggest that the SLI group performed similarly to same-age peers when linguistic complexity was low, and similarly to younger children when linguistic complexity was high. These findings provide evidence that linguistic complexity serves as a limiting factor in false belief task performance. These results were replicated in Miller (2004) in which she investigated 15 children with SLI and compared them to 15 age-matched controls and 15 language matched controls participated on five versions of the false belief tasks (think, show, pretend, pretend-show, and a nonverbal false belief task). As before, the results suggest that children with SLI can perform at age-appropriate levels when false belief tasks are less linguistically demanding. These findings support the theory that task language demands act as a constraint on the expression of false belief understanding

If the performance improvements demonstrated by SLI children can serve as a general model, then those who are low in initial language capability should benefit more from a reduction of language complexity in the theory of mind task. For those with normal or superior language, one would expect that a change in task requirements would minimally impact performance compared with the standard version. However, for many children of mid- to lower-range language skills who possess a theory of mind understanding one would expect that they would perform worse on the more difficult language condition compared with the less complex language version. Any underlying conceptual understanding would be masked by the linguistic complexity of the task. Researching the development of a complex cognitive capacity such as theory of mind is quite difficult, but achieving a greater understanding of this development can be aided by examining the extent to which task demands impact performance. Once the effects of task demands have been well explored and are more properly understood, the investigation of complex underlying factors affecting conceptualization of theory of mind becomes much easier

Conclusion

Although specific aspects of language have been related to theory of mind ability, the picture remains muddled. Clearly, there needs to be a focus on the individual trajectories of theory of mind development. There needs to be clarification of how language influences false belief task success when the required language understanding within the task is manipulated. For instance, if an individual has poor sentence complement understanding , then reducing these task demands should result in increased performance. In order to understand the relation between language and theory of mind one must tease apart the processes in order to determine whether a child’s particular level of language ability prevents the expression of an already existing understanding, or whether complex language and specific aspects of it are necessary for a construction of an understanding of other beliefs. To date, the research has not provided enough evidence for a satisfactory answer to these questions.

Summary

The literature review highlights three major points : (a) both executive function and language are related to theory of mind development, (b) inhibitory control plays a critical role in theory of mind, (c) syntax is strongly linked to theory of mind. The first point is essential as some researchers have traditionally studied aspects of cognition related to theory of mind development along party lines. Generally, they have examined theory of mind in relation to executive function or language while disregarding the literature in the other domain. However, simultaneous examination of these skills is more likely to illuminate the underlying relations to theory of mind. Previous research on language acquisition has examined the idea that learning is the result of a dynamic mix or convergence of multiple conditions (K. E. Nelson, 1991; K. E. Nelson et al., 2004; K. E. Nelson, Welsh, Camarata, Tjus, & Heimann, 2001). The development of theory of mind may require a similar convergence of executive function and language components.

Along these lines, inhibitory control has been shown to be a major contributor in the development of theory of mind. However, one needs to determine to what extent inhibitory control plays a role in the emergence of a theory of mind as compared to the expression of a theory of mind. Previous research has demonstrated that inhibitory control plays a role in the expression of theory of mind in deceit tasks, but no current research has successfully demonstrated that it plays a role in the more traditional test of theory of mind, the false belief task. Cleary, this gap in the literature needs to be filled.

Similarly, language has been shown to correlate with theory of mind. The nature of the relationship remains both ambiguous and complex. Research has indicated that children's syntactic understanding, especially around 2-3 years of age, seems to play a role in their emergence of theory of mind around 4 years. However, aspects of semantics, pragmatics, social skills, and even measures of general language relate to theory of mind. Although this confusion certainly calls for further investigation, it does hint at the idea that there are multiple pathways to success and that children can draw upon competencies in several different domains to succeed in theory of mind tasks. This sentiment is echoed in the conclusions drawn by Flynn, O'Malley, and Wood (2004) from a microgenetic study of children's theory of mind development. Still, it seems that understanding of specific and general aspects of syntax seems to play a role in theory of mind success. The extent to which syntax plays a role in the expression of theory of mind has been investigated in children with both normal and delayed language development, but replication of these results across different paradigms is warranted as the contribution of different aspects of language to theory of mind needs to be further explored and clarified.

Strong relations have been observed between theory of mind and various aspects of both executive function and language skills, but the strength of these relationships and the directions of causality suggested by correlational findings remain ambiguous. Clearly, more research is needed to help clarify these issues. Consequently, to more clearly specify the relation between language/executive function and theory of mind, manipulation of task requirements must be utilized to help determine the degree to which language and executive function demands limit the successful expression of already-existing theory of mind skills.

First Major Aim: Theory of mind experimental manipulation

The first major aim of this study is to test the expression accounts offered by both language and executive function researchers as explanations for performance on theory of mind tasks. Specifically, the goal is to test whether inhibitory control and syntax demands within traditional false belief tasks play a role in limiting the expression of an underlying theory of mind ability. The limitations of correlational research are well known, and we will address this issue through an experimental manipulation of language and executive function levels within a theory of mind measure. Prior research (Lewis & Osborne, 1990; Miller, 2001, 2004) has demonstrated that variations in complexity of language alter success rate as measured by false belief tasks. These studies suggest that a low language version is easier than a version requiring the standard complex language levels required in false belief tasks. Additionally, previous research has suggested that tasks can lower their inhibition requirements by having the participant use a physical pointer device instead of verbalizing or pointing themselves (Carlson et al., 1998). This task alteration was applied to a deception task, but a similar modification could be performed on a false belief task. Consequently, the present research includes both low and high inhibition and syntax conditions; the low conditions were designed to reduce the syntactic and inhibitory control demands required to complete the task, and the high conditions require the normal cognitive capacities used to complete standard false belief tasks. The expected outcome of this manipulation is depicted in Figure 1 below, which represents hypothetical percentages of correct responses anticipated in this study. The high language/high inhibitory control condition should pose the most difficulty for children, and the low/low condition should ease the burden of standard response requirements and allow children to be more successful in demonstrating their understanding of the theory of mind scenario.

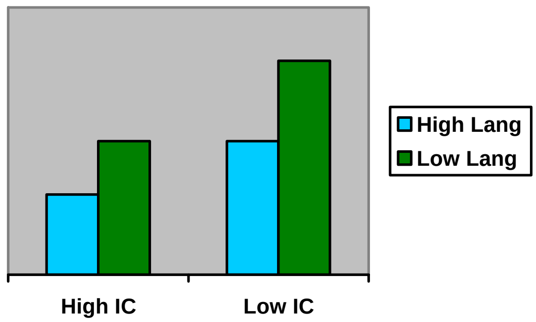

Figure 1: Anticipated proportion of correct theory of mind responses

Second Major Aim: Relate initial IC/Language to ToM differences

The second major aim of this study is to test the hypothesis that children's initial levels of inhibitory control and syntax are correlated with gains in performance when examining the difference between high/low performance. In other words, if children initially have lower levels of inhibitory control or syntax, they should have greater gains in performance when the task demands are reduced. Consistent with previous research, we expect to find significant zero-order correlations between initial measures of inhibitory control/syntax and composites of all theory of mind conditions. Furthermore, by looking at the difference in performance between high versus low conditions within both inhibitory control and syntax modifications, one can determine the extent to which initial levels of inhibitory control/syntax are related to specific alterations of these task requirements. For children who exhibit skill with inhibitory control/syntax, reducing these task demands should have minimal impact as they would already be able to express their theory of mind concepts if they possessed them.

Method

Participants

Twenty-nine children were recruited from local day-care and preschool centers. Initial contact was made with center directors to gain permission to recruit at their site, and flyers and consent forms were distributed to parents. One original participant was excluded from continued involvement after an initial session revealed that she was unwilling to participate. The remaining 28 participants were between 40 and 66 months of age (M = 52, SD = 5.6). .

Procedure

Sessions were conducted by the principal investigator and a trained research assistant on center property for the convenience of participating families. In addition, this location was thought to increase the comfort level of participants since they were already familiar with the surroundings. Quiet rooms with no other distractions were used for the testing. Most participants required two to three sessions to complete the battery of measures, and each session was approximately 20-25 minutes in duration. Each participant was carefully observed during the entire session for signs of distraction or disinterest, and tired or distracted participants were encouraged to complete the activities at a later time. This was done to ensure the most accurate assessment of cognitive capabilities. The tasks were ideally presented in specific clusters (see Table 1). The final cluster of measures was associated with an affiliated research project and were not intended to be used in the current investigation. Within the theory of mind measure, order of presentation was counterbalanced using 4 separate forms that maintained consistency of response (either veridical pointing, or using a game-board arrow) in 6 trial blocks.

Table 1: Battery of measures

	Measures
Cluster 1	Grammatical understanding (GU), Day Night Stroop (DN), Sentence Imitation (SI)
Cluster 2	ToM Control Tasks (CT), Theory of Mind (ToM), Complements, Complex Relatives, Coordinated Conjunctions,
Cluster 3	Forward Digit Span, (FDS), Backward Digit Span (BDS), Working Memory Visual (WM Vis)

Materials

Language

Six measures of language ability were administered. These included two subtests of the Test of Language Development-Primary, Third Edition (TOLD-P:3) (Newcomer & Hammill, 1997). Also used was a novel language measure assessing sentence imitation of specific language structures with four subtests: sentence complementation, complex relatives, and coordinated conjunctions of two subtypes. Raw total scores for the language measures were calculated and used in the analyses

Grammatical Understanding (TOLD-GU): The TOLD-GU subtest is a measure of receptive language ability in which children use syntactic clues to discern the meaning of a sentence. Children are read a variety of sentences of differing syntactic complexity, and they must choose the one of three slightly different pictures that matches the scene described in the sentence. The termination rule for this task is 5 consecutive incorrect responses. The maximum score for this measure is 25 points.

Sentence Imitation: The sentence imitation subtest of the TOLD-P:3 is an assessment of a child's ability to listen to and verbally reproduce a sentence which is read to him/her by the experimenter. The sentences increase in length and grammatical complexity on each trial. Only complete and accurately reproduced response were scored as correct. The termination rule was the same as for the GU task (5 consecutive incorrect response). The maximum score for this measure was 30 points.

Focused Sentence Imitation: Similar to Sentence Imitation, 12 sentences containing the grammatical structures of complements, complex relatives, or coordinated conjunctions were read to each child. The child was then asked to imitate the sentence verbatim. Scoring for these responses was more liberal than for the standardized sentence imitation task because the emphasis was on the child's ability to duplicate the grammatical structure. Responses with one substitution or deletion were scored as correct so long as the essential structure of the sentence remained intact. The maximum score for each of the three subsections (complements, coordinated conjunctions, complex relatives) was four points.

Executive Function

Day-Night Stroop: Children's executive functioning was measured using the Day-Night Stroop Task (Gerstadt et al., 1994), which tests one's ability to inhibit a prepotent response. In the training trials of the Day-Night Stroop task the child is presented with a picture of a sun on a white background and is asked to say "night." Similarly, they are presented a picture of a moon on a black background and are asked to say "day." Figure 2 displays the stimulus cards used in the Day-Night task. The participant is given up to three chances to succeed on both training items after which they are presented a series of 16 randomized sun or moon cards, and each correct response receives on point. The maximum score for this measure is 16 points.

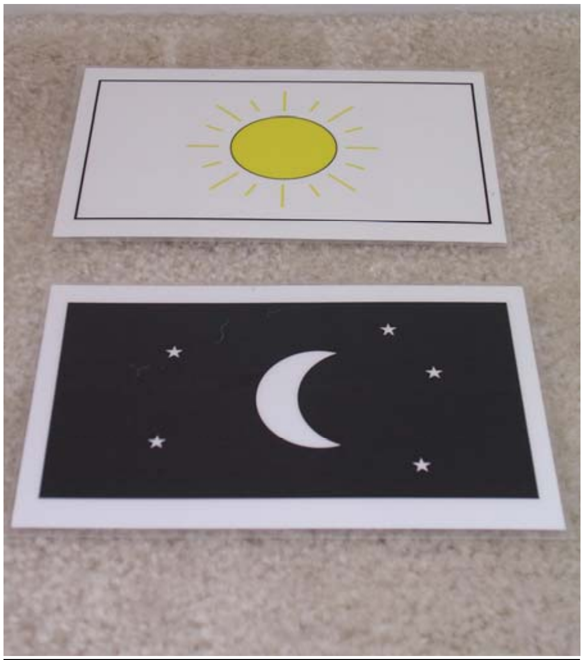

Figure 2: Day-Night Stroop cards.

