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Order of Encoding Predicts Young Children's Responses to Sequencing Questions

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Abstract

We propose that young children exhibit an *order of encoding* bias, such that they are inclined to report or act out events in the order in which they were originally encoded. This bias helps to explain why children assume that events they first hear described are in chronological order and why they often appear to understand "after" better than "before" when they are questioned about experienced events. Asking children about a sequence of events as a whole (in particular using "first") could avoid order of encoding biases, because children would not have to answer questions about events within the sequence. In the present study, 100 2- to 4-year-old children participated in creating simple stories in which a story child interacted with five objects, thus creating five unrelated events. Children then responded to questions asking them to identify which action occurred "before" and "after" the third event and which action occurred "first" and "last" in the story. We hypothesized that (1) children would exhibit a tendency to answer "before" and "after" questions with the event that occurred after the queried event, thus impairing performance on "before" questions; (2) children would respond more accurately to questions about what occurred "first" and "last" than to questions about "before" and "after"; (3) children would respond more accurately to questions about "first" than questions about "last," and (4) children's performance would improve with age. The hypotheses were supported. Critically, children's errors when responding to "before"/ "after" questions were consistent with an order of encoding bias.

Keywords

event sequence; order of encoding; relative terms; categorical terms; language comprehension

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Event sequence is a critical element of clear communication about our experiences. Young children must learn that for a listener to comprehend the nature of a series of actions, the speaker must convey not just what happened, but how those actions unfolded in time (Reese et al., 2011). Although the sequencing terms "before," "after," "first," and "last," appear quite early in children's speech, there is uncertainty in the literature regarding children's developing understanding of those terms. We propose that young children exhibit an order of encoding bias, such that they are inclined to narrate or act out events in the order in which they were encoded. If a child experiences a sequence of events (X, Y, Z), and is asked what happened before or after a target event Y, order of encoding bias will lead the child to respond with what happened after the target event ("Z"), because the child encoded Z after the target event Y. Asking children what happened "first" or "last" in a series may avoid order of encoding bias, because use of the terms does not require reference to a target action within a sequence, but to the sequence as a whole. We further expect that this bias will be particularly pronounced at younger ages given the cognitive demands associated with overriding a prepotent response (i.e. reporting in the order of encoding). As we describe below, order of encoding bias helps to explain some of the apparently conflicting findings in the literature regarding children's descriptions of sequence, specifically research that suggests children sometimes appear to understand "after" better than "before."

In the present study, we assessed very young children's responses to questions using "before," "after," "first," and "last" in reference to a five-event sequence to examine the early emergence of sequencing capacities and biases. Specifically, children's tendency to report actions in the order in which they were encoded should lead to a tendency for children to answer "before" questions with what happened after the queried event. Because questions using "first" and "last" need only refer to a single action in the sequence without considering that action's position relative to another specific action in the sequence, "first" and "last" avoid the order of encoding bias. Therefore, children should demonstrate superior performance on "first" and "last" relative to "before" and "after." In what follows, we review prior research examining children's ability to respond to "before," "after," "first," and "last" prompts before presenting the details of the present study.

Before/After

Several recent studies (Blything & Cain, 2016; Blything, Davies, & Cain, 2015; de Ruiter, Theakston, Brandt, & Lieven, 2018) found that young children exhibited better understanding of sentences containing "before" and "after" when the order in which events were mentioned matched the order of events in the real world, sometimes referred to as iconic sentences (de Ruiter et al., 2018) or chronological sentences (Blything & Cain, 2016). Specifically, when children heard a sentence in which action X was mentioned first and action Y was mentioned second, they often acted as if action X occurred before action Y, regardless of whether the term "before" or "after" was used to connect the two actions. This *order of mention* bias (Clark, 1970; 1971) leads to inaccurate responses when children hear non-iconic statements describing two actions using the terms “before” and “after” (such as “Before Y, X” and “Y after X”) and then are asked for their interpretation of the statements, either by enacting the sequence or by providing a verbal or behavioral response to questions about the sequence (e.g. “touch the matching story”; de Ruiter et al, 2018). For example, a child might be instructed “Before Y, X.” The child should act out X and then Y, but if she is exhibiting the order of mention bias, will act out Y before X since Y was mentioned first (Clark, 1971). Similarly, a child might be told “Before Y, X” and then asked to provide a response indicating the order of events. The child should indicate that X happened first and that Y happened last, but if she is exhibiting the order of mention bias, will indicate that Y happened first (Blything et al., 2015) and that X happened last (Blything & Cain, 2016).

A number of past studies have demonstrated evidence of order of mention bias in young children (Bever, 1970; Feagans, 1980; French & Brown, 1977; Goodz, 1982; Hatch, 1971; McCormack & Hanley, 2011; Richards & Hawpe, 1981; Ritter & Tuinman, 1975). De Ruiter and colleagues summarized many of these studies, replicated the findings, and in an important extension, showed that young children also often applied this strategy to sentences with “if” and “because.” Other studies, however, do not show evidence that children use an order of mention strategy (Amidon, 1976; Amidon & Carey, 1972; Gorrell, Crain, & Fodor, 1989; Keller-Cohen, 1987). Closer inspection of these latter studies reveals that order of mention strategies may not have been detected due to simplification of tasks to reduce cognitive load (Gorrell et al., 1989; Stevenson & Pollitt, 1987; Trosborg, 1982), exclusion of younger children (Amidon, 1976; Amidon & Carey, 1972) who are often more inclined to exhibit order of mention biases (Blything et al., 2015; Blything & Cain, 2016), and linkage of events through causation, which can override the order of mention strategy because children can use causal logic to support their responding (e.g. “The boy cut the cake but before that he blew out the candles”; Keller-Cohen, 1987).

