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Keeping track: the function of the Current State Buffer

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Abstract

The Current State Buffer has been proposed to account for our ability to keep track of significant stimuli in our immediate environment. The three experiments reported here were designed to test the independence of the Current State Buffer from the established components of Working Memory. Pre-schoolers were used in order to minimize the possible interference of other memory structures and complex strategies on the part of the subjects, thus allowing a cleaner test of the hypotheses. In the experiments, 180 pre-schoolers watched an Emu glove puppet tidy away toys into receptacles (the 'Tidy Emu Paradigm'), such that the number of pairings just exceeded their capacity for recall of the locations of toys in receptacles. We take this task to be a prototypical visuospatial Working Memory task. In the Object condition of Experiment 1, a Teddy was an object and was tidied away with the other toys. In the Character condition the Teddy was an animated character who interacted with the children and then went to sleep in one of the receptacles. Where Teddy was a character, all children remembered his location even though they had not been asked to; when he was an object only half of the children were correct despite explicit instructions to remember. More crucially, the location of the other toys was better recalled for children in the Character condition than those in the Object condition. These data are taken as evidence for the independence of the Current State Buffer from the Visuospatial Sketchpad. Other explanations, such as a von Restorff effect, are considered, and Experiments 2 and 3 test and reject these as possibilities. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Current State Buffer; Working Memory; Cognitive development

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1. Introduction

The idea of a separate Short-Term Memory was first proposed by William James (James, 1890). Based on introspective techniques, James postulated that holding the memory of a given event in one's consciousness for a few seconds constituted 'primary memory'. This construct has since evolved from being described as a static receptacle for learning verbal lists (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965), to a dynamic and flexible system that can satisfy a wide range of different information processing needs (Baddeley & Hitch, 1974).

The 'Working Memory' model (Baddeley & Hitch, 1974) comprises a Central Executive component that regulates and co-ordinates the flow of information between the Executive and its two slave systems, the Phonological Loop and the Visuospatial Sketchpad. The Phonological Loop retains verbal information in a speech based code, and the Visuospatial Sketchpad is specialized in retaining visual or spatial information. Hence, a cognitively flexible system is posited, thanks to the combination of the general purpose resources provided by the Central Executive and the more specialized processing and storage functions fulfilled by the Phonological Loop and Visuospatial Sketchpad. Together they are considered central to many diverse cognitive domains, such as vocabulary acquisition, learning of faces, and consciousness (Gathercole, 1994).

The fractionation of Working Memory into specialized subsystems arose from a series of experiments using dual-task methodology. The basic rationale underpinning this methodology is that if two activities both call upon a common limited capacity component of Working Memory, then subjects will be unable to maintain the same level of performance which they achieved when carrying out only one of the tasks. Articulatory suppression – requiring subjects to continuously articulate irrelevant information such as 'the, the, the' during a memory task – appears to block the operation of the Phonological Loop (Baddeley & Hitch, 1974), or to impede the rehearsal process somewhat (Macken & Jones, 1995). Use of the Sketchpad is disrupted when subjects concurrently track a moving visual target (Baddeley & Lieberman, 1980). Activities that appear to place significant burdens on the Central Executive include asking subjects to generate sequences of random letters (Baddeley, 1986).

A further feature of the Working Memory model is its application to cognitive development (Walker, Hitch, Doyle & Porter, 1994). Developmental changes in the capacity and use of Working Memory have been invoked to account for more general changes in cognitive abilities, such as reading and arithmetic. A basic assumption has been that each of the subsystems has an age-limited capacity associated with it that will account for a developmentally constrained performance on a given task (Hitch & Halliday, 1983).

The present study uses the Working Memory model as a useful heuristic for considering the nature of Short-Term Memory. Its goal is to consider a neglected, but vital component of any model of Short-Term Memory.

The component under consideration has been termed the 'Current State Buffer' (Morton, 1997). It is responsible for tracking the location and status of important stimuli in the individual's immediate environment. Baddeley and Hitch (1993) have made mention of a similar component, although it is not a part of Working Memory but seen as a function of the ubiquitous recency mechanism (Glanzer, 1972). Their account is not fully specified, and will be returned to later.

The Current State Buffer is conceived of as keeping track of, among other things, the whereabouts or status of important people, objects or other features of the surroundings. As the whereabouts or status of these parts of the environment change with time, their representations in the Current State Buffer will undergo destructive updating, since the previous values will not be relevant to Current State Buffer function. Thus, if you are a parent with a small child, it is the *current* location of the child – in the front room, for example – that is important. The previous location of the child – the kitchen, for example – may be preserved in Long-Term Memory, but its status has changed: it no longer represents reality. In an emergency, the Current State Buffer can be rapidly consulted to discover where the child currently is. At such a time, accessing the previous location could only interfere. The Current State Buffer stores these representations at the immediate level of attention, and they may be seen, to a certain extent, as comprising a part of the resources for an individual's conscious awareness. Of course the individual does not have to be conscious of the material the whole time. Indeed, one of the advantages of such a resource is that it allows material to drop out of consciousness (releasing attentional resources) while maintaining the material for ready access.

To illustrate further the functional nature of such a Buffer, consider the complex environment of a social gathering, such as a party. In a strange room, the locations of key objects such as one's drinks, the dance-floor, or specific friends in the room, are at hand. If one then engaged in a Phonological Loop task (such as rehearsing a phone number before finding a pen and paper), this is not likely to interfere with one's knowledge of these important stimuli in the immediate environment. If it did, our social interactions would be adversely affected. Similarly, our orientation within an environment (for example, negotiating the self-same environment in order to find the pen and paper) would fail.

On an experimental level, one study that involved the Current State Buffer in its conceptualization is that of Barreau and Morton (1999). The experiment explored the 'Smarties' experiment (Perner, Leekham & Wimmer, 1987). In this, the child is shown a tube of Smarties and asked what is inside it, to which they invariably respond ''Smarties''. They are then shown the true contents of the tube, namely pencils, and the lid is replaced. The child is then asked to say what is now in the tube, and they respond ''pencils''. However, when they are then asked what they thought was in the tube, about 75% of 3-year-olds fail to answer correctly, and respond ''pencils'' to this question too, and fail to reproduce the answer they made 5 s earlier. Four-year-olds, however, have no problem in this situation and respond ''Smarties''.

The central assumption in the experiment of Barreau and Morton (1999) is that the contents of a Smarties tube will be of intense interest to a 3- or 4-year-old child. We would predict, then, that the child represents the tube and its contents (inferred or otherwise) in the Current State Buffer. Thus, when they are first shown the Smarties tube by the experimenter they form a representation that there are Smarties in the tube. When the pencils are revealed a few seconds later, the current representation of the contents of the tube in the Current State Buffer would become out of date. This representation would be destructively updated, being replaced with a representation of *pencils* in the tube. The idea was that the representation in the Current State Buffer is likely the *only* representation of the Smarties that a 3-year-old would have. Thus, when the child is asked what they first thought was in the tube many of them would be unable to provide the correct answer, as this information has been replaced in the Current State Buffer and not stored anywhere else. Given that 3-year-old children cannot reconstruct the past, for this would entail entertaining a false belief (that there are Smarties in the tube), they respond with the only answer available, which corresponds to the current reality. For 4-year-olds, the capacity of their memory system is sufficient to allow them to represent past and present states. In addition, by the age of 4 years, children can entertain the false belief and reconstruct the past situation where necessary (Leslie, 1987).

The experimental procedure in the study by Barreau and Morton (1999) used this conceptual framework in order to overcome the 3-year-olds' cognitive limitations and enable them to pass the Smarties test. The central idea was that the 3-year-olds would only be able to remember their previous belief if they created an event record which they could retrieve. This would only happen (according to the theory) if the belief about Smarties in the tube formed part of a sub-event which ended before the pencils were introduced. In pursuit of this end, Barreau and Morton (1999) constructed a variation on the Smarties task which involved transferring the contents of the tube into a bag, without letting the child see what was being transferred. The empty tube was then put away. All this happened after the child had been asked about the contents of the tube. According to the theory, the transfer of the object to the bag would break the event sequence, forcing the creation of an event record in Long-Term Memory (Morton, Hammersley & Bekerian, 1985). This record would include the child's response to the question about the contents of the tube. The Current State Buffer would now contain (incorrect) information about the contents of the bag as reflected by the children's answers when questioned. After being shown the correct contents of the bag (marbles), the Current State Buffer would be updated and the children should be incapable of remembering the response they made 5 s earlier as with the original Smarties experiment. When then asked what they had originally thought was in the tube, the children should retrieve the record they created at the time of the transfer and produce the right answer. Barreau and Morton (1999) showed that this was indeed the case. Use of the Current State Buffer in conceptualizing and simulating the Smarties paradigm (Beaman & Morton, 1998) thus proved experimentally fruitful and encouraged us to explore the concept further.

