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Pulling smarties out of a bag: a Headed Records analysis of children's recall of their own past beliefs

Sofka Barreau[a,*], John Morton[b]

[a]*Department of Psychology, University of East London, Romford Road, London E15 4LZ, UK*
[b]*Institute of Cognitive Neuroscience, University College, London, UK*

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Abstract

The work reported provides an information processing account of young children's performance on the Smarties task (Perner, J., Leekam, S. R., & Wimmer, H. (1987). Three-year-olds' difficulty with false belief: the case for a conceptual deficit. *British Journal of Developmental Psychology*, *5*, 125–137.). In this task, a 3-year-old is shown a Smarties tube and asked about the supposed contents. The true contents, pencils, is then revealed, and the majority of 3-year-olds cannot recall their initial belief that the tube contained Smarties. The theoretical analysis, based on the Headed Records framework (Morton, J., Hammersley, R. H., & Bekerian, D. A. (1985). Headed records: a model for memory and its failures. *Cognition*, *20*, 123.), focuses on the computational conditions that are required to resolve the Smarties task; on the possible limitations in the developing memory system that may lead to a computational breakdown; and on ways of bypassing such limitations to ensure correct resolution. The design, motivated by this analysis, is a variation on Perner's Smarties task. Instead of revealing the tube's contents immediately after establishing the child's beliefs about it, these contents were then transferred to a bag and a (false) belief about the bag's contents established. Only then were the true contents of the bag revealed. The same procedure (different contents) was carried out a week later. As predicted children's performance was better (a) in the 'tube' condition; and (b) on the second test. Consistent with the proposed analysis, the data show that when the computational demands imposed by the original task are reduced, young children can and do remember what they had thought about the contents of the tube even after its true contents are revealed.

Keywords: Children's recall; Past beliefs; Smarties task

* Corresponding author. Tel.: + 44-181-590-7000 ext. 4149; fax: + 44-181-849-3697.
E-mail address: s.barreau@uel.ac.uk (S. Barreau)

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1. Introduction

The Smarties task (Perner, Leekam & Wimmer, 1987) is extremely simple. The child is shown a Smarties tube.[1] The child is asked ‘what is in here?’ and replies ‘Smarties’. The experimenter says ‘Let’s have a look, shall we?’, takes the top off the Smarties tube and tilts it to reveal pencils. The adult says ‘Oh look!’ and the child usually spontaneously says ‘Pencils’. The pencils are returned into the tube, the top is put on and the child is asked ‘When I first showed you this tube what did you think was in here?’ At this, 70% of 3-year-olds say ‘Pencils’. Freeman and Lacohee (1995) have performed equivalent experiments with an egg-box which turns out to contain a tomato.

This behaviour on the part of the 3-year-old is usually attributed to their inability to reconstruct a false belief (Perner et al., 1987; Gopnik & Astington, 1988; Sullivan & Winner, 1991). The argument is that since the child knows the tube really contains pencils, she cannot reconstruct the incorrect representation ‘I believed that ⟨the tube contains Smarties⟩’. It certainly seems to be the case that 3-year-old children cannot reconstruct their previous false belief, but what is as strange is that the child cannot remember the mental transaction that occurred less than 10 s ago. Indeed, the child does not seem to even remember what it was that she said, since it has been claimed that it doesn’t matter whether the child is asked ‘What did you think was in the tube?’ or ‘What did you say was in the tube?’ (Wimmer & Hartl, 1991; Riggs & Robinson, 1995). Considering the competence of 3-year-olds in recalling events from some time past (Hudson, 1986; Fivush & Hamond, 1989; Nelson, 1996), their inability to recall the last thing they said is rather unexpected.

One of the obstacles to understanding failure in the Smarties task is that the task has not been submitted to any kind of analysis inside an information processing framework. We propose to rectify this. The following analysis is based on a small number of assumptions. First, event memory consists of a collection of discrete records (after Morton, Hammersely & Bekerian, 1985). (The contrast to this would be that individual events are not differentiated in memory.) The second assumption is that records are created from the contents of (on-line) buffers which hold input information while such information is being processed. This is not a particularly novel assumption, since, for example, working memory, in its various manifestations (Miller, Galanter & Pribram, 1960; Baddeley, 1986; Newell, 1990; Anderson, 1996), is one such buffer. For the purposes of the analysis we will initially assume only one on-line buffer, which we will refer to simply as *working memory* without any initial intention of making any particular theoretical commitment either to its relative position inside a general cognitive framework or to the nature of the representations which may be found there. It may turn out that we can differentiate more than one buffer, but the logic of what follows will not be affected. Our third assumption is that records are created at significant points in the processing of information. These will include major shifts in location or protagonist. The fourth

[1] In the USA, substitute a box of M&M’s for a Smarties tube.

assumption is that the record of a past event is retrieved whenever we encounter a similar event. Again, it does not seem that such an assumption needs justification.

Given this framework, we look at the Smarties task as an event just like any other event the child may encounter, such as dinner. In doing so, we will focus on the contents of the buffer and on any event records that might have been created during the task. We assume that the interpretation and organization of this event will have to be guided by the same set of rules that guide the encoding of any other event representation.

1.1. The Smarties task revisited

When children are asked the belief-establishing question ‘What do you think is in this tube?’, they invariably respond with ‘Smarties’. To provide the information for an answer to this question, the child must either consult a record of her last experience with a Smarties tube or access a general knowledge schema concerning Smarties tubes. In addition, in order to answer the question, the child must form a representation of the *current* tube as containing ‘Smarties’.[2] We will use the term *in(t,S)* to refer to this representation, and we assume that it will reside in working memory. When the true contents of the tube is revealed (a pencil), a new representation of the tube as containing a pencil – *in(t,p)* – enters this buffer.

There are, thus, at this moment, two contradictory propositions concerning the tube which are simultaneously represented in the child’s working memory. The child is then asked what they had previously thought, and getting the correct answer would require accessing the representation *in(t,S)*. The double representation of the contents of the tube could lead to three possible outcomes:

1. Both representations continue to reside in working memory. In this case, in answer to the ‘think’ question an output is possible directly from the buffer.
2. The more recent *in(t,p)* representation triggers the transfer of the *in(t,S)* representation into long-term memory in the form of a record. In this case, the correct answer to the ‘think’ question would require retrieval from event memory.
3. The more recent *in(t,p)* representation replaces the original *in(t,S)* representation in working memory. This option is termed the *destructive up-dating* of the representation of the contents of the tube. This process enables us to keep an up-to-date representation of the *current state* of objects or people of interest. In this case, the representation *in(t,S)* would be lost to the system completely. Thus, in order to get the correct answer to the ‘think’ question, the child would have to make an inference from her general knowledge about the usual contents of Smarties tubes. In this case, the child will have to reconstruct the representation of her original belief.

