Journal of Experimental Child Psychology xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Early limits on the verbal updating of an object's location

Patricia A. Ganea [a,*], Paul L. Harris [b]

[a] Institute of Child Study, University of Toronto, Toronto, Ontario, Canada M5R 2X2
[b] Harvard Graduate School of Education, Cambridge, MA 02138, USA

ARTICLE INFO

Article history:
Received 9 February 2012
Revised 19 April 2012
Available online xxxx

Keywords:
Mental representation
Updating
Language
Working memory
Perseverative error
Toddlers

ABSTRACT

Recent research has shown that by 30 months of age, children can successfully update their representation of an absent object's location on the basis of new verbal information, whereas 23-month-olds often return to the object's prior location. The current results show that this updating failure persisted even when (a) toddlers received visual and verbal information about the prior location but no motor information, or (b) toddlers received only visual information about the prior location, or (c) toddlers received only verbal information about the prior location, and (d) whether or not the prior location was mentioned at the time they received the new verbal information. The results are explained in terms of working memory limitations on children's ability to use language when the new information conflicts with existing information.

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Introduction

Despite the importance of other people as sources of information for learning, much cognitive developmental research has portrayed children as "stubborn autodidacts" (Harris, 2002) engaging in their own search for evidence and ignoring the testimony of others (Gopnik, Meltzoff, & Kuhl, 1999; Piaget, 1954; Wellman & Gelman, 1998). According to this view, babies are little "scientists in the crib" (Gopnik et al., 1999) who observe and gather evidence, generate predictions, and do experiments to test their existing knowledge. An abundance of studies has documented the powerful learning mechanisms and knowledge that infants bring together to solve problems about the real world (Baillargeon, 1994; Kuhlmeier, Bloom, & Wynn, 2004; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Spelke, Phillips, & Woodward, 1995; Woodward, 1998).

Nevertheless, children, like adults, must often rely on other people to acquire information about things that are not available to perception (Harris, 2012). Once they learn language, much of children's

* Corresponding author.
E-mail address: patricia.ganea@utoronto.ca (P.A. Ganea).

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http://dx.doi.org/10.1016/j.jecp.2012.04.013

Please cite this article in press as: Ganea, P. A., & Harris, P. L. Early limits on the verbal updating of an object's location. *Journal of Experimental Child Psychology* (2012), http://dx.doi.org/10.1016/j.jecp.2012.04.013

exploration of the world is through language—through dialogue with others. Children ask many questions, often tenaciously, in what Tizard and Hughes (1984) described as "passages of intellectual search," and parents have the opportunity to provide children with both local and general knowledge about the world, especially by supplying information that would be difficult or impossible for children to gather on their own.

The ability to flexibly update our memory representations as a function of newly received verbal input is an important feature of human cognition, and it is critical for learning about things that we do not directly experience. A prerequisite for updating mental representations is the ability to bring to mind the representation of an object on hearing its name in its absence. Previous research has shown that this ability is in place by 12 months of age (Ganea, 2005; Osina & Ganea, 2012; Saylor, 2004), thereby setting the stage for the development of the crucial ability to acquire new information about absent entities.

Recent research (Ganea, Shutts, Spelke, & DeLoache, 2007) showed that 22-month-olds use verbal input about a property change (i.e., an object becoming wet) to update their representation of the object in its absence. Toddlers learned a proper name (Lucy) for a stuffed animal (frog). When the toy was out of sight in another room, toddlers were told that the toy had undergone a change in state ("Lucy got wet. She is all covered in water!"). When back in the room, children were asked to pick out Lucy from three test choices: a wet frog, a dry frog, and a wet pig. The 22-month-olds accurately selected the wet frog, whereas 19-month-olds did not consistently select either the wet frog or the dry frog. Nevertheless, a follow-up study showed that the 19-month-olds were more likely to update their object representation with the new information when the information was given to them in the presence of the toy.

Further research revealed that at 2 years of age, children's ability to update mental representations is fragile and prone to error. In a subsequent set of studies (Ganea & Harris, 2010), despite being told that an object had been moved from Location A to Location B, 23-month-olds often committed perseverative errors; they searched for the object at Location A. Children's difficulty with updating was not due to a general difficulty in updating mental representations. When children could watch the movement of the object to a new location, they were able to disregard the previous location and use the visual information to search for the object at the new location. The perseverative errors that children committed were specific to information in the verbal modality. However, 23-month-olds, and even 19-month-olds, could take in verbal information about a new location and use it to find the object provided that there was no interference from a prior representation of the object's specific location—for example, if they left the toy in the middle of the room and were subsequently told that it had been moved to a new location. Thus, problems in verbal updating occurred only when children needed to resolve a conflict between their knowledge of a specific prior location and information about the new location.