The present study was designed to test the independence of the Current State Buffer from the existing specified components of Working Memory. The design involved a new paradigm, the 'Tidy Emu Paradigm'. The task consisted of an Emu glove puppet (engineered by the experimenter) tidying away objects (toys) into receptacles (this activity is henceforth called *pairing*) and immediately asking for the locations of these objects. Using this paradigm in a pilot experiment we first determined the Working Memory capacity (of the Visuospatial Sketchpad) for hidden objects in pre-schoolers. Once this capacity was established, we introduced into the experimental procedure another pairing that would overload this capacity beyond ceiling performance. The experimental paradigm then involved the addition of yet another pairing. This would normally cause even more interference. However, if this additional pairing engaged the Current State Buffer rather than Working Memory, and if they are independent, there should be no further interference. In this sense, the task employed dual-task methodology.

The critical manipulation through which the additional pairing engaged either Working Memory or the Current State Buffer was achieved by using a Teddy Bear (henceforth Teddy) which for some children was just another object, and for other children was instilled with animacy. Animating the Teddy would make it sufficiently important to the children, we thought, to engage the Current State Buffer for its representation. In that case, according to the theory, there should be automatic tracking of Teddy, whose location should be stored in the Current State Buffer. We predicted, further, that there should be no interference between storage of Teddy's location in the Current State Buffer and the storage and retrieval of the location of other objects in Working Memory.

The particular choice of a spatial task with pre-schoolers was made for two main reasons. First, it was crucial that the mental representations for the pairings in the system could be confined to one place. Because studies of visual Short-Term Memory in adults have been confounded by problems stemming from the tendency for verbal memory codes to be used in visual tasks (Hitch, Halliday, Schaafstal & Schraagen, 1988), the use of pre-schoolers meant that, arguably, representations of visual-spatial stimuli would stay in the Visuospatial Sketchpad. Second, we could be fairly sure that the 3-year-olds would not be using complex meta-memoric strategies during the task which might circumvent our intent. We can be sure of this because they do, after all, fail the Smarties task.

Although other Visuospatial tasks exist for this age group (e.g. De Ribaupierre & Bailleux, 1994; Pickering, Gathercole & Peaker, 1998; Schumann-Hengsteler, 1992; Walker et al., 1994), the Tidy Emu paradigm was pioneered because other tasks did not present themselves easily for a Current State Buffer/Working Memory dissociation. In the Corsi block tapping test, for example, the subject is presented with an array of nine blocks scattered in a quasi-random manner (Milner, 1971). The experimenter taps a sequence of blocks, and the subject attempts to imitate the sequence. As with digit span, performance is measured by the longest sequence that can successfully be replicated, and is usually about two items less than digit span. Both the current task and the Corsi task test memory for location. However, the tasks differ in that order information is vital in the Corsi task, but item information is vital in the current task.

2. Experiment 1

As we have already noted, the basic task was for children to remember in which receptacles Tidy Emu put various objects. In Experiment 1 there were two conditions – Character and Object – referring to whether Teddy was an animate character or just another toy, respectively. In the Character condition, Teddy became animate by interacting with the children in a short episode which also included measuring the children's digit span. Teddy then goes to sleep in one of the receptacles before the toys were tidied away. The children were not asked to remember where Teddy was sleeping but they were asked to remember where the toys were. In the Object condition, Teddy was an additional (non-animate) object, which was tidied away with the rest of the toys. In this condition, the children were specifically asked to remember where Teddy was sleeping.

The hypothesis was that, in the Character condition, the children would automatically track the location of Teddy. This location would thus be registered in the Current State Buffer. In the Object condition, however, the location of Teddy would be registered in the Visuospatial Sketchpad, just as with all the other objects. This means that there would be an extra load for Working Memory in the Object condition, resulting in interference with performance on recall of the location of the other objects. In the Character condition, however, there should be no interference, as the location of Teddy would be registered in the Current State Buffer, independent of Working Memory. Recall of the Object locations should thus be better in the Character condition. Given that the children treat Teddy as a significant character, according to the theory they should automatically and accurately register and later retrieve Teddy's location. Thus, better memory for Teddy's location (and possibly perfect memory) was predicted in the Character condition relative to the Object condition where Teddy and the other objects will compete for overloaded Working Memory resources.

What if the Current State Buffer is not separate from Working Memory but, rather, shares resources? In this case one would also predict that Teddy would be better recalled in the Character condition relative to the Object condition since he would be more salient. However, one would not expect perfect performance, because of the interference from the Object locations which would share the overloaded Visuospatial Sketchpad. For the same reason, the cost of better recall of Teddy in the Character condition would be worse recall of the objects in that condition. Predictions from other points of view will be presented in Section 2.3.

2.1. Method

2.1.1. Design

There were two independent variables – (a) age of child (3 or 4 years) (between subjects), and (b) Teddy condition (Object – Teddy as object, or Character – Teddy as character) (between subjects), and two dependent variables – (a) correctly remembering an Object pairing (i.e. an object's location in its receptacle), and (b) correctly remembering Teddy's location.

We predicted above that both memory for Teddy and memory for objects would be better in the Character condition than in the Object condition.

2.1.2. Participants

The participants consisted of 3- and 4-year-old pre-schoolers from a number of local nurseries, representing a cross-section of varied economic status. There were 28 3-year-olds (two in each of the seven randomizations for the two conditions) and 28 4-year-olds (two in each of the seven randomizations for the two conditions). The mean ages were 3 years, 10 months (range 3 years, 1 month to 3 years, 12 months) and 4 years, 8 months (range 4 years, 0 months to 4 years, 10 months).

2.1.3. Apparatus

The apparatus consisted of two ‘characters’ (or one in the Object condition), four ‘objects’, and seven ‘receptacles’, which were manipulated on a desk.

The character that could be interchanged as an object was a small Teddy, about 5 cm high, capable of fitting inside any of the receptacles. The other character was a glove puppet Emu that could easily manoeuvre objects with its beak. The objects were a toy car, three linked bricks of Lego, a plastic cat, and a crayon. The receptacles were a hat, a cup, a little box, a small bag, a sock, a plastic bowl, and a basket.

All the objects were capable of fitting into any of the receptacles, thereby hiding them from the view of the child. In the case of the mug, basket and bowl this involved resting a small piece of white material over the top of the receptacle.

The responses of the child were recorded with pen and paper.

2.1.4. Procedure

2.1.4.1. Setting Each child was run individually in a quiet room, with the child and experimenter sitting on nursery chairs at a nursery desk. All the receptacles were randomly arranged along the horizontal, towards the back of the desk, and the objects were placed in a pile towards the front of the desk. (The characters were not on the table at this stage.) The total number of objects and receptacles used in each condition was dictated by the number of pairings that were to be tested, four for 3-year-olds, and five for 4-year-olds[1] (including Teddy). In the warm-up to the experiment we checked that each child knew the names of all the objects and receptacles. Where the child misnamed something (e.g. ‘‘pot’’ for the bowl), that name was then used to refer to that item when testing that child.

2.1.4.2. Digit span In the Character condition, the first phase of the experiment required the experimenter to assess the children’s digit span. In the Object condition this assessment occurred in the final phase. The reason for this difference between

[1] The number of pairings to be done by 3- and 4-year-olds had been explored in the pilot study, which established the basic pairing capacities of the 3- and 4-year-olds on the same task. The pilot study revealed that three pairings stretched 3-year-olds beyond ceiling performance, and four pairings stretched 4-year-olds beyond ceiling performance.

the conditions was that Teddy was used in an animated way to elicit this measure in both conditions. Thus, it was convenient for children in the Character condition to use this as an opportunity to 'get to know Teddy' before the pairings.