It is evident from 3-year-olds’ failure on the Smarties task, that the original

[2] In principle, of course, it is possible to answer the question simply as a generalization without forming any lasting representation about the contents of the current tube. The general behaviour of a 3-year-old in this situation (for example, looking at the tube with anticipation) does not invite such an explanation.

representation of the tube as containing Smarties is no longer available: it is not available for direct access in working memory, nor is it possible to retrieve it under the conditions of the experiment. It would be safe to conclude, therefore, that the original representation was either consolidated in an inaccessible record, or it was updated and lost.

Freeman and Lacohee (1995) investigated the inaccessibility hypothesis. They suggested that the failure on the Smarties task indicated a problem of access in the absence of suitable retrieval cues. In order to provide the child with the appropriate cues, and so enable the original failure to be corrected, Freeman and Lacohee added a 'posting' stage to the original 'Smarties' paradigm (first introduced by Mitchell & Lacohee, 1991). In their experiment, after the children had stated what they thought was in the Smarties tube, they were asked to post a picture of what they thought the content was, i.e. a picture of Smarties. This picture was posted through the slit in a box in front of the child. In a control condition the children posted a picture of a cartoon character. The true contents, pencils, were then shown at test, the experimenter showed the child the closed Smarties tube and asked: 'When you posted your picture in the postbox what did you think was in here?'. In the relevant picture condition most children judged correctly that they had thought the tube contained Smarties when they first saw it. In the irrelevant picture condition there was only a slight and non-significant improvement. The authors explained success in the relevant picture condition in terms of the picture of Smarties being used as the cue that helped children access their previously inaccessible belief representation.

In another study, the picture of Smarties was replaced by real Smarties and in one experiment they were allowed to eat the sweets. Lacohee (1997) writes lovingly of the sight of children, with their mouths full of chocolate, claiming they had believed the tube to contain pencils. Children's success rate in this case increased only marginally – from 30 to 44% correct in the relevant *object* condition as opposed to the 86% correct in the relevant *picture* condition. Across six studies, using Smarties tubes or egg boxes, and a variety of cues, Lacohee reported improved performance only with relevant picture cues (a picture of Smarties or eggs) but not with irrelevant picture cues nor with relevant object cues. They concluded that the data supported the inaccessibility hypothesis and also revealed differences in the efficacy of cues, most intriguingly between relevant pictures and relevant objects.

According to Freeman and Lacohee, these differences between the use of pictures and objects as reminders suggests either that the pictures are more memorable than the objects or that pictures are more associated with thoughts than objects are. However, Lacohee (1997) reports that the performance on a second control memory question, 'What did you post?' was not only excellent but did not differ between the real object and the picture of an object. We are left then merely with the observation, as indicated by the data, that the picture of a Smarties helps the child to retrieve the previous belief whereas a real Smarties does not.

Freeman and Lacohee regard their procedure as providing a cue which enables the child to access a record which they would not otherwise be able to access, but, without a model of the memory processes they have no mechanism to differentiate between the efficacy of the picture of a Smartie and the failure of the real Smartie. Within the information processing framework we have outlined, we propose that the posting procedure can cause the child to create a memory record of what has just happened which would not be created in the usual form of the experiment. This record would include the belief-establishing question about the contents of tube and the child's own answer 'Smarties'. We will take up this theme later, when we have presented more of the theoretical framework.

Returning to the previous analysis, of the three different routes to success that were outlined above, the least computationally demanding solution is a direct output from working memory. Clearly, if the answers to the test questions are directly available from working memory, then no further resources need to be expended on additional computation, such as retrieval or inferencing. However, successful performance via this solution would be conditional on the buffer's *capacity* being sufficient to allow both tube representations – *in(t,S)* and *in(t,p)* – to be available at the time of test (in addition to any other event-relevant information that maybe present). Moreover, for the answers to be correct, the two representations must be differentiated in some way so that the appropriate answers to the 'think' and the 'reality' questions may be identified. In principle, the inclusion of source information in the representations would be sufficient with the two representations being distinguished in a manner such as *in(t,S,think)* and *in(t,P,see)*. When the child is asked 'What did you think was in the tube?', the former representation would be accessed. Alternatively, some markers relating to past and present state might serve. We suggest that older children and adults resolve the task this way because their processing systems allow for both these conditions (capacity and marking) to be met. In contrast, young children might lose the *in(t,S)* representation from working memory because, in their case, neither condition is met.

The memory system of younger children is relatively restricted in terms of the amount of information it can temporarily store or process (Pascual, Leone, 1970; Halford & Wilson, 1980; Alp, 1994; Pascual, Leone, & Baillargeon, 1994). A more limited capacity will dictate more frequent updating of on-line information, and so we would expect loss of information to be more pronounced in younger children than it is in older children and adults. Generally, when capacity is exceeded, an old item of information is either overwritten or incorporated into a record and transferred to LTM. Whether or not an old item of information is incorporated into a record would largely depend on an overall understanding of that item's meaning and therefore relevance to the overall experience. We know that children organize events around goals (Nelson & Gruendel, 1981). Therefore, the relevance of any particular item will have to be judged in relation to some goal structure. We have no way of knowing how the goal of an event, particularly a novel event, is established, or at what point during the experience it is established and whether it can change as an event unfolds. But, in the context of the Smarties task, it would be reasonable to assume that the belief-establishing question ('what do you think is in the tube?') would initially set up a local goal of finding out about the contents of the tube. Subsequent information will then be organized in relation to this initial goal and information which is relevant to this goal will be preferentially preserved.

The tube, then, is first represented as containing Smarties – *in(t,S)*. However, as soon as it is opened to reveal its true contents, the *in(t,S)* representation becomes irrelevant to the current goal, ⟨*discover the contents of the tube*⟩, that was established by the initial question. Unless the child has the capacity to hold both items of information, the *in(t,S)* representation will be lost. For these children, when the ‘think’ test question finally arrives, the *in(t,S)* representation no longer exists in working memory. In principle, the children could provide a correct answer if they were able to reconstruct their thought process, i.e. ‘if I had not seen the pencil I would have thought the tube contained Smarties because they usually do’. Their performance, however, seems to indicate that they do not have the meta-skills necessary to reconstruct this belief, and they simply default to the only information available to them relevant to the content of the tube, the current *in(t,p)* representation.

