

**Today is tomorrow's yesterday:
Children's acquisition of deictic time words**

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Abstract

Deictic time words like “yesterday” and “tomorrow” pose a challenge to children not only because they are abstract, and label periods in time, but also because their denotations vary according to the time at which they are uttered: Monday’s “tomorrow” is different than Thursday’s. Although children produce these words as early as age 2 or 3, they do not use them in adult-like ways for several subsequent years. Here, we explored whether children have partial but systematic meanings for these words during the long delay before adult-like usage. We asked 3- to 8-year-olds to represent these words on a bidirectional, left-to-right timeline that extended from the past (infancy) to the future (adulthood). This method allowed us to independently probe knowledge of these words’ deictic status (e.g., “yesterday” is in the past), relative ordering (e.g., “last week” was before “yesterday”), and remoteness from the present (e.g., “last week” was about 7 times longer ago than “yesterday”). We found that adult-like knowledge of deictic status and order emerge in synchrony, between ages 4 and 6, but that knowledge of remoteness emerges later, after age 7. Our findings suggest that children’s early use of deictic time words is not random, but instead reflects the gradual construction of a structured lexical domain. (208)

Keywords: word learning; conceptual development; time; language acquisition; abstract concepts; timeline

K, age 4: “Yesterday ... that’s last night’s morning.”

1 Introduction

To learn their first words, children must rely primarily on the extra-linguistic context in which those words are used, since they are not yet able to understand the sentences in which the words are embedded. Consequently, children’s first words often label concrete referents that can be ostensively identified, like “mama,” “doggie,” and “cup.” Other words, however, are more difficult to learn through observation of the world and may require children to recruit their knowledge of the linguistic context in which those words are embedded (e.g., Gillette, Gleitman, Gleitman & Lederer, 1999; Gleitman, 1990; Gleitman et al., 2005; Snedeker & Gleitman, 2004). For example, the meanings of *deictic time words*, such as “yesterday” and “tomorrow,” cannot be gleaned solely from extra-linguistic situations. These words are abstract and describe periods in time, which are difficult to reference ostensively. Further, due to their deictic functions, these words do not have fixed denotations and cannot be understood without information about the time at which they are uttered (Fillmore, 1979/1999): Tuesday’s “tomorrow” is different from Wednesday’s “tomorrow.” Acquiring words like these is one of the greatest challenges that English-learning children face, as evidenced by the massive gap between their first use of deictic time words around age 3 and their eventual mastery of adult-like meanings in elementary school (Ames, 1946; Busby Grant & Suddendorf, 2011; Harner, 1975, 1981). However, the process through which these words are ultimately acquired—and thus the roles of linguistic and referential context—remains mysterious. Here, as a case study of abstract word learning, we explore children’s gradual construction of deictic time word meanings between ages 3 and 8.

While many children produce words like “yesterday” and “tomorrow” as early as age 2 or 3 (Ames, 1946; Busby Grant & Suddendorf, 2011; Dale & Fenson, 1996), they do not use them

as adults do for several subsequent years (Ames, 1946; Busby Grant, & Suddendorf, 2011; Harner, 1975, 1981; Nelson, 1996; Weist, 1989; Weist et al., 1991). According to parental report, two thirds of 3-year-olds produce the word “yesterday,” but fewer than 20% use the word in adult-like ways; by age 5, more than 80% of children produce “yesterday,” but, still, fewer than 60% use it like adults (Busby Grant & Suddendorf, 2011). Children struggle not just with production but also with comprehension: When asked to name an event that occurred “yesterday” or one that will occur “tomorrow,” only about a quarter of 3-year-olds can provide reasonable answers (Busby & Suddendorf, 2005; Suddendorf, 2010). These difficulties persist even later in acquisition, as 5-year-olds can correctly generate an event from “yesterday” only 66% of the time, and an event that will occur “tomorrow” only 63% of the time (Busby & Suddendorf, 2005).

Although children differ from adults in how they use time words, it remains possible that they nevertheless use them systematically, and that they construct their meanings gradually and in stages over the first 6 or 7 years of life. Consider an anecdote: When 21-month-old Franny tried to remove dirty dishes from the dishwasher, her mother stopped her and said, “We can empty it *tomorrow*.” Upon hearing this, Franny ran to her bedroom, climbed under her blanket, closed her eyes, and after a brief delay returned to the kitchen to begin the chore. For Franny, “tomorrow” seemed to mean something like “after waking up.” Just a few months later, Franny began producing the word “yesterday,” but used it to refer not only to events that happened the previous day, but also to events that happened two days ago, five minutes ago, and even several months earlier. Productions like Franny’s are thought to be quite common (Ames, 1946; Friedman, 1990; Harner, 1981; 1982; Nelson, 1996; Weist, 1989) and suggest that although

young children do not use deictic time words in adult-like ways, they may have partial knowledge of their meanings.

Critically, knowledge of partial word meanings may not have been detectable by the comprehension measures used in previous studies (i.e., parental report and event naming). For example, although adult English speakers may judge that Franny fails to use “yesterday” correctly, Franny may nonetheless know that “yesterday” refers to a period of time, and that it refers to periods prior to the time at which it is uttered. Further, even if Franny were to develop an adult-like meaning of “yesterday” and understand that it refers to a specific period exactly one day ago, she might not be able to name an event that occurred “yesterday.” The ability to associate time words with life events depends not only on knowledge of these words’ meanings, but also on the ability to recall, order, and anticipate events (e.g., a capacity for “mental time travel”; Suddendorf & Corballis, 2007). These abilities develop slowly (Busby & Suddendorf, 2005; Suddendorf, 2011; Schachner, Addis, & Buckner, 2007). These considerations suggest that other methods are required to probe children’s knowledge—or partial knowledge—of deictic time word meanings.

Understanding the nature of children’s early uses of deictic time words—and the partial word meanings they may implicate—could provide critical insight into the inductive hypotheses children make about these words’ meanings. While there has not been systematic study of children’s partial knowledge of deictic time words during the long delay between initial production and adult-like usage, there are hints that children may acquire information about different facets of their meanings independently, with some acquired before others. These facets include a word’s *deictic status* (e.g., “yesterday” is in the past; “tomorrow” is in the future), its sequential *order* relative to other time words (e.g., “next week” is a time after “tomorrow”), and

its *remoteness* from the present (e.g., “yesterday” is exactly one day from today). For instance, 3-year-olds appear to understand that “yesterday” and “tomorrow” refer to a non-present time, without knowing that they refer specifically to the past and future, respectively (Harner, 1975). Further, children struggle to grasp the differing causal implications of events from “yesterday” vs. “tomorrow” on the present until at least age 5, also suggesting that their understanding of the distinction between past and future is incomplete (Busby & Suddendorf, 2010). Together, these results suggest that children may first learn that deictic time words label periods in time, without understanding much about their deictic past/future status, order, or remoteness. Furthermore, children’s over-extension errors *within* the past or future, like Franny’s use of “yesterday,” suggest that at some stage, children may understand a word’s deictic status without understanding its remoteness (e.g., Harner, 1981; Nelson, 1996).

One reason to think that children may acquire information about a word’s deictic status, order, and remoteness separately is that there is substantial variation in how these facets of time are expressed across languages. In English, for instance, all time words refer to either the past, present, or future. By contrast, in Urdu, “kal” refers to a period exactly one day from the present—whether in the future or the past—and thus does *not* encode deictic status but *does* encode temporal remoteness. Other languages include terms that encode degrees of temporal remoteness that are not lexicalized in English. For example, German’s “übermorgen” and Georgian’s “zeg” label a period that is in the *future*, much like English “tomorrow,” except that they refer to the period exactly *two* days away. Meanwhile, German’s “vorgestern” and Japanese’s “ototoi” pick out a time in the past, like English “yesterday,” except that it refers to the period exactly *two* days ago. The fact that deictic time words vary across languages

according to factors like deictic status and remoteness is consistent with the idea that these facets of meaning are dissociable and may be learned independently by children.