De Ruiter and colleagues (2018) also noted that most studies of children’s abilities to answer “before” and “after” questions found that children appeared to exhibit better comprehension of “before” than “after,” once order of mention biases are taken into account (Blything & Cain, 2016; Blything et al., 2015; Feagans, 1980; Johnson, 1975). A number of explanations have been put forward for this finding; as just one example, it has been noted that “before” is more consistently used as a temporal connective than “after,” and therefore children may have greater difficulty in learning the semantics of “after” (Blything & Cain, 2019; de Ruiter et al., 2018).

De Ruiter and colleagues (2018) identified one study coming to the opposite conclusion, that children appeared to understand “after” better than “before” (Carni & French, 1984). This study took a different approach to assessing children’s understanding. The most common approach is to present children with statements describing two actions using the terms “before” and “after” and then test their interpretation of the statements, either by asking them to act out the sequence or answer questions about the sequence. This approach was taken by studies finding superior understanding of “before.” In contrast, Carni and French (1984) presented 3- and 4-year-old children with an event sequence (with five actions depicted on cards) and then asked them questions about the depicted sequence using the terms “before” and “after” (e.g., “what happened after they colored in coloring books?”).

Similarly, Coker (1978) showed 5- to 7-year-old children a set of three pictures sequentially and asked "what did I show you before/after the X?", and children performed better in responding to "after" than "before" questions. These latter findings have been explained by a strategy of responding with the "next-event-in-time" when recalling sequences (Coker, 1978). As a result, young children tend to respond with what happened after the target event regardless of whether they were asked what happened "before" or "after," leading to higher rates of accuracy for "after" than "before."

If children exhibit an order of encoding bias, then the studies finding superior performance on "after" can be reconciled with the bulk of studies that find superior performance on "before." Both order of mention and next-event-in-time biases involve children responding in line with how action sequences were originally encoded, rather than children's underlying understanding of the constructs "before" or "after." When children first hear stimuli described as XY, they encode the stimuli in the order mentioned. If they exhibit the order of encoding bias, they will interpret both "X before Y" and "X after Y" as XY because they encoded X before Y. As such, they would appear to better understand "before." When children are first presented with a series of events - XYZ, they encode the events in that order. They will answer "what happened before Y?" and "what happened after Y?" questions with Z because they encoded Y before Z. This makes them appear to better understand "after. Thus, children will appear to better understand "before" in paradigms asking them to enact "X before Y" and they will appear to better understand "after" in paradigms asking them to indicate "what happened after X" because both require children to respond in the same order that X and Y were presented to them - X first, Y second.

First/Last

It is possible that not all sequencing terms are equally susceptible to order of encoding bias. With respect to the series of events XYZ, any "what happened before?" and "what happened after?" questions about the series require referring to a target event within the series, whereas the ordinal questions "what happened first" and "what happened last" refer to the series as a whole. In other words, "before" and "after" require movement both forwards and backwards within that series, whereas "first" and "last" identify endpoints. It is the reference to a target event within the series that would lead to order of encoding bias: a child hears an event referenced and responds with the next event in the sequence from the original encoding. Moreover, in the series of events XYZ, only one event in the series is "first," and only one "last," whereas an event within the series (Y) can be both "before" one event (Z) and "after" another event (X). Hence, questions about the series as a whole might elicit more accurate responses.

A few of the studies examining children's comprehension of "before" and "after" found some evidence of superior performance on "first" and "last" (Amidon & Carey, 1972; Munro & Wales, 1982; Richards & Hawpe, 1981), and the latter two papers recognized the potential difficulties of the relative meaning of "before"/ "after". Some studies implicitly assume that "first" and "last" are simpler concepts, using the terms as test questions designed to assess children's understanding of "before" and "after" (Blything & Cain, 2016; Blything et al., 2015).

These studies leave several questions unanswered, however. Amidon and Carey (1972) compared "before"/ "after" to "first"/ "last" by giving children commands that included both "first" and "last" (e.g., "move X first; move Y last"). They found no order of mention biases for either pair of terms. As such, they could not assess the potential for "first"/ "last" to overcome order of encoding biases. Furthermore, using both "first" and "last" in two-action sequences made children's superior performance on "first"/ "last" difficult to interpret. For example, children who understood "first" but not "last" (or vice versa) would do well on the task simply because, by default, the action that was not first must be last. Munro and Wales (1982) were interested in 4- to 7-year-old children's understanding of duration and simultaneity, and thus created complex sentences such as "the yellow light comes on before the red light comes on, and the yellow light goes off before the red light goes off." "First" was understood better than "before" only among the older children, whereas all children understood "last" better than "after." Richards and Hawpe (1981) told 4- to 6-year-old children to "push X and Y" and then either "push X first" or "push Y last." The authors noted that children who simply initiated their actions with the item mentioned again would appear to understand "first" and not understand "last," and this was indeed the pattern with 4-year-olds. None of the studies comparing before/after with first/last examined children's facility in responding to questions using "first" and "last" to describe presented action sequences (as opposed to commands to be acted out).