To sum-up, given that they cannot solve the problem posed by the ‘think’ question through reconstruction, three factors could potentially contribute to the failure of 3-year-olds on the Smarties task: capacity, relevance and marking. When capacity is exceeded, relevance determines whether or not the *in(t,S)* representation is transferred to a permanent record; marking determines whether the *in(t,S)* and the *in(t,p)* representations are in conflict rather than coexisting. Both the marking ability and the capacity to maintain the representations are necessary for successful performance on a false belief task, but it is enough that only one of them is missing for failure to occur. In both cases, however, the failure will be due to loss of information rather than inaccessibility. Thus, 4-year-olds, who are generally successful on this task, can both maintain the representations and differentiate between them (and some will have the meta-skills necessary for reconstruction). In contrast, 3-year-olds may either not have the capacity, or not have the marking ability or both.

In our view, younger children have neither the capacity or the marking ability. However, with regard to marking, it is not that young children *cannot* mark their representations because they do not understand the difference between mental or perceptual source of knowledge, but rather they do not *spontaneously* include source information as part of their representations. Given that young children have more limited resources, we assume that the representations they form are as simple as the situation allows, and, if the necessity to delegate resources to the creation of more complex representations (which would include source information) is not explicit in the situation, they will not delegate. This explicitness is the case in pretend play, and one reason for supposing that younger children do actually understand the difference between sources of information is that even the average 2-year-old has no problem with pretend play, where marked representations of the form ⟨*I pretend that ‘this banana is a telephone’*⟩ are used without confusion and with productive outcome (Leslie, 1987, 1988). Representations produced during a pretend situation require source marking and can be retrieved at future times together with the marking (‘Let’s play X again’). Children in this situation do not suddenly start pretending that a telephone is a banana. However, in these circumstances, the pretend would normally be supported on-line by an adult who is also pretending and this would help the child to maintain the representations of the situation with an explicit marking of the source (pretend or real) of each of them. In general, though, we assume that young children have limited resources, and that the representations they form will be as simple as the situation allows.

2. Experiment 1

Suppose the source of the difficulty in the Smarties task for a particular child is the loss of the *in(t,S)* representation through destructive updating. To enable this child to solve the 'think' question, the task must be modified such that the initial *in(t,S)* representation is consolidated in a record prior to the arrival of the conflicting (i.e. *in(t,p)*) information. Material stored in a record would later be available for retrieval. The Bag task was designed to achieve this goal.

As with the original Smarties task, the child is presented with a Smarties tube and asked 'What do you think is in the tube?' Once the 'Smarties' response is returned, a bag is taken out of a drawer and the contents of the tube are emptied into the bag. During transfer the contents remain invisible to the child. As soon as the transfer operation is completed, the child is allowed to have a look inside the tube and sees that it is empty. Then the lid is put back on the tube and the child is asked: 'What is inside the tube now?' After the child answers this question, the tube is placed out of sight. The child is then asked 'What do you think is inside the bag?'. Once the 'Smarties' response is given, the bag is opened and the true contents of the bag – marbles – is revealed. The marbles are then returned to the bag and the child is asked the 'reality' and 'think' questions first about the bag and then about the tube.

The aim, as already mentioned, was to force the system to create an event record concerning the Smarties tube from the information in working memory. Transferring the contents of the tube to the bag should maintain the relevance of *in(t,S)* representation to the current goal. However, putting the tube away would signal the completion of a sub-event. According to the theory, the completion of a sub-event would trigger the creation of a record from the material in working memory. This record would contain information about the tube, the question concerning its contents and the 'Smarties' answer. All this would happen before the corrective information (marbles) enters the system. In principle, this record could later be retrieved and used at test. It was predicted that the *in(t,S)* representation will be used correctly under these conditions even if it does not include source information, since material retrieved from LTM refers to the past, and contrasts with the representation in working memory, *in(t,p)*, which refers to the current state of the tube. Such a distinction must be a part of every 3-year-old's competence.

If this analysis, based on Headed Records theory, is correct, the transfer operation should improve performance in response to the tube questions. However, performance in answer to the Bag questions would be expected to produce the same level of failure as in the original Smarties task since the computational demands in this condition are identical to those in the original. Thus, after the child observes the transfer of the contents of the tube into the bag, she will set up a representation to indicate that there are Smarties in the bag – *in(b,S)*. When the true contents of the bag are revealed as marbles, a representation *in(b,m)* would be created. For the child who fails the original Smarties test by reason of loss of the representation concerning Smarties, *in(t,S)*, there will also be loss of the equivalent *in(b,S)* representation in the modified task.

2.1. The effect of event repetition

At the end of the bag event children would create a record of what has happened to them. This will include the tube as well as the bag. There would be more than one record and we could expect them to be linked in some way. These records would provide children with a structure that would help them anticipate and interpret a similar event, if one were to be encountered. For example, on the basis of their experience, they would anticipate that they would be asked questions about the procedure. Thus, the goal of the event may be set differently on a second presentation, such that the relevance of the *in(t,S)* representation is maintained. The knowledge that two different questions were asked in the first event (‘think’ and ‘reality’) would have made them aware of some duality (even if they could not resolve it the first time), therefore, when they are asked the belief-establishing question on a subsequent occasion they may be more likely to include source information in their representations. In addition, the child’s ability to use the record of the previous event to predict what is going to happen will reduce the processing demands and increase the efficiency and reliability of the various cognitive components. If these assumptions are correct, then repetition of the Bag Event should significantly increase the number of children successfully answering the Bag questions as well as lead to some further improvement in answering the Tube questions.

2.2. Method

2.2.1. Subjects

Thirty nursery school children (15 boys and 15 girls) aged between 3:2 and 4:6 (mean age 3:10) were tested. Half the children were 4-years-old or over, and half were under 4 years. Within each of these age groups there were roughly equal numbers of girls and boys. The children were drawn from two different nurseries, one state-financed and one private, and were of varying socio-economic backgrounds.

2.2.2. Materials

The materials used for this experiment consisted of a tube of Smarties, a small soft-leather bag, three blue marbles, and a pencil. An audiotape was used to record and transcribe the procedure.

