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Authors

Tillman, Katharine A.
Marghetis, Tyler
Barner, David
et al.

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Deconstructing *tomorrow*: How children learn the semantics of time

Katharine A. Tillman[1], Tyler Marghetis[2], David Barner[1], & Mahesh Srinivasan[3]

[1]U. California, San Diego
Department of Psychology
{katillman, barner}@ucsd.edu

[2]Indiana University, Bloomington
Psychological & Brain Sciences
tmarghet@indiana.edu

[3]U. California, Berkeley
Department of Psychology
srinivasan@berkeley.edu

Abstract

Deictic time words (e.g., "tomorrow," "yesterday") refer to time periods relative to the present moment. While children produce these words by age 2-3, they use them incorrectly for several more years. Here, as a case study in abstract word learning, we explored what children know about these words during this delay. Specifically, we probed children's knowledge of three aspects of meaning: deictic (past/future) status, sequential ordering (e.g., "tomorrow" is after "yesterday"), and remoteness from *now*. We asked 3- to 8-year-olds to place these words on a timeline extending from the past (left) to the future (right). Even 4-year-olds could meaningfully represent the words' deictic status and order, and by 6, the majority displayed adult-like performance. Adult-like knowledge of remoteness, however, emerged independently, after age 7. Thus, even while children use these terms incorrectly, they are gradually constructing a structured semantic domain, including information about the deictic, sequential, and metric relations among terms.

Keywords: time; word learning; development; abstract concepts; timeline

1. Introduction

When learning a new word, children face an inductive problem: How broadly should this new word be extended? This problem is especially challenging in cases where a word's semantic boundaries cannot be inferred from perception of the world. For instance, *deictic time words* like "yesterday" and "tomorrow", which label periods of time relative to the present, lack perceptible referents and are used to refer to a changing set of experiences. Tomorrow's events, for instance, will soon become yesterday's. To make inferences about word meanings in such cases, children could rely on the structure of language itself—e.g., using linguistic cues to learn how these words are related to one another within a common semantic class—and thus construct partial meanings on the way to adult-like semantics (e.g., Carey, 2009; Gleitman et al., 2005). However, while previous studies indicate a long gap between when children initially produce deictic time words and eventual adult-like usage (Ames, 1946; Busby Grant & Suddendorf, 2011; Harner, 1975; 1981), we know relatively little about the inductive process through which they are acquired. 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.

Although many children use words like "yesterday" and "tomorrow" as early as age 2 or 3, they make frequent errors in both their use and comprehension for several subsequent years (Ames, 1946; Busby Grant, & Suddendorf, 2011; Harner, 1975). According to parental report, while two thirds of 3-year-olds produce the word "yesterday", fewer than 20% use the word correctly; by age 5, more than 80% of children produce "yesterday", but still, fewer than 60% use it correctly (Busby Grant & Suddendorf, 2011). 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, and less than 70% of 5-year-olds can do so (Busby & Suddendorf, 2005). However, while such studies suggest that children struggle with deictic time words for years, they tell us little about what children *do* and *do not* know about these words, or about how they are learned.

While there has not been systematic study of children's partial knowledge of deictic time words during the delay between initial production and adult-like usage, there are hints that children may independently acquire information about different facets of their meaning. 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., "yesterday" is a time after "last week"), and its **remoteness** from the present (e.g., "yesterday" is one day from today). In one study, 3-year-old English speakers appeared to have partial knowledge of the deictic status of "yesterday" and "tomorrow", understanding that these terms refer to a non-present time, without knowing whether they refer specifically to the past and future, respectively (Harner, 1975). Children's spontaneous speech errors also suggest partial meanings. For example, children overextend deictic time words within either the past or future (e.g., Harner, 1981; Nelson, 1996), suggesting that children may acquire deictic status prior to remoteness.

Understanding the nature of children's errors – and the partial word meanings they implicate – could provide critical insight into the inductive hypotheses children make about the meanings of deictic time words and the cues children use to guide them. Here we will consider three potential word learning strategies, which are not mutually exclusive. One possibility is that children make inferences about time word meaning based on grammatical cues in the sentence, i.e., using *syntactic bootstrapping* (Gleitman et al., 2005). In this case, we would expect native-English-speaking children to have early knowledge of **deictic status**, which is expressed by the English tense system. A second possibility is that children use linguistic cues to group terms into a common semantic class (e.g., terms referring to the past) and use lexical contrast to learn their relations within it (“last week” is before “yesterday”; see Carey, 2009; Shatz et al, 2010; Tillman & Barner, 2015) This account predicts early knowledge of **order**. A third possibility is that children use associations between time words and experienced events, i.e., *event mappings,* to estimate the distance from the present indicated by each word, predicting early knowledge of **remoteness**. In order to test these accounts, the present study aimed to separately characterize children’s knowledge of these different facets of these terms’ meanings. To do so, we asked children to map these words onto a nonverbal representation: a spatial timeline.

