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Children's use of Reasoning by Exclusion to Track Identities of Occluded Objects

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Abstract

Reasoning by exclusion allows us to infer properties of unobserved objects from currently observed objects, formalized by P or Q, not P, therefore Q. Previous work suggested that, by age 3, children can use this kind of reasoning to infer the location of a hidden object after learning that another location is empty (e.g. Mody & Carey, 2016). In the current study, we asked whether children could use reasoning by exclusion to infer the identities of previously unobserved occluded objects in a task that required them to track the locations of multiple occluded objects. Forty-nine 4-7-year-olds viewed animated arrays of virtual "cards" depicting images which were then hidden by occluders. The occluders then swapped locations during the maintenance period. Children were asked to select which card was hidden in a probed location. During the encoding period, we manipulated whether children saw all the card faces (Face-up block) or all but one of the card faces (Exclusion block), for which children had to reason by exclusion to infer the target in half of the trials. We found that all children succeeded in the Face-up block, but only 6-year-olds succeed in the Exclusion block when they had to deploy logical reasoning to identify a previously-unseen hidden target. Our results suggest that children's ability to reason by exclusion to infer the identity of a hidden target while tracking multiple objects and locations may undergo protracted development.

Keywords: Reasoning by exclusion; disjunctive syllogism; object tracking; working memory; development

Introduction

Reasoning by exclusion is a deductive inferential process that allows us to reason about possible outcomes by eliminating other alternatives (Premack, 1995). The ability to reason by exclusion has been studied in both animals and children (Call, 2004; Call, 2006; Ferrigno et al., 2021; Hill, Collier-Baker, & Suddendorf, 2012; Premack & Premakc, 1994; Watson et al., 2001), and in children has been found to support language acquisition (Halberda, 2003), understanding of others' intention (Cesana-Arlotti, Kovacs, & Teglas, 2020), reasoning about an object's location (Cesana-Arlotti et al., 2018), and navigation of efficient search behavior (Feiman, Mody, Sanborn, & Carey, 2017; Gautam, Suddendorf, & Redshaw, 2020; Grigoroglou, Chan, & Ganea, 2019; Mody & Carey, 2016).

By at least age 3, children can use reasoning by exclusion to infer the location of a hidden object. In one study, Hill et al. (2012) tested 3-5-year-old children in a task where a reward was hidden in one of the three opaque cups, and the experimenter demonstrated that one of the cups was empty. They found that even the youngest children tended to search the cups that were not shown to be empty, suggesting that they were able to infer that the reward was not in the empty cup and therefore must be in one of the other locations (see also Mody & Carey, 2016; Grigoroglou, Chan, & Ganea, 2019). To succeed, children had to hold in working memory a representation of an object, but with some uncertainty about the object's location in space. Observing the empty location reduced the uncertainty, allowing the representation of the object to be updated to include its likely spatial location.

In this previous work, the featural identity of the object was known (e.g. a ball) and its spatial location was uncertain. Here, we ask whether children can use reasoning by exclusion to infer the featural identity of an object whose spatial location is known but whose identity is uncertain. This type of reasoning occurs often in everyday life. For example, imagine you are at a buffet dinner at which there are two covered dishes. You know that one is a chicken option and one is a vegetarian option, but they are unlabeled. You lift the lid of one of the dishes and you see that it contains chicken. You can therefore infer with confidence that the other dish must contain the vegetarian option. To make this inference, you must store the relevant information in working memory – in this case, a representation of the identity of the chicken dish bound to its location in space - and use this stored representation to resolve the uncertainty in the identity of the dish in the other location, updating your representation of that spatial location to include its likely identity.