Furthermore, because all the studies examined two-action sequences, children would appear to understand "last" if they simply interpreted it as "not first." There are several reasons to expect that "first" is better understood than "last." The acquisition of sequential terms coincides with children's ability to count and the inception of counting principles (Gelman & Gallistel, 1978). "First" can be thought of as synonymous with the concept of "one," the first item in a number line, whereas "last" is not consistently mapped onto a numerical value, but changes depending on the size of the set, making it a more abstract concept. In fact, "last" is constantly updated if one is in the midst of a series; as Richards and Hawpe (1981) point out, "last… does not mean 'final' but only 'last up to the present time" (p. 510). As such, it has a relative sense that likely makes it more difficult to understand than "first."

The Present Study

Given the unclear developmental picture to date regarding children's abilities to sequence events, the present study aimed to examine children's emerging understanding of the sequential concepts "before," "after," "first," and "last" utilizing a paradigm that addresses many of the limitations observed in previous research. We presented children with an extended series of actions to be sequenced and as such were able to test performance on "before," "after," "first," and "last" with reference to separate actions within the sequence. To reduce children's memory load, and instead focus on their response tendencies, images representing each action were left in plain sight during the test, in the order in which they were originally presented (Blything et al., 2015; Carni & French, 1984; Vion & Colas, 2005). So that order of mention in the test question would not influence children's responses, and to avoid the complexity of beginning questions with the connective (Blything & Cain, 2019), children were always asked "what happened before/after [third event]?" Further, to capture the emergence and early developmental progression of children's sequencing abilities, we recruited a sample of 2- to 4-year old children. This design allowed us to test the following hypotheses: (1) children would exhibit a tendency to answer "before" and "after" questions with the event that occurred after the queried event, thus impairing performance on "before" questions; (2) children would respond more accurately to questions about what occurred "first" and "last" than to questions about "before" and "after"; (3) children would respond more accurately to questions about "first" than questions about "last," and (4) children's performance would improve with age. Finally, we examined children's patterns of responding to explore other possible response biases.

Method

Participants

Participants included 100 children (49 females and 51 males), from 30 to 61 months of age (M = 46.17, SD = 8.48). The sample size is comparable to recent research examining children's understanding of "before" and "after" (Blything et al., 2015 [91 3- to 7-year-olds]; De Ruiter et al., 2018 [71 3- to 5-year-olds]). Children were recruited from preschools around the Los Angeles area that serve predominantly middle- to upper-middle-class families. Sixty-two percent[1] of the children were Caucasian, 14% were Asian-American, 6% were African-American, 5% were Hispanic-American, and 13% were mixed ethnicities or unknown.

Procedure

Children of consenting parents were approached in their preschool classrooms. The same female experimenter conducted all sessions and began each interaction by first introducing herself to the child and asking if the child would like to read some stories and play some games. When children agreed, the experimenter brought them into a quiet room at their preschool and conducted formal verbal assent procedures. Next, children drew from a deck of cards with each card depicting a single object (e.g. an ice cream cone). They drew five cards from the deck, one at a time, for each of six total card arrays. As each card was selected, the child placed it in order on a board from top to bottom and the experimenter described an action related to the depicted object and highlighted the sequence of events to the child by using the connective "then." All of the cards within a single series were left in view of the child, in order (top to bottom), during questioning. We always ordered the cards top to bottom to avoid orders that might inherently suggest a particular sequence, such as a left to right ordering that could suggest a sequence to pre-readers, or a bottom to top ordering that could suggest a sequence to children experienced with stacking games (cf. Carni & French, 1984, who ordered both top to bottom and left to right, but found no differences in performance among 3- to 4-year-olds questioned with "before" and "after").

For example, if a participant drew the following five cards: (1) an ice cream cone, (2) a dog, (3) a book, (4) a ball, and (5) a kite, the participant placed each card, one at a time, in the order in which they were drawn, on a Velcro board, and the experimenter manually recorded

[1]Because our sample consisted of 100 participants, and in the interest of saving space and minimizing redundancy, we have opted not to include the corresponding Ns where percentages for the full sample are presented.

the images as they were selected. The experimenter told the participant a story in which a story child (gender matched to the participant) completed actions with each of the objects in the order they were drawn. In the above example, after the child placed the first card on the board, the experimenter stated "she ate an ice cream cone." After the child placed the second card, the experimenter stated "then she played with a dog" and so on. The experimenter then asked the participant to repeat the full story to confirm encoding. Although we did not systematically record children's responses, pilot testing confirmed that children had little difficulty in repeating the sequence of events.

Next, the experimenter asked the key sequencing questions. She pointed to the image depicted on the third card in the series - in the above example, the image depicting a book – and she asked the participant to indicate what happened "before" the story child read the book, what happened "after" she read the book, what happened "first," and what happened "last." Children's responses included either naming or pointing to an object depicted on the card and were recorded based on the card's location in the sequence (see Carni & French, 1984), any other response was coded as no response (which was rare). The order of these questions was counterbalanced across the six card arrays. At the completion of each card array and questioning set, the card array was removed and the procedure was repeated until six card arrays and question sets were presented. Finally, the experimenter administered the Woodcock-Johnson III, Picture Vocabulary subtest (Woodcock, McGrew, Mather, & Schrank, 2001) before thanking the child, giving them a sticker, and returning them to their classroom.