The goal of the current studies was to explore various possible reasons underlying children's difficulty in verbally updating their representation of an object's location. In the studies reported by Ganea and Harris (2010), when children hid the toy at a specific location, this was also labeled by the experimenter. Thus, children's initial representation of the toy's location included information from different modalities (visual + motor; verbal). It is possible that a representation that does not involve hiding by children can be more easily updated given evidence that preverbal infants are, in general, more likely to perseverate to an object's previous location when they have had motor experience with that location (Wellman, Cross, & Bartsch, 1986). Given prior motor experience with hiding the object at Location A, children's representation of that location may be more difficult to update.

Note that children who failed to update in the studies by Ganea and Harris (2010) did so despite encoding the new location. Thus, after searching incorrectly at Location A, children often went on to search at the new Location B. Success at using the verbal information to search at the new location requires children to actively maintain information about the toy at Location B in the face of a prior conflicting memory representation of the object at Location A. Thus, reducing the salience of the prior representation by removing children's motor experience with Location A might help them to rely on the most recent representation of the toy at Location B.

To test whether 23-month-olds' perseverative errors would persist once the action component was removed, children in Study 1 watched the experimenter hide the toy at Location A as she said, for example, "Look at this monkey. I am going to hide the monkey behind the pillow." Thus, children received visual and verbal information about the object's location but no motor information. We chose

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to still include the labeling of Location A by the experimenter in order to assess the effect of removing the motor component on children's perseverative errors. The basic procedure was similar to that used by Ganea and Harris (2010). After the first hiding event at Location A, children participated in each of two conditions. In the verbal testimony condition, children were told that the object had been moved from Location A to Location B. In the direct observation condition, children observed the change of location for themselves. Studies 2 and 3 examined the impact of providing only visual information or only verbal information about the object's initial location. In Study 4, we went on to ask whether omitting information about the toy's original location when telling them about its new location affects children's ability to update.

The goal of this series of studies was to determine whether children's ability to update on the basis of verbal input is determined by the nature or modality of their initial representation. If the results show that this is not the case, future explanations of children's limitation in verbal updating at 24 months of age will need to carefully consider the nature of the task in terms of general cognitive demands. Specifically, the spatial updating task used in this research requires children to resolve a conflict between existing information (about Location A) and newly received information (about Location B). Research so far indicates that children can resolve this conflict when the information is visual but show difficulties in updating when the information is verbal (Ganea & Harris, 2010). The developmental increase in children's updating of mental representations via language may be driven by improvements in the ability to maintain and manipulate verbal information in working memory while disregarding conflicting information from one's existing knowledge (Munakata, Snyder, & Chatham, 2012). We return to this possibility further in the General Discussion.

Study 1

Study 1 examined whether removing the motor experience at the time of encoding the first location of the object helps children to update their representation of the object's location when they are told that it has been moved to another location.

Method

Participants

The participants were 19 23-month-olds (9 girls and 10 boys, mean age = 23.4 months, range = 22.2–24.9) and 20 30-month-olds (11 girls and 9 boys, mean age = 30.9 months, range = 28.7–33.3). An additional 12 children were excluded because of fussiness (6), failure on the familiarization check (5), or experimenter error (1). The majority of participants came from White middle-class families, and all were English speaking.

Materials

Materials were the same across all four studies presented here. Four hiding locations were used: one black pillow on top of a brown couch, a three-drawer cabinet, a green cloth bag placed on top of a blue ottoman (referred to as a "bag"), and a beige box with a removable lid. An opaque curtain was hung in the room to create an inner space (218 × 113 inches) containing the hiding locations and an outer space (34 × 113 inches). A transparent plastic window was inserted in the curtain (8.5 × 11 inches) 44 inches from the ground. Children could not see through it unless they were lifted by an adult. Two stuffed animals served as hiding objects: a black and white puppy and a brown monkey. A blue puppet was used during the familiarization phase to play the hiding game.

A camera was placed near the curtain in the inner space of the room to record the experimental session.

