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Twice Upon a Time: Children Use Syntax to Learn the Meanings of Yesterday and Tomorrow

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ABSTRACT

Time words like "yesterday" and "tomorrow" are abstract, and are interpreted relative to the context in which they are produced: the word "tomorrow" refers to a different point in time now than in 24 h. We tested 112 three- to five-year-old English- and Hindi-speaking children on their knowledge of "yesterday" and "tomorrow," which are represented by the same word in Hindi-Urdu: "kal." We found that Hindi learners performed better than English learners when tested on actual past and future events, but that performance for hypothetical events was poor for both groups. Compatible with a "syntactic cues" account, we conclude that syntactic tense information—which is necessary for differentiating "yesterday" from "tomorrow" in Hindi—may play a stronger role in learning the deictic status of these words than mapping of specific words to particular past and future events ("event mapping").

1 | Introduction

Many common words in children's early vocabularies (e.g., "cat," "table," "ball," etc.) label concrete objects in their environment (e.g., Gillette et al. 1999). At the same time, children are also exposed to highly abstract words like "yesterday" and "tomorrow" that have no concrete referents in the world (Busby-Grant and Suddendorf 2011; Fillmore 1997). Although children begin to produce "yesterday" and "tomorrow" by around age 3, shortly after they begin using other time words such as "now," "later," "before," "after" (Ames 1946; Busby and Suddendorf 2005; Busby-Grant and Suddendorf 2011; Suddendorf 2010), they rarely use them in an adult-like manner, with some studies estimating that only 7- or 8-year-olds show adult-like comprehension (Ames 1946; Antinucci and Miller 1976; Busby-Grant and Suddendorf 2010, 2011; Eisenberg 1985; Busby-Grant and Suddendorf 2011; Harner 1981; Nelson 1998; Szagun 1978; Tillman et al. 2017; Veneziano and Sinclair 1995; Weist 1989; Weist et al. 1991). Words like "yesterday" and "tomorrow" likely pose a problem because, unlike many labels for concrete things, they are deictic expressions, whose reference shifts from day to day (Fillmore 1997). Consequently, to acquire their meanings, children not only need to know that "yesterday" refers to events in the past, and "tomorrow" to events in the future, but they must also learn that each word denotes a period of time exactly one day from the present—not just any time in the past or future. Thus, "yesterday" and "tomorrow" encode both tense information (i.e., reference to the past or future) and remoteness information (i.e., distance into the past or future).

In the present study, we explored two mutually compatible sources of information that children might use to acquire these words, with a particular focus on their deictic status—that is, their reference to past and future. According to an "event mapping" account of time word learning, children learn the meanings of "yesterday" and "tomorrow" by mapping them onto the events they are used to describe (e.g., Friedman 2003; Hinrichs 1970; Johnson et al. 1988). On this account, children might hear their caregiver refer to a specific event and describe it using either the

Summary

- Hindi learners performed better than English learners when tested on their knowledge of time words to reference actual past and future events.
- Children rely on syntactic cues (e.g., tense markings) to learn the meanings of deictic time words like "yesterday" and "tomorrow."
- Autobiographical measures that involve the actual passage of time may be more sensitive to children's knowledge of time words than hypothetical measures.

word "yesterday" or "tomorrow," and over many such iterations form the generalization that events described as "yesterday" tend to happen in the past, whereas events described as "tomorrow" tend to occur in the future. For example, children might anticipate future events when their caregivers tell them, "We're going to the zoo *tomorrow*," or "Halloween is *next month*" (Friedman 1990, 1993; Hudson 2002, 2006; Nelson 1998). They might similarly hear such references for past events, "I asked you to clean your room *yesterday*" or "Remember, we went to the mall *last week*?" On this view, children might also rely on memory traces to learn other temporal information conveyed by these words, such as temporal order and remoteness. For example, they might infer that a birthday party *last week* is further from the present day than dinner *yesterday* because it seems longer ago in memory (Friedman 2003; Hinrichs 1970; Hudson 2002; Nelson 1998). Compatible with event mapping, children's ability to accurately judge the relative recency of important life events (e.g., birthday vs Christmas), identify events that happen at different points in the past (e.g., 1 day vs. 7 days ago), and distinguish between past events occurring one day and several days from the present improves between 3 and 5 years of age (Busby-Grant et al. 2009; Friedman 1991; Friedman and Kemp 1998). Thus, children might use this information to make inferences about the meanings of deictic time words.