The process of using reasoning by exclusion to infer unobserved identities may place greater demands on children's representational capacities than reasoning about the contents of unobserved locations. Maintaining representations of object identities in working memory requires more cognitive resources (i.e. attention) than maintaining objects' locations (Wheeler & Treisman, 2002; Kibbe & Leslie, 2011). Likewise, the process of updating identity-location-bound object representations in working memory is more demanding than simply updating working memory for objects' spatial locations, and undergoes more protracted development (Cheng, Kaldy, & Blaser, 2019; Cheng & Kibbe, under review; Feigenson & Yamaguchi, 2009; Kibbe & Leslie, 2013; Pailian et al., 2020;). On the other hand, using reasoning by exclusion to infer identities may be an optimal strategy when working memory is taxed: as working memory load increases, it may be more efficient to maintain a subset of to-be-remembered items, and reason from the remembered subset to infer the unremembered items (e.g. van den Berg & Ma, 2018). Using reasoning by exclusion to infer unknown object identities could therefore be a fundamental component of efficient working memory use, and could therefore be available to very young children who already employ a variety of efficient working memory processes (including chunking, recoding, and metacognitive awareness; see e.g. Kibbe & Feigenson, 2014; Applin & Kibbe, 2020).

In the current study, we asked whether children could use reasoning by exclusion to infer location-bound object identities while tracking multiple occluded objects. To do so, we combined the method used to assess reasoning by exclusion in search tasks -- in which children were given partial information about locations and had to infer from that information that an object was hidden in another location (e.g. Mody & Carey, 2016) -- with a task that required children to track object *identities* hidden in multiple locations as those locations moved through space (Cheng and Kibbe, under review; Pailian et al., 2020). We manipulated the number of objects children had to track and the number of times the objects changed locations, thereby manipulating children's working memory storage and updating loads, and measured the effect of increasing working memory load on children's ability to use reasoning by exclusion to infer the identity of an unobserved object. We chose to test 4-7-year-old children, since previous studies suggested that children could make location-based inferences by excluding alternative possibilities by age 3 (e.g., Mody & Carey, 2016; Grigoroglou, Chan, & Ganea, 2019), and since the ability to hold multiple location-bound identities in working memory undergoes significant development during this period (Applin & Kibbe, 2020; Cheng & Kibbe, under review; Pailian et al., 2016; Simmering, 2012).

Our goals were to determine 1) whether children could reason about the identities of unseen hidden objects based on their representations of seen hidden objects, 2) whether this ability changed across our age range, and 3) whether this ability interacted with the demands of maintaining and updating the contents of working memory.

Children viewed animated arrays of 2-3 virtual "cards" depicting images of animals, which were then hidden by occluders. The occluders then swapped locations once or twice. Children were then prompted to identify the object hidden in one of the locations by selecting it from an array of two choices, the target object or another object in the array. In the Face-up block, all of the cards were presented "face up" such that the images on the cards were visible to children before the cards were hidden. In the Exclusion block, one of the cards was presented "face down", while the rest of the cards' images were visible during encoding. On half of the Exclusion trials, children were asked about the identity of one of the face-up cards (Target-up trials), while on the other half of trials children were asked about the identity of the face-down card (Target-down trials), requiring children to use reasoning by exclusion to infer its identity.

The Face-up block served as a control for the Exclusion block, allowing us to examine whether children's task performance differed when all information was available to be encoded (Face-up block) compared with when the information had to be inferred (Exclusion block). If children apply the correct logical inference in the Exclusion block, we would expect their performance to be similar to their performance in the Face-up block. If children are unable to use reasoning by exclusion to infer identity in the Exclusion block, we would expect their performance to be lower than in the Face-up block. Furthermore, within the Exclusion block, children could be probed on a card that was presented either face up (requiring working memory) or face down (requiring working memory + reasoning by exclusion). If children applied the exclusion strategy to reason about the hidden card, children should perform equally well on the two types of target trials. However, if children were unable to apply the exclusion strategy, children should be expected to perform better on Target-up trials compared with Target-down trials. Furthermore, we may observe that ability to successfully deploy the reasoning by exclusion strategy varies with age.

Finally, if reasoning by exclusion and tracking multiple, location-bound identities in working memory draw on the same pool of limited cognitive resources (e.g. general executive functions), we may expect that children's ability to use reasoning by exclusion to infer hidden identities may decrease as the demands of the working memory task increase (more items to track, more swaps).