The goal of the present study was to explore whether English-learning children have systematic but partial meanings of deictic time words during the long delay between their initial production of these words and eventual adult-like usage. Critically, the nature of children's partial meanings—i.e., the developmental sequence in which information about deictic status, order, and remoteness are acquired—could constrain theories of the process through which these words are learned and the informational sources that children might draw upon. Broadly, there are two sources of information a child might use to learn the meanings of these terms: The *events* that time words refer to (e.g., a birthday party), and the *linguistic context* in which these words appear. As we describe below, these sources of information are differentially suited to supporting children's inferences about deictic status, order, and remoteness.

Mappings between deictic time words and the events they are used to describe could plausibly help children learn the deictic status and remoteness of these words. For example, by noting whether deictic time words are used to describe events that are anticipated (e.g., a birthday party *tomorrow* / *next week* / etc.) or in the past (e.g., a birthday party *yesterday* / *last week* / etc; Johnson et al., 1988) children could learn the deictic status of these words. Children could also generate hypotheses about the approximate temporal remoteness indicated by these words, e.g., by using the strength of a memory trace to estimate the remoteness of a party that occurred “last week” (Hinrichs, 1970; Friedman, 2003). From an understanding of deictic status and remoteness, children could then make inferences about relative order: e.g., *last year* is before *yesterday* because it refers to a more remote time in the past. Thus, if children were to rely

primarily on *event mappings*, then they might acquire knowledge of deictic status and remoteness in tandem, and later infer information about order.

If children leverage the broader linguistic context to learn deictic time word meanings, they might exhibit a different developmental trajectory, in which knowledge of deictic status and/or order is constructed prior to knowledge of remoteness. To begin, even before children have learned anything about the meanings of deictic time words, they could use the linguistic context to infer that deictic time words belong to a common lexical class. For example, children might observe that deictic time words often appear in similar sentence frames (e.g., “The party [happened/will happen] [yesterday/tomorrow/last week/next year].”), or that they are often used in response to “When” questions, and from this infer that these words have similar kinds of meanings (Backshneider & Shatz, 1993; Tare, Shatz, & Gilbertson, 2008; Shatz, 1993).

After grouping deictic time words into a common class, children could use other linguistic cues to make inferences about the specific semantic content of these words. For example, children could use their early knowledge of English tense markings (Brown, 1973; De Villiers & De Villiers, 1978; Harner, 1976; Weist et al., 1991) to infer whether deictic expressions refer to events in the past (e.g., “He **danced** *last year*”) or in the future (e.g., “He **will dance** *tomorrow*”). This process, in which grammatical cues are used to restrict hypotheses about meaning, is known as *syntactic bootstrapping* (Brown, 1957; Gleitman, 1990; Gleitman et al., 2005; Landau & Gleitman, 1985; Naigles, 1996). Further, children could also leverage cues from *discourse structure* to infer the relations among deictic time words. For example, contrastive uses of these words such as “The package isn’t coming *tomorrow*, it’s coming later, *next week*” could provide information about relative order. Moreover, since order-of-mention in discourse typically reflects temporal order (Jakobson, 1966), children could use input such as,

“Bobby danced at his birthday party *last year*, but probably won’t dance at his friend’s party *tomorrow*,” to infer the sequential order of individual lexical items like “last year” and “tomorrow.” In sum, if children rely primarily on the linguistic context to learn deictic time word meanings, then they might acquire knowledge of deictic status (supported by syntactic bootstrapping) and order (supported by discourse structure) prior to knowledge of remoteness.

1.1 The present study

Here, to explore whether children might have systematic but partial meanings for deictic time words during the gap between initial production and later adult-like usage, we asked 3- to 8-year-old children to place these words onto a spatial timeline. As described below, this method allowed us to separately assess knowledge of these words’ deictic status (i.e., past vs. future), sequential order, and remoteness from the present.

Spatial scales have been used extensively to study children’s mental representation of number (e.g., Barth, Starr, & Sullivan, 2009; Booth & Siegler, 2006; Ebersbach et al., 2008; Kolkman et al., 2013; Laski & Siegler, 2007; Moeller et al., 2009; Siegler & Booth, 2004; Siegler & Opfer, 2003; Slusser et al., 2013; Sullivan & Barner, 2014), and a smaller number of studies have used spatial scales to assess children’s understanding of temporal sequence (Busby Grant & Suddendorf, 2009; Friedman, 2000, 2002; Friedman & Kemp, 1989; Hudson & Mayhew, 2011). However, most timeline studies involving preschoolers have explicitly *avoided* deictic time words, and, furthermore, have been limited in their ability to tease apart children’s understanding of the different semantic facets of these terms. For instance, all timeline studies of preschoolers have used scales depicting either the past or the future, but not both simultaneously (Busby Grant & Suddendorf, 2009; Friedman, 2000, 2002; Friedman & Kemp, 1998). Thus these studies could not gauge children’s knowledge of deictic status, because children never had to

decide whether events came from the past or the future. Furthermore, most timelines used to test preschoolers were divided categorically into distinct regions that represented broad periods of time, such as “a short time ago” or “a long time ago” (e.g., Busby Grant & Suddendorf, 2009; Friedman, 2002; Friedman & Kemp, 1998). Since terms placed inside the same region are not distinguished from each other, it is difficult and sometimes impossible to use categorical timelines to probe children’s knowledge of sequential order or remoteness.

We thus developed a new timeline task that allowed us to independently assess children’s knowledge of deictic status, sequential order, and remoteness. In our task, 3- to 8-year-old children and adult controls used colored pencils to mark where deictic time words (e.g., “yesterday”) and events (e.g., the participant’s last birthday) should go on horizontal timelines that extended, left-to-right, from the past (“when you were a baby”) to the future (“when you’ll be a grown-up”), with the present moment (“right now”) indicated by a dividing line between past and future. Knowledge of the deictic status of a word was assessed by its placement to the left or right of the midpoint, regardless of its placement relative to other words. Knowledge of sequential order was assessed by the ordering of words along the line (e.g., whether “last week” was placed before “yesterday”), ignoring their relation to the present and the distances between them. And knowledge of remoteness from the present was assessed by the spacing of terms along the line (e.g., the distance between “last year” and “now,” compared to the distance between “yesterday” and “now”). Finally, to confirm that timeline performance was a valid measure of children’s developing semantic knowledge, we investigated whether it correlated with children’s ability to answer verbal questions about the meanings of deictic time words (e.g., “Which will happen first: Tomorrow or next week?”).

2 Methods

2.1 Participants

Children from the greater San Diego, CA, (n=93) and Berkeley, CA, (n=25) areas participated in this experiment, along with 38 young adult controls from the UC San Diego Psychology Department subject pool. Data collection continued until we reached our target of sixteen children in each age category. Since recruited participants also participated in a related study on temporal gesture, this target sample size was based on past studies on children's gesture (e.g., Sauter et al, 2013). The total child sample¹ included 17 3-year-olds, 20 4-year-olds, 18 5-year-olds, 26 6-year-olds, 19 7-year-olds and 17 8-year-olds. An additional 15 children participated but were excluded from analysis due to failure to complete the task (n=6), illegible timelines (n=6), experimenter error (n=1), and clerical error (n=2). Children were tested in local preschools, elementary schools, museums, or our laboratories at UC San Diego and UC Berkeley. Parents gave informed consent for their children to participate in the study, and children indicated their willingness to participate before testing began. Parents who brought their children into the laboratory were compensated for their travel expenses, and children received a small gift in thanks for their participation. Adult controls were awarded course credit for their participation.

¹ In some cases, a child's video data—recorded for a related study on temporal gesture—was impossible to analyze (e.g., background noise was too loud; file was corrupted). In these cases, an additional child was recruited. All data were analyzed.