Working Memory

In a related project exploring the relation between theory of mind and working memory skills, three measures of working memory were included in the battery. These measures were given as the last measures administered to the participants so as not to negatively impact performance on the primary measures of interest. Although no specific hypotheses regarding their relation to theory of mind were initially generated in the context of this study, their inclusion in follow-up analyses helped shed light on children's performance on the theory of mind tasks.

Visual Working Memory Task: This task was an adoption of Gathercole and Pickering's (2000) static matrices designed to test a child's ability to reproduce a pattern of checkers on a board of squares. The complexity, represented by the number of checkers and the size of the board, steadily increases across trials. For example, a 2x2 grid with 2 checkers on up to a 4x4 grid with 8 checkers. Initially, the experimenter shields the board from the participant's view and arranges the checker pieces in their correct place. Then the visual shield is removed, and the participant can observe the pattern for 5 seconds. Finally, the board is cleared and the participant is asked to recreate the given pattern. Success on 2 of 3 trials within a given level results in advancing to the next level of complexity. Scoring for this task ranges from 0 to 8 points, with a ½ point given for one correct response on the highest level accomplished.

Forward Digit Span: This task is designed to test a participant's ability to listen to and reproduce a string of numbers of varying lengths. The participant must correctly reproduce 2 of the first 3 strings of numbers before advancing to the next level of difficulty. The task starts with just 2 digits initially, and can go as high as 9 digits. Responses must be entirely accurate to be scored as correct. Credit is given for completion of a full level (e.g., 4 if two of the three 4-string responses are correct). A ½ point is given when 1 response on the highest level is correct.

Backward Digit Span: The task is administered the same was as the forward digit span except that the participant is told that the responses must be given backwards. For example, if the experimenter says "two, three" the participant must respond "three, two." As this is a complex task for 4-year-olds, the experimenter is encouraged to expend extra effort on the test trials helping the participant to understand the concept of saying something "backwards." The measure can assess backward spans up to 5 digits in length, and ½ point is given for one correct response on the final level.

Theory of Mind

There are 12 theory of mind scenarios (see Appendix A), with three versions of each of four conditions (see Table 2). These conditions were derived from high versus low language demand in conjunction with a high versus low inhibitory control demand. The scenarios were presented with the use of a VCR to ensure consistency of presentation. As this number of scenarios needed to capture all four conditions might pose a potential problem for younger children who often exhibit a short attention span, the scenarios were developed as a story following two characters, a boy and a girl, as they interact with various objects in their home. In each scenario, they encounter realistic situations in which one of them has access to knowledge about a situation that the other does not. For example, the girl places a toy in the backseat of a vehicle. The boy then leaves the area for a few minutes while the girl moves the toy to the trunk of the car. The child is shown a picture of two possible scenarios (see Figure 3) and is asked to point to "where does the [person] think the [object] is?" or "where will [person] look for the object?" depending on whether the task condition calls for high or low language demand.

Table 2: Theory of Mind Task Manipulation

	High Language	Low Language
High IC	HH	LH
Low IC	HL	LL

Theory of mind situations were presented with inhibitory control and language conditions counterbalanced across participants. In order to avoid frequently adjusting the response type, the high (HH and LH) and low (HL and LL) inhibitory control conditions were grouped together as blocks, and this resulted in 4 task orders. Before each block, children were reminded of the proper response type for that condition. For each block, pictures of possible responses were placed on the table for the children to point to using either their finger or a pointing arrow. The first picture was of the location where the item was first placed and the other of the location where the item was moved. As the scenario unfolded on the monitor, a brief narration of events was provided by the experimenter. Attention was called to which characters were performing which type of action, and children were asked to name the relevant objects in the picture (e.g., a cabinet or a drawer). Initial responses were recorded for all trials with a maximum of 12 possible points.

Figure 3: Theory of Mind Testing Stimulus Book

Two types of control tasks with two questions per task were included in this measure. The first control task was designed to test whether the participant could understand a basic change of location without testing for theory of mind. Two different colored containers and a small ball were used (see Figure 4). With the participant observing, the ball was initially placed in one of the containers, and then switched to the other container. The participant was asked two questions: “where was the ball first?” and “where is the ball now?” The second control task was designed to test whether the participant could understand scenarios presented in the video format. Two separate clips depicted an individual picking up one of two objects from a table, and the child was asked “what did the girl take?” For each question the child was asked to point to the picture that correctly matched the object that the girl took.

Figure 4: Theory of mind control task materials.

Version (HH): High Lang, High EF This condition consisted of three standard change-in-location false belief tasks. A video clip showed two actors in a room using an object. The object was placed in one location, and then one of the actors would leave the room. In his absence, the other character would change the location of the object. Then the experimenter would ask the child **"where does [person] think the [object] is?"** A booklet with two pictures was placed on the table, and the child was asked to point to the correct picture.

Version (LH): Low Lang, High EF This variation of the task was identical to version HH except for a wording modification designed to reduce the linguistic complexity of the question. Instead of using a question with an embedded test complement, the experimenter asked, **"where will [person] look for the [object]?"** There were three LH clips in total.

Version (HL): High Lang, Low EF This variation also differed from the HH version. Instead of gesturing with their hands, children used a pointing arrow to indicate their response. The experimenter asked the child **"where does [person] think the [object] is?"** This version also contained three clips.

Version (LL) Low Lang, Low EF: This variation of the task used the simpler language from version LH coupled with the pointing arrow from version HL. Children were shown a scenario, and asked **“where will [person] look for the [object]?”** They were requested to indicate their responses by using the pointing arrow.

Results

Data Reduction and Preliminary Analyses

Gender

To ensure that participants' scores could be collapsed across genders, the relations between gender and the main variables of interest were examined, and Figure 5 illustrates these mean score. Non-significant relations with gender were observed for all variables except for scores on the Comparative Relatives task ($r = .41$, $p < .05$), where boys scored better than girls. However, this finding is difficult to interpret because of the small number of boys ($N = 10$) compared with girls ($N = 18$), not to mention the relatively small total sample size. Considering that subtle differences between boys and girls are common on a variety of cognitive measures, and that no gender differences were observed on the primary ToM measure, the relation between gender and the Comparative Relatives task is not thought to be critical to the specific aims of the current study. Consequently, scores were collapsed across gender for subsequent analyses.

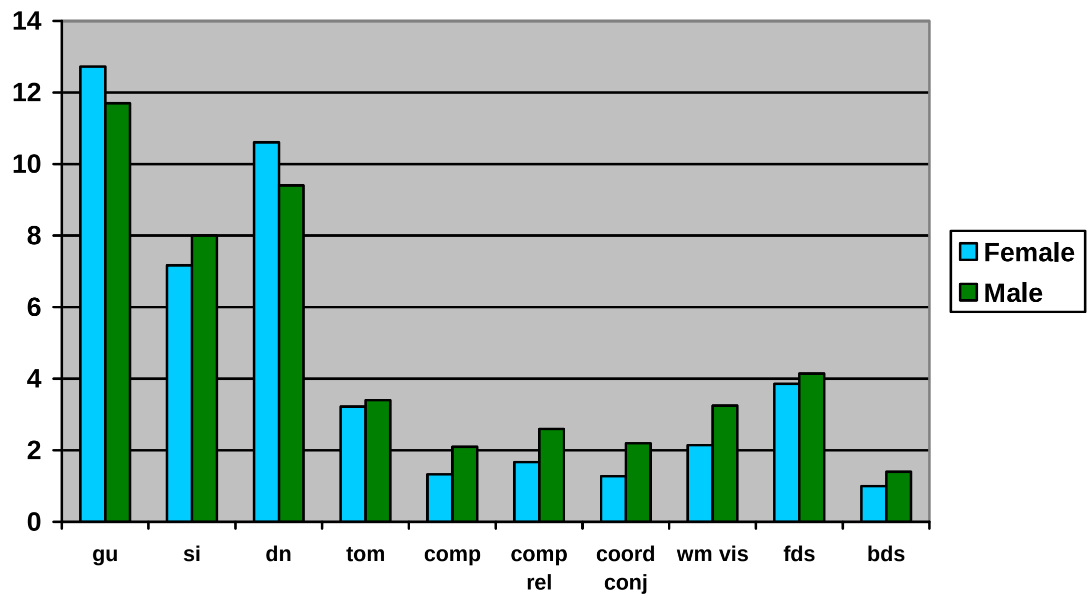

Figure 5: Observed gender differences according to task type[2].

[2] Abbreviations: grammatical understanding (gu), sentence imitation (si), day-night stroop (dn), theory of mind (tom), complements (comp), complex relatives (comp rel), coordinated conjunctions (coord conj), working memory – visual (wm vis), forward digit span (fds), backward digit span (bds)

ToM Control Tasks

As described previously, four control questions for the ToM task were administered. Ninety-seven percent of participants' responses for these control questions were correct. All of the change-in-location questions were responded to correctly, and all of the sample questions requiring a finger-pointing response were correct. However, three responses for the control task involving the pointing arrow were incorrect. It was observed that these participants' overall scores for the theory of mind task were either quite high (10), or quite low (3 and 0). Any high response pattern (10-12 correct) or low response pattern (0-2) has less than a 4% chance of occurring by chance alone. A response pattern of 3 correct has only a 15% chance of occurring randomly. Consequently, this response pattern makes it unlikely that the participant was just responding randomly during the twelve theory of mind questions. Additionally, the pointer control task was the first opportunity participants had to practice with the apparatus. Therefore, given the low likelihood of the response patterns occurring by chance alone, and given the other 3 control questions were answered correctly for each of the participants, all 12 of the participants' responses on the ToM questions were included in the analyses.

Theory of Mind measure

Are questions internally consistent?

Figure 6 shows the mean response (0-1) of the individual questions on the ToM task. Cronbach's alpha was computed for these 12 questions, and it was high (α = .90). Consequently, the individual questions collectively demonstrate high internal reliability, so it is appropriate to construct an overall sum score for the total number of correct responses.

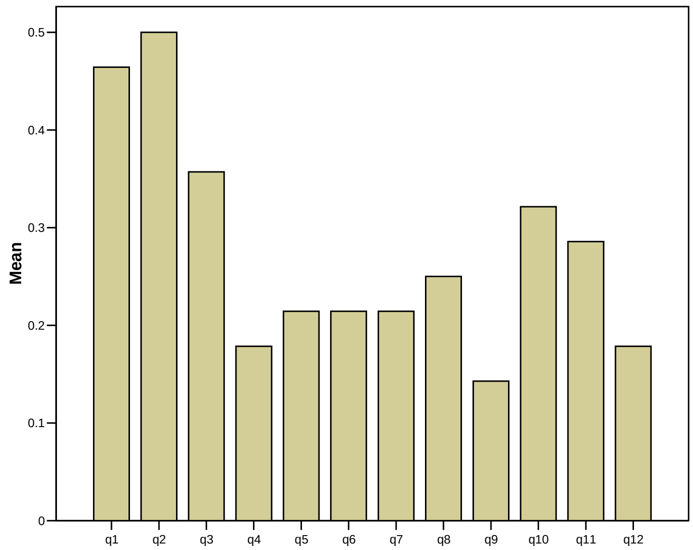

Figure 6: Mean response of individual question correctness.

Does the order in which conditions are presented (form) matter?

Technique 1

The effect of task order on success was also investigated. Bivariate correlations between the task order number and overall ToM and summary scores for specific ToM conditions revealed that task order was not significantly related to success on any of the 4 task conditions. Table 3 lists these correlations. These results suggest that the counter-balancing was successfully implemented since there was no relation between task order and overall theory of mind or the specific theory of mind conditions.