Method

Participant

Forty-nine 4-to 6-year-old children (mean age: 5 years, 5 months; range: 4 years, 0 months – 6 years 11 month; 26 girls) participated in the study. This sample size was large enough to yield 95% power to detect small-to-medium effects on children's performance using a repeated measures ANOVA with Block (Exclusion or Face-up), Trial Type (Set Size 2, two swaps, Set Size 3, one swap; Set Size 3, two swaps) and Age as factors. All participants were tested individually online using Zoom videoconferencing software. Children completed a separate, unrelated study before completing the current study. Each family received a $10 Amazon gift card for their participation. Two additional children were tested and excluded from analysis due to failure to complete the study. The study was approved by the Boston University Institutional Review Board.

Apparatus and Stimuli

We asked families to participate in a quiet room using a device with a screen at least 10 inches (48 families used a laptop or a desktop computer, and 1 used an iPad). Stimuli was presented in Keynote presentation software and displayed to children via Zoom's screen sharing feature. Stimuli included 12 animal characters from the World of Eric Carle Mini Memory Match Game (Mudpuppy Toys) (see Figure 1). The experiment was recorded using the screen recording feature in Zoom and was saved to a secure campus server.

Design

All children completed two blocks of test trials, a Face-up block and an Exclusion block (block order counterbalanced across participants). Figure 1 shows examples of the two trial types. In both blocks, children were shown sets of 2 or 3 cards (Figure 1, panel 1), which were then hidden by occluders that descended from the top of the screen (Figure 1, panel 2). In the Face-up block, all images were visible during encoding. In the Exclusion block, one of the cards remained face down during encoding. Children were given 1 second per face-up card to encode the array. During the maintenance period, the occluders swapped locations by physically moving across the screen (Figure 1, panel 3). In Set Size 2 trials, the two occluders swapped places with each other. In Set Size 3 trials, for each swap, a subset of occluders was chosen pseudo-randomly to swap. Each swap movement took 1.5 s. One second after the movement was completed, we probed children on one of the locations and asked them to select the item hidden in that location from two alternative choices, a target card or a distractor card depicting a different object in the array (labeled 1 or 2; Figure 1, panel 4). Whether the target was labeled 1 or 2 was counterbalanced across trials. All children completed two practice trials at the beginning of the study, and two additional practice trials before the Exclusion block (as described below). The number of items and number of swaps was chosen based on previous research that showed that children in this age range exhibit differences in performance with these parameters (Cheng & Kibbe, under review). The entire task took about 15 -20 minutes to complete.

Procedure

Online set-up. Parents were instructed to hide self-view and move the experimenter's window to the top center.

Initial practice trials. The experimenter first showed children the full set of 12 stimuli and said, "We are going to play a hide-and-seek game. Each time, a few of my friends will appear, they will then hide behind blocks. Your job is to help me figure out who is hiding where." Children then viewed a blank screen, on which two cards appeared. The cards were visible for 2 s, then the experimenter said, "Now they are going to hide!". The cards were then hidden by two occluders which moved downward from the top of the screen. After 1s, an animated hand pointed to one of the occluders. Two cards then appeared above the occluder, a target card and a distractor card. The experimenter then asked "Which one hides here?". After children responded, the experimenter removed the occluder to reveal the hidden card. If children answered correctly, the experimenter proceeded to the next practice trial, otherwise the experimenter repeated the trial. 46/49 children succeeded the first time. The remaining 3 children succeeded the second time.

The experimenter next introduced the swap movement by saying "Let's try this one. Here are my two friends, they are going to hide again, but this time after they hide they are going to move, and we have to keep track of where they are hiding. Here we go!" Children saw two cards, which were then occluded, and then watched as the occluders swapped locations. The experimenter probed children's memory for one of the locations as in the first practice trial, giving feedback as needed. 40/49 children succeeded the first time. The remaining 9 children succeeded the second time.