2.2.3. Procedure

Prior to testing, the experimenter (SB) spent a couple of hours in each nursery talking and playing with the children in order to establish a certain degree of familiarity. Children were then tested individually in a screened-off area of the nursery. Each child was presented with a Smarties tube and asked what they thought was inside the tube. Once the 'Smarties' response had been provided, the bag was produced and the contents of the tube were emptied into the bag. During the transfer operation the contents remained invisible to the child. As soon as the transfer had been completed, the bag was closed and the child was allowed to have a look inside the tube. The lid was then put back on the tube and the children were asked:

'What is inside the tube now?' This question was included to confirm that the children were fully aware that whatever had been inside the tube was no longer there. This procedure also eliminated the possibility that children resolved the 'think-reality' conflict by representing the tube as having contained both Smarties and marbles. Following the reply, the tube was placed out of sight and the child was then asked what s/he thought was inside the bag. Once the 'Smarties' response was given the bag was opened and the true content of the bag (marbles) was revealed. The children were encouraged to name the object(s). In cases where the word 'marbles' appeared to be unfamiliar (i.e. the child would not produce it spontaneously or as a repetition) the term 'blue balls' was offered as an alternative. The marbles were then returned to the bag and the child was asked the following questions:

1. THINK: 'Before I opened the bag, what did you think was in the bag?'
2. REALITY: 'What is really in the bag?'
   The bag was then put away. The tube was then taken out again and the test questions concerning the tube's different states were asked. Two reality questions were relevant in this condition and both were asked:
3. THINK: 'When I first showed you the tube, what did you think was inside the tube?'
4. PRESENT REALITY: 'What is inside the tube now?'
5. PAST REALITY: 'What was really in the tube?'

This order of questioning was fixed for all children. The bag-then-tube order was to ensure that the computational demands in the Bag condition were similar to those of the original 'Smarties' task.

The same procedure was repeated a week later, this time using a pencil instead of marbles in the tube. In this second event both a 'Smarties' and a 'marbles' response to the initial belief-establishing questions ('What do you think is inside the tube/bag?') were accepted as legitimate beliefs.

In the interests of clarity, the procedure of the experiment is given in Appendix A.

2.3. Results

The children's responses were categorized as either 'correct' or 'incorrect'. In order for a response to be categorized as 'correct' the child had to provide a correct answer to both the belief (Smarties) and the reality (marbles) questions. Any other pattern of response was categorized as incorrect. The patterns of response within the 'incorrect' category will be discussed shortly.

In the second event both 'marbles' and 'Smarties' were accepted as valid beliefs (i.e. as appropriate answers to the initial question 'what do you think is inside this tube?'). Therefore, a child's 'think' response at test should correspond to her original belief – whether that original belief was Smarties or marbles. In practice, a small number of children interpreted the question, 'When I first showed you the tube what did you think was in the tube?', as referring to the previous week, and responded 'Smarties' although they had believed 'marbles'. Since 'Smarties' is also a *think* answer, and corresponds to a false belief, we counted these four answers as correct. In fact, in the second event, 18 out of the 30 children believed that there were marbles in the tube when first asked, and a further six had remembered the marbles by the time the transfer had been made from the tube to the bag but before they had seen the contents. The children said they thought there were marbles in the bag although they had, a few moments earlier, said they thought there were Smarties in the tube.

An initial inspection of the data revealed no effect of age. The older group demonstrated the same level of success that would normally be expected of younger children. The most likely explanation for this is a difference in socio-economic backgrounds as most of the 4-year-olds were from the state financed nursery, whereas the majority of the younger children were from the private nursery. Thus, the two age groups were collapsed, and the total scores across ages were entered for analysis. Table 1 presents the frequencies of correct responses for the 'think' question and the past reality question broken down by Event and Condition, together with the numbers of participants who answered both of these questions correctly. All subjects except four were correct in reply to the present reality question for Tube 1 and all subjects without exception were correct for this question in the Tube 2 condition.

Firstly we can note that the performance of the children on the Bag1/'think' question was at the 30% level reported in the literature for children of this age range for the normal Smarties experiment. The improvement in performance that was predicted for the Tube condition is clearly evident. Children answered correctly the questions concerning the tube more often than they did the questions concerning the bag. The increase in the number of correct responses from the Bag1 questions to the Tube1 questions was significant (McNemar, $\chi^2 = 4.9$, $P < 0.025$). Also in line with the predictions was the observed increase in the number of correct responses in the Bag condition between events. As predicted, performance in the Bag condition in the second event (Bag 2) was significantly better than performance on the Bag condition in the first event (Bag 1). Scoring by answers on both questions gave $\chi^2 = 5.82$ ($P < 0.01$). The differences between the Tube 1 and Tube 2 conditions did not reach significance.

Table 1
Scores in Experiment 1[a]

Event 1		Event 2	
Bag1	Tube1	Bag2	Tube2
10	18	21	25

[a] $N = 30$. The number of children giving correct answers to the 'think' and 'reality' questions.

2.3.1. Response patterns within the incorrect category

More than a quarter of the children (8/30) exhibited a response pattern that has not usually been reported in the literature. This pattern was characterized by a reversal between the ‘think’ and the ‘reality’ responses. Children exhibiting this pattern returned a ‘think’ response (Smarties) to the ‘reality’ question and a ‘reality’ response (marbles) to the ‘think’ question. In the published literature (e.g. Gopnik & Astington, 1988; Freeman & Lacohee, 1995) this ‘reversed’ pattern of response is universally excluded from analysis since failure on the ‘reality’ question (or the ‘*control*’ *question*, as it is referred to in those studies) disqualified the child from further participation. The justification for the exclusion is based on the view that nothing can be concluded about their understanding of beliefs if children are confused about reality. However, we believe that it is unwarranted to assume that a child is confused about reality simply because under the particular condition of an experiment they produce a particular answer to a question. From an information processing perspective, we are led, instead, to ask the question as to where the ‘Smarties’ response comes from with these subjects. Recall that the child has, 2 s ago, seen the pencils and, indeed, usually spontaneously named the pencils. Thus, it is scarcely plausible that on being asked the ‘reality’ question a couple of seconds later, such children access their general knowledge concerning Smarties tubes (since the question is, in any case, about the bag) or retrieve a representation of their response to the initial belief-establishing question, which also referred to the tube. Neither is it plausible that such children, invited to help themselves to a sweet, would go to that bag rather than any other option. The ‘reversed’ response pattern was therefore of interest, because it indicates the availability of the initial ‘belief’ representation even as it demonstrates inappropriate use.