To measure digit span, the child was told that Teddy was very popular and had lots of friends. In the Character condition, this was preceded by an introduction to Teddy (''We'll be playing a game with this fellow, he's called Teddy. Say hello to Teddy''). The child was then told that Teddy was so popular that he needed his own telephone and telephone line. The child was then asked to repeat his telephone number (specified slowly and clearly by the experimenter) which would be a three-digit string excluding zero. The same string length was tested again with the child repeating Harry's number (one of Teddy's many friends). If two trials of the same string length were correctly repeated, then the string size was increased by one number (using other friends' numbers), and the procedure was repeated. If the child got one out of two strings correct at any length, a third deciding trial was given. The digit span was defined as the longest length at which children accurately repeated two trials with this procedure.

2.1.4.3. Teddy sleeps The next stage in the Character condition involved the experimenter commenting to the child that all of the toys (i.e. the objects at the front of the desk) belonged to Teddy, and that he had been playing with them all morning and so was very tired. The experimenter then said ''Teddy is going to sleep'', and put Teddy into one of the receptacles. Teddy was not seen again until the end of the experimental procedures. Note that in the Character condition the children were not asked to notice or remember where Teddy went to sleep nor was that receptacle named. The incidental nature of memory for Teddy's location is a central part of the concept of Current State.

2.1.4.4. Emu Immediately after putting Teddy to sleep, the experimenter produced 'Tidy Emu', and presented him to the child, who was encouraged to stroke the puppet. The children were further informed that Tidy Emu did not like mess, and had a habit of tidying things away. Emu was then seen to notice the toys that had been left in a mess and the children were told that Emu was going to tidy them up into the receptacles at the back of the desk, but that they had to remember where all the objects were so that they could be found later. For each object, the experimenter asked ''Are you watching carefully?'', but no object names were mentioned.

2.1.4.5. Pairings The next stage varied according to the age of the child and the condition. For the Object condition, Emu placed each of the four toys (which included Teddy) in four different receptacles (3-year-olds), or each of the five toys in five separate receptacles (4-year-olds). In the Character condition, Emu placed three toys in three separate receptacles for 3-year-olds, and four for 4-year-olds. Note that Teddy was 'tidied' first in the Object condition to match the fact that Teddy was always put to sleep first (and therefore paired first) in the Character conditions (and this also explains why there was one less Object pairing relative to the Object condition in this phase of the experiment). On each pairing during this tidying phase, the experimenter instructed the child to watch carefully. The order of the pairings (and the objects and receptacles used) was dictated by the seven different randomizations.

2.1.4.6. Testing of objects' locations The test phase of the experiment was the same for both Teddy conditions. Immediately after the pairings had been completed, the child was tested for the location of the objects (''Where is the cat?'') directly by the experimenter, with Emu having been put out of sight. The questioning was done in the same order in which the pairings had been made, except that Teddy's location was always asked for last. The children were encouraged to indicate the location of the objects with a verbal response, and were encouraged not to touch or point to the receptacle where they thought the object was concealed (they were told they could do this later). On the few occasions that they made no response or said they did not know, the experimenter moved on to the next pairing.

2.2. Results

For each child, the total number of correct responses was noted for the objects (excluding Teddy's pairing), along with whether or not they remembered the location of Teddy. In fact, all 14 children in each of the Character conditions, 3- and 4-year-olds, correctly remembered the location of Teddy, whereas only 6/14 3-year-olds and 7/14 4-year-olds in the Object conditions recalled Teddy's whereabouts. These differences reached significance for each age group on a Yates correct χ^2 test (3-year-olds: $\chi^2 = 8.57$, d.f. 1, $P = 0.003$; 4-year-olds: $\chi^2 = 6.86$, d.f. 1, $P = 0.009$).

The means and standard deviations of correct responses in each age group for Object locations (i.e. excluding Teddy) are shown in Table 1. Children in the Character condition seem to recall the toys' locations better than those in the Object condition.

Two-way ANOVAs were computed on the mean Object location scores for both age groups with age and condition as between subject factors. This revealed a significant main effect of conditions with $F_{(1,52)} = 12.46$ ($P < 0.001$). The main effect of age just failed to reach significance ($F_{(1,52)} = 3.12$, $P = 0.084$), and there was no interaction ($F_{(1,52)} < 1$, NS).

2.3. Discussion

Children in the Character condition performed significantly better than the Object

Table 1
Mean recall of Object locations (excluding Teddy) in Experiment 1[a]

	3-year-olds	4-year-olds
Character	2.00 (1.1)	2.71 (1.06)
Object	1.00 (0.88)	1.43 (1.65)

[a] Values are given as the mean (SD); $n = 14$ in all groups.

group on both memory for objects and memory for Teddy. In fact, all children in the Character condition recalled Teddy's location correctly. This confirmed the first experimental hypothesis. According to this, children in the Character condition consistently recalled where Teddy was sleeping because Teddy had become an important character in the game and so his location was recorded automatically in the Current State Buffer. In the Object condition, Teddy was no more important than any of the other objects and so would be represented in Working Memory, and not in the Current State Buffer. Since Working Memory was already overloaded by the other pairings, memory for Teddy's location was worse for these children than for those in the Character condition.

Subjects in the Character condition exhibited better memory for objects for similar reasons. For them, Teddy's location was stored in the Current State Buffer. For children in the Object condition, Teddy's location was stored in Working Memory. In effect, these children had to store one more pairing than the children in the Character condition, and hence suffered more interference in recalling the objects' locations.

2.3.1. Other explanations

2.3.1.1. von Restorff isolation effect An alternative interpretation of the results that needs some consideration is the possibility that better memory for Teddy in the Character condition is due to a von Restorff isolation effect. This effect is the enhanced memory that is conferred to a distinctive item in an otherwise homogenous list (von Restorff, 1933). In the present study, the very fact that Teddy had become an important character for children in the Character condition, relative to the other toys, could be viewed in this way. Hence, the relatively worse memory for Teddy in the Object condition, where he was equivalent to the other items (objects) in the list.

Analysis of the von Restorff literature, however, indicates that the finding in the present study cannot be attributed to a von Restorff Effect. In this paradigm, there is not only facilitation in memory for the distinctive item, there is a secondary effect on memory for the homogenous items within the 'isolated' list. The trade-off against the boosted memory for the isolated item (the von Restorff Effect) is a decrease in memory for the homogenous items (Wallace, 1965). For example, in a study by Cimbalo, Nowak and Soderstrom (1981), notably a study with a similar memory task and sample to the present experiment, a von Restorff Effect was found with two age groups of children. The children viewed cards of different line-drawn animals, presented successively, with the middle[2] card coloured pink in the isolated condition (and not in the non-isolated list). After each card was presented, it was placed face-down in front of the child. When the last card was placed down the child was given the name of an animal and told to point at the relevant card (i.e. remember the 'location' of the animal). Recall of the isolated pink animal was superior to its line

[2] von Restorff Effects are usually obtained with the isolated item in a central position (as in the Cimbalo et al. (1981) experiment), but can equally be obtained with the isolated item in the first serial position, matching the present study (Hunt, 1995).

drawn equivalent in a non-isolated list – the von Restorff Effect. However, memory for the other animals in the isolated list was worse when compared with memory for the equivalent items in the non-isolated list. This is exactly what one would expect if all the items were competing for scarce resources.

In the present study, then, if one attributed the better performance by the Character subjects in remembering the location of the 'isolated' Teddy to a von Restorff Effect, then one would also predict an accompanying decrement in performance for the other objects. Clearly the increase in correct performance on Object pairings by the Character group that we actually found rules out the von Restorff Effect as a possible explanation of our data.

2.3.1.2. Intentional versus incidental learning One of the more counter-intuitive aspects of the superior performance of the Character group on recall of Teddy's location is the fact that children in this condition were not instructed to remember Teddy's whereabouts. Instead, they just passively watched Teddy go off to sleep in one of the receptacles. However, in the Object condition, children were instructed to remember where Teddy as well as all the other toys were being tidied as they would need to remember this for later. Relevant here, therefore, is the distinction between intentional versus explicit learning (Greene, 1986). It might be claimed that the difference in performance on Teddy in the Character and Object conditions could simply be explained by the difference between an intentional (Object condition) and an incidental (Character condition) learning situation.

The validity of this claim can equally be checked by investigating existing empirical evidence. Neill, Beck, Bottalico and Molloy (1990) have shown that on an explicit memory test, anticipation of the test (i.e. intentional learning) actually facilitates learning relative to not anticipating a test. This would then have predicted better performance on Teddy for children in the Object condition who anticipated a test. In the present study, performance on recalling Teddy's location in the Character condition was facilitated even though this was learnt incidentally and totally unexpectedly.