According to a second hypothesis, rather than focusing chiefly on relations between words and events, children might learn the deictic status of words like "yesterday" and "tomorrow" by attending to grammatical relations between these words and other structures of language itself—an idea sometimes referred to as syntactic bootstrapping (e.g., Brown 1957; Carey 1978; Fisher et al. 2020; Gillete et al. 1999; Gleitman 1990; Gleitman et al. 2005; Landau et al. 2009; Naigles 1990, 1996; Snedeker and Gleitman 2004). For example, children might infer that because "yesterday" is used in expressions that feature the past tense (e.g., "she sang *yesterday*"), it must describe events in the past. Although English tense markings and discourse structure do not provide direct information about temporal remoteness (e.g., *last week* is exactly seven days from *today*), learning the past/future status of deictic time words like "yesterday" and "tomorrow" might help children constrain the meanings of more complex phrases like "the day before yesterday" and "the day after tomorrow," and in turn, help them learn their relative temporal remoteness from the present (Williams et al. 2021). Therefore, on this account children might rely primarily on syntactic cues early in acquisition to learn the deictic status of "yesterday" and "tomorrow," but eventually supplement this with other information, such as event mapping, to learn remoteness information.

As already noted, previous studies suggest that children acquire the meanings of "yesterday" and "tomorrow" gradually over early childhood. However, the developmental timeline of children's acquisition of these words varies across studies. For example, Harner (1975) assessed 2- to 4-year-old children's use of "yesterday" and "tomorrow" in reference to past and future events by testing them on two consecutive days. On the first day, children played with one set of toys, and on the second day, they were presented with two new sets and were allowed to play with one of them. After this, they were asked to identify "yesterday's toys" (toys from day one) and "tomorrow's toys" (the set not previously used by the child). Harner found that 2-year-olds showed little comprehension of the deictic time words, 3-year-olds showcased better understanding, especially for "yesterday," and by age 4, children understood both terms equally well. In contrast, more recent studies find that children only begin to comprehend the past/future status of "yesterday" and "tomorrow" sometime between 4 and 6 years of age, roughly 1–2 years after the timeline outlined by Harner (Tillman et al. 2017, 2018). Further, even at these ages, these studies find that children struggle to infer the temporal-causal relations between deictic time words (e.g., that events that occur yesterday might cause the events of today and tomorrow to change; Zhang and Hudson 2018), and that it takes them another 2–3 years to encode the remoteness information associated with each word (Tillman et al. 2017; Williams et al. 2021). Consequently, these studies suggest that children only fully comprehend the meanings of deictic time words by around 7–8 years of age.

While the methods of past studies differ in a variety of ways, one reason that some find later learning may be that they require children to engage in other, arguably more sophisticated forms of reasoning, such as mapping temporal events to spatial timelines (e.g., Tillman et al. 2017, 2018; Williams et al. 2021), or asking them to reason about hypothetical past and future states—for example, "past" events that did not actually occur on a previous day, or "future" events that actually occurred in the past (e.g., Busby and Suddendorf 2005; Zhang and Hudson 2018). For example, in one study by Zhang and Hudson (2018), children were asked to match a sentence describing a past action (e.g., "I carved the pumpkin yesterday") or future action (e.g., "I will carve the pumpkin tomorrow") to a picture depicting a present state (e.g., a whole or carved pumpkin) and found failure until age 5. Unlike in the study by Harner, where a child could map "yesterday" to an event they actually experienced the day before, in Zhang and Hudson, children did not experience any of the test events the previous day, but instead had to make a causal-temporal inference, that if a pumpkin was in a carved state then it must have been carved in the past, whereas if it had not been carved, then it must correspond to a future carving event. Consequently, children's difficulties on such a task could be driven, in part, by an inability to engage in more complex hypothetical reasoning skills that are also developing at these ages (see Beck et al. 2006; Buchanan and Sobel 2011; Gautam et al. 2019; Kuczaj and Daly 1979; Nyhout et al. 2023, 2019; Weisberg and Gopnik 2013).

Independent of whether some tasks are more sensitive to children's knowledge than others, previous studies leave open the

relative importance of event mapping and syntactic cues in learning the deictic status of time words. Harner's study leveraged children's autobiographical experience of playing with toys on two separate days to probe their knowledge of "yesterday" and "tomorrow," but importantly, she did not manipulate syntactic cues in her probe, and instead asked either, "Show me a toy from yesterday" or "Show me a toy for tomorrow." Consequently, the role of competing linguistic and perceptual cues in children's judgments was never explicitly tested. Meanwhile, other studies (e.g., Tillman et al. 2017; Williams et al. 2021) reasoned that children learn the deictic status and temporal order of time words earlier in development because these aspects of time words are directly supported by the broader linguistic context (i.e., tense markings and discourse structure), whereas information about temporal remoteness is not similarly conveyed by these linguistic cues. However, the tasks they used did not explicitly test the role of these linguistic cues either, and consequently, could not tease apart the relative roles of event mapping and syntax. Therefore, data from these studies are also compatible with the account that temporal language is mapped onto children's perceptual or event-related experiences (Hudson and Mayhew 2011).