Children's Vocabulary Scores

Children's performance on the Woodcock Johnson III Picture Vocabulary subtest was above average with raw scores averaging 22.58 ($SD = 3.60$). On average, children performed at the level of a typical 5-year-old (M_{age} equivalent = 5.0 years), with age equivalent scores ranging from 2;7 to 9;8 ($SD = 1.43$). Thus, no children were excluded due to their performance on the vocabulary subtest. Child's age and Woodcock Johnson scores were highly correlated ($R = .62$, $p < .001$) and age was of greater theoretical interest in the present study. Therefore, Woodcock Johnson scores were excluded from the primary analyses.

Analysis Plan

First, analyses tested whether children exhibited a bias to answer both before and after questions with what occurred after the queried event, impairing their performance on the "before" questions (Hypothesis 1). We analyzed children's pattern of errors in response to the "before" questions by comparing errors to chance and by comparing children's performance on "before" and "after" questions. Second, we tested whether children were more accurate in response to the "first/last" questions than to the "before/after" questions (Hypothesis 2). Third, we tested whether children were more accurate in response to the "first'' questions than the "last" questions (Hypothesis 3). In order to assess age effects (Hypothesis 4), we included age as a factor in all analyses examining accuracy, and included an interaction between age and question-type when it increased the fit of the model. Age in months was a continuous factor in all models. Fourth, we conducted exploratory analyses on children's patterns of errors in response to "after", "first", and "last" questions.

Analyses were conducted using GLMMs and binomial tests. Fixed effects included (question type: “before”, “after”, “first”, and “last”), and child’s age (in months, continuous), and the dependent response variable was accuracy or error response (both dichotomous). Models were cross-validated to ensure that interaction effects were included only when they increased the fit of the model based on AIC values. All GLMM models included a random intercept (i.e., ‘child’) to control for the repeated questions addressed to each child and children’s individual response proclivities. Including ‘form’ as a random effect did not explain additional variance, and thus, it was excluded from the model. For example:

Accuracy ~ Question Type (dichotomous) + Child’s age + (1 | child)

Or

Accuracy ~ Question Type (dichotomous) + Child’s age + Question Type: Child’s age + (1 | child)

Analyses were performed using the *glmer* function in the R package *lme4* with the bobyqa and Nelder-Mead optimizers and Laplace approximations (Bates, Machler, Bolker, & Walker, 2015). GLMMs combine the properties of linear mixed models (which incorporate random effects) and generalized linear models (which handle non-normal data) and are preferable to traditional analysis of variance (ANOVA) models because they have fewer assumptions, handle response variables from different distributions (e.g., binary, count, or proportion), and maximize power while simultaneously estimating between-subject variance (Bates et al., 2015; Bolker, Brooks, Clark, Geange, Poulson, Stevens, & White, 2009; Pinhero & Bates, 2000). The most complex converged models are reported below accompanied by the unstandardized fixed effect estimates (β), standard errors of the estimates (*SE*), and estimates of significance (z and p values). Only significant findings ($p < .05$) are reported descriptively in the text but output from all GLMM analyses can be found in Tables 3–5.

Results

Children’s accuracy in response to the four question types is depicted in Table 1, and the distribution of their responses is depicted in Table 2. As can be seen from Table 1, children’s responses were most likely to be accurate in response to the “first” questions (82%), and least likely to be accurate to “before” questions (46%). Children’s performance on the “after” (56%) and “last” (56%) questions fell in-between.

We examined whether children exhibited a tendency to answer “before” questions with what happened after the target event, consistent with an order of encoding bias (Hypothesis 1). Descriptively, as is apparent in the pattern of children’s responses across the events (Table 2), the most common error in response to the “before” questions was to choose the event that occurred after the target event. In fact, this error was more frequent than all other error types combined. (Below, we will explore the most frequent errors for the other question types.) Assuming no response bias, and disregarding the rare cases in which children failed to respond at all, or pointed to Event 3 (which was the target event), error responses should be evenly distributed across Event 1, Event 4, and Event 5. Thus, responses indicating Event 4 to questions asking what happened "before" the target should entail 33% of all error responses. Instead, children erred by choosing Event 4 significantly more often than would be expected by chance (62%) [$p < .001$, 95% CI [0.56, 0.68]). In comparison, children selected target 1 (21%) and target 5 (17%) less than $\frac{1}{3}$ of the time.

To compare performance on "before" questions to "after" questions, we conducted a GLMM comparing children's accuracy in response to both question types. The model included question type ("before" and "after") and age (in months, continuous). As predicted, children's accuracy increased with age (β =1.71, SE = 0.32, z = 5.31, $p < .001$), and children were more accurate in response to "after" questions than "before" questions ($\beta = -0.74$, SE = 0.16, $z = -4.64$, $p < .001$; see Table 3 and Figure 1).

To test whether children answered "first" and "last" questions more accurately than "before" and "after" questions (Hypothesis 2), we conducted a GLMM including question type ("first/last" vs. "before/after") and age (in months, continuous) as fixed effects. As predicted, children were more accurate in response to "first/last" questions (68%; β = 1.13, SE = 0.11, z = 10.53, $p < .001$) than "before/after" questions (51%). Children's performance improved with age (β = 1.63, SE = 0.28, z = 5.81, $p < .001$; see Table 4 and Figure 2). In order to identify what was driving the difference, we conducted four pairwise comparisons comparing "first" to both "before" and "after," and "last" to both "before" and "after." Analyses found that children were significantly more accurate in response to "first" questions compared to "before" and "after" questions, and children were significantly more accurate in response to "last" questions compared to "before" questions (see Table 5).