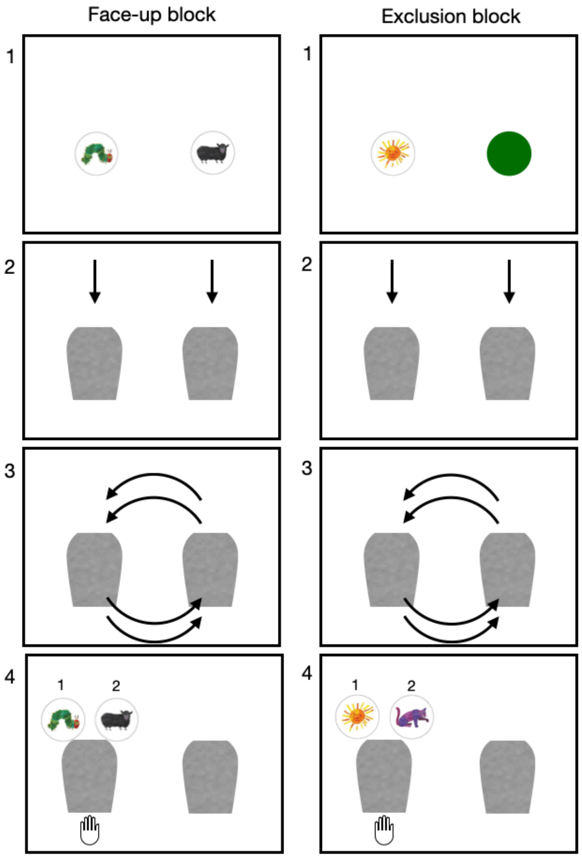

Figure 1. Examples of Set Size 2, two swap trials.

Face-up block. Each trial in the Face-up block proceeded similarly to the second practice trial, except that children were not given the opportunity to repeat trials on which they made errors. Children completed four trials of each of three types of trials: Set Size 2 two swaps, Set Size 3 one swap, and Set Size 3 two swaps, for a total of 12 Face-up trials.

Exclusion block. At the beginning of the Exclusion block, children completed 2 additional practice trials to introduce them to the task of tracking occluded cards when one of the cards faced down during the encoding period. In the first Exclusion practice trial, children saw two cards on the screen, one facing up and one facing down. The experimenter said "Here are my two friends. But this time only one of them turned around. The other friend is going to be sneaky and he won't turn around. He will only turn around once he hides behind the block. Now they are going to hide and move!" Two occluders hid the cards, after which the occluders swapped locations once. After 1 s, the animated hand appeared pointing to the location in which the face-up card was hidden. The experimenter asked "Who's hiding here?". The experimenter provided feedback as in the initial practice trials and repeated the trial if necessary. 37/49 children succeeded the first time. The remaining 12 children succeeded the second time.

The experimenter then proceeded to the second practice trial by saying, "But sometimes we are going to look for the one that we did not see before. Here are my two friends." Children saw two cards, one facing up and one facing down on the screen. The experimenter said, "They are now going to hide and move." The cards were then hidden by the occluders and swapped locations once. Children were first probed on the location of the face-up card: 42/49 children correctly chose the target card the first time; the remaining 7 children succeeded after the second demonstration. The experimenter then probed children on the location of the face-down card. Children chose between the target card (that children had not seen) and the card that was hidden in the first-probed location (the face-up card). Since the first-probed card was already revealed, all children correctly chose the target card. The experimenter then further explained, "Because we already knew that the [face-up card] is under the other block, so it cannot be here under this block. So, it had to be the other one, and that's the [face-down card]! Ok, so now you know how we can find who's hiding where even though one of them will not show up. We can just track the one that we saw, and we can guess who's the other one, right?"

