Memory Span as a Predictor of False Belief Understanding

Thomas Keenan
Department of Psychology
University of Canterbury

Recent work on the child's developing theory of mind has identified the development of working memory span as a factor which contributes to children's developing understanding of false belief (Keenan, Olson & Marini, 1998). Keenan et al. argued that working memory might be a mechanism which is partially responsible for the developmental change in false belief understanding observed around age 4. In the present study, 60 children aged 4 to 5 were given a set of false belief tasks, a test of language development, and a measure of working memory span. The goal of the study was to replicate the findings of Keenan et al., testing the hypothesis that a measure of working memory would predict children's performance on a set of false belief tasks while controlling for age and language ability. The findings supported the hypothesis and are discussed in terms of the role of working memory as a possible mechanism which drives the development of false belief understanding observed around age 4.

Given more than a decade of research on the child's development of a "theory of mind," there is a general agreement that around age 4, children begin to acquire an understanding of their own and others' minds. During the preschool years, children come to understand that people act on the basis of their beliefs, and furthermore, that these beliefs can faithfully represent or *misrepresent* reality (Olson, 1989). This has been demonstrated largely using variants of Wimmer and Perner's (1983) classic "unexpected transfer" task (e.g., Perner, Leekam & Wimmer, 1987) but similar findings have been demonstrated using tests of "informational access," assessing the child's understanding of how beliefs are determined by the quality and nature of the information available (e.g., Keenan, Ruffman, & Olson, 1994; Ruffman, Olson, & Astington, 1991).

In a typical variant of the false belief task (Baron-Cohen, Leslie & Frith, 1985), one puppet, "Sally" hides an object in a green box and then Sally leaves to go outside and play. While Sally is absent, another puppet, "Ann," takes the object and moves it to a red box. When Sally returns, the child participant who has watched this drama unfold is asked to predict where Sally would search for her chocolate or where Sally will think the chocolate is located. At 3 years of age, a majority of children fail this task, stating that Sally would look in the red box, where the chocolate is really located (Wimmer & Perner, 1983), demonstrating a failure to take into account Sally's false belief. On the other hand, most 4-year-olds will correctly state that Sally will look in the green box, where she *falsely thinks* the chocolate is located. The 4-year-olds recognize both that Sally would hold a false belief due to her restricted access to the events that have transpired and that she would act on the basis of her false belief, not on the basis of the current reality of the situation.

The consensus in theory of mind research is that the false belief task acts as a marker for the development of a representational theory of mind (e.g., Astington, 1993; Gopnik & Wellman, 1994; Keenan et al., 1994; Perner, 1991, Ruffman, Olson, Ash, & Keenan, 1993; Wellman, 1990; see however Carpendale & Chandler, 1996 for an opposite view). When children recognize that people act on the basis of their beliefs, even when these beliefs do not match the current reality of a situation, we can properly say the child understands the mind as a representational medium, that is, that the mind represents information and furthermore, that these representations can correspond or fail to correspond with reality (Perner, 1991). The development of a representational theory of mind enables individuals to understand the importance of subjectivity and individual perspectives in mental life (Carpendale & Chandler, 1996).

According to a number of recent reviews in the field, the question of what mechanisms drive children's developing theory of mind has been largely left without a reasonable explanation (Flavell & Miller, 1998; Taylor, 1996). While proponents of the "theory theory" argue that children's theory of mind develops in the same way as other cognitive domains (Astington, 1993; Gopnik & Meltzoff, 1996), following the principles of theory acquisition and conceptual change (e.g. Carey, 1985), the question as to why the development of false belief understanding occurs so regularly around age 4 remains unclear. A great deal of recent research has demonstrated that individual differences across children and their social environments predict the child's performance on a variety of theory of mind tasks. For example, Ruffman, Perner and Parkin (in press) showed that children whose mothers used mental state explanations in their attempts to discipline their children were more likely to pass tests of false belief understanding. Similarly, Perner, Ruffman and Leekam (1994) showed that children with siblings were more likely to pass tests of false belief reasoning than were children with no siblings. Finally, Meins, Fernyhough, Russell, and Clark-Carter (in press) have shown that infants who are securely attached to their caregivers were more likely to pass a test of false belief reasoning at age 3 than were children who were insecurely attached. Meins et al. argue that these differences likely stem from the tendency of mothers of securely attached infants to treat their children as individuals with minds, showing sensitivity to variations in their mental states, and using more mental state references in their interactions with their children.