To test the difference in children's performance between "first" and "last" questions (Hypothesis 3), we conducted a GLMM comparing children's accuracy in response to "first" and "last" questions. The model found a main effect of age and an interaction effect between question type and age. Again, older children were more accurate (β = 1.62, SE = 0.43, z = 3.80, $p < .001$), and children's performance on "first" questions improved earlier in development compared to "last" questions (β = 1.00, SE = 0.31, z = 3.18, p = .001; see Table 6 and Figure 3).

Last, analyses explored other potential responses biases similarly to how the "before" error responses were examined above. There were two types of unexpected errors that are worthy of mention, both of them involving Event 2. Event 2 was the most common error in response to "last" questions (21% of total responses; 55% of error responses) and in response to "after" questions (18% of total responses; 49% of error responses). We speculate about the reasons for these errors in the discussion.

Discussion

This study examined young children's developing understanding of "before," "after," "first," and "last" when questioned about a story. Our hypotheses were supported. First, children's responses to "before" questions often appeared to be driven by order of encoding bias. Namely, children showed a tendency to answer "before" questions by naming the event that occurred after the target event, that is, in the order in which they encoded the events. As such, children appeared to have better understanding of "after" than "before," though this may have been a product of response bias. Second, children's responses to "first," and to some extent, "last," questions about the series of events were more accurate than responses to "before" and "after" questions about target events within the series. Third, children's accuracy in response to "first" questions improved at a faster rate than their accuracy in response to "last" questions. Children exhibited a tendency to understand "first" at a very young age, whereas their understanding of "last" gradually emerged in a pattern more similar to their understanding of "before" and "after." In what follows, we discuss each of our primary findings in light of prior research, and then discuss limitations of the study and future directions for research.

With respect to children's understanding of "before" and "after," our findings may help to explain why some research finds that "after" appears to be better understood than "before" (Carni & French, 1984; Coker, 1978). When children are presented with an event sequence and then are asked "before" and "after" questions about that sequence, order of encoding bias increases the likelihood that they will answer both "before" and "after" questions in the order of the presented event sequence, impairing performance in response to "before" questions and boosting performance in response to "after" questions. These findings are consistent with a body of research showing that although even young children have some facility in reconstructing the sequence of experienced events, they have difficulty narrating events in reverse sequence (Brown, 1975, 1976; Brown & French, 1976; Catellani, 1991; Fivush & Mandler, 1985; Hudson & Fivush, 1983; Weist, Lyytinen, Wysocka, & Atanassova, 1997). We argue that this process underlies the order of encoding bias. Children are more likely to have difficulty in answering "before" questions about events when they encoded those events in forward sequential order. In contrast, when children are asked to enact or identify sequences they hear described (with the words "before" and "after"), order of encoding bias leads to the order of mention problem: children behave as if the events occurred in the order in which they were mentioned.

Our findings suggest that "first" and "last" are simpler concepts than "before" and "after" and therefore easier to grasp. "First" and "last" do not reference an element within a series but refer to the series as a whole. Ordering of an action relative to another specific action in the sequence, however, is essential for responding to "before" and "after" questions, increasing the conceptual complexity of these terms. Moreover, a single action may occur both before one reference point and after another reference point whereas the positions of the first and last actions in a sequence are more absolute.

The distinction between "first"/ "last" and "before"/ "after" is analogous to work in cognitive development comparing children's understanding of categorical terms and comparative terms, and finding earlier acquisition of categorical terms (Syrett, 2016). For example, research has found that children find it easier to use "big" and "little" (Sera & Smith, 1987) or "high" and "low" categorically (Smith, Rattermann, & Sera, 1988) than to use them in making comparative judgments (as when one would use "bigger/smaller" or "higher/lower"). Sera and Smith's (1987) description of preschool children's specific difficulty with flexible use of “big” and “little” is analogous to the distinction between “first”/ “last” and “before”/“after”:

> In short, when children do not label a pair of objects in terms of the direction of difference relative to each other, it is because they label the objects according to their position in a series. Notice that this usage is relational; the relation being used by the child, however, is the relation between an object and the series as a whole (Sera & Smith, 1987, pp. 108).

Sera and Smith further argue that comparison within a series is more complex than comparing an item to a series as a whole, which is in line with our results showing that “before” and “after,” which require comparison within a series, are more difficult than “first” and “last,” which only require comparison of the items to the series as a whole.

With respect to the finding that children were more accurate when asked about what happened “first” than any other question type, and the steeper course of development in response to questions asking what happened “first” compared to what happened “last,” we suspect that “first” is ingrained early in development both because it is equivalent to “one” on a number line, making it a simple numerical concept for children to master, and because the “first” action in a sequence is established the moment it occurs, requiring less flexibility in the application of the term. In other words, the first action in a sequence will remain first regardless of proceeding actions, whereas the last action in a sequence requires that there be no further actions. As such, the last action in a sequence, opposed to the first action in a sequence, shifts as actions unfold, making “last” a less stable concept. Previous research has overlooked the potential difficulties in understanding “last” because it tested children’s understanding of two event phrases in which both terms were used (e.g., “Move the red plane first; move the blue plane last”; Amidon & Carey, 1972), so that if a child understood “first” he or she would also seem to understand “last.” The present study is the first to disentangle “first” and “last” in order to directly compare children’s emergent comprehension of these terms.