Table 3: Correlation of task order with ToM

	Task Order
ToM	*r* = .19, *ns*
HH	*r* = -.10, *ns*
LH	*r* = .27, *ns*
HL	*r* = .24, *ns*
LL	*r* = .23, *ns*

Technique 2

A second technique was also used to examine whether the task order played a role in the observed response patterns. Task order were represented by four different forms used in testing, and they were coded and entered into the ANOVA as a between subjects variable. The result reveals an interaction for Language x Form (F = 2.99, p = .05), and Language x EF x Form (F = 5.29, p < .01). The graph of the means which demonstrates this interaction can be see in Figure 7 below (for additional graphs on this interaction, see Appendix B)

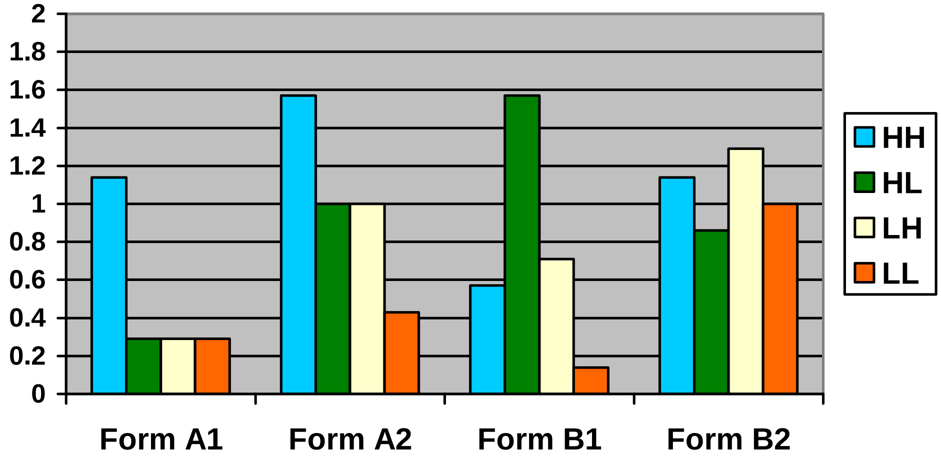

Figure 7: Means of *form* crossed with *condition*

Even though a strong three-way interaction is observed, it is still possible to interpret the observed main effects for language and EF because:

1. On 3 out of 4 task orders, the sum for high language was higher than the low language condition. For 3 out of 4 task orders, the high EF is higher than sum for low EF. This demonstrates a level of consistency with minimal modulation.

2. There was a slight bias towards better performance if it comes earlier in the presentation of conditions. This could indicate a possible tendency to focus better on the earlier examples.

3. Each condition was affected differently by the task order, but the ratio of highest to lowest score varies across forms. This helps lead to the interaction being significant. However, since the order was counterbalanced and no consistent impact of order emerged it should not preclude examination of the hypotheses.

Creation of ToM scores

Several different scores were created from the ToM task results. First, an overall score (ToM) reflecting total performance across all conditions was created. Next, individual scores for each condition (e.g., HH, HL) were created. Finally, four scores were created that combined results across high or low EF or language. For example, the score High Lang was a composite of the HH and HL condition, and Low EF was a composite of the HL and the LL conditions. The correlations among these variables are listed in the table below

Table 4: Theory of mind variable

	ToM	HH	LH	HL	LL	High L	Low L	High EF
ToM	-							
HH	.87**	-						
LH	.93**	.78**	-					
HL	.78**	.50**	.67**	-				
LL	.81**	.64**	.71**	.44*	-			
High Lang	.95**	.88**	.84**	.86**	.81**	-		
Low Lang	.95**	.78**	.94**	.61*	.91**	.81**	-	
High EF	.95**	.95**	.94**	.62**	.71**	.91**	.91**	-
Low EF	.93**	.67**	.81**	.88**	.82**	.88**	.88**	.78**

**$p < .001$, *$p < .01$

Language and Executive Function Composites

Two composite scores for overall language and executive function were created to test for relations between general cognitive abilities and ToM scores. The language composite was created by averaging the standardized z-scores of the grammatical understanding (GU), sentence imitation (SI), Complement (Comp), Complex Relatives (Comp Rel), and Coordinated Conjunctions (Coord Conj). This language composite exhibits strong internal consistency ($\alpha = .82$). Likewise, the EF composite score was created by averaging the four z-scored EF-related measures of Day-Night (DN), Working Memory Visual (WM Vis), Forward Digit Span (FDS), and Backward Digit Span (BDS). Reliability for this EF composite measures was $\alpha = .42$. The relatively low reliability of this composite is taken into consideration in the interpretation and discussion of the results.

Factor Analysis

In an effort to further clarify the contributions of underlying cognitive capacities to the success on ToM task performance, a principal components analysis was performed. In this analysis, a three factor model emerged. The loading of specific variables onto these factors is detailed in Table 5 below

Table 5: Principal Components Analysis

	Component		
	1	2	3
DN	.297	-.369	.754
WM visual	.408	.390	.444
FDS	.642	-.213	-.247
BDS	.540	.489	-.423
GU	.327	.760	.271
SI	.806	.149	.121
complements	.862	-.132	-.184
Complex relatives	.774	-.301	.010
Coord conj	.859	-.231	-.063

Factor 1: Verbal processing or working memory. This factor includes high loadings by 4 of the 5 language measures, and FDS, which one might consider to be a numerical version of the sentence imitation task. Additionally, the visual working memory task loads moderately onto this factor. Consequently, this factor appears to represent an aspect of working memory with an emphasis on verbal processing ability.

Factor 2: Central executive processing. This factor is slightly more ambiguous, but the high loadings of BDS and GU suggest that this factor represents processing other than simple storage or imitation. GU and BDS tasks both involve the mental manipulation of internal representations. For GU, one must choose between three different depictions of scenarios that match a given sentence. Success involves the encoding of the pictorial representations and the serial comparison of each representation to the given sentence. Likewise, BDS involves taking an internal representation and mentally manipulating its order. When one removes the variance associated with FDS from BDS, then BDS can represent a more accurate estimate of central executive processing (Gathercole & Pickering, 2000). Thus, the idea that grammatical understanding is related to central executive processing is supported by the significant relation between BDS and GU ($r = .40$, $p < .05$) when FDS variance is removed.

Factor 3: Inhibition or Visuospatial Sketchpad. The strong loading of DN and Visual WM onto this factor suggests it represents some aspect of EF. The DN task is classically associated with inhibition, but it is unexpected that WM visual would load highly on an inhibition factor. The WM Visual task is not designed to test inhibition of prepotent responses, and should be relatively free from inhibition requirements. Perhaps holding the chips until the experimenter says its ‘ok’ to reproduce the represented pattern requires inhibition similar to a delay task used in infants and monkeys. However, it is not expected that a task designed to measure central executive skill (BDS) would load negatively on a factor representing inhibition. Perhaps this factor represents some kind of visual fixedness related to the visuospatial sketchpad. Such fixedness would be useful in reproducing visual patterns and identifying those patterns as they relate to given descriptors (e.g., day or night). However, those who cannot fixate on the given relationship between card and word or those who cannot fixate on a given visual pattern would have difficulty staying focused on the task. Their minds might wander to the genuine semantic link between the cards picture and its accurate descriptor (leading to an incorrect response, and a failure to ‘inhibit’). Likewise, a participant who cannot rigidly ‘fix’ the pattern in the WM task will have a difficult time reproducing it. Such rigidity in thought is beneficial in the DN and WM Visual tasks, but detrimental on trying to mentally order the presentation of numbers in the BDS task. (note: rigidity and fixedness as described here differ from a failure to concentrate. Clearly, focus and concentration are required to succeed on all 3 tasks mentioned).

Descriptive statistics

Table 6: Descriptive statistics

Variable	Mean	SD	% correct	Max possible
Age (months)	51.54	5.56	NA	NA
GU	12.36	4.34	49%	25
SI	7.46	4.78	25%	30
DN	10.18	5.35	64%	16
ToM correct	3.29	3.70	27%	12
HH	1.11	1.17	37%	3
LH	.82	1.16	27%	3
HL	.93	1.09	31%	3
LL	.46	0.92	15%	3
Complement	1.61	1.23	40%	4
Comp Relative	2.00	1.12	50%	4
Coord Conj	1.61	1.29	40%	4
WM Visual	3.18	0.98	40%	8
FDS	3.96	0.85	44%	9
BDS	1.14	1.11	23%	5

Table 6 presents the descriptive statistics for the main study variables of interest.

First Major Aim: Did the experimental manipulation alter response?

A 2x2 repeated measures ANOVA was used to test the theory that the language and executive function manipulations would produce measurable differences in task performance. The ANOVA revealed a main effect for language ($F = 10.83$, $p < .01$), and a main effect for EF ($F = 4.26$, $p < .05$) (see Figure 8).

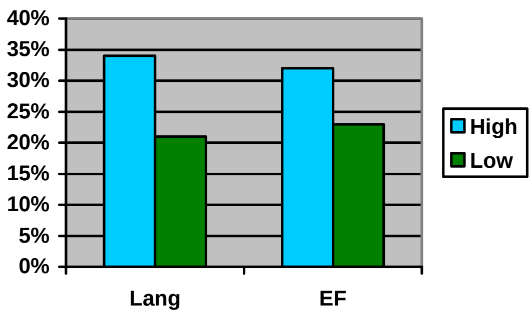

Figure 8: Mean percent correct for grouping high/low conditions

The test of interaction was not significant ($F = 0.45$, *ns*). The graph of the mean percentage of correct responses with respect to condition is demonstrated in Figure 9. Interestingly, the relationship is in the direction opposite to the prediction that the high language and executive function conditions would be more difficult.

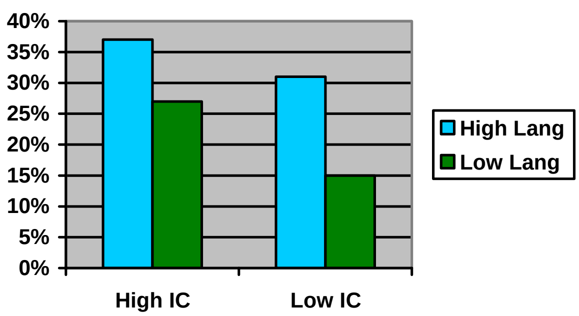

Figure 9: Mean percentage correct for the four conditions.

Second Major Aim: Initial cognitive levels relate to difference scores

Step 1: Bivariate Correlations

Investigation of the second major aim is a two-step process. The first step is to examine the simple bivariate correlations between initial cognitive scores and performance on the theory of mind measure to determine whether or not the results replicate previous findings which have shown strong relations between ToM scores and measures of both language and EF.

Does EF relate to ToM performance

Table 7 lists the bivariate correlations which shows that the initial levels of inhibitory control as measured by the Day-Night Stroop task were unrelated to either overall ToM performance or any of the components of the ToM task.

Table 7: EF and ToM *r*-value correlations

	DN	WM Vis	FDS	BDS	EF comp
ToM	-.05	-.06	.55**	.16	.25
HH	-.03	.03	.58***	.32^	.38*
LH	-.04	-.05	.60***	.19	.29
HL	.07	-.18	.34^	-.01	.10
LL	-.24	.03	.33^	.04	.07
High Lang	.02	-.08	.54**	.19	.28
Low Lang	-.14	-.02	.52**	.14	.21
High EF	-.04	-.01	.63***	.27	.35^
Low EF	-.09	-.10	.39*	.02	.10

***$p < .001$, **$p < .01$, *$p < .05$, ^$p < .10$

Does Lang relate to ToM scores

Table 8 lists the bivariate correlations of the primary measures of syntax and the ToM scores (see Appendix C for full correlation matrix). These results show that overall ToM was unrelated to any of these principal measures. However, SI and the HH condition of theory of mind were moderately correlated ($r = .30$, *ns*). Although this relationship is not significant with the given sample size, this result may suggest a potential underlying relation that might be more clearly identified in larger sample sizes or further explored through non-parametric statistics.