Several studies suggest that by age 4 or 5, children can use spatial scales to differentiate the times of events (Busby Grant & Suddendorf, 2009; Friedman, 2002; Friedman & Kemp, 1989; Hudson & Mayhew, 2011). However, no studies have probed children’s knowledge using a conventional horizontal timeline, and most have explicitly *avoided* deictic time words. Further, previous timeline studies were limited in their ability to tease apart children’s understanding of the different semantic facets of these terms. For instance, they used timelines depicting either the past or the future, but not both, making it impossible to gauge children’s knowledge of deictic status, and they were categorical, e.g., “a short time ago” vs. “a long time ago,” making it difficult to probe children’s knowledge of sequential order or remoteness precisely, because children could place multiple terms within the same category (e.g. Busby Grant & Suddendorf, 2009; Friedman, 2002; Friedman & Kemp, 1998).

Here, we assessed children’s comprehension of different facets of the meaning of deictic time words using a new timeline task. We tested adults, and children over a wide age range (age 3 to 8), in order to probe for possible partial knowledge of terms during the long gap between initial production and adult-like usage. Participants 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 continuously from the past (“when you were a baby”) on the left, to the future (“when you’ll be a grown-up”) on the right. Importantly, the present moment (“right now”) was also marked, dividing the line into the past and future.

Critically, this paradigm allowed us to independently assess children’s knowledge of a deictic time word’s deictic status (i.e., past vs. future), sequential order, and remoteness from the present. Knowledge of the deictic status of a word was indexed by its correct placement to the left or right of the midpoint, regardless of its placement relative to other words. Knowledge of sequential order was indexed by the ordering of words along the line — for example, whether “last week” was placed before (i.e., to the left of) “yesterday,” ignoring either term’s relation to the present or the distances between them. And knowledge of remoteness from the present was indexed by the spacing of terms along the line — for example, by looking at how far “last week” is placed from “now”, compared to the placement of “yesterday” relative to “now.”

Our paradigm thus probed children’s developing understanding of deictic time words, including the sequence by which they acquire different aspects of mature, adult-like meanings. For example, if a child acquires deictic status prior to the other facets, as predicted by a syntactic bootstrapping account, we would expect them to correctly assign all past terms to the past but perhaps to *fail* to respect their ordering or distance from the present, e.g., by placing “yesterday” much further in the past than “last year”.

2. Methods

2.1 Participants

Participants included 109 children between 3;0 and 8;11 years of age, recruited from the San Diego, CA and Berkeley, CA areas. Additionally, we tested 37 adult controls from the UCSD Psychology Department subject pool. Children were tested in lab or at local daycares, schools, and museums, and adults were tested in lab. Informed consent was obtained from adults and parents of participating children. Adults were given course credit; children were given a small prize.

2.2 Materials and procedure

Participants responded by drawing on three 13.5cm left-to-right timelines, printed down the center of a 8.5” × 11” sheet of paper. On each timeline, a vertical tick at the midpoint indicated the present; an icon of a baby indicated the past; an icon of an adult indicated the future (Fig. 1).

To begin, the experimenter [E] gave the paper and some colored pencils to the child. While gesturing to the appropriate sections of the top line, E stated: “Look, this is a timeline. It shows *when* different things happen. The line starts in the past and it goes to the future. So, it goes from when you were a baby all the way to when you’re going to be a grown up. And here in the middle is right now. 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, E introduced the first item, “When [did you] [eat breakfast today]? Think about when you [ate breakfast today]? Draw a line for when you [ate breakfast today].” The child then marked the line.

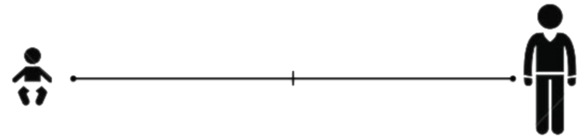

Figure 1: Timeline used by participants to indicate the relative locations of deictic time words and events.