Another individual difference factor which has been suggested to underlie children's failure on false belief tasks at age 4 is limitations in the child's information processing capacity (Fodor, 1992). Fodor has argued that children younger than age 4 already possess the competence to understand false belief, but because limitations in their information processing capacity constrain the expression of their understanding of the mind, they are forced to use heuristics which often lead to errors in their prediction and understanding of people's behavior. A number of similar proposals have been made which help to explain why children's understanding of false belief emerges with such regularity around age 4 (Case, 1989; Davis & Pratt, 1995; Frye, Zelazo, & Palfai, 1995; Keenan et al., 1998; Olson, 1989; 1993). The common argument made by these researchers is that limitations in children's information processing abilities, particularly their working memory, prevent children from co-ordinating the representations required to understand how the actor who holds a false belief would behave as a consequence of their holding a false belief.

Accounts of the nature of working memory vary across the literature. On the model of working memory developed by Baddeley (1986; Baddeley & Hitch, 1974), working memory is seen as a limited capacity short term storage system with specialized processing loops or "slave systems" (Baddeley, 1986, p. 70) for storing phonological and visual-spatial information. Baddeley (1986) also posits the existence of a 'central executive,' which is endowed with attentional capacities and the purpose of which is to select and operate control processes. Some researchers such as Pascual-Leone (1970) argue that the capacity of working memory or 'M-space' gradually increases with maturation. Others researchers (Case, Kurland, & Goldberg, 1982) have suggested instead that the overall capacity of working memory or M-space does not increase. Instead, they suggest that changes in the sophistication of control processes and strategies which children have available — primarily as a function of the growth of the central executive — make it appear as if children's capacity increases with development. In Case et al.'s view, more sophisticated control processes leads to 'operational efficiency' which means that a skill can be executed more automatically, requiring less working memory and thus leaving more capacity to be allocated to other tasks. In either case, the capacity of working memory is seen to increase with age and is believed to be strongly related to cognitive development.

In contrast to Baddeley's emphasis on a short term storage system which is separate from long term memory, a number of other researchers have suggested models of working memory which posit only a single memory system. For example, Ericsson and Kintsch (1995) suggest that working memory is simply a subset of information stored in long term memory with additional contextual markers which mark it as relevant to current processing. These properties of the information simply make it seems as if there is a short term store involved. Cowan (1994; 1995) has elaborated this model of working memory, suggesting that there is a central executive which focuses attention on the relevant subsets of long term memory. Developmental changes in the capacity of working memory under Cowan's model are explained by increases in attentional capacity which allow a greater subset of information to be held in mind at one time.

In either case, both of the models of working memory described above posit that the amount of information which can actively be held actively in mind increases in capacity with age. It is this increasing capacity to 'hold in mind' which has been suggested to be at the root of children's developing understanding of false belief. The suggestion made in the present study and in previous work (Keenan et al., 1998; Olson, 1989; 1993) is that the growth of working memory leads to increased performance on the false belief task because the increased capacity of the child's working memory allows them to form more complex representations of their social world. Children can move from simply representing a person's belief to representing a person's belief in relation to another state of affairs in the world. For example, according to Wellman (1990), by age 3 children can reason on the basis of simple propositions such as "John believes his puppy is in the garage" and thus predict John will look for his puppy at that location. However, 3-year-olds typically cannot reason on the basis of false beliefs. On Olson's account, with an increased ability to hold information in mind, the child can represent both "John believes his puppy is in the garage" and the real state of affairs in the world, "The puppy is really in the house" which allows them to compare the two representations, mark John's representation as 'false', and infer John's behavior. Thus, developmental increases in working memory play a role in the formation of concepts like 'false belief' in this very way (Olson , 1989; 1993). With enough working memory capacity, the child can represent a person's belief as a false description of some fact. The critical increase on this account is in the child's developing capacity to 'hold in mind' representations of the world.