2.3.1.3. Long-Term Memory Another possible argument against a Current State Buffer explanation is that Teddy's pairing in the Character condition may be seen as a separate event to that of the other Object pairings. On the basis of the framework in Morton et al. (1985), the end of a Teddy event, signalled by his going to sleep, could trigger the creation of a Long-Term Memory representation of what had just happened (for a similar treatment of events, see also Barreau & Morton, 1999). If this were the case, then the independence of memory for Teddy and for the objects in the Character condition would reflect the difference between Short and Long-Term Memory and not between Short-Term (Working) Memory and the Current State Buffer. In Experiment 2, therefore, Emu was introduced to the children prior to Teddy going to sleep, and this was immediately followed with the other Object pairings. The immediate temporal proximity of the Teddy and Object pairings in Experiment 2 would work against the creation of a separate event involving just Teddy's pairing.

2.3.1.4. Guessing There are two aspects to the data in Experiment 1. The first is the perfect incidental memory for Teddy's location, and the second is the increase in performance on the objects. The theory predicted the first, since the Current State Buffer is protected from interference (indeed, it would have no useful function unless this were the case). The question arises, given the former, could the latter be predicted on the basis of guessing alone? Precise calculation would depend on having a detailed theory of task performance. However, a first approximation can be achieved in the following way. Suppose that performance on each object is made up of knowledge, p_k, and guessing, p_g. Then the probability of being correct, p_c, would be given by:

$$p_c = p_k + (1 - p_k)p_g$$

For 3-year-olds, from performance in the Object condition, $p_c = 0.33$ and $p_g = 1/7$. From this, $p_k = 0.22$. The prediction from this for the Character condition involves changing the value of p_g, assuming that the location assigned to Teddy is excluded from consideration. This leaves $p_g = 1/6$. With the same value for p_k in the Character condition as in the Object condition we have a predicted value for p_c of 0.35, with a mean total of 1.05 items per subject. This compares with the value of 2.00 found in Table 1.

For 4-year-olds, the value of p_k is 0.25, and the predicted value of p_c for the Character condition is 0.375 with a total predicted correct of 1.5 items per child. This compares with the value of 2.71 in Table 1.

Slightly higher predictions can be achieved by assuming that the children know perfectly which containers have been used but are uncertain which object is in which container. This puts the guessing value for 3-year-olds in the Object condition at 1/4 (including the location of Teddy), and at 1/3 for the Character condition. The estimated value of p_k drops to 0.11 and the value of p_c for the Character condition rises to 0.41. This gives a prediction of 1.23 objects correct, compared with 2.0 in the data. For 4-year-olds, the guessing values would be 1/5 and 1/4, giving $p_k = 0.197$ and the predicted value of $p_c = 0.398$ in the Character condition. This predicts a total of 1.59 objects correct in the Character condition, compared with the value actually found of 2.71 in Table 1. Note that the prediction from guessing in the Character condition for 4-year-olds is scarcely larger than the data value of 1.43 for the Object condition. While there might be some slight advantage for the Character condition through improvements based on guessing, these come nowhere near to accounting for the observed data.

2.3.1.5. Verbalization In the Teddy condition the experimenter says ''Teddy is going to sleep'' before Teddy is hidden. In all other cases the only thing that is said is ''Are you watching carefully?'' The objects are never named. One referee queried whether the increased verbalization of 'Teddy' could have led to Teddy's location being registered in verbal memory, thus leading to the increase in accuracy for Teddy's location. This does not seem likely to us, since the locations themselves were never named. However, we investigated the effects of naming in the Object condition. This control was run as a variant of Experiment 2 and will be reported after that experiment in Section 3.4.1.

2.3.1.6. Grouping While we have ruled out the von Restorff Effect as a possible account of our data (see Section 2.3.1.1), one referee suggested that there could be other grouping or clustering principles that could be used as an alternative explanation. The general thought is that in the Object condition the 3-year-old child has to remember the locations of four undifferentiated toys whereas in the Character condition there is one group of three toys and a second group of one object, Teddy. The groups would be differentiated by the special interest engendered by Teddy's activities. There might be an advantage in the Character condition solely by virtue of grouping or organization in memory without requiring the Current State Buffer. This would be consistent with many experiments on the effect of organization on word-lists (e.g. Bower, Clark, Lesgold & Winzenz, 1969), resulting in an increase in the performance on Teddy's location and on the objects' locations.

There are a number of possible problems with this idea. First of all, it is doubtful that one can extend the principles underlying the studies of organization found in the literature to the Tidy Emu Paradigm. Does just one item (Teddy as Character) form a separate category in the same way as there are separate (hierarchically organized) categories with several exemplars per category in the organization literature? In addition, there is no precedent for supposing the organizational principles which apply in the free recall of words would also apply to objects whose location was being probed.

Second, it is questionable in any case whether children as young as 3 or 4 years use organizational strategies. For example, Moely, Olson, Halwes and Flavell (1969) showed that only 10- and 11-year-old children display organization at a level that is significantly greater than chance. There are many other studies consistent with this position (e.g. Arlin & Brody, 1976; Cole, Gay, Glick & Sharp, 1971; Lange, 1973). The only evidence for organization at a very young age is where there is a particularly high association between items within a category (e.g. Bjorklund, 1985). Lange (1978) has argued that this is because recall of any particular item more or less automatically triggers recall of closely associated items. In fact, bearing in mind that spontaneous rehearsal does not set in until the age of about 7 years (e.g. Flavell, Beach & Chinsky, 1966; Johnston, Johnson & Gray, 1987), it is not surprising that the discovery or creation of semantic relations between items, which seems to be a more complex and demanding process than rehearsal, arrives even later in development.

A further difficulty with the idea of semantic organization with 3- and 4-year-olds comes from a study by Hitch et al. (1988) who presented a series of pictures of nameable objects to 5-year-olds. Their subjects were sensitive to the visual similarity of the pictures (pen, fork, comb versus doll, bath, glove) but they were *worse* with the organized lists. In addition, these subjects were unaffected by the length of the object names, indicating that there was no phonological re-coding, no rehearsal and (presumably) no semantic reorganization.

Finally, a study by Axia and Caravaggi (1987) seems to argue against the possibility that the subjects in Experiment 1 were capable of semantic organization of the stimuli. In their study, they provide evidence that younger children (4-year-olds were the youngest group) are more sensitive than older ones to the spatial location of items than they are to semantic categories. Hence if the subjects did perform any organization, they would have had a tendency to have done so on a purely spatial basis, and any of these effects would have been cancelled out due to the randomization of the spatial layout of the stimuli and receptacles.

3. Experiment 2

Experiment 2 was similar in nature to Experiment 1 in that it contained the basic Current State Buffer manipulation, but it aimed to clarify the issues that still remained with the explanation given to the earlier results. As stated earlier, children of this age do not usually engage in phonological coding of spatial information (Hitch et al., 1988). However, in the test phase in Experiment 1, children were encouraged to vocalize their responses of the locations. Since this might have affected performance, in Experiment 2 children were instructed to point or to touch the receptacle when probed during the test phase. In this way, we could be more confident that performance on the task would engage the Visuospatial Sketchpad exclusively.

3.1. Subject confidence

A further issue is that the poorer performance of children in the Object condition might be because they have had less time than the children in the Character condition to become comfortable with the experimental situation.[3] Recall that, in Experiment 1, digit span was probed at the beginning of the experimental session for children in the Character condition, as a part of the crucial familiarization with Teddy. In the Object condition, however, the children's digit span was measured at the end of the session. A possible argument is that at the time of the test phase, children in the Character condition will be relatively more familiar and relaxed with the experimenter and the experimental set-up, possibly leading to better overall performance, relative to the Object condition. In Experiment 2, therefore, the time spent prior to the pairings and testing in both conditions was controlled for by introducing the digit span task at the beginning of the session for the Object condition. This was done by employing a different character to Teddy, since Teddy must feature as one of the toys, as in Experiment 1. A completely new character, Simba, a lion, was introduced in Experiment 2, with the sole purpose to probe digit span.