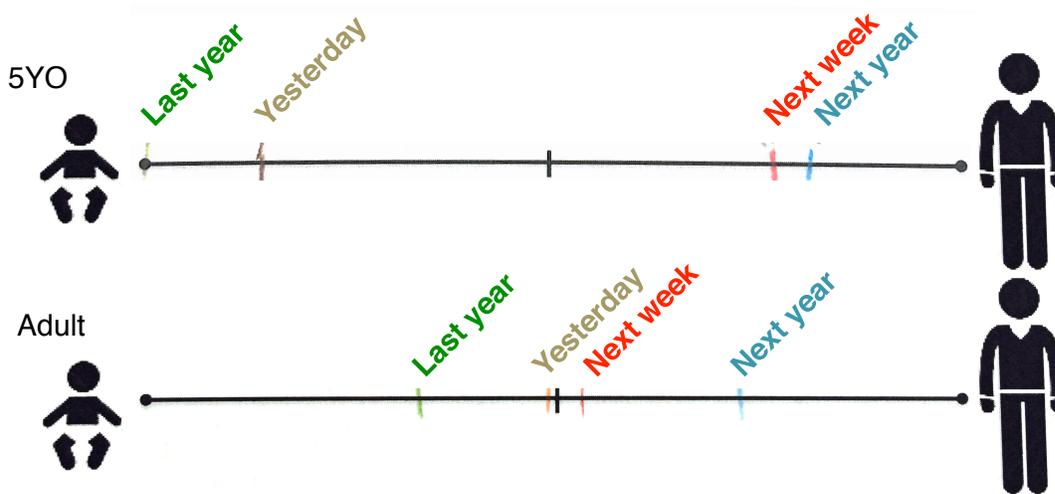


Figure 1. Timelines used by participants to indicate the relative location of deictic time words (e.g., “tomorrow”) and events (e.g., “breakfast today”), with example data from a 5-year-old and an adult. The adult placed “last year” and “next year” equidistant from the present moment, “next week” considerably closer to the present, and “yesterday” just barely in the past. By contrast, the child’s placements did not track the relative remoteness of each term: “yesterday” is farther away from now than “next week,” which is nearly as remote as “next year.” This child thus appears to exhibit knowledge of deictic status and order, but not remoteness.

2.2 Materials

Materials included one pack of colored pencils and one 8.5in. × 11in. sheet of paper with three 13.5 cm horizontal timelines printed on it. Timelines were positioned vertically down the center of the page. Small dots indicated the left and right endpoints of the line and a vertical line indicated the midpoint (see Fig. 1). An icon of a baby was placed to the left of the timeline and an adult figure to the right, to remind children of the timeline’s interpretation. Each timeline was associated with a preset list of items (Table 1), selected to test for a range of possible error

patterns. Using preset lists also maintained timeline complexity across individuals,² allowing direct comparison of error patterns across individuals and age groups.

2.3 Timeline procedure

The paper and colored pencils were placed in front of the child. The experimenter explained that a timeline “shows *when* different things happen,” from the past to the future, with the present represented in the middle, and each time having its own place on the line. The child was instructed to indicate *when* different events or time periods happen by marking their location on the line, using colored pencils to draw a vertical mark (see Appendix A for complete script). The experimenter then introduced the first target item (e.g., “breakfast today”), asked the child to think of the time or event, and asked them to draw a line using a colored pencil to indicate when the target item occurred (Fig. 1). To facilitate subsequent coding, each item was associated with a particular color of pencil. This was repeated for the rest of the items, on all three timelines. In a few cases children were unwilling to mark the timeline but were willing to point to where they thought the target should go. In these cases, the experimenter drew the lines at the point where the child’s finger met the timeline. Participants always received the Events line first (to orient

² One downside of this approach—controlling the complexity of each timeline using a preset item list—is that it limits the interpretation of item analyses. The preset lists likely made some comparisons more difficult than others: “tomorrow,” for instance, was always on a timeline with two items that occur within a day, but items placed with “yesterday” were all a week or a year away. While this study was not designed to investigate mastery of particular words or concepts, we nevertheless report some exploratory item analyses in Appendix B.

them to the task), but the order of the other two lines was counterbalanced between subjects. For each line, half of the subjects received the items in the order shown in Table 1, and the rest received the reverse order. If children asked questions about where they should put the lines, they were told, “It’s up to you! Put it wherever you think [e.g., tomorrow] goes on the line.” If participants asked to be reminded what their marks from prior trials referred to, the experimenter provided the answer.

Table 1. *Target items used in timeline tasks*

Timeline	Item 1	Item 2	Item 3	Item 4
Events	breakfast	next birthday	dinner	last birthday
Time Words 1	last week	tomorrow	tonight	this morning
Time Words 2	next week	next year	yesterday	last year

2.4 Timeline coding

All analyses were conducted using the distance from the midpoint (0) to each mark on the timeline, which was used to determine the relative ordering of items along the timeline and whether the item was placed in the past (negative values) or the future (positive values). For our analysis of remoteness, we standardized distances from the midpoint by dividing each raw distance by the maximum distance at which any item was placed on that timeline (see Results, Section 3.1.3). Thus, distances ranged from 0 (midpoint) to 1 (farthest mark along the timeline). This was done to control for possible age-related differences in absolute placements (e.g., given that 3-year-olds might systematically place their last birthday closer to when they were a baby than adults would). Analyses were conducted using the *R* software package (R Core Team, 2013).

2.5 Verbal forced-choice questions

To gauge basic event and time word comprehension in a non-spatial task, participants were also asked 8 verbal forced choice questions. These questions were of two types. *Event* questions asked about when an everyday event occurred (e.g., Can you think about when you ate breakfast? Was that *this morning* or *tonight*?). *Order* questions asked about the relative ordering of time words (e.g., Which will happen first: *tomorrow* or *next week*?). Event questions preceded Order questions. For each type, two past-related and two future-related questions were asked. The experimenter introduced the past and future sets of Order questions by saying, “Now I’m going to tell you about things that *have already happened*” or “... *are going to happen*,” respectively. Within each block, half the children received the questions in the order listed in Table 2, and half received the reverse order. Half of the participants answered the forced-choice questions before performing the timeline task, and the other half answered them afterward. Whether the correct answer was mentioned first or second within a question was counterbalanced between questions.

Table 2. *Verbal forced-choice questions.*

Question Type	Time	Prompt	1 st alternative	2 nd alternative
Event		<i>Think about when you...</i>	<i>Was that...</i>	<i>Or...</i>
	Past	<i>... ate breakfast.</i>	this morning?	tonight?
		<i>... were [age-1] years old.</i>	last year?	next year?
	Future	<i>... are going to eat dinner.</i>	this morning?	tonight?
	<i>... are going to be [age+1] years old.</i>	last year?	next year?	
Order				<i>Or...</i>
	Future	<i>Which will happen first:</i>	tomorrow?	next week?
			next year?	next week?
Past	<i>Which happened first:</i>	last week?	last year?	
		yesterday?	last week?	

2.6 Unreported measures

As part of an ongoing project on spontaneous temporal gestures, all participants (except the 3- and 4-year-olds) also completed a structured interview that was designed to elicit temporal gestures. The interview consisted of open-ended questions that contrasted animal names (“What’s the difference between a *cat* and a *dog*?”), vehicles (*car* vs. *motorcycle*), and several pairs of time words (e.g., “yesterday” vs. “tomorrow”; “next week” vs. “last year”). Children received positive encouragement but no feedback regarding their responses. The order of the gesture interview and timeline tasks was counter-balanced across subjects. Since task order did not affect any of our dependent measures (all F s < 0.4 , p s > 0.4), subsequent analyses collapsed across order. No other measures were collected.

3 Results

We report four analyses of the timeline data: First, we assessed comprehension of the deictic status, sequential order, and temporal remoteness of the deictic time words. Second, we determined the typical ages of acquisition of these facets of meaning, pinpointing the age at which the majority of children displayed adult-like comprehension of each facet. Third, we calculated the contingencies between adult-like knowledge of these three facets of meaning: i.e., the degree to which adult-like knowledge of deictic status, order, and temporal remoteness predicted one another within an individual child. Finally, we asked whether children’s performance on the timeline task predicted their ability to answer non-spatial, verbal forced-choice questions about time word meanings.