Procedure

The 23-month-olds took part in two conditions—*testimony* and *direct observation*—in counterbalanced order. Two of the 23-month-olds received only the testimony condition because they became fussy by the time the second condition was run. The 30-month-olds always received the testimony

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condition first. This was because during piloting 30-month-olds who received the direct observation condition first were distracted during the testimony condition. They wanted to be lifted up to look through the window as they had done during 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 the child was familiar with each of the four hiding locations. 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) from a puppet who was placed behind the experimenter's back so that it could not see the hiding. After the hiding, E1 asked the child to show the puppet the location of the toy. The second experimenter (E2) helped to facilitate the game (gave positive feedback when the child found the toy to show it to the puppet). This game was repeated for all four locations. Then the child was asked four reminder questions to ensure knowledge of the four locations (e.g., "Where is the pillow?"). At the end of this phase, E1 left the toy in the middle of the room. 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. At the outset of both conditions, the child was held up to the window so that he or she could watch E2 move the toy from the middle of the room to a specific location. Thus, the child watched as E2 approached the toy in the middle of the room while saying, "Oh, look at this puppy! I am going to put the puppy behind the pillow." After E2 put the puppy behind the pillow, E1 said to the child "Did you see that? She put the puppy behind the pillow." Thus, for the encoding of the toy's initial hiding place, all children received two sources of information: direct observation and verbal commentary.

In the *testimony* condition, the child was lowered to the ground so that he or she could no longer see through the window. E2 then came into the outer space, called the child's name, made eye contact with the child, and then told the child about a further change in the location of the object: "Guess what? I found a better place! I moved the puppy from the pillow to the drawer. Now the puppy is in the drawer." E1 then reinforced E2's testimony: "Did you hear that? She moved the puppy from the pillow to the drawer! The puppy is in the drawer. Now let's go find the puppy." Both experimenters ensured that the child was paying attention as they delivered the new input by calling the child's name and making eye contact with the child as they spoke.

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 again. Do you see her? Look!" Note that the verbal information in the direct observation condition did not identify the new location of the toy.

Then, in both the testimony and direct observation conditions, 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, he or she was prompted to continue searching ("Do you remember that she moved the puppy? Where is it?").

The second stuffed toy was used for the second test condition. As in the first condition, E1 asked the child to point out the four hiding locations. After leaving the toy in the middle of the room, E1 proceeded with the test phase. The hiding locations for this condition were the two locations not used in the first condition.

Coding

Films of the test sessions in all four studies were reviewed by two coders to identify children's search behavior. To count as response behavior, children needed to go in the direction of one location and either point to it or directly search for the toy. Interrater agreement ranged from 90 to 100% (Cohen's kappas = .785–1.00). Disagreements were resolved by a third person.

Results and discussion

There was no effect of order of conditions on search behavior for the 23-month-olds (Fisher's exact test, $p = .65$). We used binomial tests to compare children's search with chance levels in the two

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conditions (for children's first response, chance was set at .25 because there were four possible locations to search). When children directly observed the change in location, the majority of younger children (12 of 17) and older children (15 of 20) searched correctly (binomial tests, $p < .01$). However, when children were told about the change, approximately half of the younger children (10 of 19, $p > .05$) but most of the older children (17 of 20, $p < .01$) used the verbal information to search correctly. Fisher's exact tests indicated that the proportion of children searching correctly was significantly different across the two age groups in the testimony condition ($p < .05$) but not in the direct observation condition ($p > .05$). All 9 younger children and all 3 older children who failed to search correctly in the testimony condition searched in the initial location of the toy. On their second search, 5 of the 9 younger children and 1 of the 3 older children searched correctly. The remaining children searched in the two other locations.

To summarize, the results showed that most 23-month-olds searched correctly in the new location when they directly observed the change of location, but nearly half perseverated to the object's initial location when they were told about the change. Thus, the perseverative errors of 23-month-olds persist even when the representation of the initial hiding does not include firsthand motor experience of personally hiding the object. By 30 months of age, most children are capable of updating on the basis of either testimony or direct observation.

In Study 2, we asked whether children can verbally update a representation that is based on purely visual information. In Study 1, the linguistic information about the initial location in addition to seeing the toy placed there may have strengthened the representation of that location. Better memory consolidation when language accompanies an event has been previously shown in older children (Tessler & Nelson, 1994). To examine whether removing the language at the time of encoding leads to better updating, children in Study 2 did not hear the initial location labeled at the time when the toy was placed at Location A.