The experimenter then began the test trials by saying, "Now we are going to figure out who's hiding where. Remember, we will only see some of my friends' faces." The test trials in the Exclusion block were the same as in the Face-up block except that one of the cards in each trial remained facing down during the encoding period (Figure 1, right column). After children responded, the experimenter gave feedback as in the Face-up block. We again counterbalanced the location of the probed card and whether the target was labelled 1 or 2 across trials. Children completed 12 total trials (4 each of Set Size 2 two Swaps, Set Size 3 one Swap, and Set Size 3 two Swaps). For each trial type, children completed two trials in which asked them to choose the identity of a face-up card (Target-up trial) and two trials in which we asked about the face-down card (Target-down trial). The order of Target-up and Target-down trials within each trial type followed the ABBA or BAAB counterbalancing pattern.

Coding

We coded participants' responses as correct or incorrect. For each participant, we computed proportion correct responses for each trial type in each block. For the Exclusion block, we also computed proportion correct responses for each target type in each trial type. Analyses were computed on children's proportion correct for each target and trial type, following analysis strategies used in similar previous work (e.g. Cheng & Kibbe, under review; Applin & Kibbe, 2020; Pailian et al., 2020)

Results

We first examined children's overall performance using a linear mixed effects model. In the model, Order (Face-up block first or Exclusion block first), Block (Face-up or Exclusion block), Trial Type (Set Size 2 two swaps, Set Size 3 one swap, Set Size 3 two swaps) and Age (continuous, in years) were treated as fixed factors and Participant was treated as a random factor. The model was run in R using the lme4 package (Bates, Machler, Bolker, & Walker, 2014). The best fit model included the interaction between Block and Trial type, and interaction between Block and Age.

We observed a main effect of Age (F(1,49) = 20.61, *p* < .001, ηp2 = 0.296), providing converging evidence for developmental increases in working memory updating between the ages of 4 and 7 (Cheng & Kibbe, under review). We also observed an interaction effect between Block and Age (F(1,245) = 4.31, *p* = .039, ηp2 = 0.017); younger children performed better in the Face-up block, in which all cards were visible during encoding, compared with the Exclusion block, in which one of the cards was face-down during encoding, while older children performed similarly in the Face-up and Exclusion blocks. We observed no main effect of Trial type (F(2,245) = 0.98, *p* = .38, ηp2 = 0.008), suggesting that children in our age range performed similarly regardless of set sizes and number of swaps. There was no main effect of Order (F(1,49) = 0.23, *p* = .63, ηp2 = 0.005) and no interaction between Block and Trial type (F(2, 245) = 2.87, *p* = .058, ηp2 = 0.023) and (see Figure 2, upper panels).

We next examined whether children performed differently in the Exclusion block on trials in which the target was the face-up card (Target-up trials) and trials where the target was the face-down card (Target-down trials) using a linear mixed effects model. We included Trial type (Set Size 2 two swaps, Set Size 3 one swap, Set Size 3 two swaps), Target type (Target-up trial or Target-down trial) and Age (continuous, in years) as fixed factors and Participant as a random factor. The best fit model included the interaction between Trial type and Target type. We observed a main effect of Age (F(1, 49) = 21.25, p <.001, ηp2 = 0.302). We also observed a main effect of Trial type (F(2, 245) = 3.15, p = .045, ηp2 = 0.025); children performed better in the Set Size 2 two swaps than Set Size 3 one swap (Paired Samples Test: t(48) = 2.35, *p* = .023, d = 0.68) and Set Size 3 two swaps (t(48) = 1.96, *p* = .056, d = 0.57).. While children tended to perform better on target up compared with target down trials, the main effect of Target type did not reach statistical significance (F(1,245) =

3.80, *p* = .052, ηp2 = 0.015). We also observed no interaction between Trial type and Target type (F(2, 245) = 0.31, *p* = .73, ηp2 = 0.003) (see Figure 2, lower panels).