Consequently, the children’s responses were assigned to one of three categories: ‘correct’, ‘reversed’ and ‘double’. For the Bag questions, the last category included children who made the usual mistake of providing the ‘reality’ (marbles) answer to both the ‘reality’ and ‘think’ question. In addition, it included two children who replied with a ‘think’ (Smarties) response to both questions. In the Tube condition, there are two ‘reality’ questions, present reality and past reality, where the correct answers were ‘nothing’ and ‘marbles’, respectively. For a ‘reversed’ response, there had to be a ‘Smarties’ reply to one of the ‘reality’ questions with one of the reality

Table 2
Frequencies within each response category as a function condition (Bag/Tube) and number of exposures to the event

	Correct	Reversed	Double
Event 1			
Bag1	10	8	12
Tube1	18	2	10
Event 2			
Bag2	21	6	3
Tube2	25	1	4

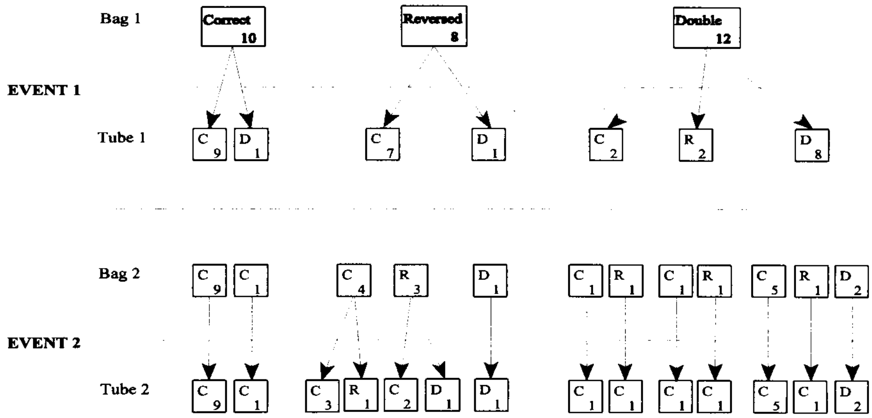

Fig. 1. Patterns of improvement within each response category.

answers (nothing or marbles) given to the 'think' question. A 'double' designation in this condition was assigned to children who gave one of the reality responses in reply to the 'think' question. This category also included a child who used the 'think' response as an answer to all three questions (Smarties, Smarties, Smarties) (Table 2).

Fig. 1 depicts the pattern of change within each of these response category. The four horizontal sections in the tree structure correspond to the four experimental stages. Each branch in the tree structure corresponds to an observed pattern of change within a given subject. The numbers in each section of a single branch indicate the number of children in which that particular pattern was observed. The tree structure consists of three main branches (correct, reversed, double) corresponding to children's initial responses in the Bag 1 condition.

We have reported that two of the comparisons were found to be significant: Bag 1 vs. Tube 1 and Bag 1 vs. Bag 2. Fig. 1 reveals certain trends that may point to the underlying factors contributing to these improvements.

The increase in the number of 'correct' responses within the Condition (Bag/Tube) factor seems to be attributable mainly to changes from 'reversed' responses to 'correct' responses. More than 85% (7 of 8) of children who provided a 'reversed' response in the Bag 1 condition were 'correct' on the Tube 1 condition, in comparison with 17% (2 of 12) improvement in the 'double' response group. This difference in performance was significant ($\chi^2 = 7.07$, df $= 1$, $P < 0.01$). The same pattern of change is evident between the Tube and Bag conditions in the second event: five out of six children whose response to Bag 2 was 'reversed' changed to 'correct' in Tube 2, whereas none of the three children who produced a 'double' response demonstrated such improvement. On the Fisher Exact Probability test, this difference is significant ($P = 0.048$). Thus, the reduction in computational demands that was afforded by the transfer operation seems to have been less effective for those children who, for reasons that we will discuss shortly, produced the 'double' pattern of response to the bag questions.

In contrast, the improvement in the Event factor seems to be equally distributed between the 'reversed' and 'double' responses. Inspection of the changes from Bag 1 to Bag 2 reveals that 50% (4 of 8) of the children who provide a 'reversed' response in the Bag 1 condition changed to 'correct' in the Bag 2 condition; similarly 58% (7 of 12) of the 'double' responses in Bag 1 changed to 'correct' responses in Bag 2. Thus, while the reduction in computational demands was less effective for the 'double' group than for the 'reversed' group, repetition of the event was of benefit to both.

2.4. Discussion

It was suggested in the introduction that in order to help children remember what they had thought about the contents of the Smarties tube, their original belief representation had to be kept relevant to the current experience long enough for it to be transferred to LTM. In addition, this transfer would have to take place before the arrival of the conflicting (and true) piece of information. The transfer operation was introduced to achieve this goal: the effect of transferring the contents of the tube into the bag was to maintain the relevance of the *in(t,S)* representation; putting the tube away was to signal the completion of an event sequence. We expected this event completion to trigger the creation of a record. The contents of the record would include the current contents of Working Memory relating to the tube. This would include the *in(t,S)* representation and possibly some representation of saying 'Smarties'. In addition, if at the time of test the *in(t,S)* representation is in a record and the *in(t,m)* representation involving marbles is in working memory, these representations could be potentially differentiated in relation to a time dimension (past and present). Therefore it was predicted that the *in(t,S)* representation would be accessed correctly. In contrast, in the Bag condition, it was predicted that the same level of failure would be observed as in the original Smarties task, since the computational demands were similar: as soon as the bag is represented as containing Smarties *in(b,S)*, the true contents of the bag (marbles) is revealed and the new *in(b,m)* representation replaces it.

Overall, the data supported these predictions. In the first event, the number of correct responses to the Tube questions was significantly higher than to the Bag questions with the success rate in the latter condition being of the same magnitude (about a third) as in the original Smarties task. However, the pattern of failure to the Bag questions was different from that reported in the usual task. Unexpectedly, almost a third of the children produced a 'reversed' pattern of response to these questions. Children producing this type of response clearly have both belief and reality representations available to them, but they appear not to be able to assign them to the appropriate questions. Their behaviour, therefore, seems to suggest that destructive updating does not remove the outdated representation from the whole system. What is the difference between this group and the 'double' group? The simplest hypothesis is that the latter do not have enough capacity to hold the 'think' representation anywhere, once the marbles are revealed.