Study 2

The goal of Study 2 was to examine whether children can update a prior representation of an object's location when the initial location is not linguistically encoded. Thus, children in this study simply saw a person place a toy at Location A and then heard about it being moved.

Method

Participants

The participants were 16 23-month-olds (8 girls and 8 boys, mean age = 23.3 months, range = 22.2–24.9) and 13 30-month-olds (6 girls and 7 boys, mean age = 30.1 months, range = 28.7–32.1). A further 11 children were excluded because of fussiness (3), shyness (1), failure on the familiarization check (4), parental interference (2), or experimenter error (1).

Materials

Materials were the same as in Study 1.

Procedure

Familiarization phase. The child was 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. Given that no effect of condition order was found in the previous experiment for the younger children, for consistency reasons, both groups of children received the testimony condition followed by the direct observation condition for all of the remaining studies included here. One 23-month-old received only the testimony condition because he became fussy by the time the direct observation condition was due to be run.

Test phase. As in Study 1, after familiarization, E1, the child, and the parent moved behind the curtain. With one exception, the procedure was the same as for Study 1. During the first hiding event (when the child watched from behind the window as E2 put the toy in Location A), E2 did not provide goal-directed language or label the hiding location as in Study 1 ("Oh, look at this puppy! I am going to put

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the puppy behind the pillow"). She simply said, "Look at this puppy," as she picked it up and then hid it behind the pillow. In addition, E1 provided minimal language input as the child watched the hiding event: "Did you see that?" (This was unlike Study 1, in which she said, "Did you see that? She put the puppy behind the pillow"). The rest of the procedure was exactly the same as in Study 1, with children either observing E2 move the toy from Location A to Location B or being told by E2 about the change in location.

Results and discussion

As in the previous experiment, the majority of children in both age groups updated their visual representation of the initial toy's location in the direct observation condition (11 of 15 23-month-olds and all 13 30-month-olds, binomial tests, $p < .01$). The majority (77%) of 30-month-olds also updated in the testimony condition (10 of 13, $p < .05$), but only 37.5% of the 23-month-olds did so (6 of 16, $p > .05$). Fisher's exact tests confirmed that the proportion of children who searched correctly across the two age groups approached significance in the testimony condition ($p = .06$) but not in the direct observation condition ($p = .10$). Of the children who failed to search correctly in the testimony condition, the majority of 23-month-olds (9 of 10) and all 30-month-olds (3 of 3) searched in the original location of the toy. On their second search, 5 of 10 23-month-olds searched in the new location and 5 children searched elsewhere; all 3 30-month-olds searched in the new location.

Together with the results of Study 1, these findings confirm that 23-month-olds update systematically when they directly observe the object being moved to a new location. By contrast, they perform at chance when they must update their search on the basis of verbal testimony. The difficulties that 23-month-olds have with verbal updating remain even when the information about the initial hiding is purely visual. Thus, children perseverate to the initial location even when they have heard no linguistic encoding of that location. By contrast, the majority of 30-month-olds updated on the basis of verbal testimony or direct observation and searched in the new location of the toy. Nonetheless, all 3 of the 30-month-olds who failed to update in the testimony condition made a perseverative error.

Study 3

As shown in the two previous studies, 23-month-olds can update an initial representation when they directly observe the object moved to a new location. By contrast, in the testimony condition, when they need to revise the initial representation on the basis of subsequent verbal information (i.e., being told that the object has been moved to a new location), they are prone to perseveration. Perseveration occurred when children received both visual and verbal information about the initial location (Study 1) and when they received visual information only (Study 2). Study 3 was designed to address the possibility that 23-month-olds' failure at updating was due to a failure to integrate information across modalities, more specifically a failure to update prior visual information on the basis of subsequent verbal information. Thus, we asked whether such updating would be easier if the modality of the new information and the modality of the initial representation were entirely consistent. In other words, can 23-month-olds use language to update a representation of an object that was initially created solely on the basis of verbal information?

Method

Participants

The participants were 18 23-month-olds (10 girls and 8 boys, mean age = 23.6 months, range = 22.2–25.0) and 16 30-month-olds (8 girls and 8 boys, mean age = 30.1 months, range = 29.0–32.8). A further 13 children were excluded because of fussiness or unwillingness to follow directions (10) or failure on the familiarization check (3).