Table 8: Lang and ToM *r*-value correlations

	GU	SI	Comp	Comp Rel	Coord Conj	LANG comp
ToM	.00	.19	.15	.13	.18	.17
HH	.06	.30	.16	.06	.10	.18
LH	.08	.20	.16	.17	.18	.21
HL	-.11	-.11	.03	.15	.11	.02
LL	-.02	.23	.13	.00	.19	.14
High Lang	-.03	.12	.11	.12	.12	.12
Low Lang	.04	.23	.16	.10	.20	.19
High EF	.07	.27	.17	.12	.15	.20
Low EF	-.09	.05	.10	.10	.17	.09

***$p < .001$, **$p < .01$, *p < .05, ^$p < .10$

Step 2: Initial IC and language should relate to differences between high/low conditions

In order to test the hypothesis that one's initial levels of inhibitory control and syntax are negatively correlated with gains in performance, differences were calculated for each participant between their high/low performance for inhibitory control and language. For the investigation of language, the sum of HH and HL conditions were compared with the sum of the LH and LL conditions. If a participant correctly answered 5 of the 6 in the low language condition and 2 of 6 in the high language condition, the resulting difference score would be 3. These difference scores were calculated for both inhibitory control (sum of HL and LL minus HH and LH) and language (sum of LH and LL minus sum of HH and HL). A correlation tested for the significance of the relation between one's initial measure of inhibitory control or syntax and the gains made by reducing that component of the theory of mind measure. In other words, if a child initially has lower levels of inhibitory control or syntax will they exhibit greater gains in performance when the task demands are reduced? For children who are already high in inhibitory control/syntax, reducing these task demands should have minimal impact on expressing an existing theory of mind.

Does initial Language relate to difference in performance on different Lang levels in ToM task?

Correlational analyses revealed that the difference in language scores between the low and the high conditions on the ToM task were unrelated to any of the initial measures of language.

	Lang Diff
GU	*r* = -.10, *ns*
SI	*r* = -.17, *ns*
Comp	*r* = -.07, *ns*
Comp_Rel	*r* = -.03, *ns*
Coord Conj	*r* = -.11, *ns*
Lang Comp	*r* = -.11, *ns*

Does initial EF relate to difference in performance on different EF levels in ToM Task?

The difference in performance between high and low EF conditions (pointer and finger pointer response types) was not correlated with initial levels of EF ability as measured by the Day Night Stroop. However, FDS, BDS, and the overall EF composite score were all related to the EF difference score. In short, this means that a participant who scored highly on FDS, BDS, or the EF composite score was likely to have a greater disparity in their scores on high versus low EF conditions compared with a participant who had lower initial FDS, BDS, or EF composite score. Overall, there was a tendency to do better on the high EF demand conditions, which is a result that is contrary to initial predictions.

	EF Diff
DN	*r* = .05, *ns*
WM Vis	*r* = .11, *ns*
FDS	*r* = .51**
BDS	*r* = .41*
EF Comp	*r* = .45*

** $p < .01$, * $p < .05$

Step 3: Non-parametric Post-hoc Analyses

To further investigate the relation between ToM and aspects of language and executive function, non-parametric chi-square post-hoc analyses were conducted. Three groups were created from the ToM scores (ToM 3G) included a low (0-5), medium (6-9), and high (10-12) group (see Table 9). These ranges were determined through a visual analysis of the clustering of data (see Appendix D). Scores from just high/low language or high/low executive function were split into two groups using a mean split. Bivariate splits of the total ToM score were not informative, and were not included in the table. The overall ToM score with 12 responses were split into 3 groups. The results reported in this table all represent patterns whereby higher scores on ToM were associated with increased performance on one of the other measures.

Table 9: Chi-square analyses

	All ToM	*High Lang*	*Low Lang*	*High EF*	*Low EF*
GU	*ns*	*ns*	*ns*	*ns*	*ns*
SI	*ns*	*ns*	$X^2 = 6.01$*	*ns*	$X^2 = 4.76$*
DN	*ns*	*ns*	*ns*	*ns*	*ns*
Comp	*ns*	*ns*	*ns*	*ns*	*ns*
complex rel	*ns*	*ns*	*ns*	*ns*	*ns*
coord conj	*ns*	*ns*	*ns*	*ns*	*ns*
Wm vis	*ns*	*ns*	*ns*	*ns*	*ns*
FDS	$X^2 = 7.90$*	$X^2 = 3.48$^	$X^2 = 2.76$^	$X^2 = 5.24$*	*ns*
BDS	*ns*	*ns*	*ns*	*ns*	*ns*
EF comp	*ns*	*ns*	*ns*	*ns*	*ns*
LANG comp	*ns*	*ns*	*ns*	*ns*	*ns*
factor 1	$X^2 = 6.60$*	$X^2 = 2.49$^	*ns*	$X^2 = 4.09$*	*ns*
factor 2	*ns*	*ns*	*ns*	*ns*	*ns*
factor 3	*ns*	*ns*	*ns*	*ns*	*ns*

*$p < .05$, ^$p < .10$

Performing a high number (98) of post-hoc analyses often raises concern about increasing the number of type I errors (false positives), but the results from the post-hoc analyses may be interpretable. First of all, there is general consistency across the groupings for significant findings. In other words, regardless of where the cut-points were made, many of the results were consistent. If random error was responsible for the observed results, then this should be randomly distributed among the results. The clear patterns suggest that these results are not random. The measures that reveal a significant relation with ToM performance are either factor 1 or a measure, sentence imitation or forward digit span, which loaded highly on factor 1. Recall that factor 1 seems to represent some form of overall verbal ability or phonological memory capacity. This consistent response pattern suggests that these results did not occur by chance, and should be considered in the context of the overall interpretation of results.

Discussion

Experimental Manipulation of Task

The main results of this experiment are the strong differences observed across the experimentally manipulated conditions in the theory of mind task. Both language and executive function manipulations of the traditional false belief task resulted in observable performance differences. This finding points to an important aspect of false belief tests that has not been adequately explored in the literature to date: the way in which the question is asked or the manner in which the participants responds can have important effects on the overall performance.

It is remarkable that the subtle difference of phrasing a question as “where will Brett look for the candy?” compared with “where does Brett think the candy is?” can produce measurable differences in performance. These two sentences both contain the identical number of words (7) and syllables (8), and yet participants in this study found it more difficult to correctly respond to questions phrased like the former example involving “look” versus “think.” This result is in the opposite direction from the predictions set forth in the initial stages of this paper, but this finding is still remarkably informative. Despite the incorrect prediction of the direction of effect, the overall hypothesis that changes in the task would result in performance differences was supported. These results expand on Miller’s (2001) findings in which SLI children (*M* = 5;6 years old), language control (*M* = 3;9), and age controls (*M* = 5;6) were tested on a battery of theory of mind measures. In her study, Miller discovered no significant difference in scores between the “look” and “think” conditions for the non-SLI controls. However, the current study looks at this difference in children with a mean age of 4;4. Consequently, the groups in Miller’s study were probably either too skilled or too young for the task for one to notice much variation in the performance. Ceiling effects in the older children and random responding in the younger children prevented the identification of differences between the two language conditions.

The current study examines this important age-range for theory of mind development between highly skilled 5½ year-olds and the lesser skilled 3¾ year-olds. Differences between conditions were not observed in the older children in Miller’s study due to their highly accurate responding. On the other hand, the younger children in Miller's study may not have established a set pattern because they were "unable to compute false belief at all" (p. 80). The results of the current study suggest that, in the important developmental timeframe between novice and expert level, the language itself may provide a cue to the correct response pattern. Contrary to the initial prediction that the linguistically simpler "look" condition would be easier, these results indicate that the "think" condition was easier. It is conceivable that the more complex language structure served as a cue to the participant. If the child confused the point of the task and interpreted the goal as (a) where the object really is, or (b) where the character might eventually look, or (c) where the character should look if they wish to locate the object, then the child would respond incorrectly. Asking where the character "thinks" the object is may serve as a syntactic cue that the character's belief does not match up with reality, and that the participant's response should take this into consideration.

The observed main effect for the executive function manipulation of response type is also intriguing. Similar to the trend for language, the main effect for executive function manipulation is in the opposite direction than that predicted. Examination of the difference scores between performance on the high versus low executive function conditions reveals forward and backward digit spans are both significantly related to this difference. This suggests that those children who could hold strings of numbers in mind and recite them either verbatim or backwards had greater disparity between performance on the finger versus arrow pointing conditions. Closer investigation revealed that this disparity was due to an increase in performance on the finger pointing condition (see Figures 10 & 11). These results suggest that overall, low responders on the forward digit span and backward digit span tasks were poor at the theory of mind task with either type of response mechanism (finger or arrow). However, those who perform well on forward digit span and backward digit span do better at the theory of mind task, but have a more difficult time when the response type is the use of a pointing arrow versus the prepotent finger pointing. Clearly, something about using an arrow to respond interfered with performance for those with high working memory scores. Perhaps the high working memory participants might normally be able to accurately respond to the theory of mind question, but the increased cognitive load of having to remember the correct response type prevented success. In other words, the very act of remembering to point *in this manner* rather than *in that manner* may have impacted performance.

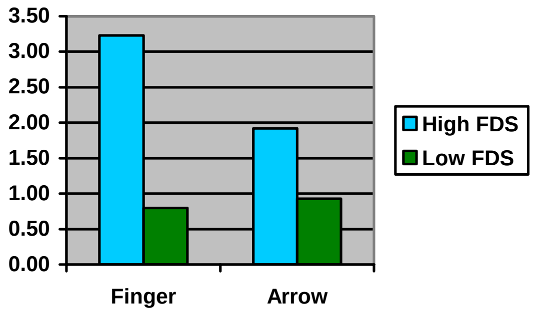

Figure 10: Theory of mind correct (response type by forward digit span)

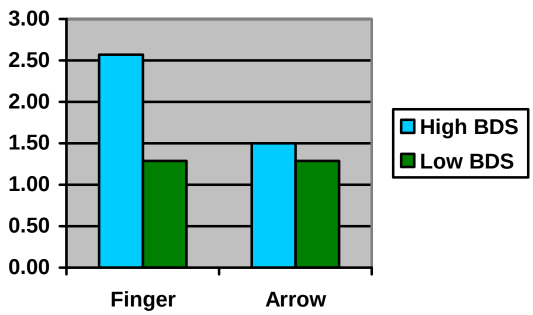

Figure 11: Theory of mind correct (response type by backward digit span)

Executive Function and Language scores should relate to differences between high and low conditions

The first step in addressing the second major aim of this study involved examination of the bivariate correlations to test whether results are consistent with previous findings which reveal strong relations of theory of mind with aspects of language and executive function (particularly syntax and inhibitory control). Surprisingly, bivariate correlations did not reveal the expected relations. In fact, the only significant results of relations between theory of mind and measures of language or executive function were for forward digit span and the executive function composite (the latter only with the HH theory of mind condition) relating to theory of mind. This second result, however, seems driven by the forward digit span score which help comprise the executive function composite score.

Non-parametric post-hoc analyses confirmed a relation between forward digit span and theory of mind, and in addition to the forward digit span score there is a significant relation between the factor 1 score (verbal ability) and some theory of mind groupings. More specifically, higher scores on either forward digit span, the factor 1 score, or Sentence Imitation were related to higher performance on several theory of mind scores. Recall that forward digit span, sentence imitation, and the three specific language imitation tasks (complements, complex relatives, and coordinated conjunctions) all loaded highly on this factor. Additionally, higher sentence imitation scores were significantly related to higher theory of mind scores, but only when they were grouped according to low language or low executive function conditions.