Evidence in support of the relationship between false belief understanding and children's working memory has recently been generated by Davis and Pratt (1995) and Keenan et al. (1998). Keenan et al. gave children a test of working memory based on a memory span task designed by Case et al. (1985) and a battery of false belief tasks. The *counting span* task requires concurrent processing and storage (Daneman & Carpenter, 1980) and thus is a stringent test of children's memory span. In the counting span task, the child must perform an operation (counting the red dots only), store the product of that process (e.g., 3 red dots on the first card), process further information, store the product, and eventually, recall the products in the correct order. Keenan et al. showed that children's performance on the counting span measure predicted their performance on the false belief measure, even when age was controlled for, accounting for about 7% of the variance in the false belief measure.

One problem with Keenan et al.'s findings is that a language measure was not included in the original study. This oversight seems an important one to rectify as individual differences in language ability might potentially provide a reasonable "third variable" explanation for the relationship between working memory and false belief. First, the suggestion has been made that language might act as a "scaffold" for developing representational systems like those which might underlie a child's folk psychological understanding of the mind (Plaut & Karmiloff-Smith, 1993). Children's understanding and use of mental state language is an important part of a mature theory of mind, thus one might reasonably expect children with strong language skills to do well on theory of mind tasks. Second, research by de Villers and Pyers (1997) has suggested that children's understanding of false belief is in part, a product of linguistic constructions such as 'complementation.' They argue that a mastery of these linguistic forms are required in order to construct the mental representations necessary to understand false belief. Third, in their work on cognitive and family factors associated with theory of mind, Jenkins & Astington (1996) showed a relationship between false belief understanding and performance on the Test of Early Language Development (TELD; Hresko, Reid & Hammill, 1981). Their results suggested that in order to pass false belief tasks, children need to reach a linguistic performance threshold on the TELD (a raw score of 14 or better). While a different test of the effects of language on theory of mind development than that provided by deVillers, Jenkins and Astington's work suggests a strong relationship between linguistic ability and false belief performance. In summary, each of these positions would suggest a connection between language ability and false belief understanding, a relationship that may explain the correlation between working memory and false belief demonstrated by Keenan et al.

In the present study, the major limitation of the Keenan et al. study was addressed. In order to test the hypothesis that linguistic ability might serve as a third variable which explains the relationship between false belief understanding and working memory, children in the present study were given a measure of working memory (the counting span task used by Keenan et al., the TELD (Hresko et al., 1981), and a battery of false belief tasks. The prediction made in the present study was that the counting span measure should account for a significant amount of variance in children's false belief scores, when controlling for language performance and age.

Method

Subjects

A total of 60 four- and five-year-old children participated in the study. The mean age of the sample was 4 years, 10 months (Standard Deviation = 6 months) and ranged from 48 to 62 months. Eight additional children were tested but were not included in the final analysis as they failed to complete all of the tasks. Parents and children were recruited from around Christchurch through a series of advertisements in local newspapers.