3.1 Facets of meaning

3.1.1 Deictic status. As an index of knowledge of deictic status, we calculated the average accuracy for all items’ placement relative to “now” (e.g., “tomorrow” should be in the

future) for each timeline and subject, and then calculated a mean deictic status accuracy for each subject and each type of timeline (i.e., Deictic vs. Event). We then analyzed deictic status accuracy with a mixed ANOVA, with Timeline Type (Deictic vs. Event) as a within-subjects factor and Age (3 through 8 years old, and adults) as a between-subjects factor. There was no effect of Timeline Type, suggesting that children were equally able to represent the past/future status of time words and events on the timelines. The only effect to reach significance was the main effect of Age, $F_{(6, 146)} = 32.6, p < .001$ (Fig. 2A). While 3-year-olds performed at chance (0.5) overall, $t_{16} = 0.36, p = 0.73$, 4-year-olds were better than chance, $t_{19} = 4.5, p < .001$. Mean accuracy improved monotonically among 3- to 7-year-olds, $M_3 = .51 < M_4 = .65 < M_5 = .75 < M_6 = .85 < M_7 = .94$, and but did not differ between 7- and 8-year-olds, $M_8 = .92, t_{32} = 0.44, p = .67$. Six-year-olds performed significantly worse than adults, $t_{62} = 4.2, p < .001$, while 7-year-old performance did not differ significantly from adults, $M_{adults} = .97, t_{54} = 1.9, p = .07$.

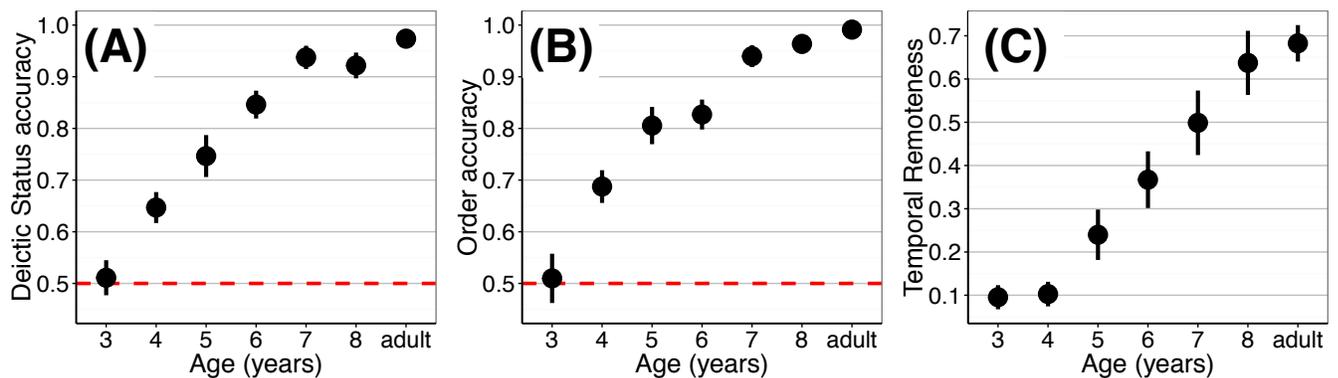


Figure 2. Developmental time-course of (A) deictic status, (B) order, and (C) remoteness knowledge. For all three facets, knowledge improved with age, although improvement was delayed for remoteness. Error lines = SEM; dashed line = chance performance.

3.1.2 Order. We next assessed knowledge of relative sequential order, separately from deictic status. Because children had to place four items on each timeline, this could have taxed their working memory, leading them to forget which items they had already placed on a timeline when placing other items. To control for this possibility, we compared the placement of each item relative to the placement of the immediately preceding item, rather than to the timeline as a whole (e.g., if “last week” is tested just after “tomorrow,” it should be placed to the left of “tomorrow”). This measure of pairwise order knowledge places minimal working memory demands on children, since they need only recall the meaning of an immediately preceding item. We calculated mean accuracy on this 1-back measure of order knowledge, for each participant and Timeline Type. There was only a main effect of Age, $F_{(6, 146)} = 27.8, p < 0.001$ (Fig. 2b). Just as with deictic status, 4-year-olds performed significantly above chance, $t_{19} = 4.9, p < 0.001$, while three-year-olds did not, $t_{16} = 0.18, p > .8$. Eight-year-olds’ orderings were indistinguishable from those of adults, $t_{52} = -1.6, p = .10$, but 7-year-olds’ were significantly different, $t_{54} = -2.5, p = .02$.

We also conducted analyses involving two additional measures of order knowledge, reported in Appendix C. The first was a whole-timeline measure, which assessed children’s rank ordering of all four items on each timeline. Analyses using this measure yielded the same pattern of results as those using the 1-back measure of order knowledge. The second additional measure of order knowledge evaluated participants’ relative placement of the two items involving the past for a given timeline (e.g., *yesterday*, *last year*) separately from their placement of the two items involving the future (e.g., *next week*, *next year*). Although this measure relied on only two comparisons from each timeline, it ensured that participants who only understood the past/future status of the items – e.g., that *yesterday* is in the past and *next week* in the future – wouldn’t also

be credited with knowledge of their order. Analyses using this measure converged with those using the other two order measures, with the exception that children did not reliably perform above chance until age 5 (likely due to a loss of statistical power).

3.1.3 Remoteness. We next evaluated knowledge of the temporal remoteness of each item—i.e., its relative distance from “now.” To account for absolute differences in the amount of space used by participants, we first standardized distances from the midpoint by dividing each raw distance by the maximum distance at which any item was placed on that timeline. This approach controls for possible age-related differences in absolute placements (e.g., adults might place “last year” farther from “when you were a baby” than do 3-year-olds), and focuses instead on remoteness relative to the placement of other items on the same timeline. The median distance of each item placed by participants in each age group is shown in Figure 3.

To characterize the maturity of children’s representations of remoteness, for each child, we used multiple regression to see how well each item's remoteness was predicted by its mean remoteness among adults. A child’s knowledge of temporal remoteness was measured by the strength of the relationship between their placements and adult-like placements, after factoring out the child’s knowledge of order (i.e., semi-partial correlation squared). Thus, this measure assessed how much children understood about the remoteness of these terms *above and beyond* knowledge of their order.

Mean remoteness knowledge for each age group is shown in Fig. 2c. A linear regression revealed that children’s knowledge of remoteness improved gradually with age, $b = 0.12$, $t_{113} = 7.934$, $p < .001$. In contrast to our analyses of deictic status and 1-back order knowledge, we found that 4-year-olds performed no differently than 3-year-olds on our measure of remoteness knowledge, $t_{35} = 0.18$, $p = .86$. Five-year-olds’ understanding of remoteness was significantly

more adult-like than that of 4-year-olds, $t_{36} = 2.2, p = .04$. Seven-year-olds performed significantly differently from adults, $M_7 = .50$ vs. $M_{\text{adult}} = 0.68, t_{54} = 2.3, p = .025$, but 8-year-olds did not, $M_8 = 0.64, t_{52} = 0.6, p = .58$ (Fig. 3).