Let us recapitulate the other changes to Experiment 2. First, we varied the Character condition by presenting Emu to the children before Teddy went to sleep, thereby minimizing the possibility of the child treating Teddy sleeping as the end of a separate event (see Section 2.3.1.3). This procedure aimed to minimize the

[3] We are grateful to Alan Baddeley for pointing out this possibility.

possibility of Teddy's location being stored in event memory. In addition, all children were encouraged to point or to touch the appropriate receptacle when probed rather than say where the target was. A summary of Experiment 2 is sketched in Table 2. The new Object condition is called Object(Simba), and the new Character condition, Character.

3.2. Method

3.2.1. Design

The design was identical to that in Experiment 1. The conditions were named 'Object(Simba)' – Teddy as object, and 'Character' – Teddy as character. As with Experiment 1, it was hypothesized that recall for Teddy and recall for objects would be better in the Character condition than in the Object(Simba) condition.

3.2.2. Subjects

The children were 3- and 4-year-old pre-schoolers from a number of local nurseries, representing a cross-section of varied economic status. No child had participated in Experiment 1. As with Experiment 1, there were 28 4-year-olds (two in each of the seven randomizations for the two conditions) and 28 3-year-olds (two in each of the seven randomizations for the two conditions). The mean ages were 3 years, 7 months (range 3 years, 2 months to 3 years, 12 months) and 4 years, 5 months (range 4 years, 0 months to 4 years, 12 months).

3.2.3. Apparatus

The apparatus was as employed in Experiment 1, with the addition of Simba, a baby lion, similar in size to Teddy.

3.2.4. Procedure

The procedure, shown in Table 2, was similar to Experiment 1, but with one major alteration to each of the conditions and one change in the testing phase. The procedures before the testing stage for each condition will be dealt with separately. The testing phase – which was the same for both conditions – will then be described.

Table 2
Summary of Experiment 2 conditions

Character	Object(Simba)
1. Interaction with Teddy	1. Interaction with Simba
2. Naming objects and receptacles	2. Naming objects and receptacles – 'objects' include Teddy
3. Introduced to Tidy Emu	3. Introduced to Tidy Emu
4. Teddy goes to sleep in a receptacle	4. Emu tidies away Teddy
5. Emu tidies away objects into receptacles	5. Emu tidies away objects into receptacles
6. Probed recall of location of objects	6. Probed recall of location of objects
7. Probed recall of location of Teddy	7. Probed recall of location of Teddy

3.2.4.1. Character condition The procedure was similar to that carried out in the first experiment, except that the order of events was changed slightly in order to remove the time gap between Teddy 'sleeping' and the objects being hidden. The first event involved Teddy being introduced and administering the digit span measurement, following which the child named the toys and receptacles. Next, instead of Teddy going straight to sleep, the child was told that Teddy was tired and that they would soon see what he would do next. Teddy was then placed to the side of the toys on the table. At this stage, Emu is presented, as in the previous experiment, with the same commentary. However, just before Emu begins to tidy the toys, the child is told that Teddy is going to sleep. Teddy was then placed by the experimenter in one of the receptacles as in the previous experiment. Immediately following this, Emu begins the pairings as in Experiment 1.

3.2.4.2. Object(Simba) condition This condition was exactly the same as the Object condition in Experiment 1, except that before the naming of the toys and receptacles, the child is introduced to Simba. Subjects are told that Simba is very popular, and that he has so many friends that he needs his own telephone line. The digit span procedure, as carried out in the Character condition in Experiment 1, is then continued, but using Simba instead of Teddy. At the end of the digit span procedure, Simba is placed under the table, out of sight, ''as he needs to go to sleep''. This procedure equalized the amount of time children spent with the experimenter in the two conditions prior to the pairings. Emu is then presented as in Experiment 1, and the objects are tidied away. Subjects were asked at the end of the testing phase where Simba was.

3.2.4.3. Testing of toys' locations The test phase was the same for both conditions in Experiment 2, but the instructions were slightly different to those in Experiment 1. Subjects were told to touch or point to the relevant receptacles when probed, as opposed to instructing them to make a vocal response. The order of probing the objects was the same as in Experiment 1, namely the objects were probed in the order of hiding, followed by probing Teddy. We can represent this as *123(4) Teddy*.

3.3. Results

The total number of correct responses for each child was noted along with whether or not the subject remembered the location of Teddy. As in Experiment 1, all 14 children in each of the Character conditions remembered the location of Teddy, compared with 7/14 3-year-olds and 9/14 4-year-olds in the Object(Simba) condition. Yates corrected χ^2 tests were carried out to investigate whether there was a difference between the Character and Object(Simba) conditions for each of the age groups. Both tests yielded significant differences (3-year-olds: $\chi^2 = 6.86$, d.f. 1, $P = 0.009$; 4-year-olds: $\chi^2 = 3.9$, d.f. 1, $P < 0.05$).

The performance of children on Object locations (i.e. excluding Teddy) are shown in Table 3. Subjects in the Character condition recall the toys' locations better than those in the Object(Simba) conditions. Two-way between-subject ANOVAs were computed on the mean Object location scores, revealing an effect of condition on the

Table 3
Mean recall of Object locations in Experiment 2[a]

	3-year-olds	4-year-olds
Character	2.21 (0.97)	2.71 (1.38)
Object(Simba)	1.43 (1.22)	1.93 (1.33)

[a] Values are given as the mean (SD); $n = 14$ in all groups.

toys' locations ($F_{(1,52)} = 5.65$, $P = 0.021$). There was no main effect due to age ($F_{(1,52)} = 2.29$, NS), and no interaction between age and condition ($F_{(1,52)} < 1$, NS).

3.4. Discussion

Children in the Character conditions performed significantly better than those in the Object(Simba) conditions both on memory for objects and on memory for Teddy. This replicated the findings in the first experiment. As before, these data were predicted on the basis of the function of the Current State Buffer. For children in the Character conditions, this buffer would store the location of Teddy, allowing perfect recall, as Teddy had become an important character to these children. The children in the Object(Simba) group, however, had to store Teddy's location in their Visuospatial Sketchpad and so suffered interference from their recall of the other objects. In addition, Character children had to store one less item in their Visuospatial Sketchpad, and so were able to perform better on the objects. Because children did not produce any spoken responses when probed, the possibility of phonological re-coding is very slight, allowing us to suppose that the representations of the objects' locations would be held in the Visuospatial Sketchpad.

The replication of the basic Current State Buffer dissociation, even after the alterations to the temporal order of Teddy's pairing in the Character conditions, makes it difficult to posit that Teddy's location had been stored in Long-Term Memory. Teddy's pairing occurred immediately before the other Object pairings and therefore was unlikely to have become a separate event.

The claim that the difference in performance in Experiment 1 between the two groups can be accounted for by the difference in time spent in the experimental situation can also be ruled out. In the Object(Simba) conditions, children spent equally as long in the experimental set-up before they observed the pairings and were tested on them. Nevertheless, the difference in performance was still found.

Finally, a little word about the fate of Simba. At the time that Simba interacted with the children, he would have an entry in the Current State Buffer in just the same way as Teddy would in the Character conditions. Simba then goes off to sleep underneath the table. The experimenter just remarks on this event as it happens but gives no indication to the child that this location has to be remembered. The focus of interest immediately returns to the table top, and it is of interest whether the entry for Simba would be maintained in the Current State Buffer throughout the hiding and finding part of the task, in spite of Simba having, effectively, left the scene. In fact, after the experiment, the experimenter asked the children in the Object(Simba) condition where Simba was. Of the 3-year-olds, 12 out of 14 were correct and for the 4-year-olds, 14 of 14 were correct. Moreover, this level of recall of Simba's location did not seem to interfere with these subjects' recall of the Object locations as the average recall for objects in Experiment 2 was 1.68 across both age groups, and when Simba was not present (Experiment 1) performance was actually lower at 1.33 (independent t-test: $t(54) = 1.33$, NS). Thus, it can be seen that the incidental storage of Simba's location is maintained for the vast majority of the children, without affecting their Object performance, in spite of Simba's having departed the scene.