Procedure

Three tasks were administered to children. The counting span task was designed to provide a measure of children's working memory capacity. This task was used in Keenan et al. (1998) and was originally adapted from Case et al. (1982). The administration procedure and scoring instructions are given in Keenan et al. In the warm up phase, the child is told they will play a memory game, where they have to count all the red dots on a card and then remember how many dots were on the card. Cards have between one and four red dots, plus a number of distractor dots in blue and green. The task is composed of three levels, and three trials are given at each level. At Level 1, children see one card at a time, count the red dots, and when the card is turned over they are asked how many red dots were on the card. At Level 2, the child is presented with one card, asked to count the red dots, after which the card is turned over. This procedure is then repeated a second time. The child is asked how many red dots were on the first card, and how many red dots were on the second card. At Level 3, the procedure is exactly the same but one more card is added. When a child gets two or more consecutive items incorrect at any level, the procedure is terminated. To score correctly, the child must repeat the correct number of red dots that were on each card. The child's score is determined by the number of correct answers, each of which is given a score of 1, thus scores can range between 0 and 9.

Children were also given three variants of the false belief task originally devised by Wimmer and Perner (1983). Children watched as one member of a pair of dolls placed a toy in one of two locations. This doll then left the scene and was placed in a large file box. The child was told that when the doll was in the "playground", that s/he could not see nor could hear what the child and the experimenter were doing. The second doll then moved the object to the second location. At this point, the experimenter announced the first doll's return but before it was brought into view, the child was asked three control questions based on Perner et al. (1987): the *memory* question "Where is the object now?"; the *reality* question "Where is the chocolate right now?"; and the *knowledge* question "Did (doll 1) see (doll 2) move the object?" Children were given a score of 1 *only* if they correctly answered *all three* of these control questions for any given trial. Scores across the three trials were summed to form a control question composite score which ranged from 0 to 3. Finally the first doll was brought back into view and the child was asked the false belief test question, "Where will (name of doll 1) look for his/her (name of object)?" Children were given a score of 1 for each correct answer, and the scores were totalled across trials to form a false belief composite score (as in Keenan et al., 1998) which ranged from 0 to 3.

Finally, children were administered the TELD (Hresko et al., 1981) following the standardized instructions given in the manual. Following Jenkins and Astington (1996), children's raw scores were used in the subsequent analyses.

The order of presentation of the false belief and counting span tasks was counterbalanced across children. Children were always given the TELD last. Pilot testing revealed that children who were given the TELD first were often left somewhat tired and restless. The testing session was carried out in the child's classroom in a quiet room familiar to the child. Some children were accompanied by their teacher or a teacher's aide who sat quietly behind or to the side of the child but did not participate in the tasks. To ensure that they were familiar with the testing material, when the tasks were introduced, the children were asked to pay careful attention to a demonstration and were encouraged to handle all of the objects that were used. The items on each task were then presented. Children were tested individually in one session, which usually lasted about 40 minutes.

Results

The order of presentation of the counting span and false belief tasks was tested by comparing the mean scores on the two tasks for children receiving each of the two orders of tasks. These analyses revealed no significant effects for order of task presentation.

Table 1 gives the means and standard deviations for the counting span, TELD, control question composite, and false belief composite measures. The mean for the counting span task was very similar to the performance of the 5-year-olds observed in Keenan et al. (4.65 in the present study vs. 4.75 in the previous study). In sum, most children were passing all the

Table 1. Means and Standard Deviations for the Counting Span, False Belief Control Questions, False Belief Composite, and TELD

Measure	Mean	Standard Deviation
Counting Span	4.65	1.35
TELD	20.10	4.44
Control Question Composite	2.93	0.25
False Belief Composite	2.42	0.81

Level 1 items and getting at least one or two items at Level 2 correct. Children's performance on the TELD was slightly higher than the sample (mean age of 4 years) reported in Jenkins and Astington (1996). In addition, the mean TELD score of the present sample is well above the threshold of 14 which Jenkins and Astington argue is required for children to pass the false belief task.