The forward digit span task is a measure of one's working memory. Examination of the forward digit span reveals that it is a numeric-string imitation task similar to the sentence imitation task. In both the forward digit span and sentence imitation tasks the participant is asked to listen to and repeat either a collection of words or a collection of numbers. Both require an aspect of working memory known as phonological memory (Baddeley, 1995) that allows a representation to be held in mind. There is evidence that phonological memory plays a strong role in early word learning (Gathercole & Baddeley, 1993), but is not as heavily recruited once the language processing system becomes more automatic. If the theory of mind task is novel, then perhaps it too needs to be held in working memory longer than automatic tasks. Therefore, it is possible that these findings suggest that some aspect of language, in the form of phonological memory or encoding into memory, played a role in success on the theory of mind task. This interpretation conflicts with other findings which suggest that working memory does not play a major role (Carlson et al., 2002), so further research would help clarify any relationship.

Various influences on theory of mind performance

One of the fascinating results from this study is the discovery that systematic alteration of the language in which a false belief question is asked, even if remarkably subtle, can result in genuine performance differences. Recall that in the "think" condition the question is phrased as "where does [person] think the [object] is?", and in the "look" condition one is asked "where will [person] look for the object?" Clearly, there was some sort of advantage for using the “think” phrasing compared with the “look” phrasing, and there is something in the “think” condition that helped alert the participant to the fact that it was not a typical task in which reality was the most prominent aspect. Focusing on the “look” question, one observes that it contains an element of ambiguity as both responses could, in theory, be correct. The character in the story might end up looking in both locations, but they would look in the incorrect location first since they had not witnessed the change. It was considered as a possibility to include the question “where will [person] look for the [object] first?” to highlight the importance of responding in accordance with the first location. This modification has shown improvement in theory of mind performance in normally developing children (Surian & Leslie, 1999). However, it was decided prior to testing that the inclusion of the additional word would disrupt the matching for word and syllabic length between the two language conditions. Furthermore, testing revealed that definite patterns emerged in responses indicating that strategies were being utilized fairly consistently across conditions as demonstrated by the strong ($r = .81$, $p < .001$) correlation between high versus low language conditions. This pattern suggests that the phrasings were not viewed as entirely different questions. Finally, results of Miller (2001) demonstrated that older (M = 5;6) and younger children (M = 3;9) have, on average, no difference between a “look” and a “think” false belief task. This suggests that a fairly uniform strategy is used, but inclusion of a word like “think” may provide subtle cues to children in the appropriate age range (around 4 years of age) that can result in slight performance improvements.

The lack of replication of earlier findings that syntax plays an important role in theory of mind performance is puzzling. The above results suggest that it is vocabulary development and an understanding that the “think” question phrasing that serves as a cue for a non-reality based response. Previously, some researchers have proposed that syntax plays an essential role because understanding the complexity of sentential complements was thought to be a barrier to understanding theory of mind situations (de Villiers & Pyers, 2002). The present research failed to find links between theory of mind and the tests of grammatical understanding, complements, relatives, or coordinated conjunctions. On the complements task, an ANOVA revealed that there were no differences between the theory of mind task means grouped by complement task score ($F = 0.46$, *ns*). Thus, the picture that de Villiers et al. paint regarding the necessity of complement understanding in order to achieve theory of mind task success is not supported by the current research. This finding is supported by other research which failed to find a relation between theory of mind performance and complementation understanding (Cheung et al., 2004). Although development of syntactic understanding may certainly help in the development of theory of mind understanding, it does not seem to be a prerequisite. This conclusion is supported earlier work in which improvements in theory of mind performance resulted from training in both syntactic and deceptive skills, but the largest gains were achieved by children who were trained in both areas (Lohmann & Tomasello, 2003b).

Identifying the role of different aspects of executive function in success on theory of mind tasks became quite difficult after analyzing the results of this experiment. The anticipated relation between the Day-Night Stroop task and the false belief task failed to manifest itself. Quite interesting though was the relation that forward digit span had with theory of mind. That, coupled with the strong relation of sentence imitation with theory of mind may lead one to conclude that some form of working memory or verbal ability (e.g., phonological memory) may play an important role in the theory of mind task. The fact that it may be phonological memory as opposed to visual working memory is intriguing since one might presume that the visual presentation of this version of the false belief task would provide an advantage for those with highly developed visual spatial memory which allows one to more accurately recall locations and objects. Therefore, not finding that visual working memory is related to theory of mind supports the idea that the false belief task as presented was not overly taxing on visual memory. If the type of working memory that is important is really phonological memory, then perhaps it is because phonological memory is more heavily recruited because the theory of mind task represents a novel situation requiring storage of novel questions like “where does Brett think the candy is?” Those who can hold the test question in mind the longest have the best opportunity to think about the response, whereas those who cannot hold the representation in mind at once might have a reality bias that leads them to answer incorrectly. Additionally, success on the theory of mind tasks requires the integration of several processes: encoding and maintenance of the critical verb question and subsequently derived goal state, the object hiding, possible locations of the object, and the characters in the scenario. It may not be so surprising then that children who were better able to hold these pieces of information in mind performed better in the theory of mind task (Gordon & Olson, 1998). Evidence from the current study supports this interpretation. Specifically, better performance on the theory if mind task was related to factor 1 as well as to two measures which loaded highly on factor 1: forward digit span and sentence imitation.

In addition to suggesting that working memory may play a role in theory of mind performance, the current findings offer insight into the role of inhibition. One aspect of the design of this study was that it could test the expression versus emergence account of the role of inhibition in theory of mind performance. The experiment failed to yield support for the idea that aspects of inhibition prevent the expression of an underlying capacity for comprehending theory of mind situations. It was proposed that the use of a pointing arrow would reduce the prepotent reality bias of pointing towards where an object really is versus where another individual thinks it is. If the use of an arrow reduced inhibition in the same manner as it had with deception tasks, then the lack of finding an improvement in the low inhibitory control condition suggests that the expression account of the role of executive function is inaccurate. As reported earlier, the use of a pointing arrow reduced performance, which is quite the opposite of what the expression account would predict. The novel response style should have prevented the use of any prepotent response and thus could reflect a more accurate understanding that was just not being expressed. Thus the present research suggests that, for 4-year-olds, inhibition is not preventing the expression of an already existing underlying capacity for understanding theory of mind situations.

Summary and Suggestions for Future Research

There are two major themes which emerged through the course of this study. First, there is a definite contribution of language to the success of the false belief task designed to assess theory of mind understanding. Previous research has implicated detailed aspects of syntax as being likely to influence success on theory of mind tasks. The present research failed to support such hypotheses. Rather, the findings of this study suggest that some form of verbal ability, possibly a phonological memory capacity, plays a role in theory of mind task success. In this interpretation, overall language level as represented by a sentence imitation measure may work together with memory capacity measured by forward digit span to support the complex events and behaviors that require representation in theory of mind tasks. Taken together with previous research, the failure to find syntax separately playing a significant role in these findings points towards the complexity of theory of mind. In all likelihood, both syntax and phonological loop capacity play a role, and strong individual differences are likely leading to widespread variations in results depending on the specific abilities and overall developmental levels of the investigated population.

The second major theme that has emerged in this study is that the specific task design and structure used to assess one's theory of mind ability may significantly alter the results. It was surprising to see that variations in the task which were designed to ease the cognitive requirements needed to comprehend and/or respond to the task in fact increased the demand and created a lower success rate. The executive function task manipulation was based on a review of similar tasks designed to test deception, which was thought to share many of the essential inhibition components with theory of mind. The results of this study do not support the idea that inhibition is as important as traditionally thought when it comes to success on false belief tasks. Perhaps it is the other aspects of executive function, like working memory, that help account for theory of mind task success. Further investigation of the traditional executive function tasks would help address this question. Clearly, research into the measurements themselves (whether for theory of mind or executive function) need to be considered. Well validated measures exist for language, but there is less of an understanding of the basic measurements used to assess executive function and theory of mind. It is essential that researchers continue to expand our domain of understanding by creation of innovative tasks that stretch the boundary of our conception of theory of mind and provide multiple response opportunities for participants in our studies.

Overall, this study has several positive aspects to its design. First, it introduces a bi-dimensional experimental manipulation of task demands that have previously been studied uni-dimensionally. Second, it helps clarify the aspects of traditional false belief tests that may limit the expression of children's underlying conceptual understanding of theory of mind social situations. Understanding the strength of these relations is important in helping to decipher the previously observed correlations between language/executive function and theory of mind. Finally, measures of inhibitory control and syntax may help elucidate the contribution that specific task adjustments have depending on the cognitive capacities of children. For example, some children may suffer difficulties on theory of mind tasks because they fail to understand syntax, not because their inhibitory control is low. In these types of children, adjusting the level of syntax should result in observable gains, but adjusting the inhibitory control requirements should not result in improvements. This type of design can directly test these related hypotheses and help clarify the growing (and often confusing) body of literature concerning theory of mind's relations with cognitive skills like syntactic understanding and inhibitory control.

There are several logical next steps for one interested in continuing to elucidate the complex phenomenon of theory of mind. First, attention should be given to the investigation and validation of the false belief tasks and others like them that are used to assess some of the most important cognitive aspects related to theory of mind. The present research helped highlight some important performance differences that emerged from taxing the participant at different levels of complexity. It is essential that researchers understand the difference between task related artifacts that impact the expression of an underlying understanding of theory of mind, and those cognitive capabilities that are required to comprehend and respond to the presented theory of mind scenario. A balance must be struck between presenting a scenario which challenges a child's cognitive capacities and one which requires so few cognitive resources that the answer is self evident. The measure should be intelligently designed such that it requires use of specific 'theory of mind processing', and success should be difficult to achieve through a less complex heuristic. In this study, easier language was used to present the task to the child and an easier response mechanism was provided with the pointing arrow. These alterations were specifically designed to test potential differences between the presentation and response types. Detailed investigation using systematic alterations of presentation and response mechanisms will help identify whether the existing standard theory of mind task makes sense. In the process, task validation will help bring the varied conceptualizations within the field closer to sharing a common understanding of *what* theory of mind is.

A second major area of research to be further explored is the role that working memory plays in theory of mind task success. This study, while not specifically investigating the influence of working memory, did find that certain tasks traditionally associated with working memory were highly linked to theory of mind task success. It was intriguing to discover that forward digit span also shares many similarities to the sentence imitation task (which was also related to performance on theory of mind tasks). This converging evidence strongly indicates the need for further clarification of the influence of working memory on theory of mind task success. Investigation of the impact of working memory capacity on theory of mind performance may also help bridge the gap between those investigating language and theory of mind and those investigating executive function and theory of mind. Working memory, in the form of phonological loop capacity, represents a strong bridge between the cognitive domains of executive function and language which are too often viewed as being disparate.

Finally, another avenue requiring investigation is the exploration of the numerous language capabilities that may help or hinder theory of mind success. Whether it be overall verbal ability, phonological loop capacity, syntax understanding, or mastery of sentence complementation, by specifically addressing the deficiency in one of these areas one may increase the likelihood of success on theory of mind tasks. The investigation of the language components or a combination of components that offer the greatest improvement of theory of mind ability can help increase our knowledge of the way in which cognitive capabilities affect social development. Such knowledge is essential for those practitioners who intervene with mildly or severely delayed children in an effort to equip them with the abilities to function in our highly social world.

References

Andrews, G., Halford, G. S., Bunch, K. M., Bowden, D., & Jones, T. (2003). Theory of Mind and Relational Complexity. *Child Development, 74*(5), 1476-1499.

Arunkumar, G. S., & Kotagal, P. (1998). Lateral frontal lobe seizures. *Epilepsia, 39* (Suppl 4), S62-68.

Astington, J. W. (2000). Language and metalanguage in children's understanding of mind. In J. W. Astington (Ed.), *Minds in the making: Essays in honor of David R. Olson* (pp. 267-284). Malden, MA: Blackwell Publishers.

Astington, J. W., & Jenkins, J. M. (1999). A longitudinal study of the relation between language and theory-of-mind development. *Developmental Psychology, 35*(5), 1311-1320.