After all four events were placed on the top timeline, the 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]?” Each child placed 8 deictic time words and 4 events on three timelines (Table 1). Participants always received the Events line first 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.

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

2.3 Coding. For each timeline, the distance in centimeters from the left endpoint of the line to each color-coded mark was measured, as well as its distance, positive (right) or negative (left), from the midpoint of the line

3. Results

To characterize children’s knowledge of deictic time words, we undertook the following analyses: First, we assessed comprehension of the deictic status, order, and remoteness of the deictic time words (and, by way of comparison, the life events). Second, we determined the ages of acquisition of these facets of meaning, pinpointing the age at which the majority of children displayed adult-like comprehension. Finally, we calculated the contingencies between adult-like knowledge of these facets of meaning: i.e., the degree to which adult-like knowledge of deictic status, order, and temporal remoteness predicted one another.

3.1 Facets of meaning

3.1.1 Deictic status. For each timeline and subject, we calculated the mean accuracy for all items’ placement relative to “now” (e.g., “tomorrow” should be in the future), and then calculated 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 Time 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 Time Type, suggesting that children were equally able to represent the past/future status of time words and events. The only effect to approach significance was the main effect of Age, $F(6, 138) = 26.3$, $p << .001$ (Fig. 2). While 3-year-olds performed at chance overall, $t_{14} = .14$, $p > .8$, 4-year-olds were better than chance, $t_{16} = 4.7$, $p << .01$. Mean accuracy improved monotonically from 3- to 7-years-old, $M_3 = .50 < M_4 = .67 < M_5 = .77 < M_6 = .84 < M_7 = .94$ at which point mean performance was no longer distinguishable from adults ($M_{adults} = .94$), $t_{56} = -0.1$, $p > .9$.

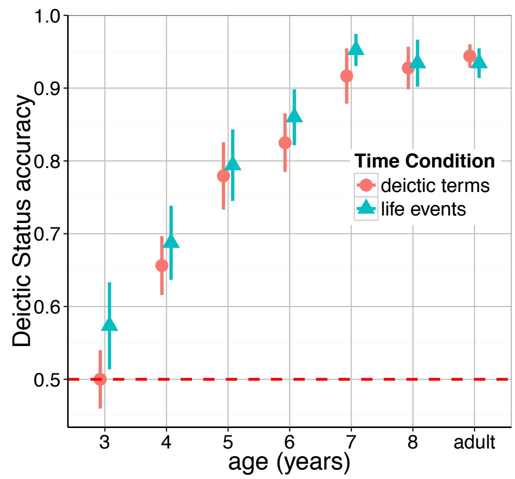

Figure 2: *Deictic Status Knowledge.* Accuracy improved with age, for both time words (e.g., “tomorrow”, circles) and events (e.g., “last birthday,” triangles). Error lines = SEM; dashed line = chance performance.

3.1.2 Order. We assessed knowledge of relative sequential order—independent of deictic status—in two ways. The first method examined the rank ordering of all four items on a timeline. The second, designed to minimize concerns about working memory demands, evaluated knowledge of sequential order on a trial-by-trial basis, by comparing the placement of each item to the placement of the immediately preceding trial (e.g., if “last week” is tested just after “tomorrow,” it should be placed to the left of “tomorrow”). Both analyses yielded the same pattern of results. Here we report only the latter analysis.

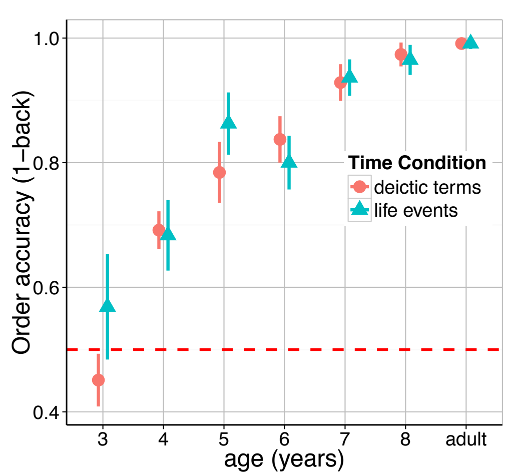

Figure 3: *Order Knowledge.* Performance improved with age, for both deictic time words and events. Error lines = SEM; dashed line = chance performance.