3.4.1. Verbalization – Sub-experiment 2v

As mentioned in Section 2.3.1.5, we ran a condition to test the effects of the experimenter verbalizing the name of an object. This condition was run in exactly the same way as the Object(Simba) condition in Experiment 2, but using only 3-year-olds. The one difference from the Object condition in Experiment 2 was that for one of the four objects the experimenter said ''Now Emu will put the car/cat/crayon away'' with the name of the object used explicitly (the fourth object was a teddy, but this was never named). For the other three objects, the simple ''Are you watching carefully?'' was used that had been used for all the objects in Experiment 1 (see Section 2.1.4.4). The position of the named object was varied. Twelve children were tested. Only seven of the 12 children pointed to the correct location of the named object with a probability of 0.58. This compares with 12 out of 12 children correctly locating Teddy in Experiment 1. The 2×2 table comprising these data has a probability of 0.0186 (one-tailed), indicating that naming an object does not have the same effect as animating Teddy. For the unnamed objects, the probability of being correct was 0.42, which compared with 0.74 in the Character condition of Experiment 2. On a Mann–Whitney test the difference between these two was significant ($U = 41.5$, $z(12, 14) = 2.19$, $P = 0.029$). Thus, while naming an object gave it a slight advantage over the other objects, the data still resemble the Object condition of Experiment 2 (where the probability of being correct was 0.48) rather than the Character condition. When we also consider that in this extra Verbalizing condition the memory instructions were explicit, whereas memory for Teddy's location was incidental, we feel justified in concluding that verbal memory did not play a role in the memory for Teddy's location.

4. Experiment 3

4.1. Recency effects

The notion of a Current State Buffer has some similarities to a construct mentioned by Baddeley and Hitch (Baddeley, 1986; Baddeley & Hitch, 1993). These authors invoke the ubiquitous *recency* effect to explain one's orientation in time and space. The recency effect refers to the increased memory performance for the last item (and sometimes items) in a list (Glanzer, 1972). Baddeley and Hitch's idea is that we possess recency effects for every aspect of our lives; we know what day it currently is, as it is the most recent, we know where we parked our car as it is the most recent place that we have parked our car, and so on. The implication is that one can have multiple recency effects for all types of event in our lives. As part of the support for this contention, a study by Watkins and Pernicióuglu (1985) is cited, where multiple recency effects were found for different types of categories of items.

It is possible to argue that the results from Experiment 1 could be explained along these lines. The argument would be that when Teddy is animated for the Character children, he forms a category of items that is distinct from the other objects. The question of what criteria are necessary to create a separate category for multiple recency effects is in fact raised by Watkins and Perniciouglu (1985), and these authors have conceded that the boundary is unclear and that they needed to work very hard to design stimuli which gave rise to multiple recency effects. For the sake of argument, however, we might assume that the Teddy and object manipulation is sufficient to create two separate categories of item. This would mean that the location of Teddy would have a distinct recency effect associated with it as a member of the category of significant objects. Therefore, children in the Teddy-as-Character conditions would be expected to recall his location better than children in the Object group for whom Teddy is just another object. In summary, recency effects would be expected for both Teddy-like and Object-like items in the Character conditions, but there would be just one recency effect for Object-like items in the Object condition.

The aim of Experiment 3, therefore, was to assess this claim by inducing a recency effect when probing locations, and then compare the predictions of a multiple recency effect with that of the Current State Buffer effect. Recall that, in the first experiment, the objects were probed in the order in which they were hidden, meaning that the most recent object was probed the last (excluding Teddy). In order to induce a recency effect, the order of probing was designed such that recency effects were maximized (these conditions are termed Character(Recency) and Object(Recency)). Specifically, the order of probing proceeded in the reverse order of hiding, with the last object hidden being probed first and so on (*(4)321 Teddy*). The position of Teddy's hiding and probing was kept as it was in the first two experiments. This difference in the order of item probing is illustrated in Table 4, contrasting children in Experiment 3 with those in Experiments 1 and 2.

The nature of multiple recency effects is relevant to assessing this interpretation of the results. As stated above, Watkins and Perniciouglu (1985) produced multiple

Table 4
Order of Object probing in the three experiments

Age group	Experiment number	Items hidden	Items probed
4-year-olds	1 and 2	T1234	1234T
	3	T1234	4321T
3-year-olds	1 and 2	T123	123T
	3	T123	321T

recency effects. In their study, they interwove three different categories of lists together into one long list, and tested for recall of each category. They documented that multiple recency effects result in lower recall of all of the final items compared with that found in a single category. In addition, the category that was cued first was better recalled. In the present study, therefore, it will be important to investigate recency effects for the objects in the Object(Recency) condition. These approximate to a single category. Similarly, it is necessary to investigate the nature of the recency effects for both Teddy and the Objects in the Character condition. This would approximate, according to the terms of Baddeley and Hitch (1993), to a multiple recency effect.

If the findings in Experiment 1 were indeed simply attributable to a multiple recency effect, one would predict, from Watkins and Pernicciouglu (1985), that overall performance in the single category list (Object(Recency) condition) will be better than that of the multiple category list (Character(Recency) condition). Next we consider that in Watkins and Pernicciouglu (1985), the category which was cued first was better recalled. By analogy, this predicts that because the Teddy category is cued last in the Character(Recency) condition, 'recency' will be lower than the final item of the Object category, which is cued first. Under our theory of the Current State Buffer, we would predict the opposite result, a pattern similar to that found in Experiments 1 and 2, irrespective of recall order.

Based on the previous experiments, it is predicted that overall performance in the single category list (Object(Recency) condition) will be worse than that of the multiple category list (Character(Recency) condition). Similarly, it is predicted that although the Teddy category is cued last in the multiple recency situation (Character(Recency) condition), 'recency' will be higher than the final item of the Object category, which is cued first.

4.2. Teddy's toys

Another possible problem with Experiments 1 and 2 is that performance may be superior in the Character condition simply because the objects involved are presented as Teddy's objects. The fact that in the Object conditions the objects do not belong to anyone in particular may have resulted in a reduced performance in remembering the items. The claim here is that the more meaningful schema of Teddy's toys confers an advantage on their subsequent processing. Therefore, in Experiment 3, children are told that the toys in the Object condition belong to Simba. All other aspects, apart from the order of probing, remain the same as in Experiment 2.

4.3. Method

4.3.1. Design

The design was identical to that of Experiment 2. The only change was a renaming of the two conditions that manipulated the nature of the extra pairing. The conditions were Object(Recency) – Teddy as object, or Character(Recency) – Teddy as character.

4.3.2. Subjects

Individual participants were different to those used in Experiments 1 and 2, but also consisted of 3- and 4-year-old pre-schoolers from a number of local nurseries, representing a cross-section of varied economic status. As with former experiments there were 28 4-year-olds (two in each of the seven randomizations for the two conditions) and 28 3-year-olds (two in each of the seven randomizations for the two conditions). The mean ages were 3 years, 7 months (range 3 years, 0 months to 3 years, 12 months) and 4 years, 5 months (range 4 years, 4 months to 4 years, 12 months).

4.3.3. Apparatus

The apparatus were the same as employed in Experiment 2.

4.3.4. Procedure

The procedure was identical to Experiment 2 apart from the order of testing for locations. The order was the reverse order with respect to hiding (see Table 4).

4.4. Results

The total number of correct responses for each participant was collected (out of the number of objects paired, excluding Teddy's pairing), along with whether or not the participant remembered the location of Teddy. All 14 children in each of the Character(Recency) conditions remembered the location of Teddy, compared with 5/14 3-year-olds and 4/14 4-year-olds in the Object(Recency) conditions. Yates corrected χ^2 tests were carried out to investigate whether there was a difference between the conditions for each of the age groups. Both tests yielded significant differences (3-year-olds: $\chi^2 = 10.48$, d.f. 1, $P = 0.002$; 4-year-olds: $\chi^2 = 12.6$, d.f. 1, $P < 0.001$).

The means and standard deviations of correct responses in both age groups for Object locations are shown in Table 5. Children in the Character(Recency) conditions recall the toys' locations better than those in the Object(Recency) conditions. A two-way ANOVA revealed a significant effect of condition on recall of the toys' locations ($F_{(1,52)} = 7.03$, $P = 0.039$). There was a main effect due to age ($F_{(1,52)} = 4.50$, $P = 0.039$), and no interaction between age and condition ($F_{(1,52)} = 0.28$, NS).

Table 5
Mean recall of Object locations in Experiment 3[a]

Condition	3-year-olds	4-year-olds
Character(Recency)	1.64 (1.01)	2.36 (1.15)
Object(Recency)	1.07 (1.00)	1.50 (0.85)

[a] Values are given as the mean (SD); $n = 14$ for every cell.