We identified another form of bias that impaired children’s performance on “last” questions. Specifically, children showed some tendency to answer “last” questions with what happened second. This might occur for several reasons. First, children may encode the second action in the sequence as “last” the moment it is presented and struggle to update that designation as further actions are listed. Another possibility is that children may simply confuse “last” with “second.” By the same token that associating “first” with the number line might facilitate understanding of “first,” association of “last” with the number line might undermine understanding. These possibilities further highlight the importance of considering larger sets of events (that is, larger than two) when attempting to study children’s sequencing abilities and biases. Third, it is possible that children responded to “last” questions with reference to the target event in the “before” and “after” questions (the third event). From the perspective of the third event, the “last” event could be the second event (i.e., “last year” refers to the year before this year). However, we view this explanation as unlikely, because it would require children to keep in mind the target event from prior questions. At any rate, future research can vary the target event, or ask about “first” and “last” without use of "before" and "after" questions, in order to ascertain the source of younger children's difficulty with "last."

A limitation of the study is that we did not manipulate order of mention within our "before" and "after" questions, and this may have impaired children's performance in response to the "after" questions. Children consistently responded to "before" questions in forward order ("what did he do before X?") and "after" questions in backward order ("what did he do after X?"). That is, "what did he do" was mentioned before X in both the "before" and "after" questions. We made this decision in order to minimize the syntactic complexity of the questions (e.g. "what did he do after X?" is less complex than "after X, what did he do?") (Blything & Cain, 2019). This may have made "after" questions more challenging because of the discrepancy between the order of mention in the question and the order in which the events were originally presented. Indeed, we found that the most common error in response to the "after" questions was to choose the event that occurred before the target event, consistent with an order of mention bias. However, because we did not vary order of mention, future research should directly test its effects. If order of mention matters, then children should be more accurate in responding to "After X, what did he do?" than to "What did he do after X?" Conversely, it is possible that children responding to "What did he do after X?" questions mentally begin their response with "after X…" thus essentially preserving order of mention. If this is the case, then wording the question as "After X, what did he do?" would not affect performance.

An important issue for future research concerns the relation between children's understanding of sequencing terms and the memorability of different events within a sequence. The greater memorability of items at the beginning of lists (primacy effects) and at the end of lists (recency effects) is a classic finding (Ebbinghaus, 1885), and a long line of studies have examined these effects in children, both with stimuli similar to those used in this study (Atkinson, Hansen, & Bernnach, 1964) and in more naturalistic contexts (Powell, Thomson, & Ceci, 2003). Because we were interested in language comprehension, we deliberately minimized differences in memorability by keeping the array in view. One could examine possible interactions between comprehension of sequencing terms and memorability by asking children sequencing questions with and without a visible array, or with and without an array that preserves the original sequence.

The present research has important implications for developmental theories of children's ability to describe sequence and may have practical implications for practitioners invested in eliciting accurate event sequences from children about their prior experiences. As noted above, children are naturally inclined to report events in forward sequential order and struggle when they are asked to report events in reverse sequence. This finding has been replicated in applied research: In the lab, children have exhibited difficulty with narrating events in reverse sequence (a component of the Cognitive Interview, Geiselman & Padilla, 1988), and in the field, children interviewed about abuse have had difficulty in identifying what occurred before a target event (Orbach & Lamb, 2007). Field researchers should examine whether children's difficulty with "before" questions reflects a tendency to respond with what happened after the reference event, and whether children may be able to identify events prior to reported details through questions asking about the "first" event.

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Highlights

- We propose an *order of encoding bias* driving children's early event sequencing.
- Responses to first/last questions were not affected by order of encoding bias.
- Children were most accurate at identifying what happened first.
- Sequencing performance improved across early development.