For each child and Time Type, we calculated mean accuracy on this 1-back measure of order knowledge. Once again, there was only a main effect of Age, $F(6, 138) = 33.1$, $p << .01$ (Fig. 3). Just as with Deictic Status, four-year-olds were significantly better than chance, $t_{16} = 4.1$, $p << .01$, while three-year-olds were not, $t_{14} = -0.6$, $p > .5$. Compared to adults, seven-year-olds were significantly worse, $t_{56} = -2.8$, $p < .01$, but eight-year-olds were indistinguishable, $t_{52} = -1.7$, $p > .1$.

3.1.3 Remoteness. We next evaluated knowledge of the temporal remoteness of each item from "now." In essence, we wanted to know to how well children used spatial distance to represent temporal remoteness. Since we were interested in the use of relative and not absolute space, we first standardized the total amount of the line used by each child by dividing each distance from zero by the maximum distance at which any item was placed by that child. Distances thus ranged from 0 to 1. This approach acknowledges that the absolute location of, e.g., "last year", relative to the line's endpoint (infancy) is likely to differ with age, letting us focus on whether participants differentiated how much closer e.g., "yesterday" is to the present, relative to wherever they assigned "last year."

To characterize the maturity of children's representations of remoteness, for each child, we used multiple regression to see whether each item's distance was predicted by (1) the item's correct order, relative to the midpoint, and (2) the mean distance, from the midpoint, where adults placed that item. As a measure of each child's knowledge of temporal remoteness, we used the strength of the relationship between the child's placements and adult-like placements, after factoring out the children's knowledge of order (i.e., semi-partial correlation squared). Mean remoteness knowledge for each age group is shown in Fig 4. Children's knowledge of remoteness improved gradually across our entire age-range, with even 8-year-olds performing significantly differently from adults.

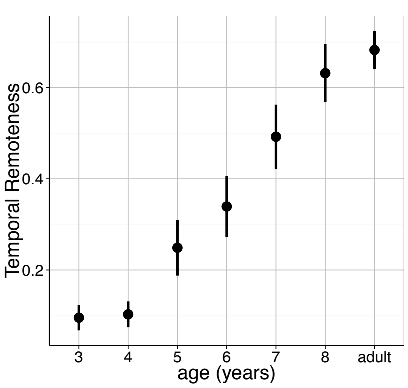

Figure 4: *Remoteness Knowledge*. Children improved gradually but did not reach adult-like performance. Error lines = SEM.

3.2 Order of acquisition

Having characterized children's developing understanding of deictic status, order, and remoteness, we next investigated the order in which these facets of the meaning of deictic time words are learned. We used a threshold approach, comparing the ages at which the majority (50%) of children had made the transition from partial to adult-like understanding of each facet of meaning.

First, based on the continuous measures of their knowledge of deictic status, order, and remoteness, each participant was characterized, via k-means clustering, as a "knower" vs. "non-knower" of that domain (Fig. 5, black dots). "Knowers" included all of the adult participants and the children who clustered with them. Then, for each facet of meaning, we modeled the transition to adult-like knowledge using a Weibull function, where age predicted whether or not a child exhibited adult-like knowledge. This allowed us to estimate the age at which the majority of children acquire adult-like knowledge of each facet, independently of the other two.

The age at which the majority of children transitioned to adult-like knowledge of deictic status and order was the same, around age 6 (Deictic Status: 6.0, 95% bootstrapped confidence interval: [5.45, 6.39]; Order: 5.9 years, [5.42, 6.37]). By contrast, most children did not transition to adult-like knowledge of temporal remoteness until more than a year later, at 7.30 years ([6.81, 7.66]). Since the confidence interval for remoteness does not overlap with the other confidence intervals, this delay is statistically significant.