Materials

The materials were the same as in Study 1.

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Procedure

Familiarization phase. This phase was the same as in the previous two experiments. At the end of this phase, E1 left the toy in the middle of the room.

Test phase. As before, after familiarization, E1, the child, and the parent moved behind the curtain. The child then received each of two test conditions: testimony and direct observation. In each condition, information about the initial location was purely verbal. E2 first moved the toy from the middle of the room to a specific location. Then E2 came into the outer space and told the child about this initial hiding: "Guess what? I moved the puppy! I put the puppy behind the pillow. Now the puppy is behind the pillow." E1 then reinforced E2's testimony: "Did you hear that? [E2] put the puppy behind the pillow! The puppy is behind the pillow." Then E2 said, "Oh, I know a better spot! I'll be right back," and she went back into the room to move the toy from the first location to another location in the room.

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!" In the testimony condition, E2 came back into the outer space again and told the child about the location change: "I found a better spot. I moved the puppy from the pillow to the drawer. Now the puppy is in the drawer." Before asking the child to go search for the toy, E1 reinforced the verbal information given by E2: "Did you hear that? She moved the puppy from the pillow to the drawer! The puppy is in the drawer. Now, let's go find the puppy."

Results and discussion

The majority of 23-month-olds (15 of 18) and all 30-month-olds (16 of 16) searched correctly in the direct observation condition (binomial tests, $p < .001$). When children were told about the location change after the initial verbal encoding of the toy's location, most of the 30-month-olds searched correctly in the new location (13 of 16, $p < .001$), but less than half of the 23-month-olds did so (7 of 18, $p > .05$). Fisher's exact tests confirmed that the proportion of children who searched correctly was significantly different across the two age groups in the testimony condition ($p < .05$) but not in the direct observation condition ($p > .05$). When children failed to search correctly in the testimony condition, the majority of 23-month-olds (8 of 11) and 1 of 3 30-month-olds perseverated to the initial location of the toy. On their second search, 3 of 11 23-month-olds searched in the new location, another 3 children searched in the original location of the toy, and the remaining 5 children searched in a third location. Of the 3 30-month-olds who failed to search correctly on their initial search, 1 child searched in the original location and 2 children searched in a third location.

These results indicate that the difficulties that 23-month-olds have with verbal updating are not restricted to the updating of prior visual information. Those difficulties persist when the prior information is only verbal; thus, the updating requires modification of information within the same domain.

Study 4

In Study 4, we examined whether not referring to the initial location in the testimony about the change of location helps 23-month-olds to update. This was done to examine whether not activating children's representation of the initial location of the toy, and thereby reducing the interference with the new location information, would help children to overcome the perseverative error. We did not test 30-month-olds in this study because they successfully updated in the testimony condition in the previous three studies. We used the same experimental procedure as in Study 1. The only difference was that the verbal statement about the location change did not mention the initial location. Children were told only that the toy was moved and where to. This verbal input was similar to the input used by Ganea and Harris (2010) in their Study 2, which showed that both 19- and 23-month-olds could follow verbal input when no container or landmark signaled the initial location (i.e., the object was left in the middle of the room).

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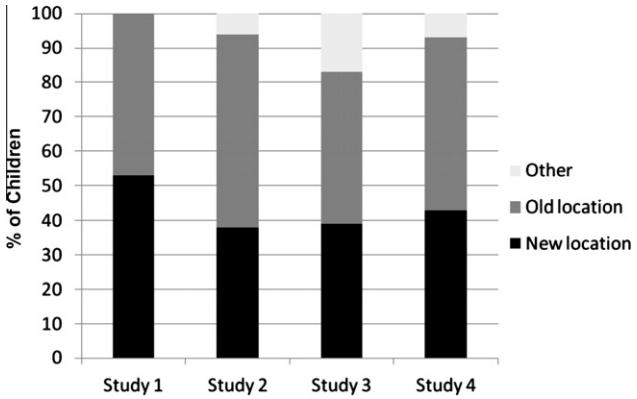

Fig. 1. Percentages of 23-month-olds who searched in the new, old, and other locations across Studies 1 to 4.

Method

Participants

The participants were 14 23-month-olds (9 girls and 5 boys, mean age = 23.6 months, range = 22.2–24.8). An additional 7 children were excluded because of fussiness (3), failure on the familiarization check (2), parental interference (1), or experimenter error (1).