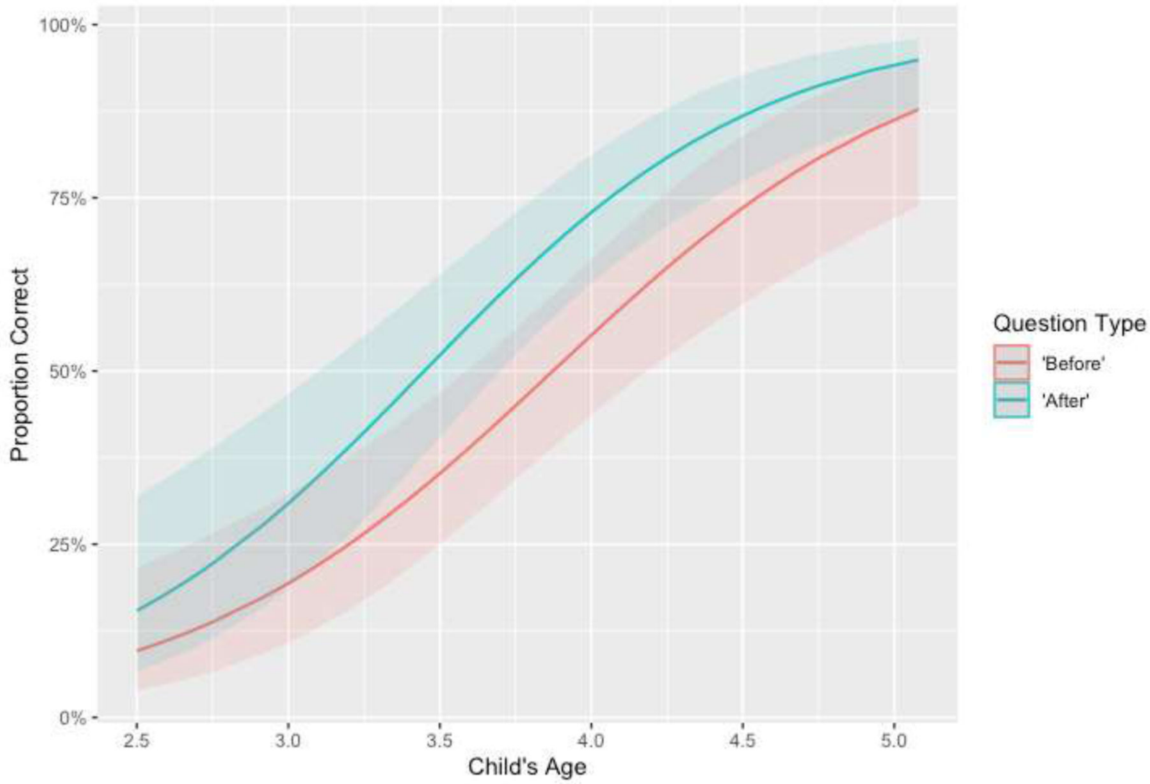

Figure 1.
Children's proportion correct to "before" and "after" questions by age with confidence intervals.

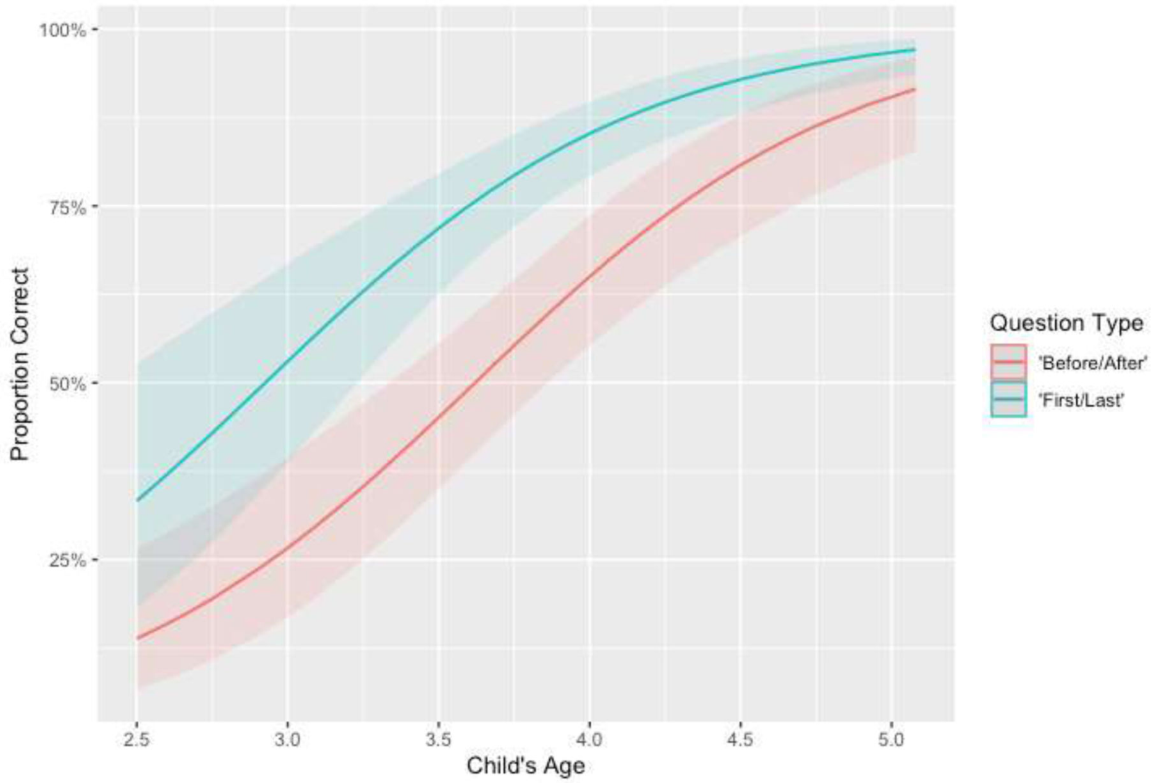

Figure 2.
Children's proportion correct to "before/after" and "first/last" questions by age with confidence intervals.