In regard to the false belief task, children's performance on the control question composite measure was very close to ceiling indicating that children had grasped the critical information required to correctly answer the false belief questions. On the critical false belief test questions, children in this sample were averaging at least 2 out of 3 correct. Scores on the false belief composite variable ranged from 0 to the maximum of 3. A full 60% of the sample (36 children) achieved a perfect score on the false belief tasks whereas 25% (15 children) answered 2 out of 3 correctly, and 15% (9 children) only managed to get one correct answer. Thus, it seems safe to conclude that children's performance on this variable was not simply all or none. Rather, it represents a continuum of performances from a fully consolidated understanding of false belief to a more transitional understanding.

Table 2 provides the correlations between the child's age in months, TELD, counting span, and false belief composite variables. All variables were significantly and positively correlated with each other. Of particular interest are the correlations of the counting span and TELD scores with false belief. The observed relationship of false belief and TELD scores ($r = .30$) was somewhat smaller than the $r = .64$ reported by Jenkins and Astington, but was close to the correlation of $r = .37$ between false belief understanding and Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1981) scores reported by Davis and Pratt (1995).

Given that the sample ranged in age from 4 years to 5 years, and that each of these measures is known to relate to age, partial correlations controlling for the child's age in months were computed. These partial correlations are given in the bottom half of Table 2. Of note is the fact that each of these correlations remained significant except for that between false belief and TELD scores, which fell below significance. While age clearly accounts for some of the variance in

Table 2. Pearson Product Moment Correlations of False Belief Composite Scores, TELD, Counting Span Task Scores, and Children's Age in Months

	Counting Span Task	TELD	False Belief Composite	Age in Months
Counting Task	1.00			
TELD	.40**	1.00		
False Belief Composite	.59**	.30*	1.00	
Age in Months	.34 **	.36**	.34**	1.00

Partial Correlations Controlling for Age in Months

	Counting Span Task	TELD	False Belief Composite
Counting Task	1.00		
TELD	.31*	1.00	
False Belief Composite	.53**	.20	1.00

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

these measures, the pattern of correlations remains similar when age is partialled. However, it would seem that the observed relationship between language and false belief understanding in this sample is mediated largely by the child's age.

In order to test the hypothesis that working memory predicts false belief understanding when controlling for both age and language ability, a hierarchical multiple regression analysis was conducted. The false belief composite measure served as the dependent measure, and the child's age in months, TELD score and finally counting span score were added. With age alone in the equation, 11.5% of the variance was accounted for [$R = .34$, R^2 Change = 11.5, F Change = 7.57, $p < .01$]. Adding TELD scores on Step 2 did not result in a significant change in the amount of variance accounted for [$R = .39$, R^2 Change = .04, F Change = 2.45, n.s.]. Adding the counting span scores on Step 3 accounted for a significant amount of additional variance in false belief scores [$R = .61$, R^2 Change = .21, F Change = 18.92, $p < .001$]. The addition of counting span scores clearly accounts for a significant amount of variance in false belief scores, unique variance not accounted for by the child's age or language scores.

Discussion

The results of the present study strongly support the hypothesis that children's performance on the working memory measure (the counting span task) would predict their performance on the false belief tasks even when controlling for the child's age and individual differences in language ability. A hierarchical regression analysis indicated that working memory was a significant predictor of children's correct performance on the false belief composite measure, uniquely accounting for 21% of the variance in false belief understanding. Using hierarchical regression techniques allowed for the control of the effects of age and language ability, and provided an estimation of the unique variance in false belief understanding accounted for by the working memory measure.

Thus, the current findings replicate and extend previous work by Keenan et al. (1998), demonstrating that the relationship between working memory and false belief scores is not simply accounted for by general language ability. Instead, they suggest a fairly robust and stable contribution of working memory to children's performance on false belief tasks. These findings are also congruent with findings reported by Davis and Pratt (1995) who, using a different measure of working memory and slightly different false belief tasks, demonstrated a similar relationship between working memory and false belief understanding. Taken together, the finding of a significant relationship between working memory and false belief in these three studies goes some way towards eliminating explanations based on some particular artifact such as the nature of the memory task. Instead, they present a picture which clearly suggests a relationship between children's false belief understanding and developmental increases in working memory.

