CHILD DEVELOPMENT

Child Development, March/April 2010, Volume 81, Number 2, Pages 457–463

Not Doing What You Are Told: Early Perseverative Errors in Updating Mental Representations via Language

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This research examined the ability of young (N = 96) children to learn about a change in the location of a hidden object, either via an adult's verbal testimony or from direct observation. Thirty-month-olds searched with equal accuracy whether they were told about the change or directly observed it. By contrast, when 23-month-olds were told about the change of location, they often returned to the container where they had last observed the object—even when that container was visibly empty. When interference from prior observational encoding was minimized, 23-month-olds, and even 19-month-olds, successfully updated their knowledge of the object's location on the basis of language. The processing demands of updating experience-based representations from new verbal information are discussed.

A century of research has revealed marked developmental changes in children's ability to update their knowledge of an object's location. We review those developmental changes and then discuss an important gap in our understanding of such updating.

One-year-old infants can watch an object being hidden and search correctly some 5–10 s later (Hunter, 1917). Indeed, they search correctly at successive locations, provided the delay between hiding and search trial is brief (Diamond, 1985; Harris, 1973). In the 2nd year, infants can keep track not just of visible displacements but also of invisible displacements. If an object is carried in a container (Haake & Somerville, 1985; Piaget, 1954), infants search at potential hiding places along the route of the transported object. Toddlers can even decode symbolic information about an object's displacement. For example, if a miniature toy dog is hidden at a particular location in a scale model of a room, 36-month-olds—but not 30-month-olds—treat that information as a representation of where a larger toy dog can be found in a full-size room (DeLoache, 1987, 2004).

We thank the children who participated and their parents. We also thank Jasmine DeJesus, Carina Wind, and the undergraduate research assistants at the Language & Learning Lab at Boston University for their help with data collection and coding.

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Thus, there are major developments in the information that children use to update their knowledge of an object's location: 12-month-olds process an object's visible displacements; 18-month-olds process hidden displacements signaled by movements of a container; 3-year-olds decode the implications of a symbolic displacement—the movement of an object within a scale model. These changes suggest an emerging capacity to entertain more than one mental model of the world. Thus, theorists have proposed that infants entertain a single model but during the 2nd and 3rd years start to process more than one model: They compare successive sightings of a container to infer the hiding place of an object or they map the location of an object within a scale model to its location in a larger space (Perner, 1991; Suddendorf & Whiten, 2001).

Despite these changes, we know little about children's ability to update their knowledge of an object's location via language. Yet children do update on the basis of verbal input well before they use the symbolic information in a scale model. For example, having learned the name for a toy, toddlers went to an adjacent room where they were told that it had undergone a change (become wet). On their return, 22-month-olds, but not 19-month-olds, indicated the wet toy as opposed to a dry exemplar when asked for it by name (Ganea, Shutts, Spelke, & DeLoache, 2007).

We modified this paradigm to compare children's ability to update their knowledge of an object's location on the basis of verbal testimony or direct observation. In the testimony condition, we asked if 23- and 30-month-olds who had seen an object placed in location A would search at location B, if they were told—during their brief absence from the room—that the object had been moved from A to B. In the direct observation condition, children observed the change of location for themselves.

We expected toddlers to successfully search for the object at the new location in the observation condition. This corresponds to the classic ''A-not-B'' search paradigm, which children solve by the middle of the 2nd year. In the testimony condition, by contrast, two possible outcomes were anticipated. Children might update their initial representation of the object's location on the basis of language and correctly search for it at B. Such competence would be consistent with the findings of Ganea et al. (2007).

Alternatively, children might have difficulty with verbal updating, particularly when the revision of a prior, observation-based representation is required (Zelazo, Sommerville, & Nichols, 1999). On this hypothesis, children should initially search at A despite having been told that the object is at B. Only when prompted to search further might children turn from A to B. The executive difficulties faced by infants aged 9–12 months in searching at an object's most recent location, particularly in the face of interference from a prior representation, have long been entertained as an explanation for errors in the A-not-B search paradigm (Aguiar & Baillargeon, 2000; Diamond, 1985; Harris, 1973; Marcovitch & Zelazo, 1999, 2009). We anticipated that such difficulties might re-emerge if information about an object's new location were provided via language rather than direct observation.

Study 1

Method

Participants

Twenty 23-month-olds (9 girls, range = 22.4–24.7, M = 23.5) and sixteen 30-month-olds (9 girls, range = 28.3–33.3, M = 30.6) were tested. Five children were excluded—for fussiness (4) or lack of English proficiency (1). The majority were White, middle class, and English-speaking.