We may now note again that 7/8 of the children who gave 'reversed' responses to the Bag1 questions were correct on the Tube 1 questions, compared with only 2/12 correct on Tube 1 for the children giving 'double' responses on Bag1. The simplest explanatory principle for this is that it, too, reflects the more limited computational capacity of the 'double' children. Any account must start with the assumption that the record created of the events involving the tube, from its introduction, through the transfer of the contents to the bag, to the tube being put away is created by all children. We assume this since all children seem to benefit from the repetition of the event. Such benefit can only be due to retrieval of the memory of the event. The 'double' group, then, can retrieve the record during the second running of the event, but cannot retrieve this record during the Tube1 questions. This could be due to differences in the way the two groups created the Heading for this record, the heading being the specification of the kinds of cues which can be used to access the event record (Morton et al., 1985). Thus, both groups have headings of the context of the event – the experimenter and the production of the Smarties tube and so on – but the 'reversed' group also has a heading of ⟨tube⟩, which allows access to the information concerning the tube event when they are questioned about the tube.

The results from the second event clearly demonstrated the benefits of repetition. Significant parts of the record of the previous event had already been accessed by 18/30 children by the time the Smarties tube was presented to them, and they either spontaneously remarked 'marbles' or produced it in response to the first belief question. A further six children had accessed the previous event by the time they were asked the question about the contents of the bag, following the transfer. That is, these children had answered 'Smarties' in answer to 'what do you think is inside this tube?' but, after the transfer, answered 'marbles' in response to 'what do you think is inside the bag?'. We assume that these children had not been reminded of the details of the previous event by the (relatively commonplace) Smarties tube, but that the transfer operation was sufficiently unusual to jog their memories. The remaining six children did not mention marbles at any time during the second event, but there is no evidence that they improved between Bag1 and Bag2 any less as a group than the other children.

On the second presentation, a significantly larger number of children were able to provide correct responses to the questions concerning the bag. Since they were questioned immediately after the pencils had been revealed, they could not have transferred their former belief [e.g. *in (tube, marbles)*] from their temporary memory. Thus, it can be concluded that those children who accessed these representations correctly could differentiate them at the structural level, i.e. through marking.

The success of the 'posting' paradigm (Mitchell & Lacohee, 1991; Freeman & Lacohee, 1995) could be explained along lines similar to those used for the bag task. Recall that this task involves the normal start to the Smarties test. After the children have responded 'Smarties', the experimenter suggests that they select an object which corresponds to their response and post that object in a box. In two conditions of the crucial experiment, the object was either a picture of Smarties or was actual Smarties. The posting of the *picture* of Smarties led to subsequent good performance when the children were first shown the pencils and then asked the 'think' and 'reality' questions. The posting of real Smarties, however, made no difference to the responses. Since neither group of children had trouble in recalling what it was that they had posted, we conclude that they all formed a record of this event. The issue is exactly what other material is included in the 'posting' record. Our inference is that children who post a picture of Smarties will include in the 'posting' record the details of their initial interaction with the tube, including their response to the (belief establishing) question. Children who post real Smarties, on the other hand, will see the posting event as a separate, embedded event and will not include *in(t,S)* in the 'posting' record. The justification for this inference is the perceived relevance of the posting event to the current goals. Unlike the transfer event, the posting event is independent of the tube and its real or believed contents. Therefore, the relationship between the *in(t,S)* representation and those components that make up the posting event would determine whether or not the *in(t,S)* representation is integrated within this record. The difference between the object condition and the picture condition is that in the former the *in(t,S)* representation is not relevant to the posting event. This is because the Smarties that are being posted are necessarily different from those Smarties that are believed to be in the tube – they are different Smarties, whereas the Smarties in the picture could represent the Smarties that are in the tube. In other words, a picture can represent any particular Smarties, but real Smarties cannot. Use of real Smarties, then, leads to the record being restricted to the posting itself. Use of a picture of Smarties maintains the relevance of the *in(t,S)* representation to the posting event, and therefore the 'posting' record would contain this representation which could later be addressed and used at test.

3. Experiment 2

The following study was designed with the aim of eliminating the 'reversed' pattern of response. The 'reversed' pattern of response, as already noted, indicates that the child has two representations of the contents of the tube which are unmarked and therefore indistinguishable. To reiterate, two representations are formed in the context of the task as it unfolds over time; one regarding the belief about the contents of the bag, *in(b,S)*, and the other regarding the observed contents of the bag, i.e. *in(b,m)*. The representations concern the same relationship (i.e. containment) between one and the same container and two different objects. If the relationships between the container and the two objects are to be differentiated, it is either the case that the more recent representation *in(b,m)* receives a current state marker, or each representation receives a source marker (e.g. knowledge or inference vs. perceptual) at the time it is formed. If no marking procedure is carried out, the representations will remain identical on all but the 'object' dimension. Thus, those children who produce the 'reversed' pattern of response have two representations of a single container that are not differentiated on any meaningful dimension (i.e. time or source).

In addition, the 'reversed' pattern of response also appears to suggest that in the case where a question is asked, and there are two seemingly identical representations competing in terms of appropriateness, the more recent of the two would be addressed. Since the 'think' question in experiment 1 was first, the answer to this question was wrong because the more recent representation was the reality representation. The second, 'reality' question would then address (again wrongly) the alternative representation.

We mentioned earlier that in the theory of mind literature this pattern of response is rarely reported, and when it is reported the children that have produced it are typically excluded from analysis. However, in many of these studies the reality (control) question was asked first (e.g. Perner et al., 1987; Sullivan & Winner, 1991). There were no reports of failure on the control question (i.e. a potential 'reversed' response pattern) in these studies. Gopnik and Astington (1988) asked the 'think' question first, but reported no failure on the control question. Freeman and Lacohee (1995) also asked the 'think' question first, however, unlike Gopnik and Astington, in four of the six experiments they reported the level of failure on the control 'reality' question was quite high (12, 8, 17 and 16% in four separate experiments). These correspond to the 'reversed' pattern of responding.[3]

Thus, if the recent assumption is correct and the first question leads to the retrieval of the most recent of two relevant and therefore competing, representations, then if the 'reality' question is presented first, the answer to this question should be correct since the most recent representation is the reality representation *in(b,m)*. The answer to the 'think' question should also be correct since a second (and different) question should address the alternative representation – *in(b,S)*. It is therefore predicted that switching the order of the 'think' and 'reality' questions in the original design will eliminate the 'reversed' pattern of response in favour of the 'correct' pattern.