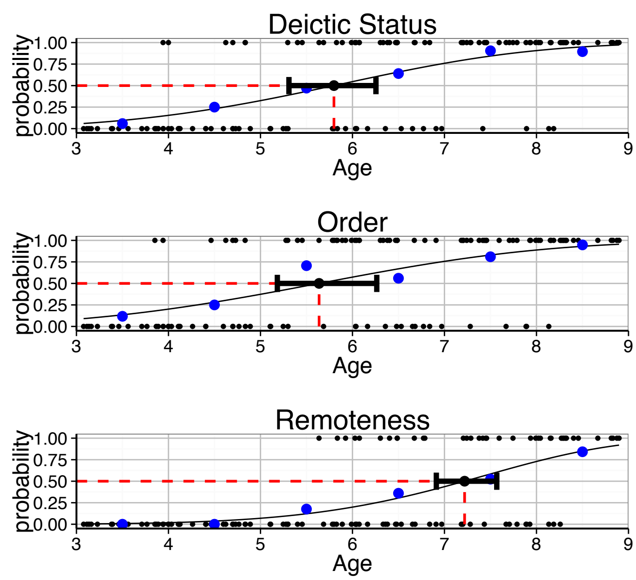

Figure 5: *Age of acquisition for three facets of time word meaning*. Each black dot is an individual child, categorized as either a "knower" (top) or "non-knower" (bottom) of that dimension. Blue dots indicate the mean probability of being a knower in that age group. Red dotted lines indicate age-thresholds for $p = 0.5$; black horizontal error bars indicate bootstrapped confidence intervals on those age-thresholds.

3.3 Learning contingencies

The previous analysis revealed that on their sixth birthday, only a quarter of children exhibit an adult-like grasp of the remoteness of deictic time words, while half of children know their deictic status, and half know their relative order. But this analysis does not tell us whether the very 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. 6). Deictic status and order were highly linked: children who knew one of them almost always knew the other as well. However, while it was extremely uncommon for a child to be a remoteness-knower without also being an order knower (97%) and deictic-status knower (88%), the reverse was not true. The average deictic-status-knower had only a 53% chance of being a remoteness-knower, while the average order-knower had only a 57% chance of being a remoteness-knower. This is exemplified by the top timeline in Fig. 6b, produced by a 5-year-old who knows both deictic status and order, but is far from adult-like in her representation of remoteness. Compare this to the bottom timeline, from an adult, where items are placed based not only on 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, these results reveal a clear developmental trajectory in which both deictic status and order emerge early and in synchrony, while knowledge of temporal remoteness is developed independently and often much later.

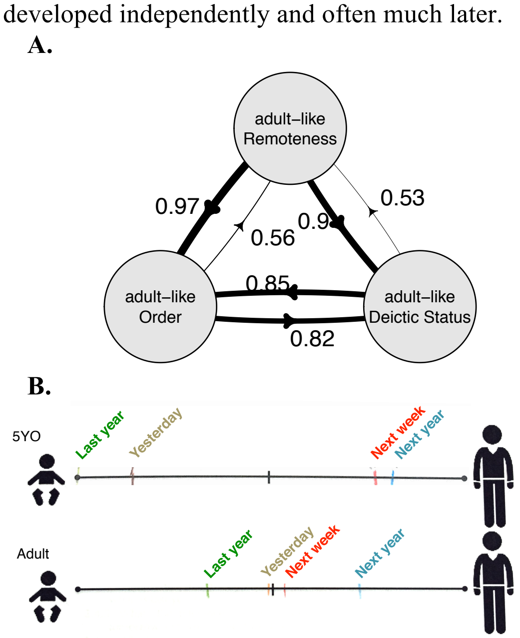

Figure 6: *A. Contingencies among facets of meaning*. Arrows from A to B denote direction of influence. Line width indicates conditional probability of knowing facet B, given knowledge of facet A (scaled from .5 to 1). *B. Example timeline data* from a 5-year-old and an adult. The child exhibits knowledge of deictic status and order, but not remoteness.

4. Discussion

Here, as a case study in abstract word learning, we explored the prolonged trajectory over which deictic time words, like "yesterday," are learned. Prior studies have shown that children produce their first deictic time words at age 2 or 3, but make errors in their use until age 5 or older (e.g., Busby Grant & Suddendorf, 2011). The current study further investigated this delay between production and comprehension, by independently assessing children's knowledge of three facets of the meanings of these words: deictic status, order, and remoteness. Despite their speech errors, we found that even 4-year-olds have partial understanding of the words' deictic status (e.g., that "yesterday" was in the past) and order (e.g., that "yesterday" was before "this morning"), and that most children master these elements of meaning by their 6th birthday. However, our results suggest that fully adult-like mastery of deictic time words, including knowledge of temporal remoteness (and the ability to represent it spatially), may be achieved even later than prior work has revealed. While the majority of children showed evidence of mastery of all three facets of word meaning between their 7th and 8th birthdays, some were not adult-like on our task even shortly before age 9.