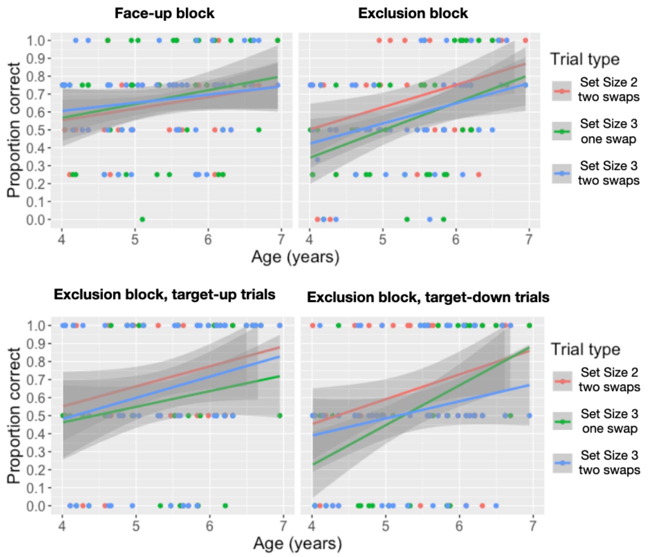

Figure 2. Children's performance on Face-up and Exclusion blocks (top panels) and on Target-up and Target-Down trials of the Exclusion block (bottom panels). Dots represent individual children's data, lines represent linear regression of proportion correct on age, shaded region represents 95% CI.

Finally, we further investigated the observed main effect of Age on children's performance by investigating whether and when children's performance exceeded chance levels across the blocks. We divided children into three groups based on their age in years (19 4-year-olds, 16 5-year-olds, and 14 6-year-olds). Since we did not observe a main effect of Trial type, we collapsed across Set Sizes and Number of Swaps and compared children's mean proportion correct performance in the Face-up and Exclusion blocks at each age group to chance using six separate one-sample t-tests (alpha = .008) and Bayes factor analysis. We found that children from all age groups performed significantly above chance in the Face-up block (all t > 3.08, *p* < .007, d > 1.45, BF_{10} > 6.76). However, only 6-year-olds' performance exceeded chance in the Exclusion block (t(13) = 6.48, *p* < .001, d > 2.9, BF_{10} > 1300). We further compared 6-year-olds' proportion correct for each Target type in the Exclusion block to examine whether 6-year-olds were truly able to apply the logical inference. 6-year-olds were significantly above chance in both Target-up trials (t(13) = 7.21, *p* < .001, d = 4.0, BF_{10} = 3773.6) and Target-down trials (t(13) = 3.63, *p* = .003, d = 2.01, BF_{10} = 15.04), and children's performance was not significantly different on Target-up compared with Target-down trials (*t*(13) = 1.86, *p* = .086, *d* = 1.03). Further, 6-year-olds' performance was not different in the Face-up block compared to the Exclusion block (*t*(13) = -.73, *p* = .477, *d* = 0.40 ; BF_{10} = .25), suggesting that children were successfully using reasoning by exclusion to "fill in" the missing identity.

Discussion

We investigated the development of the ability to use logical reasoning to infer the identity of a hidden object when tracking multiple occluded objects. We examined children from 4-7 years of age, during which previous studies suggested significant developmental changes in the ability to track location-bound identities in working memory (e.g., Applin & Kibbe, 2020; Cheng & Kibbe, under review; Pailian et al., 2016; Simmering, 2012). We found that when children were tasked with tracking multiple location-bound identities in working memory when all the items were available to be encoded (Face-up block), all children performed above chance and performance increased with age, consistent with previous work showing increases in working memory during this age range. However, when one of the items was not visible during the encoding period (Exclusion block), only 6-year-olds could use reasoning by exclusion to infer the identity of the target successfully. These results suggest that the ability to reason by exclusion about hidden identities may emerge around age 6, at least under the conditions tested here.

Previous work suggested that, by age 3, children can use reasoning by exclusion to infer the location of a hidden item (e.g., Mody & Carey, 2016; Grigoroglou et al., 2019). Yet, 4- and 5-year-old children in our task had difficulty using reasoning by exclusion to infer the identity of a hidden item. These children's difficulty is unlikely to stem from limitations to working memory capacity (Cowan, 2001; Cowan, Saults, & Clark, 2015; Kibbe, 2015); younger children performed better on Face-up trials, in which all information was available to be encoded, compared with Exclusion trials, in which only a subset of information was available, suggesting that they have sufficient working memory capacity to track at least the visible identities.