Currently, there is little consensus about how children learn the deictic status of the time words. To address this question, the present research investigated children's early knowledge of yesterday and tomorrow's words in English and Hindi. Hindi offers a unique window into children's learning of time words, because unlike English it uses only one word, "kal," to refer to both yesterday and tomorrow (i.e., 1 day from the present, either in the past or future). Consequently, differentiating yesterday from tomorrow in Hindi relies necessarily on tense marking, since mapping the word "kal" to events in the past and future would result in conflicting cues about its meaning. Also, while Hindi features morphological marking of both past and future tense, English only has morphological tense marking of the past, and describes future events through alternative lexical and grammatical cues (for discussion, see Clark 1973; Fillmore 1997; Hall and Waxman 2004; Kush 2015; Van Olphen 1975). These differences are theoretically interesting because if children rely mainly on event mapping to learn these words, then Hindi children should struggle to interpret "kal," whereas English children may perform better, since "yesterday" and "tomorrow" are distinct words that can in principle be associated with different events. However, if early stages of learning rely more on syntactic cues, then Hindi learners may learn these words as early as or earlier than English learners, given their more robust tense marking system.

Also potentially relevant to addressing the relative importance of event mapping and syntactic cues in early learning is whether children perform differently for "yesterday" and "tomorrow." Interestingly, however, the use of event mapping and syntax appear to make similar predictions about the order in which these words are acquired. First, if children use event mapping early in learning, then English-speaking children may understand "yesterday" earlier than "tomorrow" because they have memory for past, but not future events (making it harder to associate "tomorrow" with specific events; Prabhakar and Hudson 2014). By contrast, event mapping should be unhelpful to Hindi-speaking children, since they use the same word to describe both yesterday and tomorrow, resulting in no difference in order of acquisition, all else equal. Meanwhile, if syntax plays an important role, we might again expect English-speaking children to understand "yesterday" earlier than "tomorrow," since English has overt past tense morphology, while Hindi-speaking children should again perform similarly for both, since Hindi features tense marking for both past and future. While the two theories make similar predictions about the order in which "yesterday" and "tomorrow" should be acquired, syntax and event mapping are of course not the only factors that might impact order of acquisition. For example, children's acquisition of these words should also depend on how often they are used in their input, though available evidence suggests they may be used with similar frequency by caregivers. In a preliminary analysis of available English corpora on the CHILDES database (MacWhinney 2000; Sanchez et al. 2019), we found that "yesterday" and "tomorrow" were used in similar frequency by caregivers ("yesterday" = 4036; "tomorrow" = 3099), while children produced yesterday somewhat less frequently ("yesterday" = 692; "tomorrow" = 1098), though their average first uses of these did not differ ("yesterday" = 49.11m; "tomorrow" = 49.68m).[1] Unfortunately, no similar data for Hindi were available. Nevertheless, the relative frequency of past and future uses should have minimal impact on how Hindi children comprehend these words so long as they are sensitive to past and future tense, which unambiguously differentiate between the two uses of "kal" when uttered.

In the present study, we tested children's use of event mapping and syntactic tense information to acquire the deictic status of "yesterday" and "tomorrow" in 3- to 5-year-old Indian children who were learning either Hindi or English as their first language. Our primary question was what role syntax and event mapping might play in understanding the deictic status of words for yesterday and tomorrow. We reasoned that if children are sensitive to tense information when interpreting "yesterday" and "tomorrow," then Hindi-speaking children should differentiate these words, despite using the same word, "kal" to label both. Meanwhile, if they are not sensitive to tense information, then Hindi children should fail to differentiate uses of "kal." In English, if children are more sensitive to tense information than to event mapping in early acquisition, we should expect them to perform better when experimental sentences include explicit tense information (e.g., "Show me the toy you *played with* yesterday") than when they do not. Finally, if event mapping plays a more important role than syntax for learning deictic information, then we may expect English-speaking children to outperform Hindi-speaking children, since event mapping is only useful to differentiate yesterday from tomorrow in English. However, if event mapping plays a minimal role in this early learning, we may find either no cross-linguistic difference, or even an advantage among Hindi children, since only Hindi features overt future tense. To explore these predictions, we compared performance across three language groups: (1) English no-tense, in which no tense markings were used to probe children's responses, (2) English tense, which used tense markings, and (3) Hindi, which require the use of overt syntactic cues, as in the English tense group.

A secondary question was how the use of real versus hypothetical events might impact children's temporal reasoning. To evaluate this, we tested children using two different tasks: a "Two-Day Real Events" task, modified from Harner's (1975) paradigm, and

a novel "One-Day Hypothetical Events" task, in which children made judgments about a hypothetical character's toys relative to their present state. Crucially, all that differed between the events in the One-Day Hypothetical Events task and the Two-Day Real Events task was whether the events featured the deictic status of yesterday and tomorrow, relative to the child's own timeline. In the One-Day task, the events compatible with yesterday occurred on the child's "today," as did the events for tomorrow.

2 | Method

All methods were pre-registered, and materials are available on the Open Science Framework.