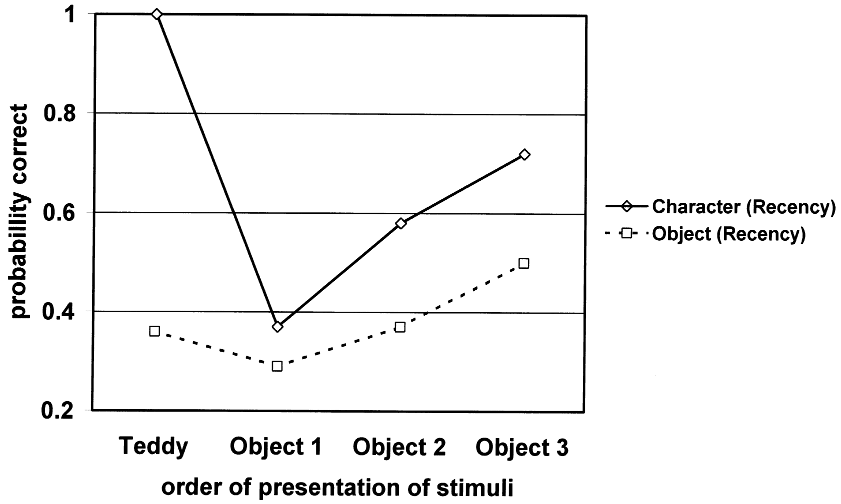

Fig. 1. Three-year-olds' recall of items according to item presentation order. Recall order was *321 Teddy*.

4.4.1. Recency

Mean correct responses were plotted as a function of item presentation order for the two conditions in Fig. 1 (3-year-olds) and Fig. 2 (4-year-olds). The mean correct recall of the final (recency) item of both conditions for both age groups was compared with the mean probability of correct recall of Teddy, presented in Table 6.

There is a recency effect for both 3- and 4-year-olds in both conditions, much

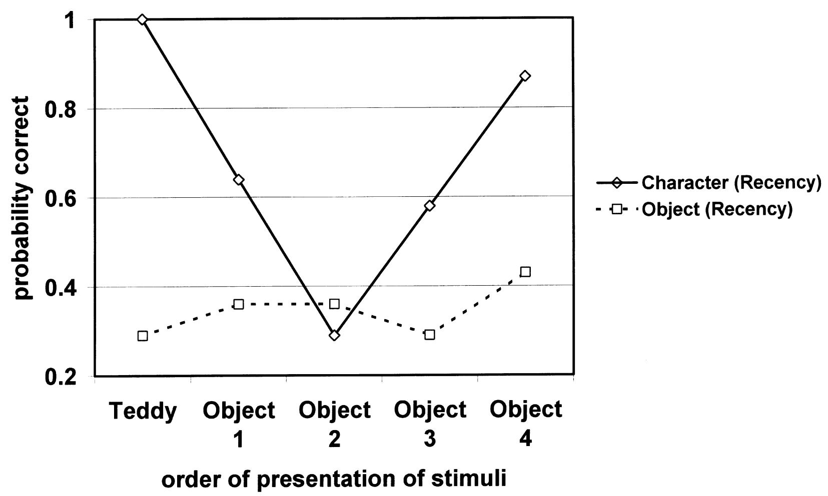

Fig. 2. Four-year-olds' recall of items according to item presentation order. Recall order was *4321 Teddy*.

Table 6
Mean correct probability of recall of the most recent object and of Teddy in Experiment 3[a]

Condition	3-year-olds		4-year-olds	
	Last object	Teddy	Last object	Teddy
Character(Recency)	0.7 (0.47)	1.0 (0)	0.9 (0.36)	1.0 (0)
Object(Recency)	0.5 (0.52)	0.4 (0.5)	0.4 (0.5)	0.3 (0.5)

[a] Values are given as the mean (SD); $n = 14$ for every cell.

more marked in the Character conditions. The probability for both 3- and 4-year-olds recalling Teddy's location was not significantly different from the probability of recall of the last Object's location (first recalled) in the Character(Recency) conditions (sign tests, $n = 14$ for both groups; 3-year-olds: $z = 1.5$, NS; 4-year-olds: $z = 0.71$, NS).

The main point to note is that for the Character(Recency) children, performance was not *worse* on recalling Teddy's location, relative to recalling the location of the last item. Since the location of Teddy was recalled after the objects, Watkins and Pernicciouglu (1985) would have predicted that Teddy would be worse recalled.

Table 7 compares the overall mean performance of all the children in Experiment 3. The means comprise the subjects' total overall score on all the objects (out of three or four), plus their score on Teddy. A two-way between subjects ANOVA was computed, indicating that there was an advantage for overall performance for subjects in the Character(Recency) conditions ($F_{(1,52)} = 24.26$, $P = 0.001$). There was no age effect ($F_{(1,52)} = 3.59$, NS) or interaction ($F_{(1,52)} < 1$, NS).

4.5. Discussion

The results replicated the previous two experiments with the basic Current State Buffer and Working Memory contrasts. One important change was that in the Object(Recency) condition the objects were referred to as Simba's toys. Although this might have led to an improvement in performance in the Object(Recency) condition by making the objects more important, performance in this condition was actually similar to that in the parallel conditions in the first two experiments.

The results also displayed recency effects for the Objects, as indexed by an increase in memory for the final item (final with respect to presentation order – but actually the first item to be probed). Although Teddy's location in the Charac-

Table 7
Mean recall of the location of all items for children in Experiment 3[a]

Condition	3-year-olds	4-year-olds
Character(Recency)	2.64 (1)	3.36 (1.15)
Object(Recency)	1.43 (1.22)	1.79 (0.8)

[a] Values are given as the mean (SD); $n = 14$ for every cell.

ter(Recency) condition was probed last, performance was better than on the recency item of the toys. This goes against the prediction based on Watkins and Perniciouglu (1985), and suggests that the increased performance of Teddy does not have anything to do with recency effects in the sense used by those authors. This belief is further strengthened by the finding that overall performance was worse in the 'one category' recency condition of the Object(Recency) children, whereas a recency account based on Watkins and Perniciouglu (1985) would predict that the 'multiple recency' condition in the Character(Recency) condition would lead to worse performance.

5. Overview of results of the three experiments

In Table 8 we summarize the data from all three experiments on recall of objects. A three-way between subjects ANOVA on this data (factors age, condition and experiment) showed a significant effect of age ($F_{(1,156)} = 9.41$, $P < 0.001$) and of condition ($F_{(1,156)} = 24.36$, $P < 0.001$) but no effect of experiment ($F_{(1,156)} = 1.99$, NS) and no significant interactions. Planned comparisons of the age groups separately gave significant differences between the Character and Object conditions for both 3-year-olds ($F_{(1,156)} = 9.69$, $P = 0.002$) and 4-year-olds ($F_{(1,156)} = 14.96$, $P < 0.001$).

5.1. Digit span

The mean digit spans of subjects averaged over the three experiments were 3.33 and 4.31 items, respectively, for 3- and 4-year-olds in the Character condition and 3.20 and 4.26, respectively, in the Object condition. A two-way ANOVA with age and condition as independent variables was computed on digit span. This revealed a main effect of age ($F_{(1,164)} = 35.96$, $P < 0.001$) but not for condition ($F_{(1,164)} < 1$, NS). The interaction was not significant ($F_{(1,164)} < 1$, NS). The age-related shift in Visuospatial Sketchpad performance of one item is thus complemented by the increase in Phonological Loop span of about one digit. These data are consistent with those of Chi (1978). The ANOVA on digit span also demonstrates that children in the Character condition did not differ from children in the Object condition on performance in this task, suggesting that children in the two conditions were equiva-

Table 8
Mean recall of Object locations in all experiments[a]

Experiment	3-year-olds		4-year-olds	
	Character	Object	Character	Object
1	2	1	2.71	1.43
2	2.21	1.43	2.71	1.93
3	1.64	1.07	2.36	1.5

[a] $n = 14$ for every cell.

lent in terms of general Working Memory capacity. A Spearman's rank order correlation was calculated on digit span and Object location performance, failing emphatically to reveal a correlation between the two measures ($n = 168$, $r = 0.09$, NS). This gives reason to suggest that visuospatial and phonological Working Memory capacities are dissociable in children of a relatively young age, and is consistent with the results of Pickering et al. (1998).

5.2. Working Memory performance in all three experiments

Working Memory performance in each experiment can be roughly calculated by adding together the Object and the Teddy scores of children in the Object conditions, and taking the Object scores only of children in the Character conditions. This simply follows from the basic assumption behind all three experiments, namely that in the Character conditions the Visuospatial Sketchpad is used for the Object pairings and the Current State Buffer is used for the Teddy pairings. Children in the Object conditions use the Visuospatial Sketchpads for both tasks. These Working Memory performances are tabulated in Table 9.