Nevertheless, in the Exclusion block, younger children performed similarly poorly regardless of whether they were probed on an item that was visible at encoding (Target-up trials, requiring working memory) or not visible at encoding (Target-down trials, requiring logical inference), even though the total number of identities that children had to track decreased. Furthermore, children's performance varied as a function of set size only in Exclusion trials. We speculate on a few possible explanations for this observed pattern.

One possibility is that children's ability to update working memory for object identities is less robust under representational uncertainty. In Exclusion trials, children may have created object-file representations for each object (visible and not-visible) and tracked all of these objects as they moved through space. Children's uncertainty about the identity of one object-file may have interfered with maintaining and tracking identity-bound object files for the other object(s) in the set, especially as set size increased (see Ma & Flombaum (2013) for evidence of representational uncertainty impacting multiple object tracking in adults).

Another, non-mutually exclusive possibility is that success in the task depends on children's ability to *avoid* tracking the unobserved object. Employing a strategy of tracking only a subset of items requires children to proactively plan which item they should attend to (Chevalier et al., 2014) while inhibiting the other items (Zelazo et al., 2014) and may also rely on metacognitive awareness of one's own limitations (Applin & Kibbe, 2020). Previous work suggests children shift from more reactive to more proactive working memory recall strategies between ages 5 and 7 years (Chevalier et al., 2014). If children's difficulty comes from the demands of tracking and updating working memory as objects move, we would expect children performance to decrease with set size in the Exclusion block. We may also therefore expect that children may perform better, or perhaps display some competence with reasoning by exclusion for unobserved identities, if the objects remain static during the maintenance period. We are currently investigating this possibility.

The current study examined whether children could explicitly reason by exclusion when only partial information was available, and therefore deductive inference was necessary to achieve the goal. On other occasions, inference by exclusion can also be applied when all information is available. For example, when given five items to remember, one can encode only four of them, and infer the fifth item by excluding the remembered alternatives. Therefore, remembering fewer items in working memory may be an efficient or even the only way (when storing all items exceeds the working memory limit) to achieve a goal. Future studies are needed to explore the developmental trajectory of using deductive inferences implicitly in working memory processes, and when and how children may strategically apply deductive reasoning to help them remember more information when working memory is taxed.

References

Applin, J. B., & Kibbe, M. M. (2020). Young children monitor the fidelity of visual working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

Call, J. (2004). Inferences about the location of food in the great apes (Pan paniscus, Pan troglodytes, Gorilla gorilla, and Pongo pygmaeus). *Journal of Comparative Psychology,* 118(2), 232.

Call, J. (2006). Inferences by exclusion in the great apes: the effect of age and species. *Animal cognition,* 9(4), 393-403

Cesana-Arlotti, N., Kovács, Á. M., & Téglás, E. (2020). Infants recruit logic to learn about the social world. *Nature communications,* 11(1), 1-9.

Cesana-Arlotti, N., Martín, A., Téglás, E., Vorobyova, L., Cetnarski, R., & Bonatti, L. L. (2018). Precursors of logical reasoning in preverbal human infants. *Science,* 359(6381), 1263-1266.

Cheng, C., Kaldy, Z., & Blaser, E. (2019). Two-year-olds succeed at MIT: Multiple identity tracking in 20-and 25-month-old infants. *Journal of experimental child psychology*, 187, 104649.

Cheng C., & Kibbe M. (*under review).* Development of updating in working memory in 4-7-year-old children.

Chevalier, N., James, T. D., Wiebe, S. A., Nelson, J. M., & Espy, K. A. (2014). Contribution of reactive and proactive control to children's working memory performance: Insight from item recall durations in response sequence planning. *Developmental psychology*, 50(7), 1999.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and brain sciences*, 24(1), 87-114.