2.1 | Participants

Participants were 112 native Hindi- and English-speaking children between 3 and 5 years of age.[2] Children in both language groups were recruited from schools in the Delhi National Capital Region (NCR) of India. Children in the region typically learn two or three languages, including English, Hindi, and regional languages spoken by their parents (see for discussion Mohanty 2010). Native proficiency was determined through parental report and medium of instruction at the school. The sample consisted of 50 native Hindi learners, as well as 62 native English learners, who were randomly assigned to one of two English language groups: tense (n = 32) or no-tense (n = 30). Twenty-one 3-year-olds, forty-five 4-year-olds, and forty-five 5-year-olds were included in the study. Most English learners were also fluent in Hindi (N = 60/62), whereas no Hindi learners spoke English (N = 0/50). Although no specific data about participants' socio-economic status were collected, the average household income in the NCR is $455/month. Families are predominantly of Hindu religious tradition, though other major religious and ethnic groups include Islam, Sikhism, Christianity, Jainism, and so forth.

2.2 | Materials and Procedure

Participants first completed the "Two-Day Real Events" task over two consecutive days (described in Section 2.2.1), and on the second day of testing, completed the "One-Day Hypothetical Events" task.

2.2.1 | Two-Day Real Events Task

Adapted from Harner (1975), this task was administered over two consecutive days. Children played with one set of toys the first day and another set the next day. On the second day, they were shown three sets of toys and asked to identify the toys associated with "yesterday" and those associated with "tomorrow." Each set varied in color (i.e., red, yellow, and blue), but contained the same toys: three cars, two balls, and five blocks. On the first day, the experimenter showed the child three bags, saying: "Look! Each of these has toys of a different color. We get to play with toys of a different color every day". The experimenter then chose one of the bags and took out its contents saying, "These are the toys for today!". Children played with toys of one color (e.g., red toys) on the first day. After a few minutes, the child put the toys back in the bag.

On the second day, the experimenter reminded the child of the game while showing them the three bags: "Remember, we get to play with toys of a different color every day! These are the toys for today." The child was then given toys of a different color (e.g., yellow toys) to play. The remaining procedure resembled the first day. The experimenter then took out one toy (e.g., a ball) from each of the three bags and asked the child to identify the toy from yesterday (i.e., the toy they played with the previous day) and the toy for tomorrow (i.e., a toy with which they had not yet played). After the child put the second day's toys back in the bag, the experimenter suggested to the child that they will return the following day (i.e., Day 3): "When I come back, we get to play with toys of a different color!"

The test question differed across the Hindi and two English language groups. In the English no-tense group, the experimenter asked: "Show me the toys *from yesterday / for tomorrow*". In the English tense condition, children were asked: "Show me the toys *you played with yesterday*" and "Show me the toys *you will play with tomorrow*". In Hindi, the questions resembled the English tense group: "मुझे वे खिलौने दिखाओ जिनसे तुम *कल खेले थे*" (1) and "मुझे वे खिलौने दिखाओ जिनसे तुम *कल खेलोगे*" (2), which refer to the past and future respectively.

(1)

मुझे	वे	खिलौने	दिखाओ	जिनसे	तुम	कल	खेले थे
mujhe	ve	khilaune	dikhao	jinse	tum	kal	khele the
me	the	toy.PL	show.IMP.2SG	which	you	yesterday	play.PST.2SG

Show me the toys you played with yesterday

(2)

मुझे	वे	खिलौने	दिखाओ	जिनसे	तुम	कल	खेलोगे
mujhe	ve	khilaune	dikhao	jinse	tum	kal	kheloge
me	the	toy.PL	show.IMP.2SG	which	you	tomorrow	play.FUT.2SG

Show me the toys you will play with tomorrow

Questions were divided across six trials with each toy (i.e., ball, block, or car) presented twice. Children were asked to identify the toy associated with "yesterday" on half the trials and the toy associated with "tomorrow" on the other half. Children always saw red toys on Day 1 (i.e., yesterday's toys), yellow toys on Day 2 (i.e., today's toys), and blue toys were reserved for Day 3 and presented only at test (i.e., tomorrow's toys). The order in which children were asked about a lexical item (i.e., yesterday-first or tomorrow-first) was counterbalanced across participants. Objects (i.e., balls, blocks, and cars) were also presented in a pseudo-randomized order.

2.2.2 | One-Day Hypothetical Events Task

This task was used to test children's reasoning about yesterday and tomorrow for hypothetical events. On the second day of testing, children were told a story about a character playing with different sets of toys. They were then asked to identify the toy associated with "yesterday" and one associated with "tomorrow" (see Figure 1).

Test questions were phrased in a manner similar to the Two-Day Real Events task. A total of six stories were presented: three stories asked children to identify the toy associated with "yesterday" and three asked about the toy associated with "tomorrow." For each participant, lexical items were queried in the same order (i.e., yesterday-first or tomorrow-first) as the Two-Day Real Events task.