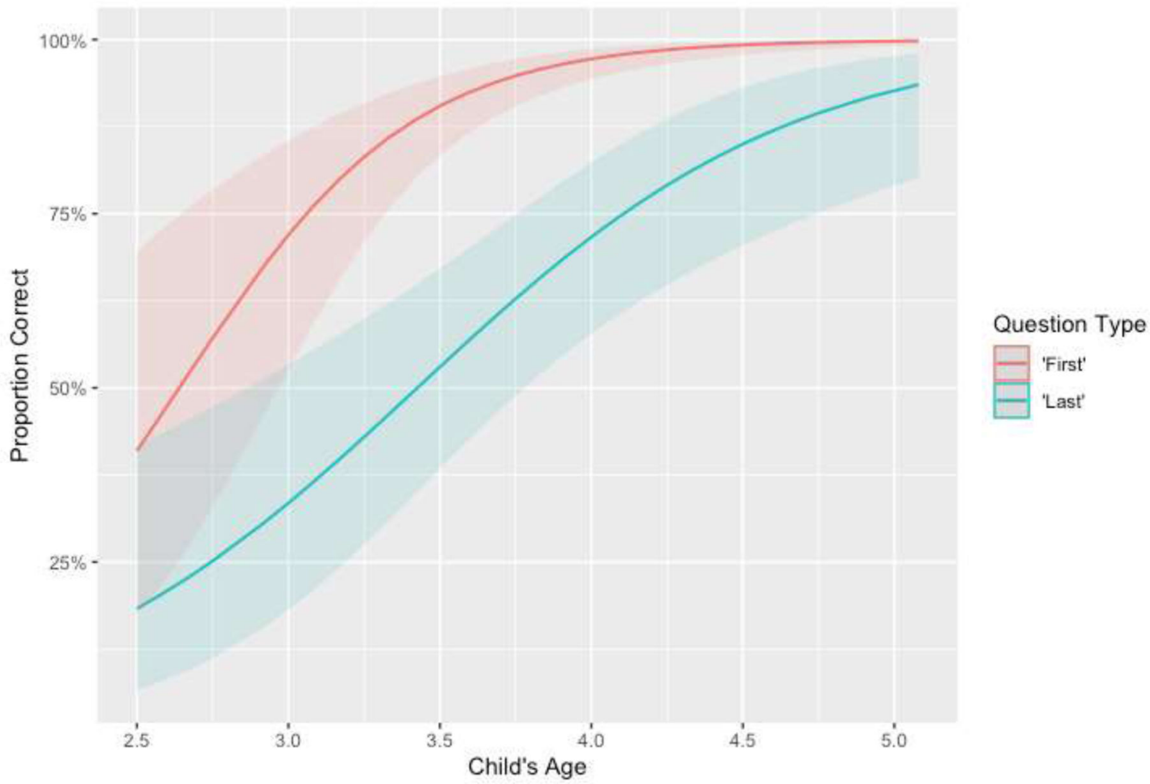

Figure 3.
Children's proportion correct to "first" and "last" questions by age with confidence intervals.

Table 1

Children's Proportion Correct by Question Type and Age

Question	30–35 Mo.	36–41 Mo.	42–47 Mo.	48–53 Mo.	54–61 Mo.	Overall
First	0.65	0.66	0.83	0.86	0.96	0.82
Last	0.40	0.37	0.60	0.52	0.75	0.56
Before	0.26	0.23	0.43	0.51	0.71	0.46
After	0.35	0.40	0.49	0.70	0.75	0.56

Table 2

Proportion of Children's Responses Across Events in Response to Each Question Type

Question	Event 1	Event 2	Event 3	Event 4	Event 5	No Response
First	**0.82**	0.05	0.04	0.03	0.06	0.01
Last	0.09	0.21	0.04	0.09	**0.56**	0.02
Before	0.10	**0.46**	0.04	0.28	0.08	0.05
After	0.06	0.18	0.03	**0.56**	0.12	0.05

Note. Correct responses are bolded. For Before and After questions, Event 3 was the target event.

Table 3

Results of GLMM Analyses Exploring Effects of "Before" and "After" Questions and Child's Age on Children's Accuracy

Fixed Effect	***β***	***SE***	***z***	***p***
Intercept	−5.88	1.23	−4.78	<0.001
Question Type	−0.74	0.16	−4.64	<0.001
Age (Months)	1.71	0.32	5.31	<0.001

Note. Base level: before

Table 4

Results of GLMM Analyses Exploring Effects of “Before/After” and “First/Last” Question Types and Child’s Age on Children’s Accuracy

Fixed Effect	*β*	*SE*	*z*	*p*
Intercept	−5.91	1.08	−5.46	<0.001
Question Type	1.13	0.11	10.53	<0.001
Age (Months)	1.63	0.28	5.81	<0.001

Note. Base level: first/last

Table 5

Pairwise Comparisons Exploring Effects of "Before/After" and "First/Last" Question Types Controlling for Child's Age on Children's Accuracy

Contrast	OR	SE	df	*z*	*p*
First/Before	0.06	0.01	Inf	−14.23	<.0001
First/After	0.14	0.03	Inf	−10.69	<.0001
Last/Before	0.54	0.08	Inf	−3.95	0.004
Last/After	1.16	0.18	Inf	0.98	0.76

Note: Analyses were conducted within child's age (3.85 years old).

Table 6

Results of GLMM Analyses Exploring Effects of "First" and "Last" Questions and Child's Age on Children's Accuracy

Fixed Effect	***β***	***SE***	***z***	***p***
Intercept	−5.53	1.61	−3.45	<0.001
Question Type	−1.37	1.12	−1.22	0.22
Age (Months)	1.61	0.43	3.80	<0.001
Question: Age	1.00	0.31	3.18	.001

Note. Base level: last