Procedure

The procedure was the same as in Study 1. The only difference was that in the testimony condition, the experimenter did not mention the original location of the toy. Instead of saying, "I moved the puppy from the pillow to the drawer. Now the puppy is in the drawer," in this study the experimenter simply said, "I moved the toy. The puppy is in the drawer. Now the puppy is in the drawer."

Results and discussion

The results replicated those reported so far for children in this age group. Most 23-month-olds failed to update in the testimony condition; only 6 of 14 children (43%) searched at the new location (binomial test, $p > .05$), but most updated successfully in the direct observation condition (11/14, 79%, binomial test, $p < .01$). Of the 8 children who failed to search correctly in the testimony condition, 7 perseverated to the old location. When children searched a second time, 5 children searched at the new location, indicating that they had encoded information about the new location.

Given the similar pattern of performance across the four studies presented here, we conducted an analysis of children's searches across studies in both the testimony and direct observation conditions. A generalized estimating equation (GEE) model with age group as the between-participants variable and condition as the within-participants variable was used to test for whether type of condition and age group to which children belonged affected their responses in the updating task. This analysis revealed significant effects for condition, $\chi^2(1,116) = 14.52$, $p = .000$, and age group, $\chi^2(1,116) = 17.93$, $p = .000$.

An examination of children's responses across the two conditions for each age group revealed different patterns of behavior[1]. In the direct observation condition, the majority of children in both the younger group (76%, 49/64) and the older group (90%, 44/49) used the visual input to search in the new location of the toy. There was no significant difference between the two age groups in the proportion of children who searched correctly, $\chi^2(1,113) = 0.17$, $p > .05$. By implication, both younger and older

[1] Although the total number of 23-month-olds included in this research was 67, 3 children were not tested in the visual trial (2 in Study 1 and 1 in Study 2).

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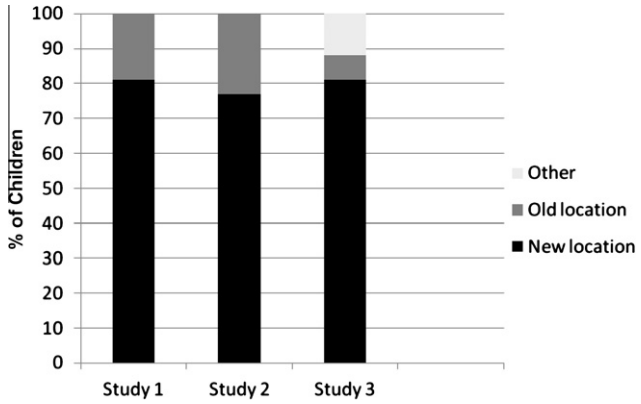

Fig. 2. Percentages of 30-month-olds who searched in the new, old, and other locations across Studies 1 to 3.

children could use the visual input to update their existing representation of the toy's location. By contrast, in the testimony condition, as illustrated in Fig. 1 (23-month-olds) and Fig. 2 (30-month-olds), there was a significant age change in the percentage of children who searched correctly (43% [29/67] of 23-month-olds vs. 82% [40/49] of 30-month-olds), $\chi^2(1,116) = 17.27$, $p < .0001$. Whereas the majority of 30-month-olds searched in the new location of the toy, less than half of the 23-month-olds did so.

Of the 23-month-olds who failed to search correctly, the majority of them (87%, 33/38) committed a perseverative error by searching in the original location of the toy ($p < .0001$, chance = .33, binomial test). Similarly, of the few older children who failed to search correctly, the majority of them (78%, 7/9) perseverated across Studies 1 to 3. Thus, although the rate of perseverative errors declined with age, such errors still occurred among 30-month-olds.

Finally, McNemar tests confirmed an effect of condition for 23-month-olds but not for 30-month-olds. The number of 23-month-olds who failed to search correctly in the testimony condition but not in the direct observation condition (29/64) was significantly greater than the number who showed the reverse pattern (9/64), $\chi^2(1,128) = 13.51$, $p < .0001$. By contrast, the number of 30-month-olds who failed to search correctly in the testimony condition but not in the direct observation condition (8/49) was no greater than the number who showed the reverse pattern (4/49), $\chi^2(1,98) = 0.85$, $p > .05$.