3 | Results

We first analyzed children's comprehension of the deictic time words within each task, that is, the Two-Day Real Events Task and the One-Day Hypothetical Events Task. Second, we compared children's performance across the two tasks to examine whether both tasks are equally sensitive to children's early knowledge of "yesterday" and "tomorrow." Our primary analyses were based on a pre-registered plan available on OSF, though the findings reported below also include several exploratory and post hoc tests. Model comparisons were performed using likelihood ratio tests, and the best fitting models were selected on the basis of a significant chi-squared statistic and reduced AIC value. All post hoc pairwise comparisons were adjusted for multiple comparisons using a Bonferroni correction.

3.1 | Two-Day Real Events Task

To test whether children's early meanings of deictic time words differed across linguistic groups (English tense, English no-tense, or Hindi), we constructed generalized linear mixed models predicting children's accuracy on the Two-Day Real events tasks using the lme4 (Bates et al. 2015) R package (Table 1). Our base model included age (months) and language group (English no-tense/English tense/Hindi) as fixed factors, and participant as a random factor with accuracy (1/0) on Two-Day Real Events as the dependent variable. Relative to a simpler model with only age (months) as a fixed factor, the base model significantly improved fit to the data ($\chi^2(2) = 10.28$, $p = 0.005$), suggesting that children's accuracy differed across language groups. To assess differences in children's acquisition of "yesterday" and "tomorrow," we added a term for lexical item (yesterday/tomorrow) to our base model. Adding a term for Item did not significantly improve model fit ($\chi^2(1) = 1.68$, *n.s.*), suggesting that lexical item did not drive overall differences in children's performance across groups. Post hoc pairwise comparisons conducted using the emmeans R package (Lenth 2024) showed that Hindi learners were significantly more accurate than English learners in both the tense ($\beta = 1.03$, $p = 0.02$) and no-tense groups ($\beta = 1.11$, $p = 0.01$). Thus, despite using the same word for both yesterday and tomorrow, Hindi children were not delayed in learning "kal," and even outperformed their English-speaking peers, compatible with a strong role for syntax early in learning. However, we also found no significant difference in performance between the English tense and no-tense groups ($\beta = -0.08$, *n.s.*), suggesting that although children used tense information early in learning, the explicit presence of tense information during the task was not necessarily critical to performance for English learners (though see post hoc pairwise comparisons & *t*-tests against chance for evidence it might still play a small role).

To better understand the developmental trajectory of children's acquisition of deictic time words, we next explored how age and language interacted (see Figure 2). To do so, we constructed an exploratory model to ask how children in each age of three age groups (3-, 4-, and 5-year-olds) understood yesterday and tomorrow within each language group. We found that a three-way Age * Language Group * Item interaction model did not improve model fit ($\chi^2(4) = 6.15$, *n.s.*) relative to a simpler model [Accuracy ~ Age + Language Group + Item + Age * Language Group + Age * Item + Item * Language Group + (1|PID); see Supporting Information]. Post hoc pairwise comparisons showed that 5-year-olds performed better than 4-year-olds ($\beta = -0.93$, $p = 0.02$) and 3-year-olds ($\beta = -1.63$, $p = 0.004$) overall. However, there was no difference in performance between 3- and 4-year-olds ($\beta = -0.69$, *n.s.*). To tease apart these findings, we explored Language Group × Item interaction within each age group and found that 4-year-olds in the English tense group performed significantly better on "yesterday" relative to "tomorrow" trials ($\beta = -1.43$, $p = 0.01$), but this difference was not found among 3- and 5-year-olds. Moreover, no such differences were found among the English no-tense and Hindi groups at any age, indicating developmental differences in their comprehension of these words relative to the English no-tense and Hindi groups (see Supporting Information for the results of all pairwise comparisons). These results are consistent with the idea that English-speaking children used past tense marking during the task to facilitate comprehension of "yesterday," but that they did not show similar benefits for "tomorrow."

To understand when in development children begin to comprehend words for yesterday and tomorrow, we next used post hoc one-sample *t*-tests to compare their performance for each item against chance (set at 33%, since there were three possible options from which to choose). Among Hindi learners, whereas 3-year-olds' performance on the task did not differ from chance, 4-year-olds understood references to both yesterday ($t(62) = 4.98$, $p < 0.001$) and tomorrow ($t = 3.83$, $p < 0.001$). In the English tense group, 4-year-olds understood "yesterday" ($t(32) = 2.44$, $p = 0.02$), but not "tomorrow" ($t(32) = -1.15$, *n.s.*) at above chance levels. In

(1) "This is my friend Joey. Joey likes to play with a different toy everyday"

(2) "One morning, he wakes up…"

(3) "…and plays with *this* toy all day"

(4) "Then he goes to sleep at night"

(5) "The next morning, he wakes up…"

(6) "…and plays with *this* toy all day"

Test: "Show me the toy *for tomorrow* (no tense) / *he will play with tomorrow* (tense)"

FIGURE 1 | Example of a story used in the One-Day Hypothetical Events Task. Events were presented sequentially from (1) to (6).