Materials

Four hiding locations were used: one green pillow on top of a brown couch, a three-drawer cabinet, a blue ottoman (called ''chair''), and a wicker basket. For 30-month-olds, the basket was replaced by a beige box with a removable lid, a green cloth bag was placed on top of the ottoman (referred to as ''bag''), and the green pillow was replaced with a black pillow. These changes were made because the 30-month-olds were overly interested in the basket during pilot testing and seemed confused when the experimenter called the ottoman a chair.

An opaque curtain was hung in the room to create an inner space (218 × 113 in.) containing the hiding locations and an outer space (34 × 113 in.; see Figure 1). A transparent plastic window was inserted in the curtain (8.5 × 11 in.), 44 in. from the

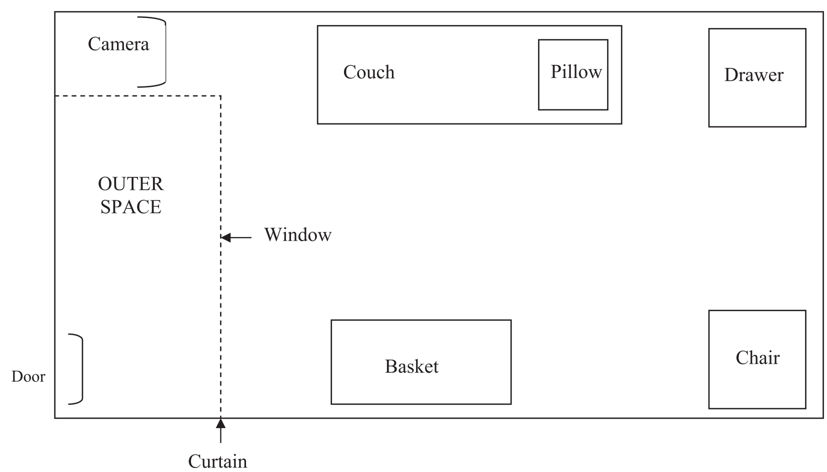

Figure 1. Illustration of experimental room layout.

ground. Children could not see through it unless lifted by an adult. Two stuffed animals served as hiding objects: a black and white puppy and a brown monkey. One camera was placed near the curtain to record the experimental session.

Procedure

The 23-month-olds received the two conditions (testimony and direct observation) in counterbalanced order. The 30-month-olds received the testimony condition first (during piloting children were distracted during the testimony if they had previously watched through the window in the direct observation condition). Each condition was presented following a familiarization phase.

Familiarization phase. Two experimenters sat with the child in the inner space, with the parent in the outer space. The familiarization phase was designed to ensure that children were aware of the four hiding locations and remembered the initial hiding location of the toy. To introduce the child to the hiding locations, the experimenters played a hiding game. One experimenter (E1) hid a toy with the child in one of the four locations (e.g., behind the pillow), while the other experimenter (E2) covered his or her eyes. After the hiding, E1 asked the child to show E2 the location of the toy. This game was repeated for all four locations.

E1 and the child then hid the toy a final time. E1 asked the child to point out each of the four hiding locations (e.g., ''Can you show me the basket?'') and the hidden animal (e.g., ''Can you show me where the puppy is?''). If the child did not indicate the animal's location, E1 showed the child where the animal was, returned it to its location, and asked the child to identify the location again. If the child failed a second time, the session continued but the child's data were excluded. Then E1, the child, and the parent moved behind the curtain for the test phase.

Test phase. The child participated in two conditions—testimony and direct observation. In both conditions, E2 moved the toy from its hidden location diagonally across the room to a new location (e.g., from the pillow to the chair). In the testimony condition, E1 looked through the window and told the child about the change in location: ''Look *E2* is moving the puppy! *E2* is moving the puppy from the pillow to the chair. The puppy is behind the chair. Yeah the puppy is behind the chair!'' In the direct observation condition, the child was lifted up to the window and told: ''Look *E2* is moving the puppy! *E2* is moving the puppy to a new place. Now the puppy is in a new place!'' Note that the verbal information in the direct observation condition did not identify the new location of the toy, only the fact that the toy was moved. For 30-month-olds, E1 used less verbal input during the direct observation condition—''Let's see what *E2* does in there. Do you see her? Look!'' The input given to younger children was judged to be redundant for older children. Then, E1 asked the child to get ready to find the toy and opened the curtain to allow the child to search. If the child did not find the toy on the first try and did not continue to search, she or he was prompted to continue searching (''Do you remember that she moved the puppy? Where is it?'').