Bach, L., Davies, S., Colvin, C., Wijeratne, C., Happe, F., & Howard, R. (1998). A neuropsychological investigation of theory of mind in an elderly lady with frontal leucotomy. *Cognitive Neuropsychiatry, 3*(2), 139-159.

Bach, L. J., Happe, F., Fleminger, S., & Powell, J. (2000). Theory of mind: Independence of executive function and the role of the frontal cortex in acquired brain injury. *Cognitive Neuropsychiatry, 5*(3), 175-192.

Baddeley, A. (1995). Working memory. In M. S. Gazzaniga (Ed.), *(1995). The cognitive neurosciences* (pp. 755-764). Cambridge, MA: The MIT Press.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition, 21*(1), 37-46.

Baron-Cohen, S., Ring, H., Moriarty, J., Schmitz, B., & et al. (1994). Recognition of mental state terms: Clinical findings in children with autism and a functional neuroimaging study of normal adults. *British Journal of Psychiatry, 165*(5), 640-649.

Bretherton, I., & Beeghly, M. (1982). Talking about internal states: The acquisition of an explicit theory of mind. *Developmental Psychology, 18*(6), 906-921.

Brown, R. (1973). *A first language: The early stages*. London: George Allen & Unwin Ltd.

Cadinu, M. R., & Kiesner, J. (2000). Children's development of a theory of mind. *European Journal of Psychology of Education, 15*(2), 93-111.

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development, 72*(4), 1032-1053.

Carlson, S. M., Moses, L. J., & Breton, C. (2002). How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development, 11*(2), 73-92.

Carlson, S. M., Moses, L. J., & Hix, H. R. (1998). The role of inhibitory processes in young children's difficulties with deception and false belief. *Child Development, 69*(3), 672-691.

Carruthers, P. (1996). *Language, Thought and Consciousness: An Essay in Philosphical Psychology*: Cambridge University Press.

Channon, S., & Crawford, S. (2000). The effects of anterior lesions on performance on a story comprehension test: Left anterior impairment on a theory of mind-type task. *Neuropsychologia, 38*(7), 1006-1017.

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2001). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive Development, 15*(4), 481-498.

Cheung, H., Hsuan Chih, C., Creed, N., Ng, L., Wang, S. P., & Mo, L. (2004). Relative Roles of General and Complementation Language in Theory-of-Mind Development: Evidence From Cantonese and English. *Child Development, 75*(4), 1155-1170.

Craven, P. L., & Nelson, K. E. (2005). A longitudinal investigation of the relationship between children's performance on language, executive function, and theory of mind tasks. *Manuscript in Preparation*.

Cutting, A. L., & Dunn, J. (1999). Theory of mind, emotion understanding, language, and family background: Individual differences and interrelations. *Child Development, 70*(4), 853-865.

Davis, H. L., & Pratt, C. (1995). The development of children's theory of mind: The working memory explanation. *Australian Journal of Psychology, 47*(1), 25-31.

de Villiers, J. G., & de Villiers, P. A. (2000). Linguistic determinism and the understanding of false beliefs. In P. Mitchell & K. J. Riggs (Eds.), *Children's reasoning and the mind* (pp. 191-228). Hove, England: Psychology Press/Taylor & Francis (UK).

de Villiers, J. G., & Pyers, J. E. (2002). Complements to cognition: A longitudinal study of the relationship between complex syntax and false-belief-understanding. *Cognitive Development, 17*(1), 1037-1060.

Diamond, A. (1993). Neuropsychological insights into the meaning of object concept development. In M. H. Johnson (Ed.), *Brain development and cognition: A reader* (pp. 208-247). Malden, MA: Blackwell Publishers.

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In *Stuss, Donald T. (Ed); Knight, Robert T. (Ed). (2002). Principles of frontal lobe function. (pp. 466 503). London, Oxford University Press. xxi, 616 pp.SEE BOOK*.

Fahie, C. M., & Symons, D. K. (2003). Executive functioning and theory of mind in children clinically referred for attention and behavior problems. *Journal of Applied Developmental Psychology, 24*(1), 51-73.

Farrar, M. J., & Maag, L. (2002). Early language development and the emergence of a theory of mind. *First Language, 22*(65,Pt2), 197-213.

Fine, C., Lumsden, J., & Blair, R. J. R. (2001). Dissociation between "theory of mind" and executive functions in a patient with early left amygdala damage. *Brain, 124*(2), 287-298.

Flynn, E., O'Malley, C., & Wood, D. (2004). A longitudinal, microgenetic study of the emergence of false belief understanding and inhibition skills. *Developmental Science, 7*(1), 103-115.

Frith, C. (1994). Theory of mind in schizophrenia. In A. S. David (Ed.), *(1994). The neuropsychology of schizophrenia. Brain damage, behaviour and cognition series* (pp. 147-161). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Frith, C. D., & Frith, U. (2000). The physiological basis of theory of mind: functional imaging studies. In S. Baron-Cohen, H. Tager Flusberg & D. Cohen (Eds.), *Understanding of other minds: perspectives from developmental cognitive neuroscience* (2nd ed., pp. 334-356). Oxford: Oxford University Press.

Frye, D. (1999). Development of intention: The relation of executive function to theory of mind. In P. D. Zelazo & J. W. Astington (Eds.), *Developing theories of intention: Social understanding and self control* (pp. 119-132). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development, 10*(4), 483-527.

Gallagher, H. L., Happe, F., Brunswick, N., Fletcher, P. C., Frith, U., & Frith, C. D. (2000). Reading the mind in cartoons and stories: an fMRI study of 'theory of the mind' in verbal and nonverbal tasks. *Neuropsychologia, 38*(1), 11-21.

Garfield, J. L., Peterson, C. C., & Perry, T. (2001). Social cognition, language acquisition and the development of the theory of mind. *Mind and Language, 16*(5), 494-541.

Garner, C., Callias, M., & Turk, J. (1999). Executive function and theory of mind performance of boys with fragile-X syndrome. *Journal of Intellectual Disability Research, 43*(6), 466-474.

Gathercole, S. E., & Baddeley, A. D. (1993). *Working memory and language*. Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Gathercole, S. E., & Pickering, S. J. (2000). Assessment of working memory in six- and seven-year-old children. *Journal of Educational Psychology, 92*(2), 377-390.

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: performance of children 3½-7 year old on a Stroop-like day-night test. *Cognition, 53*, 129-153.

Goel, V., Grafman, J., Sadato, N., & Hallett, M. (1995). Modeling other minds. *Neuroreport: An International Journal for the Rapid Communication of Research in Neuroscience, 6*(13), 1741-1746.

Gopnik, A. (1990). Developing the Idea of Intentionality: Children's Theories of Mind. *Canadian Journal of Philosophy, 20*(1), 89-113.

Gopnik, A., & Wellman, H. M. (1992). Why the child's theory of mind really is a theory. *Mind and Language, 7*(1-2), 145-171.

Gordon, A. C. L., & Olson, D. R. (1998). The relation between acquisition of a theory of mind and the capacity to hold in mind. *Journal of Experimental Child Psychology, 68*(1), 70-83.

Gray, C. D., Hosie, J. A., Russell, P. A., & Ormel, E. A. (2001). Emotional development in deaf children: Facial expressions, display rules, and theory of mind. In M. D. Clark & M. Marschark (Eds.), *Context, cognition, and deafness* (pp. 135-160). Washington, DC: Gallaudet University Press.

Hala, S., & Russell, J. (2001). Executive control within strategic deception: A window on early cognitive development? *Journal of Experimental Child Psychology, 80*(2), 112-141.

Happe, F. G. E. (1993). Communicative competence and theory of mind in autism: A test of relevance theory. *Cognition, 48*(2), 101-119.

Happe, F. G. E. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders, 24*(2), 129-154.

Hickling, A. K., & Wellman, H. M. (2001). The emergence of children's causal explanations and theories: Evidence from everyday conversation. *Developmental Psychology, 37*(5), 668-683.

Hill, E. L. (2004). Executive dysfunction in autism. *Trends in Cognitive Sciences, 8*(1), 26-32.

Holmes, A. M. (2002). Theory of mind and behaviour disorders in children with specific language impairment. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 62*(11-B), 5376.

Hughes, C. (1998a). Executive function in preschoolers: Links with theory of mind and verbal ability. *British Journal of Developmental Psychology, 16*(2), 233-253.

Hughes, C. (1998b). Finding your marbles: Does preschoolers' strategic behavior predict later understanding of mind? *Developmental Psychology, 34*(6), 1326-1339.

Hughes, C. (2002). Executive functions and development: Emerging themes. *Infant and Child Development, 11*(2), 201-209.

Hughes, C., & Dunn, J. (1997). "Pretend you didn't know": Preschoolers' talk about mental states in pretend play. *Cognitive Development, 12*(4), 381-403.

Jenkins, J. M., & Astington, J. W. (1996). Cognitive factors and family structure associated with theory of mind development in young children. *Developmental Psychology, 32*(1), 70-78.

Jenkins, J. M., Turrell, S. L., Kogushi, Y., Lollis, S., & Ross, H. S. (2003). A longitudinal investigation of the dynamics of mental state talk in families. *Child Development, 74*(3), 905-920.

Keenan, T. (2000). Mind, memory, and metacognition: The role of memory span in children's developing understanding of the mind. In J. W. Astington (Ed.), *Minds in the making: Essays in honor of David R. Olson* (pp. 234-249). Malden, MA: Blackwell Publishers.

Lalonde, C. E., & Chandler, M. J. (1995). False belief understanding goes to school: On the social-emotional consequences of coming early or late to a first theory of mind. *Cognition and Emotion, 9*(2-3), 167-185.

Lehto, J. E., Juujarvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21*(1), 59-80.

Leslie, A. M. (1987). Pretense and representation: The origins of "theory of mind." *Psychological Review, 94*(4), 412-426.

Leslie, A. M., & Happe, F. (1989). Autism and ostensive communication: The relevance of metarepresentation. *Development and Psychopathology, 1*(3), 205-212.

Lewis, C., & Osborne, A. (1990). Three-year-olds' problems with false belief: Conceptual deficit or linguistic artifact? *Child Development, 61*(5), 1514-1519.

Lohmann, H., & Tomasello, M. (2003a). Language and social understanding: Commentary on Nelson et al. *Human Development, 46*(1), 47-50.

Lohmann, H., & Tomasello, M. (2003b). The Role of Language in the Development of False Belief Understanding: A Training Study. *Child Development, 74*(4), 1130-1144.

MedicineNet.com. (2002). *Fragile X syndrome*, from http://www.medterms.com/script/main/art.asp?articlekey=3517

Meins, E. (2003). Emotional development and early attachment relationships. In *(2003). Bremner, Gavin (Ed), Slater, Alan (Ed), An introduction to developmental psychology. (pp.141 164). Malden, MA, US: Blackwell Publishers. xxv, 583 pp.*

Meins, E., Fernyhough, C., Wainwright, R., Gupta, M. D., Fradley, E., & Tuckey, M. (2002). Maternal Mind-Mindedness and Attachment Security as Predictors of Theory of Mind Understanding. *Child Development, 73*(6), 1715-1726.

Meltzoff, A. N., Gopnik, A., & Repacholi, B. M. (1999). Toddlers' understanding of intentions, desires and emotions: Explorations of the dark ages. In P. D. Zelazo & J. W. Astington (Eds.), *Developing theories of intention: Social understanding and self control* (pp. 17-41). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Miller, C. A. (2001). False belief understanding in children with specific language impairment. *Journal of Communication Disorders, 34*(1-2), 73-86.

Miller, C. A. (2004). False belief and sentence complement performance in children with specific language impairment. *International Journal of Language and Communication Disorders, 39*(2), 191-213.

Mitchell, P. (1997). *Introduction to theory of mind: Children, autism and apes*. London, England: Edward Arnold Publishers, Ltd.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., & Howerter, A. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49-100.

Moore, C., Jarrold, C., Russell, J., Lumb, A., Sapp, F., & MacCallum, F. (1995). Conflicting desire and the child's theory of mind. *Cognitive Development, 10*(4), 467-482.