TABLE 1 | Models predicting children's accuracy on the Two-Day Real Events task.

Model	Coefficient estimates(β)				Summary statistics	
	Age (months)	English no-tense	English tense	Yesterday	AIC	Log-lik
Age (months)	0.46**				832.2	−413.1
Base model: Age (months) + Language Group	0.59***	−1.11**	−1.03**		826.0	−408.0
Age (months) + Language Group + Item	0.59***	−1.12**	−1.03**	0.24	826.3	−407.1

Note: Reference groups were as follows—Language Group = Hindi; Item = Tomorrow.
Significance codes: ***$p < 0.001$, **$p < 0.01$, and *$p < 0.05$.

TABLE 2 | One-sample *t*-tests comparing children's accuracy on the Two-Day Task to chance.

		Hindi				English no-tense				English tense			
		t	*df*	*p*	Sig	*t*	*df*	*p*	Sig	*t*	*df*	*p*	Sig
Yesterday	3 years	1.00	38	0.32		−0.73	8	0.48		−2.16	14	0.04	*
	4 years	4.98	62	<0.001	***	0.37	38	0.71		2.44	32	0.02	*
	5 years	3.65	44	<0.001	***	2.79	41	0.007	**	3.84	47	<0.001	***
Tomorrow	3 years	0.69	38	0.49		0.02	8	0.98		0.02	14	0.97	
	4 years	3.84	62	<0.001	***	−1.45	38	0.15		−1.15	32	0.25	
	5 years	6.05	44	<0.001	***	3.46	41	0.001	**	2.04	47	0.04	*

Significance codes: ***$p < 0.001$, **$p < 0.01$, and *$p < 0.05$.

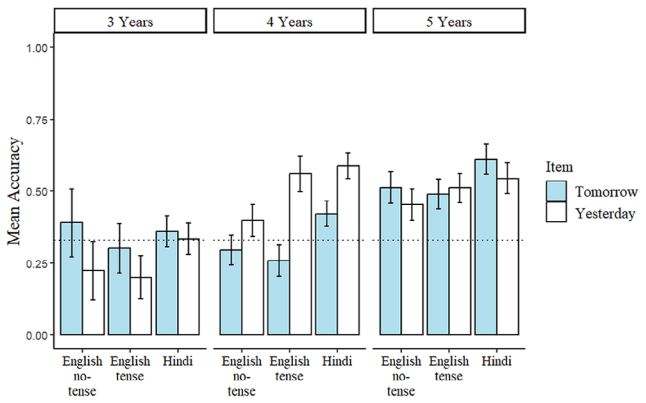

FIGURE 2 | Children's item-based performance on the Two-Day Real Events Task across English tense, English no-tense, and Hindi groups. The dotted line represents chance accuracy. All data visualizations were created using the ggplot2 R package (Wickham 2016).

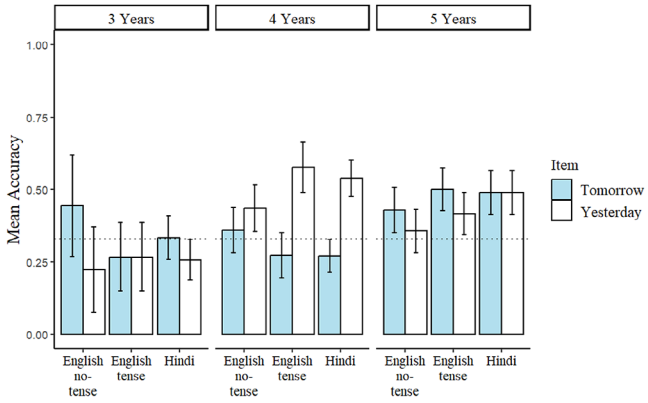

FIGURE 3 | Children's item-based performance on the One-Day Hypothetical Events Task across three language groups: English tense, English no-tense, and Hindi. The dotted line represents chance accuracy.

contrast, in the English no-tense group 4-year-olds' performance was not significantly different from chance on either "yesterday" ($t(38) = 0.37$, *n.s.*) or "tomorrow" ($t(38) = -1.45$, *n.s.*), though they succeeded by age 5. These data suggest that, sometime after age 4, both Hindi and English-speaking children begin to use tense to interpret deictic time words, and that in absence of tense information, English-speaking children perform at chance at this same age, indicating an inability to use other types of information, like event mapping. For the full set of *t*-tests, see Table 2.