The procedure was repeated for the other test condition with the other stuffed animal. As in the previous condition, E1 hid the toy and asked the child to point out the four hiding locations and the location of the hidden toy. After the child identified the toy's location, E1 proceeded with the test phase. The hiding locations for this phase were the remaining two not used in the first trial and the child received the opposite condition from the first trial. Across the three studies reported here, there was no effect of order of conditions on search behavior.

Coding

Films of test sessions for all three studies were coded to identify children's search behavior. Interrater agreement ranged from 94% to 100% (Cohen's kappa = .85–1.00). Disagreements were resolved by another person.

Results and Discussion

We used chi-square or binomial tests to compare children's search in the two conditions with chance levels (for the first response, chance was set at .25 because there were four possible locations to search; when children searched a second time after an error on their initial search, chance was .33).

When children directly observed the change in location, both younger (20 of 20) and older children (14 of 16) searched correctly (binomial tests, $p < .01$; see Figure 2). However, when children were told about the change, few of the younger (4 of 20) but most of the older (12 of 16) children used the verbal information to search correctly ($p < .01$). A chi-square test confirmed that the proportion of children searching correctly in the testimony condition was larger in the older than in the younger group, $\chi^2(1, 36) = 8.77$, $p < .001$.

Of the 16 younger children who failed to search correctly, most (87%) searched in the initial location

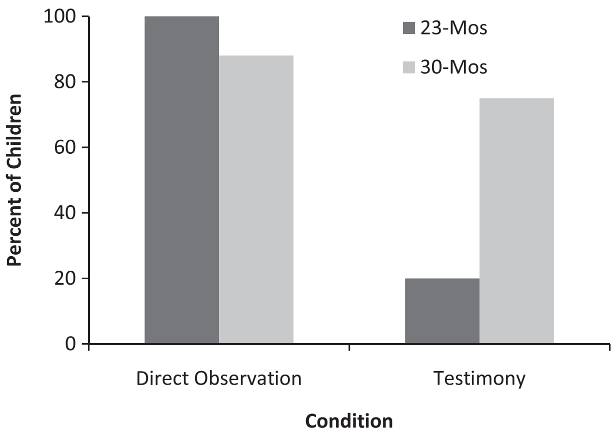

Figure 2. Percentage of children in each of the two conditions who searched correctly in the new location in Study 1.

of the toy ($p < .01$). On their second search attempt, 50% of children searched correctly. Thus, some children may have successfully encoded the new location. However, caution is needed in interpreting this finding because the number of correct second choices was not significantly different from chance, $\chi^2(1, 16) = 2.09$, $p = .14$.

Why did most 23-month-olds not use the verbal information for their initial search? According to the second hypothesis described earlier, toddlers' utilization of verbal information about the new location was prone to interference from the visual representation of the object's initial location. However, children may not have understood the testimony in the first place. This interpretation seems unlikely because Ganea et al. (2007) showed that 23-month-olds can understand verbal information about an invisible change. However, testimony about a location change may be harder to understand than testimony about a state change (i.e., dry to wet).

Study 2 was designed to discriminate between these two interpretations. At the end of the familiarization phase, the toy was left in the middle of the room. If children's utilization of verbal testimony in Study 1 was prone to interference from a prior visual representation of the object's specific location, interference should be reduced in Study 2 because there was no specific prior location. Thus, if children can understand verbal information about a toy's displacement, they should search correctly. However, if children cannot understand information about a location change (as opposed to a state change) they should fail to search correctly.

Because 30-month-olds responded accurately in both the visual and verbal conditions of Study 1, they were not included in Study 2. Instead, to probe the origins of toddlers' updating skills, 19-month-olds were also tested. Recall that the 19-month-olds tested by Ganea et al. (2007) did not respond systematically when given information about a state change.

Study 2

Method

Participants

Sixteen 23-month-olds (9 girls, range = 22.0–24.4, $M = 23.0$) and sixteen 19-month-olds (9 girls, range = 18.3–20.9, $M = 19.4$) were tested. Ten children were excluded—for fussiness (8) or lack of English proficiency (2).

Materials

Materials were the same as in Study 1, except that only two hiding locations were used for the 19-month-olds. The 23-month-olds were tested as in Study 1 with four hiding locations available in the room.

Procedure

Familiarization phase. Children were introduced to the testing locations and asked to identify them as in Study 1. At the end of this phase, E1 left the toy in the middle of the room.