General discussion

When new information is provided about an absent object, we update our knowledge of that object with the new information. For instance, if we are told that our favorite coffee shop changed its location, we update our mental representation based on what we have been told, and next time we go to the new location to buy our coffee. The ability to flexibly update our memory representations as a function of newly received input is critical for learning.

The current research documents an important limitation on young children's ability to update their mental representation of an object's location on the basis of verbal input. Despite being told about an object's new location, 23-month-olds often perseverate to the object's prior location. This finding shows that the difficulties faced by preverbal infants in searching at an object's most recent location—that is, the classic A-not-B error (Aguiar & Baillargeon, 2000; Diamond, 1985; Harris, 1973; Marcovitch & Zelazo, 1999; Marcovitch & Zelazo, 2009)—reemerge when the information about the object's new location is provided via language rather than direct observation.

The current series of studies, together with previous work, shows that the perseverative errors committed by toddlers occur no matter what the modality of the initial representation. Thus, 23-month-olds tended to perseverate to the initial location of a toy when they had motor, visual, and verbal information about the prior location (Ganea & Harris, 2010), visual and verbal information but no motor information (Study 1), only visual information (Study 2), or only verbal information (Study 3).

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Moreover, they perseverated whether or not the prior location was mentioned at the time they received the new verbal information (Study 4).

Prior research on children's ability to update mental representations via language has shown that by 23 months of age, children have the appropriate language skills to encode and act on verbal information concerning a change of state or a change of location. However, they can do so only when there is no conflict between the new information and specific aspects of the old information. For example, when children learn about a new state of an object as in Ganea and colleagues (2007; "Lucy is now wet") or about a new location for an object as in Ganea and Harris (2010; "The object is now in B"), in the absence of specific information about the object's prior state or location, they can successfully update their object representation via language. These findings suggest that the developmental difference in verbal updating reported here, as well as in Ganea and Harris (2010), occurs only when the updating task requires children to resolve a conflict between their knowledge of a specific prior location and verbal information about a new location. An interesting study for future research would be to test whether the perseverative effect is unique to spatial tasks, like the one used in the current research, or whether it applies to other tasks as well. For example, if children had first learned about a specific state of a toy (a toy being "wet") and then were told that a change of state had occurred (the toy became "dry"), would 23-month-olds also have difficulty with this change in state, just as they do with a change in location?

As noted, the tendency to perseverate in the face of conflicting information or conflicting cues has been widely documented in the developmental literature. When searching for toys, infants tend to perseverate to an object's prior location despite seeing the object moved to a new location (Aguiar & Baillargeon, 2000; Diamond, 1985; Harris, 1973, 1974; Marcovitch & Zelazo, 1999, 2009; Piaget, 1954). In addition, young preschoolers often continue to sort cards by one rule (e.g., according to shape) even when they have been told repeatedly to switch the rule (e.g., to sort by color) (Kirkham, Cruess, & Diamond, 2003; Perner & Lang, 2002; Zelazo & Reznick, 1991).

A common characteristic of these tasks and the current updating task is that previously stored information about an object or a task becomes invalid and, therefore, is in conflict with current information. In this series of experiments, when information about the current Location B was in conflict with information about its prior Location A, 23-month-olds often perseverated to Location A. To be successful in updating their existing mental representation of the object with information about its current location, children need to engage in several mental operations: (a) understand and encode the verbal input about the new location; (b) activate their representation of the object as they hear new information about it; (c) maintain and act on their new representation of the toy at Location B while disregarding the conflicting information about the toy's prior location.

One might try to explain children's perseverative errors in terms of the first operation, a failure to understand and encode the verbal input about the new location. However, this explanation is unlikely for two reasons. First, even at 19 months of age, children can understand and use verbal input to update an object's representation when the task does not involve a conflict between that location and a specific prior location (Ganea & Harris, 2010, Study 3). Second, in Study 3, children received only verbal information about both the initial and new locations of the toy. Nevertheless, the majority of 23-month-olds (83%, 15/18) directed their initial search to either the initial or new location, showing that children encoded what they were told even if they were confused about which of those two locations to choose.

Turning to the second operation, previous research has shown that at the beginning of their second year (i.e., at approximately 12 months of age), children have the ability to bring to mind representations of objects when the objects mentioned are not in view (Ganea, 2005; Osina & Ganea, 2012; Saylor, 2004; Saylor & Ganea, 2007). Thus, it is implausible to attribute the failure of 23-month-olds in the updating task to an inability to activate the representation of the object at the time they received the new information.