What can the present findings tell us about how deictic time words are acquired? Unlike most terms in the early lexicon, their meanings cannot be constrained simply by observing the perceptual structure of the world and performing simple "word-to-world" mappings. In particular, constraints like the *whole-object bias* and the principle of *mutual exclusivity,* which can explain much about how toddlers rapidly acquire hundreds of new nouns, are counterproductive in this case (see Markman, 1994 for discussion of word learning biases). Not only are the referents of deictic time words non-objects, but to the extent that these words *do* denote perceptual experiences (i.e., lived or anticipated events), those associations are transient. There are many-to-many relations between deictic time words and events—any number of events could occur *tomorrow*, and each one of them will cease to be *tomorrow,* and become *yesterday*.

It has been proposed that, to acquire "hard words" such as these, children may rely on structure of language itself (e.g., Gleitman et al., 2005). We posited two potential mechanisms by which linguistic cues could support time word learning -- *syntactic bootstrapping* and *lexical ordering* -- and the present findings provide support for both. In particular, the early acquisition of deictic status supports a syntactic bootstrapping hypothesis, because deictic status is indicated by the morphological tense system of English. Long before they use deictic time words accurately, children comprehend the distinction between past and future tenses (e.g., Weist et al., 1991). For instance, they understand that adding *-ed* to a regular verb indicates that the action has already occurred, and could use this cue to infer the deictic status of a term like "yesterday" if it appears in the same sentence. However, tense alone is insufficient to acquire either order or remoteness -- the tense cues in, e.g., "she played yesterday and worked last week", can't tell us which event happened first, or how long ago either event was.

The fact that order is learned simultaneously with deictic status indicates that other inferential processes are also at work. Under the *lexical ordering* account, other linguistic cues might help children place time words in a common semantic category (e.g. all past words) and then learn their relative order within it. For instance, children might infer that time words form a common class from their appearance in similar sentence frames, and direct contrast could support learning their order (e.g., "That party wasn't *yesterday*, it was all the way *last week*"). Prior work on the acquisition of duration words, such as 'week' and 'year,' also supports this account: at 4, children grasp that duration terms comprise a category (Shatz et al., 2010), and by 5 they begin to work out their ordering (i.e., *year* > *week* > *hour* > *minute*; Tillman & Barner, 2015).

Understanding the temporal remoteness of deictic time words trails knowledge of the other facets of time-word meaning by over a year. Unlike deictic status and order, which could plausibly be inferred from language alone, it is difficult to imagine how children might learn the remoteness of time words from speech input without relying on considerable lived experience. Under the *event mapping* account, after developing a sense of how long ago their last birthday was, a child might be able to associate a deictic term like "last year" with the remoteness of an event, like a party, said to occur then (i.e., by abstracting the time of the event, relative to its time of utterance, as the relevant dimension). However, the finding that remoteness is acquired so late suggests that such mappings are an inefficient means of learning the set of deictic time words, perhaps due to the pitfalls of standard word-to-world mappings described above.

Interestingly, the transition to mature knowledge of remoteness 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). This raises the possibility that adult-like representations of remoteness depend upon exact definitions for time words. In the case of duration words, children have little understanding of the absolute duration of each word (e.g., *hour*=*minute*×60; *year*=*day*×365) until around age 7, when they are taught definitions. If adult-like representations of remoteness also rely on this understanding, we would expect children to fail until the same age, as we observe. In both cases, children infer early on that time words are inter-defined, but often cannot use them accurately to reference events until much later.

Here, we leveraged the spatial timeline as a tool to characterize children's knowledge of time words more precisely than prior methods. However, this method necessarily conflates children's semantic understanding of the target items with their ability to express that knowledge spatially. Confusion about timelines could potentially mask semantic knowledge of time words. Though evidence suggests children as young as 3 can comprehend continuous spatial number-lines (e.g. Bartelleti et al., 2010), future research will be needed to directly test the possibility that this timeline method underestimates children's knowledge of deictic time words.

Strikingly, we have mapped out a developmental trajectory for time-word learning that can take children *five years* or more. Arguably, this process represents a profound conceptual breakthrough. In order to use deictic time words like adults do, a child must have the idea that there is dimension of time that is separate from the events that occupy it. While this might challenge the child's early assumptions about what words can label, mastering this insight may provide a transformational framework for interpreting the past and planning for the future.

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