Test phase. After familiarization, E1, the child, and the parent moved behind the curtain. Twenty-three-month-olds then received each of two test conditions—testimony and direct observation. Nineteen-month-olds were tested only in the testimony condition. In both conditions, E2 moved the toy from the middle of the room to a specific location. In the testimony condition, E2 came into the outer space and told the child about the new location: ''Guess what? I moved the puppy! I put the puppy behind the pillow. Now puppy is behind the pillow.'' E1 then reinforced E2's testimony: ''Did you hear that? *E2* put the puppy behind the pillow!'' In the direct observation condition, E1 simply told the child to watch the change in location through the window in the curtain: ''Let's see what *E2* does in there. Do you see her? Look!''

Results and Discussion

The majority of 23-month-olds searched correctly in both the testimony (12 of 16 children, $p < .01$)

and direct observation condition (14 of 16 children, $p < .01$). Thus, when the verbal information about the new location was not vulnerable to interference from visual information about the object's prior location, most 23-month-olds searched correctly. Indeed, most 19-month-olds (13 of 16, $p < .05$) also searched correctly based on testimony.

Study 2 supports two conclusions. First, toddlers can understand and use verbal testimony about an absent object's location. Second, when considered in relation to the perseverative errors observed in Study 1, the findings from Study 2 suggest that 23-month-olds have difficulty acting on testimony that is vulnerable to interference from specific previously encoded visual information. Study 3 was designed to probe this vulnerability.

In Study 3, a new group of 23-month-olds was tested. The initial location of the toy was either an open or a closed container. In the open container condition, children could see that the toy was not in the container upon re-entry.

Study 3

Method

Participants

Twenty-eight 23-month-olds (12 girls, range = 22.0–24.4, $M = 23.3$) were tested. Five children were excluded—because of fussiness (3), lack of English proficiency (1), and parental interference (1).

Materials

The hiding locations were the same as in Study 1, but the box was altered. In the closed box condition, an opaque box with a removable lid was used. In the open box condition, the box had a hole cut in its front panel so that its contents remained visible.

Procedure

With few exceptions, the procedure was the same as for Study 1. First, before the test phase, the initial hiding location of the toy was always in the box (either open or closed, depending on the condition). The location of the box was varied so that in each condition, the box was placed either in the front or in the back of the room, and either on the right or on the left side. Box location was counterbalanced both across trials and across children. Because the box had a different location on each trial and to avoid using the previous location of the box on the next trial, one hiding location was removed. (In this study there were only three hiding locations, bringing the chance level for the first search to .33.) The box was placed on a furniture item (drawer set, couch, ottoman, small table), so that it was at the child's eye level when entering the room.

Children received *testimony* that the toy was moved in both the open and closed conditions, counterbalanced for order. After E2 moved the toy, she told the child about the new location (e.g., "Guess what? I moved the puppy! I moved the puppy from the box to the bag. Now the puppy is in the bag"). E1 reinforced E2's testimony and asked the child to get ready to find the toy. If the child did not find the toy and did not continue to look for it, she or he was prompted to continue searching. The procedure was repeated with the other box (open or closed) and stuffed animal for a second trial.

Results and Discussion

Few children correctly searched in the new location in either the closed (2 of 28) or open box condition (8 of 28). A Fisher exact test confirmed that there was no significant difference in the rate of errors across conditions ($p = .09$). Children who failed to search correctly mostly searched in the old location of the toy: 92% in the closed box condition and 75% in the open box condition, $p < .05$ (chance level .33). Children who failed to update (20) in the open box condition exhibited four types of search: the majority (15) went to the open box and looked inside or searched in it, some (3) approached the open box but halfway switched direction to another location, one child looked at the box upon entry but did not approach it, and finally, one child went straight to an incorrect location without looking at the old location. Of the children who failed to search in the closed box condition (26), the majority (24) went all the way to the box and searched in it, whereas 2 children went to another location in the room.

On their second attempt to find the toy, over half of the children searched correctly (compared to a chance level of .50): 18 of 26 (69%) in the closed box condition, $p < .05$; 14 of 19 (74%) in the open box condition (one child did not search a second time), $p < .05$, indicating that children retained verbal input regarding the new location of the toy despite not searching there immediately. Figure 3 illustrates 23-month-olds' performance across the three studies.

To summarize, 23-month-olds have difficulty in updating their representation of an object's location despite visible evidence that their prior visual encoding is no longer valid. In the open box condition, the majority of children approached the visibly empty container and many searched in it.

General Discussion

Study 1 showed that 30-month-olds were able to search accurately whether they observed the object's change of location or were told about it. Twenty-three-month-olds, by contrast, searched correctly only after observing the change of location. When told about it, they often searched where they last observed the object. Study 2 showed that children could take in verbal information about a new location. When the object was left in the middle of the room, both 19- and 23-month-olds searched correctly when told that it had been moved. Study 3 underlined the lure of earlier observation-based encoding. Twenty-three-month-olds made perseverative errors not only when the initial hiding place was a closed box (replicating the results of Study 1) but also when it was an open box. They could see that the open box was empty yet still approached it, ignoring what they were told about the object's new location. Indeed, many children searched inside the visibly empty box.