Moore, C., Pure, K., & Furrow, D. (1990). Children's understanding of the modal expression of speaker certainty and uncertainty and its relation to the development of a representational theory of mind. *Child Development, 61*(3), 722-730.

Moses, L. J. (2001). Executive accounts of theory-of-mind development. Commentary on "Meta -analysis of theory-of-mind development: The truth about false belief." *Child Development, 72*(3), 688-690.

Nelson, K., Plesa, D., & Henseler, S. (1998). Children's theory of mind: An experiential interpretation. *Human Development, 41*(1), 7-29.

Nelson, K., Skwerer, D. P., Goldman, S., Henseler, S., Presler, N., & Walkenfeld, F. F. (2003). Entering a community of minds: An experiential approach to "theory of mind'. *Human Development, 46*(1), 24-46.

Nelson, K. E. (1991). On differentiated language-learning models and differentiated interventions. In N. A. Krasnegor & D. M. Rumbaugh (Eds.), *Biological and behavioral determinants of language development* (pp. 399-428). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Nelson, K. E., Craven, P. L., Xuan, Y., & Arkenberg, M. E. (2004). Acquiring art, spoken language, sign language, and text: developmental and evolutionary observations from a dynamic tricky mix theortetical perspective. In P. J. Bauer, J. Hudson, R. Fivush & J. Lucariello (Eds.), *The mediated mind: essays in honor of Katherine Nelson* (pp. 175-222). Hillsdale, NJ: Erlbaum.

Nelson, K. E., Welsh, J. M., Camarata, S. M., Tjus, T., & Heimann, M. (2001). A rare event transactional model of tricky mix conditions contributing to language acquistion and varied communicative delays. In K. E. Nelson & A. Aksu-Koc (Eds.), *Children's language: Interactional contributions to language development, Vol. 11* (pp. 165-195). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Newcomer, P. L., & Hammill, D. D. (1997). Test of Language Development - Primary (TOLD-P;3) 3rd edition. USA: PRO-ED.

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin, 126*, 220-246.

Ozonoff, S., & McEvoy, R. E. (1994). A longitudinal study of executive function and theory of mind development in autism. *Development and Psychopathology, 6*(3), 415-431.

Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 32*(7), 1081-1105.

Perner, J. (1988). Developing semantics for theories of mind: From propositional attitudes to mental representation. In J. W. Astington & P. L. Harris (Eds.), *Developing theories of mind* (pp. 141-172). New York, NY: Cambridge University Press.

Perner, J., Kain, W., & Barchfeld, P. (2002). Executive control and higher-order theory of mind in children at risk of ADHD. *Infant and Child Development, 11*(2), 141-158.

Perner, J., & Lang, B. (1999). Development of theory of mind and executive control. *Trends in Cognitive Sciences, 3*(9), 337-344.

Perner, J., Lang, B., & Kloo, D. (2002). Theory of mind and self-control: More than a common problem of inhibition. *Child Development, 73*(3), 752-767.

Perner, J., Sprung, M., Zauner, P., & Haider, H. (2003). Want that is understood well before say that, think that, and false belief: A test of de Villier's linguistic determinism on German-speaking children. *Child Development, 74*(1), 179-188.

Perner, J., Stummer, S., & Lang, B. (1999). Executive functions and theory of mind: Cognitive complexity or functional dependence? In P. D. Zelazo & J. W. Astington (Eds.), *Developing theories of intention: Social understanding and self control* (pp. 133-152). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Peterson, C. C. (2003). The social face of theory of mind: The development of concepts of emotion, desire, visual perspective and false belief in deaf and hearing children. In *Slaughter, Virginia (Ed), Repacholi, Betty (Ed), Individual differences in theory of mind: Implications for typical and atypical development. (pp.171 196). New York, NY, US: Psychology Press. xi, 366 pp.*

Peterson, C. C., & Siegal, M. (1995). Deafness, conversation and theory of mind. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 36*(3), 459-474.

Povinelli, D. J., & Preuss, T. M. (1995). Theory of mind: Evolutionary history of a cognitive specialization. *Trends in Neurosciences, 18*(9), 418-424.

Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences, 1*(4), 515-526.

Remmel, E., Bettger, J. G., & Weinberg, A. M. (2001). Theory of mind development in deaf children. In M. D. Clark & M. Marschark (Eds.), *Context, cognition, and deafness* (pp. 113-134). Washington, DC: Gallaudet University Press.

Ruffman, T., Slade, L., & Crowe, E. (2002). The relation between children's and mothers' mental state language and theory-of-mind understanding. *Child Development, 73*(3), 734-751.

Ruffman, T., Slade, L., Rowlandson, K., Rumsey, C., & Garnham, A. (2003). How language relates to belief, desire, and emotion understanding. *Cognitive Development, 18*(2), 139-158.

Russell, J., Hala, S., & Hill, E. (2003). The automated windows task: The performance of preschool children, children with autism, and children with moderate learning difficulties. *Cognitive Development, 18*(1), 111-137.

Russell, P. A., Hosie, J. A., Gray, C. D., Scott, C., Hunter, N., Banks, J. S., et al. (1998). The development of theory of mind in deaf children. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 39*(6), 903-910.

Sabbagh, M. A., & Callanan, M. A. (1998). Metarepresentation in action: 3-, 4-, and 5-year-olds' developing theories of mind in parent-child conversations. *Developmental Psychology, 34*(3), 491-502.

Sabbagh, M. A., & Taylor, M. (2000). Neural correlates of the theory of mind reasoning: an event-related potential study. *Psychological Science, 11*, 46-50.

Shields, J., Varley, R., Broks, P., & Simpson, A. (1996). Social cognition in developmental language disorders and high-level autism. *Developmental Medicine and Child Neurology, 38*(6), 487-495.

Smith, M., Apperly, I., & White, V. (2003). False belief reasoning and the acquisition of relative clause sentences. *Child Development, 74*(6), 1709-1719.

Sodian, B. (1991). The development of deception in young children. *British Journal of Developmental Psychology, 9*(1), 173-188.

Stone, V. E., Baron-Cohen, S., & Knight, R. T. (1998). Frontal lobe contributions to theory of mind. *Journal of Cognitive Neuroscience, 10*(5), 640-656.

Stone, V. E., Baron Cohen, S., Calder, A., Keane, J., & Young, A. (2003). Acquired theory of mind impairments in individuals with bilateral amygdala lesions. *Neuropsychologia, 41*(2), 209-220.

Stuss, D. T., Gallup, G. G., Jr., & Alexander, M. P. (2001). The frontal lobes are necessary for "theory of mind". *Brain, 124*(2), 279-286.

Surian, L., & Leslie, A. M. (1999). Competence and performance in false belief understanding: A comparison of autistic and normal 3-yr-old children. *British Journal of Developmental Psychology, 17*(Pt 1), 141-155.

Tager Flusberg, H. (1994). The relationship between language and social cognition: Lessons from autism. In Y. Levy (Ed.), *Other children, other languages: Issues in the theory of language acquisition* (pp. 359-381). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Tager Flusberg, H., Sullivan, K., & Boshart, J. (1997). Executive functions and performance on false belief tasks. *Developmental Neuropsychology, 13*(4), 487-493.

Thelen, E., & Smith, L. B. (1998). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA.

Trevarthen, C., & Aitken, K. J. (2001). Infant intersubjectivity: Research, theory, and clinical applications. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 42*(1), 3-48.

Varley, R., Siegal, M., & Want, S. C. (2001). Severe impairment in grammar does not preclude theory of mind. *Neurocase, 7*(6), 489-493.

Vygotsky, L. (1986). *Thought and language*. Cambridge, MA.

Watson, A. C., Painter, K. M., & Bornstein, M. H. (2001). Longitudinal relations between 2-year-olds' language and 4-year-olds' theory of mind. *Journal of Cognition and Development, 2*(4), 449-457.

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: The truth about false belief. *Child Development, 72*(3), 655-684.

Wellman, H. M., Phillips, A. T., Dunphy Lelii, S., & LaLonde, N. (2004). Infant social attention predicts preschool social cognition. *Developmental Science, 7*(3), 283-288.

Wimmer, H., & Hartl, M. (1991). Against the Cartesian view on mind: Young children's difficulty with own false beliefs. *British Journal of Developmental Psychology, 9*(1), 125-138.

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition, 13*, 103-128.

Woolfe, T., Want, S. C., & Siegal, M. (2002). Signposts to development: Theory of mind in deaf children. *Child Development, 73*(3), 768-778.

Zelazo, P. D. (2003). *Understanding the Relation Between Theory of Mind and Executive Function: A "Hot/Cool" Framework.* Paper presented at the Society for Research in Child Development, Tampa, FL.

Zelazo, P. D., Jacques, S., Burack, J. A., & Frye, D. (2002). The relation between theory of mind and rule use: Evidence from persons with autism-spectrum disorders. *Infant and Child Development, 11*(2), 171-195.

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of Childhood Cognitive Development* (pp. 445-469). Oxford: Blackwell.

Appendix A: Theory of Mind Task

Theory of Mind Task   Version A1   ID______   Date______

When we use this side of the folder, point with your finger, ok?

Table 1: Training Clip 1

		Response		Score
T1	***What did the girl take?***	**Coke**	Book	

When we use this side of the folder, point using this arrow, ok? Don't point with your finger.

Table 2: Training Clip 2

		Response		Score
T2	***What did the girl take?***	Fish food	**Phone**	

This is Brett, and this is Sara, see? We're going to see a story about Brett and Sara now.

Now remember, use your finger to respond.

Table 3: Finer Pointing

		Response		Score
1	**Where does Brett think the candy cane is?**	Cabinet	**Breadbox**	
2	**Where does Sara think the bagel is?**	**Microwave**	Oven	
3	**Where does Sara think the shirt is?**	Dryer	**Washer**	
			HH	
4	**Where will Brett look for the bottle?**	**Drawer**	Cabinet	
5	**Where will Brett look for the coffee?**	Refrigerator	**Cabinet**	
6	**Where will Sara look for the cat?**	**Laundry**	Room	
			LH	

Now remember, use the pointing arrow to respond.
[Reset pointing arrow after each use]

Table 4: Pointing Arrow

		Response		Score
7	**Where does Sara think the water is?**	**Small Pot**	Large Pot	
8	**Where does Brett think the glass is?**	**Dishwasher**	Cabinet	
9	**Where does Brett think the remote is?**	White Pillow	**Dark Pillow**	
			HL	
10	**Where will Brett look for the frog slipper?**	**Cat Carrier**	Closet	
11	**Where will Brett look for the Goofie toy?**	**Backseat**	Trunk	
12	**Where will Sara look for the movie?**	**Box**	Laundry	
			LL	