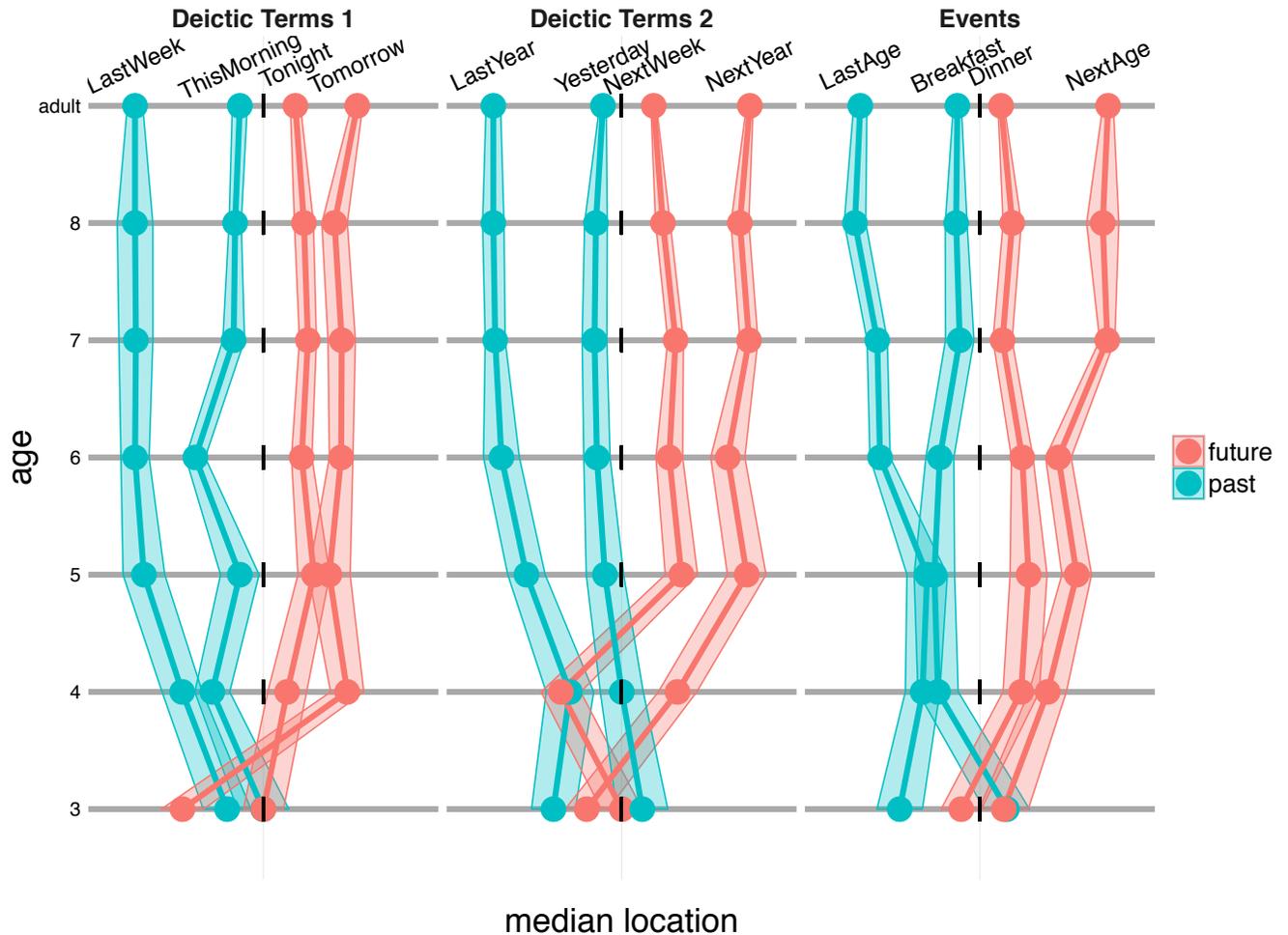


Figure 3. Median placements of each item on the timeline. Only the youngest children reliably made errors representing the deictic status and relative ordering of deictic time words (bottom timelines). Knowledge of relative temporal remoteness continued to develop until quite late (cf., the placement of “next week” vs. “next year” in 8-year-olds vs. adults). In order to control for effects of age on raw timeline placements, locations were rescaled for each participant, such that the location of the most distant item was equal to ± 1 . Error bands = SEM.

3.2 Order of acquisition

Together, the analyses described above suggest different time courses for the acquisition of different facets of deictic time word meaning. On the one hand, mean levels of performance on our deictic status and 1-back order measures were above chance by age 4. Further, by age 7, deictic status accuracy reached adult levels, and order accuracy exceeded 90% correct. On the other hand, performance on our remoteness measure accelerated more slowly, and continued to increase through age 8.

Next, we directly investigated the sequence in which these different facets of meaning are acquired. In order to make direct comparisons across our three different measures, we used a threshold approach, comparing the ages at which the majority (50%) of children had made the transition to adult-like understanding of each facet of meaning. First, based on the continuous measures of deictic status, order, and remoteness described above, we characterized each child, via k-means clustering, as a “knower” or “non-knower” of that facet of meaning. (“Knowers” were those children who clustered with adult participants; Fig. 4, A-C.) Next, for each facet, we modeled the transition to adult-like knowledge using a Weibull function, allowing us to estimate the age at which the majority of children exhibit adult-like knowledge of each facet, independently of the other two facets.

Our analyses reveal that the majority of children transitioned to adult-like knowledge of deictic status and order before their sixth birthday (deictic status: 5;4, bootstrapped 95% CI [4;10, 5;9]; order: 5;8, [5;1, 6;1]). By contrast, most children did not transition to adult-like knowledge of temporal remoteness until nearly two years later (7;3, [6;11, 7;9]). Since the confidence interval for remoteness does not overlap with the other confidence intervals, this delay is statistically significant.