If children encode the information about Location B and can bring the hidden object to mind, we may consider the third possibility, namely that at the time of updating their existing representation children fail to actively maintain the new information about the location change in working memory because they need to disregard conflicting information about the object's prior location. In particular, we may consider an explanation based on graded representations in working memory.

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Munakata and Yerys (2001) argued that children's knowledge is graded in nature, and stronger representations are required to solve tasks that involve conflicting information. The perseverative errors that infants and children often exhibit are due to competition between two memory traces: a "latent" memory for Location A (or the old rule) and an "active" memory for Location B (or the new rule) (Munakata, 1997; Munakata, Morton, & Yerys, 2003; Munakata & Yerys, 2001). In the face of conflict, children have problems in maintaining the new information about Location B (or the new rule) in working memory because their representation of Location B is not strong enough. When there is no conflict inherent in the task, children can succeed even with weak representations of the new information. According to this view, developmental differences in perseverative behavior reflect increasing working memory capacity, which enables children to maintain active representations of new information and to flexibly update prior representations.

The nature of the verbal updating task used in this research requires children to activate an object's representation in its absence and to maintain information about its new location while setting aside information about its prior location. Note that children's difficulty in updating via language is not part of a general difficulty in updating given that 23-month-olds can update when they directly observe the object's change of location. By implication, in the case of direct observation, children's representation of Location B is strong enough to compete with the prior representation of the toy in Location A. However, in the case of updating representations on the basis of verbal input, children need to manipulate more abstract linguistic information in the absence of any visual support, and this type of updating may require a special type of improvement in working memory capacity.

Developmental differences might be expected depending on whether updating via language requires children to simply add new information to their existing representation or to revise an existing representation. For example, when learning that an object has entered a new state ("Lucy is now wet"), children need to add this piece of information to their existing representation. This is a process of *enriching* an existing representation based on new information. This type of updating is within the competence level of 19-month-olds (Ganea & Harris, 2010).

In some cases, however, updating requires one to *revise* an existing representation—to discard information from the previous representation and replace it with the more accurate information. For instance, when learning that an object has been moved from one particular location to another—for example, from Location A to Location B—children need to delete or overwrite information about the prior location, replacing it with correct information. Thus, the first type of updating involves addition and enrichment, whereas the second type involves deletion and replacement. The current findings indicate that the second type of updating can lead to perseverative errors, where children are inappropriately using prior information that is no longer valid despite having been given new information.

So far, we have proposed that the perseverative errors observed among 23-month-olds reflect limitations in working memory capacity for information derived from testimony rather than direct observation. If the ability to flexibly update representations via language calls for an increase in the ability to actively hold in mind information, we can predict that children who perseverate in the location task and those who search successfully should display qualitative differences on other tasks. Across all four studies, 43% of 23-month-olds searched successfully, 49% of them perseverated to the previous location of the toy, and the remaining 8% searched elsewhere. Future tasks could include additional measures of working memory strength to try to differentiate between the children who appropriately switch to the new location and those who perseverate to the old location at a given age. Recent research suggests that children who flexibly switch between old and new information (e.g., in a card sorting task) have stronger representations of the new rule, which leads to their faster responding in other non-conflict tasks relative to children who perseverate (Cepeda & Munakata, 2007). Unlike children who perseverate, children who flexibly update card switching rules have also been found to be better at generalizing information to new situations, indicating that their representation of the information is more abstract (Kharitonova, Chien, Colunga, & Munakata, 2009).

To the extent that variation in working memory does explain the observed variation in children's tendency to perseverate, it will also be important to probe the scope of its impact. In all four studies, children were presented with new verbal information about the object's location and then asked to act on that information. It is possible that acting on new verbal information in the face of existing

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conflicting information is especially likely to tax the resources of working memory. On this hypothesis, children might be more accurate if they were asked to simply name the object's new location or to point to it rather than to go to retrieve the object. Similarly, instructions likely to strengthen children's representation of the verbal input, such as asking children to repeat what they have been told, should also improve accuracy.

In conclusion, recent research has only begun to probe the way that young children revise their representation of the world on the basis of what they are told. Further research should provide important information about processes that both limit and facilitate this fundamental source of leaning.

Acknowledgments

We thank the children who participated and their parents. We also thank Carina Wind, Amanda Rhoads, Caitlin Ford, and Martyna Galazka for their help with data collection and coding.

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