Appendix B: Additional ToM Order Effects Graphs

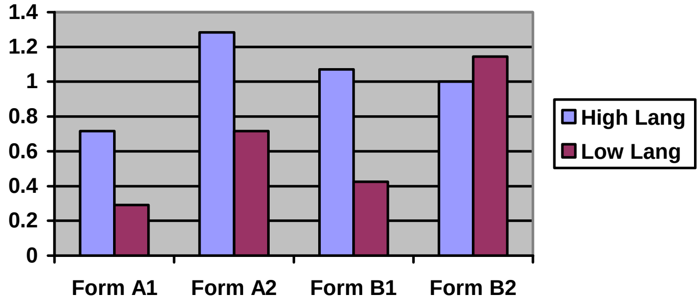

Figure 12: Form by High/Low Language Response pattern

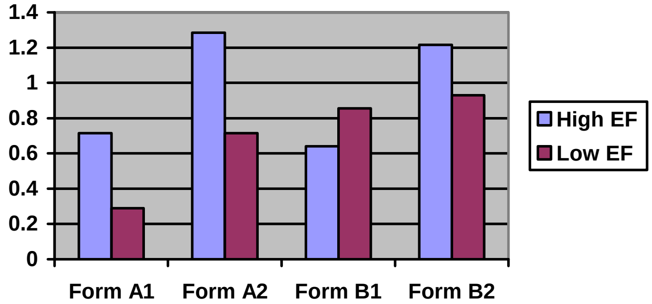

Figure 13: Form by High/Low EF response pattern

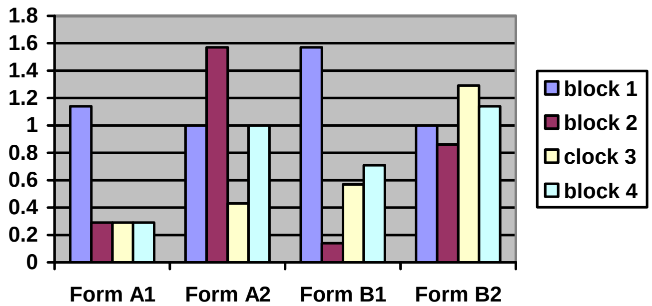

Figure 14: Mean response by 3-question block order

Appendix C: Full Correlation Tables

Table 10: Full Correlation Table A

		Sex	Gu	Si	dn	tom	comp	comp_rel	coord_conj	wm_vis	fds	bds
Sex	Pearson Correlation	1	-.115	.085	-.111	.023	.305	.406(*)	.350	.055	.166	.175
	Sig. (2-tailed)	.	.560	.667	.576	.906	.115	.032	.068	.781	.398	.372
	N	28	28	28	28	28	28	28	28	28	28	28
gu	Pearson Correlation	-.115	1	.349	.027	-.002	.229	.122	.112	.306	-.107	.334
	Sig. (2-tailed)	.560	.	.069	.890	.992	.241	.537	.569	.114	.588	.082
	N	28	28	28	28	28	28	28	28	28	28	28
si	Pearson Correlation	.085	.349	1	.276	.187	.613(**)	.435(*)	.609(**)	.344	.470(*)	.419(*)
	Sig. (2-tailed)	.667	.069	.	.155	.341	.001	.021	.001	.073	.012	.027
	N	28	28	28	28	28	28	28	28	28	28	28
dn	Pearson Correlation	-.111	.027	.276	1	-.046	.141	.278	.253	.145	.087	-.129
	Sig. (2-tailed)	.576	.890	.155	.	.817	.475	.152	.194	.461	.659	.513
	N	28	28	28	28	28	28	28	28	28	28	28
tom	Pearson Correlation	.023	-.002	.187	-.046	1	.148	.125	.180	-.060	.552(**)	.161
	Sig. (2-tailed)	.906	.992	.341	.817	.	.452	.527	.359	.760	.002	.414
	N	28	28	28	28	28	28	28	28	28	28	28
comp	Pearson Correlation	.305	.229	.613(**)	.141	.148	1	.753(**)	.813(**)	.106	.395(*)	.409(*)
	Sig. (2-tailed)	.115	.241	.001	.475	.452	.	.000	.000	.590	.038	.031
	N	28	28	28	28	28	28	28	28	28	28	28
comp_rel	Pearson Correlation	.406(*)	.122	.435(*)	.278	.125	.753(**)	1	.641(**)	.201	.447(*)	.222
	Sig. (2-tailed)	.032	.537	.021	.152	.527	.000	.	.000	.304	.017	.255
	N	28	28	28	28	28	28	28	28	28	28	28
coord_conj	Pearson Correlation	.350	.112	.609(**)	.253	.180	.813(**)	.641(**)	1	.233	.512(**)	.325
	Sig. (2-tailed)	.068	.569	.001	.194	.359	.000	.000	.	.232	.005	.091
	N	28	28	28	28	28	28	28	28	28	28	28
wm_vis	Pearson Correlation	.055	.306	.344	.145	-.060	.106	.201	.233	1	.274	.179
	Sig. (2-tailed)	.781	.114	.073	.461	.760	.590	.304	.232	.	.158	.362
	N	28	28	28	28	28	28	28	28	28	28	28
fds	Pearson Correlation	.166	-.107	.470(*)	.087	.552(**)	.395(*)	.447(*)	.512(**)	.274	1	.349
	Sig. (2-tailed)	.398	.588	.012	.659	.002	.038	.017	.005	.158	.	.069
	N	28	28	28	28	28	28	28	28	28	28	28
bds	Pearson Correlation	.175	.334	.419(*)	-.129	.161	.409(*)	.222	.325	.179	.349	1
	Sig. (2-tailed)	.372	.082	.027	.513	.414	.031	.255	.091	.362	.069	.
	N	28	28	28	28	28	28	28	28	28	28	28

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 11: Full Correlation Table B

		HH	LH	HL	LL	Factor 1	Factor 2	Factor 3	Form
HH	r	1	.784(**)	.504(**)	.641(**)	.286	.060	-.236	-.098
	p	.	.000	.006	.000	.140	.764	.226	.621
LH	r	.784(**)	1	.668(**)	.706(**)	.278	-.045	-.245	.267
	p	.000	.	.000	.000	.151	.819	.209	.169
HL	r	.504(**)	.668(**)	1	.441(*)	.074	-.260	-.146	.240
	p	.006	.000	.	.019	.709	.182	.459	.219
LL	r	.641(**)	.706(**)	.441(*)	1	.166	.001	-.247	.229
	p	.000	.000	.019	.	.399	.997	.205	.241
Factor 1	r	.286	.278	.074	.166	1	.000	.000	.235
	p	.140	.151	.709	.399	.	1.000	1.000	.230
Factor 2	r	.060	-.045	-.260	.001	.000	1	.000	-.004
	p	.764	.819	.182	.997	1.000	.	1.000	.983
Factor 3	r	-.236	-.245	-.146	-.247	.000	.000	1	.086
	p	.226	.209	.459	.205	1.000	1.000	.	.665
Sex	r	-.005	.117	-.090	.029	.290	-.154	-.238	.067
	p	.981	.553	.649	.882	.135	.435	.224	.736
gu	r	.058	.080	-.112	-.024	.327	.760(**)	.271	.247
	p	.769	.687	.570	.902	.089	.000	.163	.204
age	r	.151	-.019	-.116	-.108	.463(*)	.395(*)	.108	-.056
	p	.444	.923	.556	.584	.013	.038	.583	.779
Form	r	-.098	.267	.240	.229	.235	-.004	.086	1
	p	.621	.169	.219	.241	.230	.983	.665	.
si	r	.303	.196	-.108	.227	.806(**)	.149	.121	.160
	P	.117	.316	.586	.246	.000	.451	.539	.416
dn	r	-.027	-.043	.066	-.235	.297	-.369	.754(**)	.046
	P	.892	.830	.738	.228	.125	.053	.000	.818
tom	r	.869(**)	.930(**)	.779(**)	.806(**)	.245	-.088	-.248	.193
	p	.000	.000	.000	.000	.208	.654	.204	.324
complements	r	.160	.157	.034	.134	.862(**)	-.132	-.184	.146
	p	.416	.423	.865	.495	.000	.503	.350	.459
complex_relatives	r	.057	.171	.152	.000	.774(**)	-.301	.010	.348
	P	.775	.384	.440	1.000	.000	.119	.959	.070
coord_conj	r	.103	.175	.112	.191	.859(**)	-.231	-.063	.291
	p	.601	.373	.571	.331	.000	.238	.749	.133
wm_vis	r	.031	-.052	-.178	.028	.408(*)	.390(*)	.444(*)	.033
	p	.875	.791	.364	.889	.031	.040	.018	.867
fds	r	.584(**)	.597(**)	.338	.329	.642(**)	-.213	-.247	.038
	p	.001	.001	.078	.087	.000	.276	.206	.847
bds	r	.316	.193	-.007	.041	.540(**)	.489(**)	-.423(*)	-.029
	p	.101	.324	.974	.835	.003	.008	.025	.883

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Appendix D: Non-parametric analysis support graph

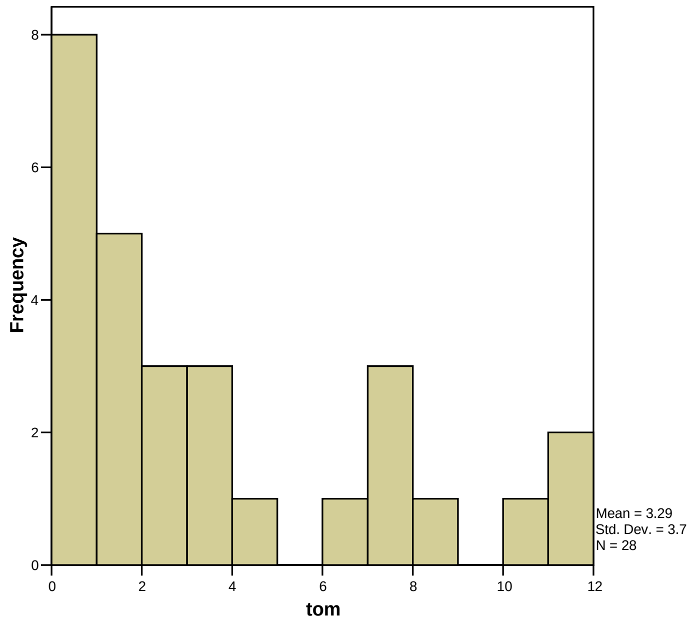

Figure 15: ToM histogram which illustrates natural cut-points

VITA

Patrick L. Craven

EDUCATION
The Pennsylvania State University, State College, PA
Doctor of Philosophy (Ph.D.) degree in Psychology, May 2005
Master of Science (M.S.) degree in Psychology, May 2002

The University of Edinburgh, Edinburgh, Scotland
Master of Science (M.Sc.) degree in Cognitive Science, December 1998

Dartmouth College, Hanover, NH
Bachelor of Arts (B.A.) degree in Cognitive Science, June 1997

PROFESSIONAL EXPERIENCE
Lockheed Martin Advanced Technology Laboratories, Cherry Hill, NJ
Senior Member, Engineering Staff

Elizabethtown College, Elizabethtown, PA
Instructor – Applied Developmental Psychology

The Pennsylvania State University, State College, PA
Teaching Assistant/ Research Assistant in Psychology and Information Sciences and Technology

AWARDS
2002, Fellowship, Summer Workshop in fMRI Informatics (Dartmouth College). 2000, Fellowship, Summer Institute in Cognitive Neuroscience (Dartmouth College). 1998, Scholarship, American Friends of the University of Edinburgh. 2002, Student Travel Award Recipient, Joint IX International Congress for the Study of Child Language and the Symposium for Research in Child Language Disorders (Madison, WI). 2003, 2002, & 2000, Travel Award recipient, Penn State Psychology Department.

SELECTED PUBLICATIONS AND PRESENTATIONS
Nelson, K. E., Craven, P., Xuan, Y., Arkenberg, M. (2004) *Acquiring Art, Spoken Language, Sign Language, Text, and Other Symbolic systems: Developmental and Evolutionary Observations From a Dynamic Tricky Mix Theoretical Perspective.* In Lucariello, J., Hudson, J., Fivush, R., Bauer, P. J. (Eds.) The development of the mediated mind. Lawrence Erlbaum

Connors, E. S., Craven, P. L., McNeese, M. D., Jefferson, T., Hall, D. An application of the AKADAM approach to intelligence analyst work. *Proceedings of the 48th Annual Human Factors and Ergonomics Society*

Craven, P. L., Nelson, K. E., Welsh, J., & Domitrovich, C. (2002, July). *Language Development and Its Relation to Children's Performance on Theory of Mind and Executive Function Tasks: Results from an Intervention Study*. Poster presented at the Joint Conference of the IX International Congress for the Study of Child Language and the Symposium on Research in Child Language Disorders, Madison, WI.

Craven, P. L., Nelson, K. E., Welsh, J., & Domitrovich, C. (2001, October). *Preliminary findings of the effects of language intervention on children's performance on theory of mind and executive function tasks.* Poster presented at the Cognitive Development Society Meeting, Virginia Beach, VA

Craven, P., Nelson, K. E. *Investigation of the relationship between children's concurrent performance on language, executive function, and theory of mind tasks*. Manuscript in preparation.