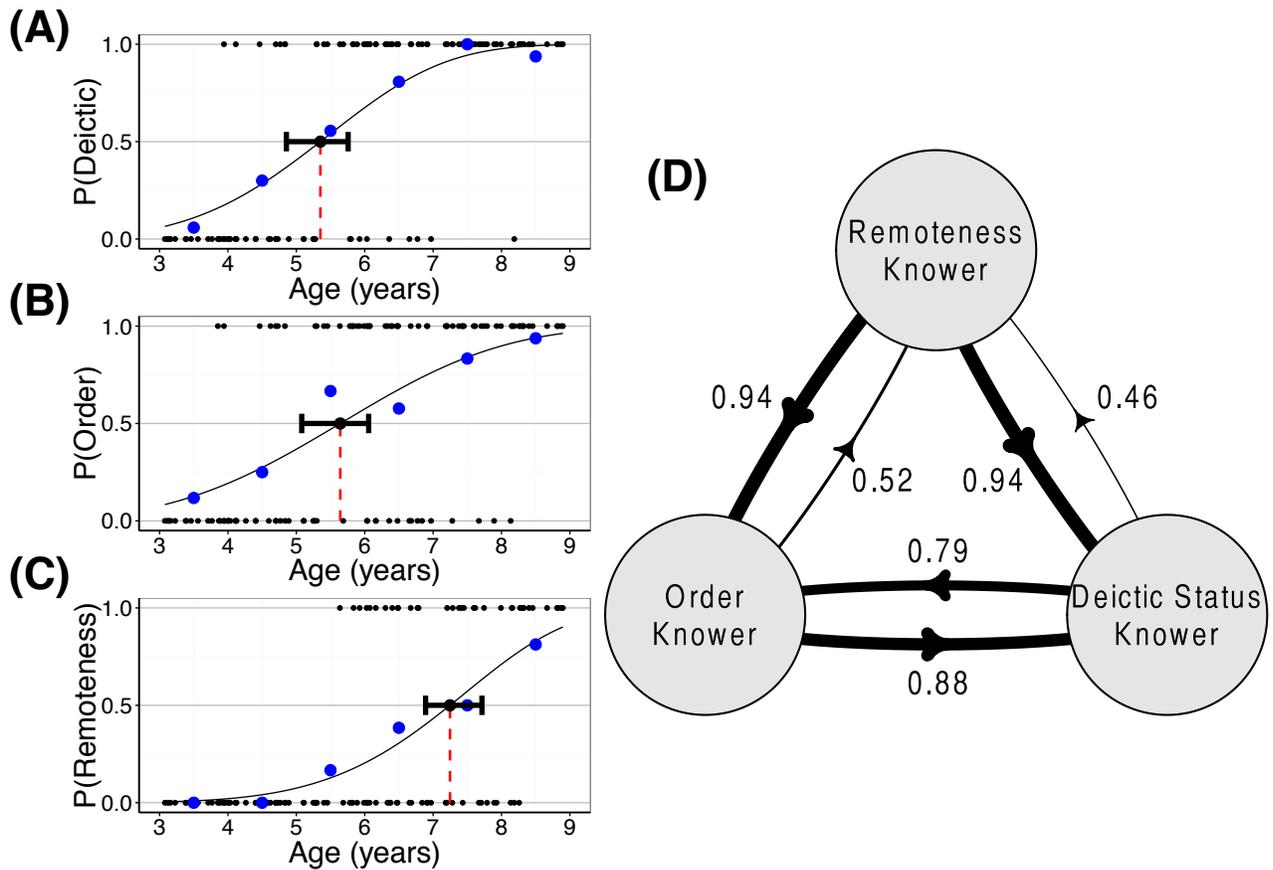


Figure 4. (A) Age of acquisition for three facets of deictic time word meaning. Each black dot represents an individual child, categorized as either a “knower” or “non-knower” of that dimension. While adult-like knowledge of deictic status and order emerged around the same time, before age 6, adult-like knowledge of remoteness was delayed for nearly another two years. Blue dots indicate the mean probability of being a knower in each age group. Block dots and red vertical lines indicate age-thresholds after which the majority of children are knowers (i.e., $p \geq 0.5$); error bars indicate bootstrapped confidence intervals on those age-thresholds. (B) Contingencies among facets of meaning. Arrows denote direction of influence; numbers indicate the conditional probability of knowing the target facet of meaning, given knowledge of the source facet; line widths visualize these conditional probabilities (scaled from .4 to 1).

3.3 Learning contingencies

The previous analysis (section 3.2) suggests that on their sixth birthday, only a quarter of children exhibit an adult-like understanding of the remoteness of deictic time words, while the majority of children know their deictic status and their relative order. But this analysis does not tell us whether the *same children* who understand one facet of deictic terms' meanings also understand other facets. To address this, we calculated the conditional probability of being each type of "knower," given one's "knower" status on each other facet of meaning (Fig. 4d).

Interestingly, we found that knowledge of deictic status and order were highly linked: Among deictic-status-knowers, 79% also exhibited adult-like knowledge of order (95% CI [69%, 88%]); conversely, among order-knowers, 88% also exhibited adult-like knowledge of deictic status ([79%, 96%]). However, while it was extremely common for a child who was a remoteness-knower to also be a knower of deictic status or order (both 94%, [87%, 100%]), the reverse was not true. Children who were deictic-status-knowers had only a 46% chance of being a remoteness-knower ([35%, 58%]); if they were order-knowers, they had only a 52% chance ([39%, 64%]). This is exemplified by the top timeline in Fig. 1b, produced by a 5-year-old who appears to understand both deictic status and order, but does not exhibit adult-like knowledge of remoteness. Compare this to the bottom timeline, from an adult, where items' placements reflect not just their deictic status and order, but also their relative remoteness (i.e., "yesterday" is close to now; "next week" is farther away; and "next year" even farther). Together with the cross-sample age-of-acquisition data described in section 3.2, these results reveal a clear developmental trajectory in which deictic status and order emerge early and in synchrony, while knowledge of temporal remoteness is developed independently and often much later.

3.4 Forced-choice questions

Because timelines are complex spatial artifacts, young children’s ability to use them could be affected by factors other than their semantic knowledge of the temporal items, e.g., their spatial reasoning or motor skills. To validate our timeline measure, we investigated the relation between children’s ability to express their temporal knowledge using the timeline and a purely verbal measure of time word knowledge: i.e., children’s answers to verbal forced-choice questions about the relative ordering of time words and their relations to events (Table 2). Overall performance on the Verbal Forced Choice task³ improved with age throughout childhood, $b = .09, p < .001$, increasing monotonically ($M_3 = 0.52 < M_4 = 0.71 < M_5 = 0.83 < M_6 = 0.93 < M_7 = 0.96 < M_8 = 0.97 < M_{\text{adults}} = 0.98$). Four-year-olds performed significantly above chance, $t_{19} = 3.5, p < .01$, but 3-year-olds did not, $t_{16} = 0.4, p = 0.70$. While 6-year-olds performed significantly differently from adults, $t_{62} = -2.0, p < .05$, 7-year-olds were indistinguishable from adults, $t_{55} = -1.24, p > .2$.

Critically, the results of our non-spatial task provide evidence that the timeline task is a valid measure of semantic knowledge. Measures of each of the three facets of deictic time word meaning from the timeline (i.e., deictic status, order, and remoteness) were predictive of children’s performance on the verbal forced-choice task, ($\beta_{\text{deictic}} = 0.12, p < .001$; $\beta_{\text{order}} = 0.13, p$

³ Data from two forced-choice questions about the relative ordering of past items were excluded due to ambiguity in the instructions. These ambiguous instructions produced two distinct response patterns in both children and adults: some participants interpreted the “first event” to be the one closest to the present moment, while others interpreted it to be the event that was more distant in the past.

< .001; $\beta_{\text{remoteness}} = 0.09, p < .001$). Even after controlling for age, knowledge of deictic status and order remained reliable predictors of verbal forced-choice performance ($\beta_{\text{deictic}} = 0.19, p = .01$; $\beta_{\text{order}} = 0.14, p = .02$), although knowledge of remoteness was only a marginally significant predictor ($\beta_{\text{remoteness}} = 0.18, p = .06$). When all three measures of timeline performance were included in a multiple regression model of performance on the forced-choice task, knowledge of deictic status ($\beta_{\text{deictic}} = 0.08, p < .01$) and order ($\beta_{\text{order}} = 0.06, p = .04$) each accounted for variance in forced-choice accuracy, but knowledge of remoteness did not ($\beta_{\text{remoteness}} = 0.01, p = .59$). This finding—that deictic status and order knowledge account for unique variance in forced choice accuracy—confirms that, despite the very similar developmental trajectories we observed for these facets of meaning, the two measures themselves are distinct.

4 Discussion

Our study investigated what children know about deictic time words during the long delay between when they begin producing these words, around age 3, and eventual adult-like usage in elementary school. Specifically, we asked whether children assign systematic, preliminary meanings to these words during this period, by using a timeline measure to independently assess children's knowledge of three facets of their meanings: deictic status, order, and remoteness. Consistent with previous studies (e.g., Ames, 1946; Busby Grant, & Suddendorf, 2011; Harner, 1975, 1981; Weist et al., 1991), we found that learning deictic time words is a slow and difficult process for children. However, we also found evidence that many of children's early "errors" in speech may belie a nascent, though partial, understanding of these words. Our findings suggest that children assign systematic, partial meanings to deictic time words even at ages when they are said to use them in "incorrect" ways.

Together, the results of this study reveal a trajectory of deictic time-word learning that spans four or more years from the time that children begin using the words in speech. Although children struggle to map deictic time words to experienced or anticipated events until at least age 5 (Busby & Suddendorf, 2005; Busby & Suddendorf, 2010; Suddendorf, 2010), our timeline measures revealed that some 4-year-olds understood these words' deictic status (e.g., that "yesterday" is in the past) and order (e.g., that "yesterday" is before "this morning"). Further, children who understood one of these facets of meaning almost always understood the other, suggesting that they emerge in synchrony. However, in contrast to the relatively early emergence of deictic status and order knowledge, we found that adult-like knowledge of remoteness (e.g., how much further away from the present "next week" is than "tomorrow") emerges nearly two years later, after age 7.