Cowan, N., Saults, J. S., & Clark, K. M. (2015). Exploring age differences in visual working memory capacity: Is there a contribution of memory for configuration?. *Journal of experimental child psychology*, 135, 72-85.

Feigenson, L., & Yamaguchi, M. (2009). Limits on infants' ability to dynamically update object representations. *Infancy*, *14*(2), 244-262.

Feiman, R., Mody, S., Sanborn, S., & Carey, S. (2017). What do you mean, no? Toddlers' comprehension of logical "no" and "not". *Language Learning and Development*, 13(4), 430-450.

Ferrigno, S., Huang, Y., & Cantlon, J. F. (2021). Reasoning Through the Disjunctive Syllogism in Monkeys. *Psychological Science*, 0956797620971653.

Gautam, S., Suddendorf, T., & Redshaw, J. (2020). When can young children reason about an exclusive disjunction? A follow up to. *Cognition,* 104507.

Grigoroglou, M., Chan, S., & Ganea, P. A. (2019). Toddlers' understanding and use of verbal negation in inferential reasoning search tasks. *Journal of experimental child psychology*, 183, 222-241.

Halberda, J. (2003). The development of a word-learning strategy. *Cognition*, 87(1), B23-B34.

Hill, A., Collier-Baker, E., & Suddendorf, T. (2012). Inferential reasoning by exclusion in children (Homo sapiens). *Journal of Comparative Psychology,* 126(3), 243.

Kibbe, M. M. (2015). Varieties of visual working memory representation in infancy and beyond. *Current Directions in Psychological Science,* 24(6), 433-439.

Kibbe, M. M., & Feigenson, L. (2014). Developmental origins of recoding and decoding in memory. *Cognitive psychology*, *75*, 55-79.

Kibbe, M. M., & Leslie, A. M. (2011). What do infants remember when they forget? Location and identity in 6-month-olds' memory for objects. *Psychological science*, 22(12), 1500-1505.

Kibbe, M. M., & Leslie, A. M. (2013). What's the object of object working memory in infancy? Unraveling 'what'and 'how many'. *Cognitive Psychology*, 66(4), 380-404.

Ma, Z., & Flombaum, J. I. (2013). Off to a bad start: Uncertainty about the number of targets at the onset of multiple object tracking. *Journal of experimental psychology: human perception and performance*, *39*(5), 1421.

Mody, S., & Carey, S. (2016). The emergence of reasoning by the disjunctive syllogism in early childhood. *Cognition,* 154, 40-48.

Pailian, H., Carey, S. E., Halberda, J., & Pepperberg, I. M. (2020). Age and Species comparisons of Visual Mental Manipulation Ability as evidence for its Development and evolution. *Scientific reports,* 10(1), 1-7.

Premack, D. (1995). Cause/induced motion: Intention/spontaneous motion. In J. P. Changeux & J. Chavaillon (Eds.), *Origins of the human brain* (pp. 286–308). Oxford, England: Oxford University Press.

Premack, D., & Premack, A. J. (1994). Levels of causal understanding in chimpanzees and children. *Cognition,* 50(1-3), 347-362.

Simmering, V. R. (2012). The development of visual working memory capacity during early childhood. *Journal of experimental child psychology,* 111(4), 695-707.

Van den Berg, R., & Ma, W. J. (2018). A resource-rational theory of set size effects in human visual working memory. *ELife*, *7*, e34963.

Watson, J. S., Gergely, G., Csanyi, V., Topal, J., Gacsi, M., & Sarkozi, Z. (2001). Distinguishing logic from association in the solution of an invisible displacement task by children (Homo sapiens) and dogs (Canis familiaris): Using negation of disjunction. *Journal of Comparative Psychology,* 115(3), 219.

Wheeler, M. E., & Treisman, A. M. (2002). Binding in visual short term memory. *J Exp Psychol Gen*, 131, 48-64.

Zelazo, P. D., Müller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., ... & Carlson, S. M. (2003). The development of executive function in early childhood. *Monographs of the society for research in child development*, i-151.