Note that an alternative prediction is made by a different account of the 'reversed' responses in experiment 1. In this account, the two representations are both present and unmarked and they are selected at random. In this case, reversing the order of the questions will make no difference to the proportion of 'reversed' responses. Note, also, that if all the 'reversed' responses are produced by random ordering of the two representations, we would account for all the supposedly 'correct' responses as further examples of random ordering of the two representations.

3.1. Method

3.1.1. Subjects

Twenty-four nursery school children (12 boys and 12 girls) aged between 3:0 to 4:6 (mean age 4:0) took part in this study. Half the children were over 4-years-old and half under 4 years. The children were from two state-financed nurseries and were of varying socio-economic backgrounds.

3.1.2. Design and procedure

The design and procedure were the same as in the previous study, except that the

[3] The basic finding of around 30% 'reversed' responses has been replicated with a further sample of 80 children, when 22 gave reverse responses. C. Dillon and J. Morton, BPS Developmental Section Conference, Lancaster, UK, September 1998.

order of questions was different. In this study the 'reality' question was always asked first.

Bag condition:

1. REALITY: 'What is really in the bag?'
2. THINK: 'Before I opened the bag, what did you think was in the bag?'
3. Tube condition:
4. PRESENT REALITY: 'What is inside the tube now? '
5. THINK: 'When I first showed you the tube, what did you think was inside the tube? '
6. PAST REALITY: 'What was really in the tube?'

There was no repetition of the event.

3.2. Results and discussion

Children were classified into three response categories, using the same classification criteria employed in the previous study. Table 3 presents the frequencies within each response category in the Tube and Bag conditions that were observed in Experiments 1 and 2.

Inspection of the data reveals almost identical patterns of response in the Tube conditions in the two studies, and quite large differences in the patterns of response between the Bag conditions in each study, in particular with respect to the 'reversed' and 'double' patterns of response. As predicted, the proportion of correct responses in the tube condition was the same in both studies. Thus, the effect of reduction of computational complexity on performance in the Tube condition was replicated. Also in line with the predictions, the frequency of the 'reversed' pattern of response was almost eliminated. However, contrary to the prediction, the reduction in the number of 'reversed' responses in the bag condition did not shift the balance in favour of the correct pattern, which maintained a similar frequency of occurrence as that observed in experiment 1. Instead, there was a significant shift in favour of the 'double' pattern of response. The distribution of incorrect responses on Bag 1 in the two experiments was significantly different with $P = 0.029$ (Fisher exact probability test). This shift towards the 'double' pattern of response rules out the recency explanation as the account of the 'reversed' pattern. It also rules out the account whereby the representations are selected at random. So, what are the alternatives?

Table 3
Frequencies within each response category in Experiment 1 (first event) and Experiment 2

	Experiment 1 ($n = 30$) ('think' question first)		Experiment 2 ($n = 24$) ('reality' question first)	
	Bag	Tube	Bag	Tube
Correct	10 (33%)	18 (60%)	9 (38%)	15 (63%)
Reversed	8 (27%)	2 (7%)	1 (4%)	1 (4%)
Double	12 (40%)	10 (33%)	14 (58%)	8 (33%)

Two conclusions can be drawn on the basis of the results of these experiments. First, there were identical levels of success on the Tube conditions in the two experiments. In addition, we found that the improvement in the Tube condition in experiment 1 was significantly associated with changes from ‘reversed’ responses on Bag 1 to ‘correct’ responses on Tube 1. These two facts suggest that a similar proportion of children in Experiment 2 had the same developmental profile as those children who produced the ‘reversed’ pattern of response in the first experiment, i.e. children who have the capacity to maintain both representations but lack the marking ability.

Second, this group of children (who we will continue to refer to as the ‘reversed’ group) in the second experiment, did not have the belief representation [i.e. *in(b,S)*] available to them at the time the *second* (‘think’) question was asked, although it must have been available at the time the *first* (‘reality’) question was asked, since the experimental conditions up to that point were the same as in the previous study. It seems reasonable to conclude, then, that the ‘reality’ question caused the loss of the *in(b,S)* representation in this group, otherwise they would have used it as they did in the previous experiment. This in turn suggests first that there is something different about the ‘think’ and ‘reality’ questions that helped to maintain the belief representation in one case and led to its loss in the other, and second that children *know* that there is a difference and respond to it.

One difference between the ‘think’ and ‘reality’ questions is the effect each would have on the perceived goal, and consequently on the relevance of the belief representation to this goal. The ‘reality’ question reinforces the original goal of finding out about the content of the bag, which renders the *in(b,S)* representation irrelevant. In contrast, the ‘think’ question is likely to change or expand the goal and therefore maintain the relevance of the *in(b,S)* representation. But, if the representations are indistinguishable, this effect should not in principle be expressed; both representations should pass as appropriate answers to either the ‘think’ or the ‘reality’ question. However, the second experiment seems to indicate that this was not the case. Once the reality representation was provided as an answer to the ‘reality’ question, the belief representation was lost, which suggests that the response in this case motivated updating of the belief representation. This would necessarily mean that the representations are distinguishable. However, we know from the first study that the representations were indistinguishable at the structural level, or else the children who had both representations available would have produced a ‘correct’ pattern of response. The only solution that would allow the representations to be distinguished in relation to reality – but not in relation to ‘thought’ – is one that assumes that there is something special about ‘reality’ representations, not in terms of their structure but in terms of their location.

A similar solution was proposed as a way of resolving the problem of differentiating between unmarked representations in the Tube condition. The belief and reality representations associated with the tube are also unmarked and structurally similar, however, they can be distinguished in terms of their location in the system – the belief representation in a record in LTM, and the reality representation in working memory. The belief and reality representations associated with the bag could be distinguished along similar lines if it is assumed that they each reside in different on-line buffers, and if one of these buffers imposes itself as reality. Thus, 'think' will be associated with one specific buffer, whereas reality could in principle be associated with both. Elsewhere (Barreau, 1997), we have postulated the need for at least two on-line buffers, the Interpreter Buffer for the temporary storage of interpreted or retrieved information, and a Current State Buffer storing post attentional perceptual information which imposes itself as reality (See also Abeles & Morton, 1999). Thus, the belief representation, which derives from retrieved general knowledge together with inference from the transfer event, originates in the interpreter buffer from the start, whereas the reality representation (marbles or a pencil), is initially in the current state buffer and it is only subsequently transferred to the interpreter buffer where it either replaces the belief representation or is integrated with it into a single structure.