A three-way ANOVA (factors age, condition and experiment) was conducted on the data. It revealed significant effects of age ($F_{(1,156)} = 8.41$, $P = 0.004$) and condition ($F_{(1,156)} = 5.21$, $P = 0.02$), but not for experiment ($F_{(1,156)} = 2.82$, NS). No interactions were significant. The age effect mirrors the developmental shift in Working Memory capacity expected between the ages of 3 and 4 years. The fact that there is still a difference between the two conditions in Working Memory performance is somewhat surprising, but the decrement in Working Memory performance for children in the Object conditions may be due to the fact that, according to our view, their Visuospatial Sketchpads are more overloaded, and this could result in a reduction in useful capacity.

6. General discussion

Our starting point was the proposal that representations of important features of the environment are automatically registered. In the three experiments presented here, involving 180 children, we have shown that memory for the location of a character with whom children have engaged is independent of memory for the

Table 9
Mean Working Memory performance in all experiments[a]

Experiment	3-year-olds		4-year-olds	
	Character	Object	Character	Object
1	2	1.43	2.71	1.93
2	2.21	1.93	2.71	2.57
3	1.64	1.43	2.36	1.79

[a] $n = 14$ for every cell.

location of other objects. In theoretical terms, we have concluded that the Current State Buffer is distinct from the Visuospatial Sketchpad component of the current Working Memory model of Baddeley and Hitch (1993).

We have considered the possibility that the data could be accounted for on the basis of the von Restorff Effect or in terms of incidental versus intentional learning. These were ruled out since the basic pattern of data in the present experiments simply does not correspond to that found in the relevant literature on those topics. We also considered our data as a phenomenon involving a memory record (autobiographical memory) and in terms of a generalized recency effect, along the lines of Baddeley and Hitch (1993), or as due to verbalization. The modifications in procedure we introduced to Experiments 2 and 3 make these accounts relatively implausible, compared with the simple account based on the Current State Buffer.

In thinking about the contribution of general Long-Term Memory structures to the task, it may be argued that the superior performance of children in the Character conditions can be explained in these terms. For example, perhaps these children benefit from the documented effects of scene schemata on memory for spatial representations. Mandler (1983) has emphasized the importance of general world knowledge in remembering the locations of objects, and this has generated studies on children's memory for Object locations. Mandler (1983) postulates that knowledge is organized in scene schemata. They are activated whenever spatial information is presented in the usual, i.e. everyday, way. In this context, two developmental studies (Mandler & Robinson, 1978; Mandler & Stein, 1974) demonstrate that organized scenes are easier to recognize than disorganized scenes. However, this particular 'Long-Term Memory' explanation is unsatisfactory to account for the present set of results because the task is totally novel for the children and so no existing scene schemata will exist. In addition, it is not clear why children in the Character condition would benefit more from scene schemata than children in the Object condition as the physical scene layout of Object pairings did not vary between the Character and Object conditions and, in Experiment 1 at any rate, the cover narrative was more complex, interactive and unusual in the Character condition.

Another way of considering a 'Long-Term Memory' explanation of the results is to consult contemporary frameworks in which 'Long-Term Memory' contributes to Working Memory functioning. One such framework is that of Hulme (e.g. Hulme, Maughan & Brown, 1991). In their study they found a *lexicality effect* (i.e. a recall advantage for words over non-words) and concluded that this must arise from the additional long-term knowledge one possesses about the familiar words (Brown & Hulme, 1992; Hulme et al., 1991). This framework could not directly explain the findings of the present experiments. Hulme's studies highlight Long-Term Memory advantages for *lexical* representations, and one would have to contend that the representation of Teddy's location is essentially phonological (a possibility that has been ruled out elsewhere). In addition, Hulme's studies involved intentional learning, and recall of Teddy's location is incidental. A slight variation on this theory (which is similar in many ways to 'scene schemata', as mentioned above) might say that the imperfect representation of Teddy's location is 'filled in' by semantic knowledge about the receptacle. This also does not seem plausible, as Axia and Caravaggi (1987) have shown that 4-year-olds are not sensitive to the semantic details in spatial arrangements as they concentrate more on the spatial aspects. In addition to all this, even if there is some 'filling in' Teddy's location in the Character conditions, why should performance on Object locations in these conditions also be better?

The 'Long-Term Working Memory' of Ericsson and Kintsch (1995) is another framework in which the hybrid 'Long-Term Working Memory' is employed. This framework deals with skilled activities such as text comprehension and chess-playing. These authors contend that performance in these tasks must be aided by the use of Long-Term Memory for the storage of immediately accessible information which can easily be retrieved back into Short-Term Memory. However, it is somewhat problematic to try and compare these tasks to the Character conditions of the current tasks and contend that the children were employing their 'Long-Term Working Memory' for storing Teddy, which gave them the advantage over the children in the Object conditions. The children in the current studies were not familiar with the task, and as stated above, Long-Term Working Memory is employed when one is at the 'expert' level and presumably very familiar with the task. Furthermore, the comparison breaks down because the examples of 'Long-Term Working Memory' are all complex knowledge-rich tasks. In the current paradigm, the task is simply just one of memory.

Now that the Current State Buffer has been established as independent from Working Memory, its capacity needs to be explored. This would be another feature of the Current State Buffer which would distance it from Long-Term Memory. Such experiments have been carried out by employing the existing design, but having more than one character being hidden in the receptacles. We found a limited capacity for the Current State Buffer with both 3- and 4-year-old children together with complex interactions between the Current State Buffer and Working Memory when the former was overloaded (Abeles, 1999). These data will be reported elsewhere.

It should be noted that the Current State Buffer is not restricted to animate beings. Animating Teddy seemed to us, à priori, to be a likely way of engaging the child. We would imagine that a promised piece of chocolate would have the same properties, as in the Smarties task. As we noted in Section 1, in the Smarties task, children are presented with a Smarties tube and asked what they think is in it. We supposed that they form a representation of the contents in the Current State Buffer in some form such as IN(tube, Smarties). They are then shown that the contents are pencils. When asked immediately afterwards about their initial belief, they can no longer recall Smarties. We proposed that this inability of a 3-year-old to remember the initial belief is because the Current State Buffer representation is updated to something like IN(tube, pencils), with the previous representation being deleted. Animacy, then, was a convenience, not a necessity, in the present experiments. For adults, we would expect that the location of a promised sum of money or of an important document or loved one would also be automatically tracked in the Current State Buffer.

We should reiterate that the Current State Buffer was originally conceived of through introspection on the adult processing system. We ran our experiments with children because they have more restricted meta-processing abilities and are less likely to reflect on what is happening and so would be more likely to pay full attention to the Object location task. An adult who started thinking ''I wonder if I am supposed to remember where Teddy is?'' would end up with a representation of Teddy in Working Memory (as well as the representation in the Current State Buffer) and a resulting impairment in the Object location task. In our experience, 3- and 4-year-olds are very unlikely to adopt such strategies. Equally, it is important to remember that tracking Teddy is an incidental task. If the children had been asked to remember Teddy's location, we would expect that information would be put in the Visuospatial Sketchpad as well as remaining in the Current State Buffer, and performance of the objects would have been impaired. Here, then, is a take-home message for cognitive psychologists: if one believes (as we do) that there is little or no development of memory structures with age, but that what develops are meta-abilities, then what this paper illustrates is that use of pre-schoolers is a very effective way of having a clean look at structure without interference from the subject's strategies.

Finally, we should note that the Current State Buffer was conceived of within an information processing framework which includes Headed Records (Morton et al., 1985). However, the concept of the Current State Buffer itself does not depend on the framework, nor is it necessary that the Current State Buffer is localized cortically. For people who theorize within other frameworks, it would, without doubt, be possible to construct an alternative way of representing information characterized at one and the same time as being important and transitory. Such a representation would be equivalent to the Current State Buffer because it would have to perform the same function. The location of Teddy is tracked because Teddy is important to the children. It is *tracking* because Teddy may move on. In the same way, when the 3-year-old discovers that the Smarties tube actually contains pencils, the Current State Buffer representation is updated, and the previous belief is lost. It is this combination of importance and transitoriness which uniquely characterizes information in the Current State Buffer.

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