3.2 | One-Day Hypothetical Events Task

We next assessed children's use of deictic time words to reason about hypothetical, non-autobiographical events in the One-Day Hypothetical Events task (see Figure 3). We followed the same approach as the Two-Day task, and constructed a base generalized linear mixed model with age (months) and language group (English no tense/English tense/Hindi) as fixed factors, and participant as a random factor, with Accuracy (1/0) on One-Day Hypothetical Events as the dependent variable. Relative

TABLE 3 | Models predicting children's accuracy on the One-Day Hypothetical Events Task.

Model	Coefficient estimates (β)				Summary statistics	
	Age (months)	English no-tense	English tense	Yesterday	AIC	Log-lik
Age (months)	0.24**				891.5	−442.7
Base model: Age (months) + Language Group	0.26**	−0.18	−0.07		894.8	−442.4
Age (months) + Language Group + Item	0.26**	−0.18	−0.07	0.23	894.6	−441.3

Note: Reference groups were as follows—Language Group = Hindi; Item = Tomorrow.
Significance codes: ***$p < 0.001$, **$p < 0.01$, and *$p < 0.05$.

TABLE 4 | One-sample *t*-tests comparing children's accuracy on the One-Day Hypothetical Events task against chance.

		Hindi				English no-tense				English tense			
		t	*df*	*p*	Sig	*t*	*df*	*p*	Sig	*t*	*df*	*p*	Sig
Yesterday	3 years	−1.03	38	0.30		−0.73	8	0.48		−0.53	14	0.60	
	4 years	3.31	62	0.001	***	1.31	38	0.19		2.81	32	0.008	*
	5 years	2.10	44	0.04	*	0.36	41	0.71		1.20	47	0.23	
Tomorrow	3 years	0.04	38	0.96		0.65	8	0.53		−0.53	14	0.60	
	4 years	−1.06	62	0.29		0.37	38	0.71		−0.72	32	0.47	
	5 years	2.10	44	0.04	*	1.27	41	0.20		2.33	47	0.02	*

Significance codes: ***$p < 0.001$, **$p < 0.01$, and *$p < 0.05$.

to a model with only age as a predictor of accuracy, the base model did not improve model fit ($\chi^2(1) = 0.66$, *n.s.*). This is perhaps because the task was not as sensitive to children's early knowledge, as reported below. Similar to the Two-Day Real Events task, we added a term for Item to the base model, which also did not improve model fit ($\chi^2(1) = 2.15$, *n.s.*), suggesting no overall differences in accuracy on each item (Table 3). Next, we binned children into 3-, 4-, and 5-year-olds to determine when they succeed on the task. A model with age (binned) predicting accuracy revealed that 5-year-olds performed significantly better than 3-year-olds ($\beta = -0.69$, $p = 0.02$), but not 4-year-olds ($\beta = -0.17$, *n.s.*). Also, there was no significant difference between 3- and 4-year-olds' accuracy on the task ($\beta = -0.52$, *n.s.*).

To better understand when children begin to comprehend words for yesterday and tomorrow on the One-Day Hypothetical Events Task, we used post hoc one-sample *t*-tests to compare children's accuracy on each item to chance (set at 33%, since there were three possible options from which to choose). Among Hindi learners, whereas 5-year-olds performed above chance for both yesterday ($t(44) = 2.10$, $p = 0.04$) and tomorrow ($t(44) = 2.10$, $p = 0.04$), 4-year-olds were only above chance for yesterday ($t(62) = 3.31$, $p = 0.001$). Note that this contrasts with the results for the Two-Day Real Events task, where Hindi 4-year-olds were above chance for both yesterday and tomorrow. Notably, whereas 4-year-olds in the English tense group performed better than chance on only yesterday trials ($t(32) = 2.81$, $p = 0.008$), 5-year-olds performed better than chance only for "tomorrow" trials ($t(47) = 2.33$, $p = 0.02$). Meanwhile, in the English no-tense group, children did not differ from chance in any age group. The results of all other *t*-tests are reported in Table 4. In summary, in contrast to the Two-Day Real Events task, which found some success among both Hindi and English 4-year-olds, the results of the One-Day task suggest that children struggle to understand the use of deictic time words in reference to hypothetical events even at age 5. These data therefore suggest that the One-Day Hypothetical Events task may not be as sensitive to children's early knowledge of deictic time words. We explore this question next.

3.3 | Comparisons Between Tasks

In a final set of analyses, we compared children's performance across the One-Day Hypothetical Events and Two-Day Real Events tasks (see Figure 4). We first constructed a base generalized linear mixed models predicting children's accuracy on the Two-Day Real events tasks with the following formula: Accuracy ~ Age (months) + Task (Two-Day/One-Day) + Language Group (English no-tense/English tense/Hindi) + (1|PID). Relative to a simpler model with no fixed term for Task, this base model significantly improved model fit ($\chi^2(1) = 12.78$, $p < 0.001$), suggesting that children's performance differed across tasks. Moreover, a model accounting for a Task × Language significantly improved model fit relative to the base model ($\chi^2(2) = 7.25$, $p = 0.02$), suggesting that children's performance on the two tasks differed between language groups. However, a 3-way Age (months) × Task