4. General discussion

Let us review our conclusions. At the time of asking the Bag questions, there is information in three locations, as indicated in Table 4.

The Current State Buffer contains information that the Bag contains marbles and that the Tube contains nothing. The Interpreter Buffer will contain information concerning the current goal together with the representation of the Smarties in the Bag which had been inferred from the Smarties in the Tube representation together with the transfer operation. In the case of the more developmentally advanced children, the representation in the Interpreter Buffer is marked as referring to a belief in some way. In addition, there will be an event record which will include the representation of the initial belief about Smarties. Note that in order to make a response, any material has to be retrieved into the Interpreter Buffer.

This is the state of the system when the child is asked what they had thought was in the Bag. The more advanced children correctly identify the necessary information in the Interpreter Buffer. The other children get information from the Current State Buffer thus producing the reality error to their 'think' question. For the children with least capacity available, retrieving information from the Current State Buffer into the Interpreter Buffer, in order to make a response, results in the deletion of $in(b,S)$. These children, on then being asked the 'reality' question, have no other information available to them than the marbles response. The 'reversed' group of children preserve the $in(b,S)$ representation in the Interpreter Buffer and have it available at the time of being asked the 'reality' question. However, for these children, if the 'reality' question is asked first then the contents of the Interpreter Buffer are wiped

Table 4
The information content of each buffer at the time of test

Current State Buffer	$in(b,m)$, $in(t,\phi)$
Interpreter Buffer	$in(b,S)$
Event Record System	$[in(t,S), tr(x,t,b)]$

out because the *in(b,S)* representation is not relevant for the revised goal, that of confirming the real contents of the Bag.

When the Tube questions are asked, the subjects have to retrieve information from the record system. It is from here that many of the children can get the correct response to the 'think' question. The current reality question can be answered from the Current State Buffer. The remarkable achievement is in response to the past reality question. The vast majority of children correctly report that the Tube really contained marbles. This conclusion is entirely inferential on the children's part. It has to be inferred from the knowledge that the Bag currently contains marbles and from the facts of the transfer of the contents from the Tube to the Bag. There then has to be an inferential routine which says that if there has been a transfer from A to B then the contents which are in B must have been in A. This requires that the transfer be represented in a way which is not tied to the Smarties which the child believed were being transferred. We might also note that all eight of the children who made 'reversed' responses to the Bag 1 questions, that is who claimed that there really were Smarties in the Bag, nonetheless correctly concluded that there had been marbles in the Tube. This is additional evidence for our assertion that these 'reversed' responses did not represent actual beliefs but were artifacts of the experimental procedure.

We should note that the specific operations used in the bag procedure will only help children in respect of their own previous behaviour and beliefs. We help the children by enabling them to create a memory record of their actions and thoughts at the time. This overcomes the limitations of the child's cognitive architecture which would not normally enable such information to be available. It is not clear that such procedures would be sufficient in situations where the crucial element was other people's beliefs. Consider the standard Sally-Ann task (Baron-Cohen, Leslie & Frith, et al., 1985). To recap this task briefly, the child observes another person (or doll), *A*, hide an object in a location *X*. *A* then leaves the scene, and, during this time, the object is moved to location *Y*. The child is then asked, 'When *A* returns, where will she look for the object?' One way of answering this question correctly is by reconstructing *A*'s thought processes, i.e. '*A* saw the object being hidden in location *X*, since she did not see the object being moved she would look for it in location *X*'. We know from children's failure on the original Smarties task that they do not have the necessary meta-skills to enable them to reconstruct their own thought process. It is, therefore, highly unlikely that they would be capable of reconstructing another person's thought processes. Bypassing the need to reconstruct by making all the necessary representations available, as we did in the bag task, however, may not be all that simple. This is because the computational demands of the Sally-Ann task are much greater. In order to resolve the Sally-Ann task, the child must construct a set of representations for Sally which are distinguishable from the child's representation of reality. With limited capacity such an operation would be extremely difficult. But we can sketch some kind of research programme.

Suppose that, during the demonstration of the Sally-Ann situation to an observing child, we ask the child certain questions. Thus, as soon as Sally has hidden the object we can ask: ‘Where does Sally think the object is?’ Then, when Sally leaves the scene we can ask the same question again. Next, after Ann has changed the location of the object we ask the question a third time. It seems to us possible that a good proportion of 3-year-olds will still respond correctly. Finally, we ask the question again when Sally re-enters the room. In this way, we continue to maintain a representation of Sally’s belief in the child’s Current State Buffer. What will now happen when we ask the crucial question ‘Where will Sally look for the object?’ It is possible that the presence of the appropriate information concerning Sally’s belief will help to overcome the computational difficulties with the reasoning and enable the correct response to be produced.

If this procedure does not work then we could consider making it even more directive. Each time we ask the child ‘Where does Sally think the object is?’, we could follow it with the question ‘When Sally wants the object again, where will she look for it?’ The first two times this question is asked there will be no ambiguity in the situation. It is only when Ann has moved the object that conflict could occur. However, if the child has already answered the *think* question correctly, and has previously given the same response to the *think* and *look* questions twice running, we feel there is a good chance that some children will continue to give the correct answer. When Sally finally enters the room and the crucial question is posed there will be even more support available to the child in producing the correct answer. This will include not only the representation of Sally’s belief in the child’s Current State Buffer, but a model for the inferential connection between belief and action.

These procedures move us some way from the effortless computation based on the 4- or 5-year-olds mentalising capacity when they produce the correct answer to the Sally-Ann task.

Finally, we should reiterate that we are in no way claiming that the Bag procedure has enabled the child to perform cognitive operations of a type that they were previously incapable of. All we would claim is that we had demonstrated that children who cannot master the standard false belief can nonetheless produce the correct answer in response to the false belief question. Concern with the child’s processing machinery and computational capacity makes such distinctions possible. Understanding the nature and operation of the Current State Buffer is crucial in this regard.

Appendix A. Specification of the bag experiment

Smarties tube is presented
‘what do you think is inside this tube?’
the bag is produced and the contents of the tube emptied into the bag.
the child looks inside the tube.
‘What is inside the tube now?’
the tube is placed out of sight.
‘What do you think is inside the bag?’

the bag is opened and the marbles are revealed.
'Before I opened the bag, what did you think was in the bag?'
'What is really in the bag?'
The bag is put away and the tube taken out again.
'When I first showed you the tube, what did you think was inside the tube?'
'What is inside the tube now?'
'What was really in the tube?'

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