The work reported here supports the argument that general processing capacity is a significant factor in children's development of a theory of mind (Case, 1989; Olson, 1989, 1993). Developmental increases in processing capacity allow the child to "hold in mind" (Olson, 1989) more information, and furthermore, to represent connections or relationships between these representations. Thus, children can represent increasingly complex mental states required to pass the false belief task such as "John thinks that the chocolate is in the red box but it's really in the green box." In turn, this representational development allows for the understanding of more complex social interactions with others (e.g., Perner, 1988). As Keenan and Quigley (in press) have suggested, a developing understanding of mental states is implicated in children's ability to understand speech acts like sarcasm, where the speaker means something other than what s/he says.

The present data do not permit one to go much beyond claiming that working memory is relevant to performance on these tasks. However, it seems reasonable to speculate in line with previous suggestions, that working memory plays at least two roles in children's development of a theory of mind. First, as Fodor (1992) has suggested, the increase in working memory capacity may allow children to express concepts for which they did not previously have the resources, reducing their need to rely on heuristics which might lead to errors in predicting other's mental states. Second, congruent with Olson's (1989, 1993) suggestions as well as with the arguments made by working memory theorists such as Case (1985, 1992) and Halford (1993), working memory might also play a role in the very development of theory of mind concepts such as *belief*, *desire*, and *intention*, the linguistic constructions which support these concepts, and finally, the system of inferences which relates them to one another. This second suggestion in particular is at odds with recent arguments by Gopnik (1996; Gopnik & Meltzoff, 1996) who explicitly disavows the role of working memory in the acquisition of a theory of mind in favour of the "theory theory". Further work is required to sort out what role (or roles) developmental changes in working memory might play in children's acquisition of a theory of mind and how exactly changes in memory span might lead to an understanding of false belief.

The present findings, taken together with those of Keenan et al. (1998), Davis & Pratt (1995), and Gordon & Olson (1998) present a challenge to Gopnik's claim, demonstrating that working memory shows both a robust and consistent association with children's acquisition of an understanding of false belief. In the present study, the working memory measure accounted for 21% of the unique variance in children's false belief understanding. However, as noted previously by Keenan et al. (1998), in order to play an important part in the development of a more comprehensive developmental account of theory of mind development, the field must progress beyond looking at single factor accounts to a multifactorial view. The child's acquisition of a theory of mind is likely to be governed by a multiplicity of factors including biological constraints, developing cognitive resources like working memory, aspects of the child's the social ecology such as parental talk about mental states (Brown & Dunn, 1991; Ruffman et al., in press) and sibling interactions (Perner, Ruffman, & Leekam, 1994), as well as by the child's construction of increasingly adequate theories (Gopnik & Meltzoff, 1996). Specifically, in regard to the role of working memory in children's acquisition of a theory of mind, the formulation of more precise measures of working memory that relate specifically to the information children need to "hold in mind" will be required, as will a more precise description of the internal composition of the concepts involved (Keenan et al., 1998). Gordon and Olson (1998) have recently begun this process.

To reiterate, the claim made in this paper is not that working memory is the sole determinant of a child's acquisition of a theory of mind, but rather, one of several factors which has a role in the child's developing understanding of the mind. Developing an understanding of mind is not simply a memory problem; certain concepts (belief, desire, intention) must also be in place. However, it is likely that working memory has some role in the developing ability to form and to express those concepts, as it does in many other areas of cognitive development (Case, 1985, 1992; Halford, 1993). These findings challenge the developmental story outlined in the "theory theory" and suggest that a reasonable addition to the theory, on the basis of the available evidence, would be the inclusion of a role for developmental changes in working memory.

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Address for correspondence:

Dr. Thomas Keenan
Department of Psychology
University of Canterbury
Private Bag 4800, Christchurch
New Zealand.
Internet: t.keenan@psyc.canterbury.ac.nz