4.1 Implications for how deictic time words are learned

As noted in the Introduction, children could in principle rely on event memories to make inferences about the meanings of deictic time words that refer to those events. An event mapping strategy most plausibly predicts a trajectory in which knowledge of deictic status and remoteness emerge in tandem, *followed* by knowledge of order. This is not what we found, as children rarely demonstrated adult-like knowledge of remoteness prior to demonstrating mastery of deictic status and order (Fig. 4B). Instead, our finding that children understand deictic status and order before remoteness is consistent with accounts of word learning in which children initially draw on the linguistic context to constrain their early hypotheses about word meanings. For example, children may learn deictic status early in life by using their knowledge of tense markings to make inferences about the past or future status of time words (e.g., "He **danced** *last year*"; "He **will dance** *tomorrow*"), a process known as syntactic bootstrapping (Brown, 1957; Gleitman, 1990;

Gleitman et al., 2005; Landau & Gleitman, 1985; Naigles, 1996). Meanwhile, to acquire knowledge of order, children might learn from contrastive uses of these words (“The package isn’t coming *tomorrow*. It’s coming later, *next week*.”), or exploit the fact that order-of-mention in discourse typically respects temporal order (“We will go to school *tomorrow* and can go to the zoo *next week*”; Jakobson, 1966). Discourse structure and tense marking, in contrast, are unlikely to provide children with information about remoteness, which could help explain its late emergence in our study.

Although our findings are consistent with an account in which children exploit linguistic cues to learn deictic time word meanings, they do not provide direct evidence for such an account. Also, this account leaves open how children acquires the semantics of tense in the first place—and what types of conceptual representations this might draw upon. One way to explore both of these questions is to investigate how tense markers and deictic words are acquired in other languages. For example, cross-linguistic differences in temporal morphology suggest that a reliance on tense marking will be differentially viable across languages. Languages like Inuktitut (spoken in Alaska and northern Canada) and Zulu (spoken in South Africa) have a metrical tense system that encodes different degrees of remoteness in the past and/or future in addition to deictic status (Comrie, 1985; Chung & Timberlake, 1985; Dahl, 1983), while other languages, like Mandarin Chinese, lack a morphological tense system altogether (Comrie, 1985). This type of variation presents the possibility of asking whether tense marking plays a causal role in deictic word learning, and also whether the late acquisition of remoteness is restricted to deictic terms, or also found in the acquisition of tense systems, too (see Swift, 2004, for discussion).

Regardless of what informational sources support learning about deictic status and order in English, our findings suggest that these two facets of knowledge are tightly linked. In

particular, although our timeline method could have documented distinct developmental trajectories for deictic status and order, we found that they appear to arise simultaneously, around age 4, and at the same developmental moment within individual children. In practice, an understanding of deictic status may scaffold understanding of order, and vice versa. For example, if a child understands that “tomorrow” is in the future (deictic status) and that “next week” is after tomorrow (order), she might infer that “next week” must also be in the future (deictic status). Conversely, if a child knows that “yesterday” is in the past (deictic status) and “tomorrow” is in the future (deictic status), she can then infer that “tomorrow” must be after yesterday (order).

To learn about remoteness, children might require particularly structured and explicit information—e.g., “Next week is seven days away”—which they may only receive in formal educational settings. Consistent with this, one previous study suggests that children may have to be taught explicit definitions to work out the meanings of duration words like “week” and “year,” which are components of deictic terms like “next week” and “last year” (Tillman & Barner, 2015). Interestingly, the acquisition of duration words follows a similar trajectory to the one presented here for deictic time words. At age 4, children grasp that duration terms indicate durations (Shatz et al., 2010); at age 5, they have begun to work out their order (i.e., *year* > *week* > *hour* > *minute*; Tillman & Barner, 2015); but children have little understanding of their proportional relations (e.g., how much more time an hour is than a minute) until early in grade school. Further, the transition to mature knowledge of duration words, and the remoteness of deictic time words, occurs around the same time that clock reading becomes a major focus in standard elementary school curricula, in Grade 2 (Common Core State Standards Initiative, 2012). These considerations suggest that knowledge of the metric structure of time—both for

duration and for deictic time—may require exposure to explicit definitions, and knowledge of one set of definitions (e.g., 1 year = 52 weeks) may support learning about the other (e.g., next week is up to 52 times more remote than next week).

4.2 Implications for abstract word learning

Our findings bear similarity to several other case studies of word learning, including the acquisition of color words (e.g., Bakscheider & Shatz, 1993; Sandhofer & Smith, 1999; Wagner, Dobkins & Barner, 2013), emotion words (e.g., Widen & Russell, 2003), and duration words (e.g., Shatz et al., 2010; Tillman & Barner, 2015). In each of these cases, there is a gap between children’s initial production of a set of words and their eventual adult-like usage of these words. Further, within this gap, children do not use words in haphazard ways, but instead in systematic ways that reflect their partial meanings for these words.

By some accounts, such findings reveal a bootstrapping process through which children build the meanings of words not simply by understanding how they relate to the world, but also by understanding how they relate to other words (Carey, 2009). For example, children may begin acquisition for a particular lexical domain by grouping words from the domain together (e.g., by observing that these words appear in similar distributional profiles; Tare et al., 2009). These words may initially serve as placeholders with little semantic content, but might gain content as children directly learn about how each word relates to the others. As children begin to relate some of these words to experience, they may use such information to enrich the meanings of other words within the same placeholder structure. Number word learning provides an illustrative example: Children appear to learn the count list (“one, two, three, ...”) before they learn exact meanings for any of the individual number words or can reliably map them to approximate numerical magnitudes (Wynn, 1990; 1992; Davidson et al., 2012; Le Corre &

Carey, 2007). Later in acquisition, children can use the structure of the count list to learn the successor principle and bootstrap richer, exact meanings (e.g., such that each successive number in the list denotes a set with one more individual in it; see Carey, 2009 for discussion).

The bootstrapping account described above may provide a useful framework for understanding the acquisition of deictic time words. Children may initially group these words into a common semantic class because they appear in similar discursive contexts (e.g., that “yesterday”, “last week”, and “last year” are used in response to “When did that happen?”), and may then learn about their contrastive relations to one another by leveraging cues from the linguistic context (e.g., from morphosyntax and discourse structure). Finally, as children gradually link some of these words to experience, they could bootstrap richer meanings for other words.

4.3 Spatial tools for time

Our study used spatial timelines as a tool to characterize children’s knowledge of deictic time words, and to track the development of different facets of time-word meaning. Although this method requires children to use an external spatial representation, we showed that it is sensitive to children’s semantic knowledge, since children’s ability to use the timeline predicted their ability to answer verbal questions about time words. By allowing us to independently assess knowledge of deictic status, order, and remoteness, the timeline method was more sensitive than previous studies to the possibility that children could have partial meanings for deictic time words.

The question of how readily children can use timelines is interesting in its own right. Although timelines are now widespread and commonplace, their use and comprehension has been relatively understudied. In particular, there has been little empirical research on

effectiveness of timelines as learning aids for children, despite their prevalence in elementary school textbooks (Burny et al., 2008). Precursors of an ability to use timelines are well-documented: Even pre-linguistic infants associate spatial length and temporal duration (de Hevia et al, 2014; Srinivasan & Carey, 2010; Winter, Marghetis, & Matlock, 2015), and, by the time children enter kindergarten, they overwhelmingly use conventional linear arrangements to represent the order of temporal events (e.g., left-to-right for English-speakers; Tversky et al, 1991).

Building on these previous findings, our studies indicate that children as young as 4 can represent the temporal locations of both events and time words using a canonical timeline – i.e., one that is horizontally-oriented, bidirectional (encompassing the past and future), and continuous. To our knowledge, this is the most sophisticated use of a canonical timeline by preschoolers yet recorded. Previous studies have relied primarily on modified, non-standard timelines, which were also less sensitive to partial knowledge. For example, in one set of studies, time was represented by a road taking a diagonal, upward path, with distance conveyed using visual perspective (Friedman 2000; 2002), and in another, children placed items along ruler-like wooden boards extending away from the body into either the past or future (Friedman & Kemp, 1989; Friedman, 2000; Busby Grant & Suddendorf, 2009). Our findings have immediate implications for pedagogy, and indicate that, as early as preschool, timelines can be used both as a learning aid and as a measure of children’s comprehension of temporal words and concepts.