The pattern of error displayed by 23-month-olds is reminiscent of the pattern shown by younger infants in the A-not-B paradigm in two notable respects. In that paradigm, infants also return to B even when it is visibly empty (Harris, 1974). Second, when given an opportunity to search after an error, infants display evidence of having encoded the new location. They search there rather than elsewhere (Webb, Massar, & Nadolny, 1972). By implication, children's difficulties in updating on the basis of language are part of a more general difficulty in updating. Nevertheless, the 23-month-old children in this study could update on the basis of visual information. How does language-based updating impose different cognitive demands compared to visually based updating?

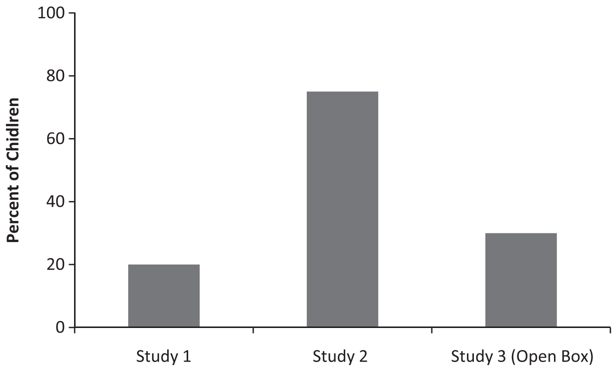

Figure 3. Percent of 23-month-old children in each study who searched in the new location in the testimony condition.

Recent studies with adults suggest that the cognitive mechanisms involved in the perception of action are also involved in processing action descriptions (Yaxley & Zwaan, 2007; Zwaan & Taylor, 2006). Thus, spatial imagery is automatically activated during language processing (Barsalou, Simmons, Barbey, & Wilson, 2003; Bergen, Linday, Matlock, & Narayanan, 2007; Fischer & Zwaan, 2008; Spivey & Geng, 2001; Zwaan, Stanfield, & Yaxley, 2002). Currently, there is little information about the emergence of children's ability to activate such imagery when processing verbal descriptions. Thus, we do not know whether the children tested in our study imagined the transformation of the toy's location when the updating involved language. What our results do indicate is that at 30 months—but not at 23 months—comprehension of action sentences (''The toy was moved from A to B'') is equivalent to action observation (seeing the toy moved from A to B).

What changes take place in language-based updating between 23 and 30 months?

First, language-based representation of the new location might increase in strength relative to the visually based representation of the initial location. By analogy, in the classic A-not-B paradigm, infants initiate an action toward the hidden object only when they have a strong representation of the object (Munakata, 2001; Munakata, McClelland, Johnson, & Siegler, 1997). In the current studies, when the basis for updating was visual information, children could form a strong representation of the new location and disregard the initial location. However, when the basis for updating was verbal information, younger children were lured to location A, even when it was visibly empty, suggesting that their visual representation of that location was stronger than the language-based representation of the new location.

A second explanation is that updating in the testimony condition required integration of information from two modalities—visual and verbal. In the direct observation condition, the updating required integration only within the visual modality. In the testimony condition, children had to revise a visual representation on the basis of verbal information. Arguably, younger children's ability to integrate information across different modalities is less efficient than that of older children. One way to test this hypothesis is to manipulate both input (verbal or visual) and initial representation (verbal or visual) for both age groups.

Finally, children's ability to *edit* a prior visually based representation on the basis of subsequent verbal information may change between 23 and 30 months. The editing process may be straightforward when it involves only the addition of new information, as in Study 2 (''The object is now in B'') or as in Ganea et al. (2007; ''Lucy is now wet''), but more demanding if it involves deletion and replacement of specific information as in Studies 1 and 3 (''The object was in location A. Now it is in location B''). In Study 2, children may have stored a generic representation that the toy was ''in the room'' so that subsequently, they only needed to supplement that generic representation. In Studies 1 and 3, the toy was placed in a particular location so that updating called for deletion of that specific initial location and replacement with information about its new location. Developmental differences might be expected, depending on whether updating involves simple addition or deletion and replacement.

In conclusion, toddlers can update on the basis of verbal testimony by 19 months—almost at the onset of language production. Nevertheless, even at 23 months the updating process is error prone. Echoing the difficulties shown by preverbal infants in shifting from one hiding place to another, toddlers display perseverative errors when they have been told about a shift in location instead of observing it for themselves.

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