4.4 Conclusion

Acquiring mature meanings for deictic time words can take children four years or more. Our findings suggest that, during the long delay between children’s initial production of these words and eventual adult-like usage, children construct systematic, partial meanings, including

information about deictic status and order. One intriguing possibility is that these partial meanings are built through a gradual inductive process in which children construct an ordered, semantic domain for these words based on cues found in natural language, in the structure of both morphosyntax and discourse. Ultimately, to learn deictic time words, children must make the insight that there is an invisible and highly-structured dimension of time, which can be described by a rich system of linguistic labels, but is nonetheless separable from the events that occupy it. This represents a profound conceptual breakthrough, providing a transformational framework for organizing events, interpreting the past, and planning for the future.

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Appendix A: Full procedure scripts for Timeline task

The paper and colored pencils were placed in front of the child. The experimenter (E) explained the task by pointed out the top timeline and stating: “Look, this is a timeline. It shows *when* different things happen. The line starts in the past [E points to left endpoint] and it goes to the future [traces the line with her finger, ending on the right endpoint]. So, it goes from when you were a baby [E to points to left endpoint] all the way to when you’re going to be a grown up [E gestures along line to right endpoint]. And here in the middle is right now [E points to vertical line at midpoint]. Each time has its own place on the line. You're going to show me *when* different things happen by showing me *where* they go on the line. Look, when you were a baby goes here [E draws a vertical line on the left end point to demonstrate the procedure] and when you are going to be a grown up goes here [E draws a vertical line at right endpoint]. And right now goes here [E draws line at midpoint]. I’m going to give you a pencil, and your job will be to draw an up-and-down line to show me where each thing goes. Ready?”

At this point, the experimenter introduced the first target item, “When [did you] [eat breakfast today]? Think about when you [ate breakfast today]? Draw a line for when you [ate breakfast today].” Each item was associated with a particular color of pencil. The child marked the line, as shown in Figure 1, and the experimenter proceeded to the next trial. The items relating to the child’s first and last birthday used the phrasing “draw a line for when you [turned/are going to turn] [child’s age-1/child’s age+1].” In a few cases children were unwilling to mark the timeline, but were willing to point to where they thought the target should go. In these cases the experimenter drew the lines herself. This procedure was repeated for the remaining two timelines, with trials in the form, “Now you’re going to show me where [last week] goes. Where does [last week] go? Can you draw a line for [last week]?” Participants

always received the Events line first (to orient them to the task), but the order of the other two lines was counterbalanced between subjects. For each line, half of the subjects received the items in the order shown in Table 1, and the other half received the reverse order. If children asked questions about where they should put the lines, they were told, “It’s up to you! Put it wherever you think [tomorrow] goes on the line.” If participants asked to be reminded what their marks from prior trials referred to, the experimenter provided the answer.

Appendix B: Item Effects

Item effects for Deictic Status were assessed with a mixed ANOVA, with Age as a between-subjects variable and Time Word (e.g., “yesterday”, “next year”, etc.) as a within-subjects variable. The main effect of Time Word was not significant, $F(7, 1022) = 1.6, p = 0.1$), though there was a marginal interaction with Age, $F(42, 1022) = 1.3, p = 0.09$. Table S1 shows the mean Deictic Status accuracy for each time word for each age group.

Table S1. Deictic status accuracy for 8 temporal terms. Percentage of participants at each age (in years) who correctly assigned past items to the left or future items to the right of “now.”

Age	Percentage of participants demonstrating correct deictic status (SEM)							
	Last year	Last week	Yesterday	This morning	Tonight	Tomorrow	Next week	Next year
3	71 (11)	59 (12)	41 (12)	59 (12)	47 (12)	29 (11)	53 (12)	35 (12)
4	60 (11)	70 (11)	45 (11)	80 (9)	70 (11)	75 (9)	40 (11)	65 (11)
5	82 (10)	76 (11)	59 (12)	71 (11)	88 (9)	76 (11)	82 (10)	82 (10)
6	95 (7)	85 (8)	83 (8)	92 (6)	88 (7)	88 (7)	79 (8)	75 (9)
7	95 (5)	85 (8)	90 (7)	100 (0)	95 (5)	90 (7)	90 (7)	95 (5)
8	94 (6)	94 (6)	89 (8)	89 (8)	100 (0)	94 (6)	89 (8)	94 (6)
Adult	97 (3)	100 (0)	100 (0)	97 (3)	92 (4)	100 (0)	100 (0)	100 (0)

Appendix C: Confirmatory analyses of order knowledge

To confirm our findings related to order knowledge, we constructed two additional measures. The first was a whole-timeline measure that looked at ordering errors across the timeline as a whole, not just errors within the past and future in isolation. The second assessed knowledge of relative sequential order, independent of deictic status, by considering the past and future separately.

We assessed the total order error for each timeline as follows: For each item from that timeline, we calculated the absolute deviation between its correct rank (i.e., 1st, 2nd, etc.) and its actual position along the timeline, and then summed across all items. For example, on the Event line, if the mark for “next birthday” – which should have been the *fourth and final* item – was actually the *first* mark on the timeline, this would contribute $|1-4| = 3$ to the total order error for that timeline. A perfectly ordered timeline would thus receive a score of 0, while a maximally disordered timeline would receive a score of 8 (chance performance was 5). For each participant, we also calculated the mean Order error for each type of timeline (i.e., Deictic vs. Event).

Order error was analyzed with a mixed ANOVA, with Timeline Type (i.e., Deictic vs. Event) as a within-subjects factor and Age (3 through 8 years old, and adults) as a between-subjects factor. The only effect to approach significance was the main effect of Age, $F(6, 146) = 31.8, p < .001$ ($p > .19$ for all other effects). Indeed, performance improved monotonically with age, $M_3 = 4.7 > M_4 = 3.5 > M_5 = 2.4 > M_6 = 1.8 > M_7 = 0.9 > M_8 = 0.4 > M_{adults} = 0.1$, and, among children, a linear regression revealed that order error was predicted significantly by age, $b = -0.86 \pm 0.09$ SEM, $p < .001, r^2 = .45, p < .001$. Three-year-old children performed at chance, $M_3 = 4.7, t_{16} = -0.88, p = .39$. By contrast, 4-years-olds had significantly lower error than 3-year-olds, $t_{35} = 2.4, p = .02$, and their performance was significantly better than chance, $M_4 = 3.5, t_{19} =$

-4.0, $p < .001$. Seven-year-olds still had significantly higher error scores than adults, $t_{54} = 3.0$, $p < .01$, but 8-year-olds were indistinguishable from adults, $t_{52} = 1.6$, $p = .13$.

We next assessed knowledge of relative order independently from deictic status, by evaluating the relative placement of the two items that were in the past, and, separately, the relative placement of the two items that were in the future. Thus, simply knowing the past status of ‘yesterday’ and the future status of ‘next year,’ for instance, was insufficient to succeed on this measure of relative order knowledge. Instead, if ‘yesterday’ were placed to the right of ‘last year,’ this would count as a correct ordering, regardless of where the items were placed relative to either the ‘now’ midpoint or the future items. This measure was thus designed to completely isolate order knowledge from knowledge of deictic status—at the cost of power, however, since it involves only two comparisons per timeline.

We calculated mean accuracy on this measure of order knowledge, for each participant and Timeline Type. There was only a main effect of Age, $F_{(6, 146)} = 11.95$, $p < 0.001$, with knowledge of order increasing monotonically with age, $M_3 = .57 < M_4 = .58 < M_5 = .69 < M_6 = .74 < M_7 = .86 < M_8 = .93$. Just as with deictic status, 3-year-olds were not above chance, $t_{16} = 0.68$, $p > .5$ — but neither were 4-year-olds, $t_{19} = 1.60$, $p = .13$. It was not until children were five years old that they were reliably above chance on this measure of order knowledge, $t_{17} = 3.29$, $p < .01$. Eight-year-olds were indistinguishable from adults, $M_{\text{adults}} = .98$, $t_{52} = -1.58$, $p = .12$, but 7-year-olds had significantly more error than adults, $t_{54} = -2.76$, $p < .01$.