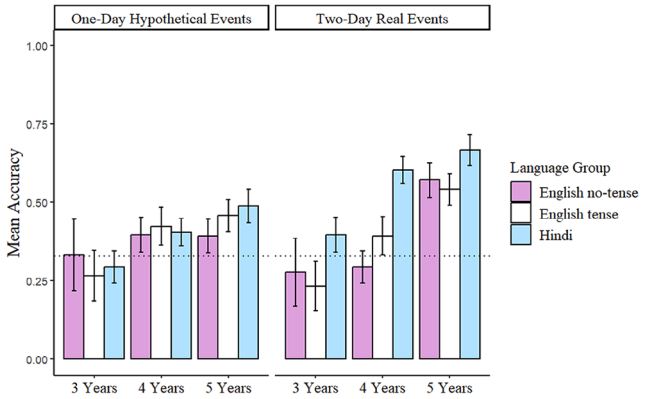

FIGURE 4 | Children's overall performance on the One-Day Hypothetical Events task (left) and the Two-Day Real Events Task across Age and Language Groups. The dotted line represents chance accuracy.

× Language did not significantly improve model fit ($\chi^2(5) = 8.44$, *n.s.*). *Post hoc* pairwise comparisons examining overall differences in task performance within each Language Group showed that Hindi learners performed better on the Two-Day task relative to the One-Day task ($\beta = -0.79$, $p = < 0.001$), though no such differences were found in the English tense ($\beta = -0.12$, *n.s.*) and no-tense ($\beta = -0.15$, *n.s.*) groups (Table 5).

To build on these findings, we constructed exploratory models to see how age, language group and task interact by binning children into 3-, 4-, and 5-year-olds. Relative to a simpler model with 2-way interaction terms [Accuracy ~ Age + Language Group + Task + Age * Language Group + Age * Task + Task * Language Group + (1|PID)], a 3-way Age * Task * Language Group predicting children's accuracy, did not improve model fit ($\chi^2(4) = 4.88$, *n.s.*). We conducted *post hoc* pairwise comparisons to explore Age * Task interactions within each Language Group, and found that 5-year-old Hindi learners performed significantly worse on One-Day task relative to the Two-Day task ($\beta = -1.19$, $p < 0.0001$). However, there was no significant difference in children's performance on these tasks among 3- and 4-year-olds. Also, we found no task-based comparisons among English learners in any age group (see Supporting Information for a full list of pairwise comparisons). Altogether, these data suggest that the Two-Day Real Events task may be more sensitive to children's early emerging knowledge of temporal terms relative to the One-Day Hypothetical Events task.

4 | Discussion

We examined how 3- to 5-year-old children learn the deictic status of time words like "yesterday" and "tomorrow" by testing Hindi and English learners in India. Children were tested on their knowledge of time words on actual autobiographical events, as well as hypothetical events. When children were tested on autobiographical events (i.e., on the Two-Day Real Events task), we found that their performance improved with age across groups, but that Hindi learners exhibited an earlier comprehension of "yesterday" and "tomorrow" relative to their English counterparts. This was despite the fact that Hindi children used only one word to refer to both yesterday and tomorrow, suggesting that children can use tense information alone to differentiate these words. Data from this task also found that English-speaking children understood "yesterday" but not "tomorrow" at age 4 when provided overt tense cues, but that they were at chance for both when they were not provided syntactic cues, also consistent with the use of syntactic cues, and an early failure to use event mapping. By contrast we found no differences between the different language groups when the events in question were hypothetical (i.e., on the One-Day Hypothetical Events Task), and children performed worse on this task.

TABLE 5 | Models predicting children's overall accuracy across tasks and language groups.

Models	Age + Language Group	*Base model*: Age + Language Group + Task	Age + Language Group * Task	Age * Language Group * Task
Age (months)	0.39***	0.39***	0.39***	0.50**
English no-tense	−0.56*	−0.57*	−0.25	−0.18
English tense	−0.46*	−0.46*	−0.13	−0.13
Two-Day Task		0.42***	0.79***	0.77***
Age: Two-Day Task				−0.06
Age: English no-tense				−0.53
Age: English tense				−0.19
Two-Day: English no-tense			−0.63*	−0.74*
Two-Day: English tense			−0.66*	−0.73*
Age: Two-Day: English no-tense				0.60 *
Age: Two-Day: English tense				0.34
AIC	1744.6	1733.8	1730.5	1732.1
Log-likelihood	−867.29	−860.9	−857.27	−853.05

Note: Reference groups were: Language Group = Hindi; Item = Tomorrow; Task = One-Day Hypothetical Events. Age is continuous (months).
Significance codes: ***$p < 0.001$, **$p < 0.01$, and *$p < 0.05$.

These results have potentially important consequences for understanding the sources of information that children use to acquire abstract words like "yesterday" and "tomorrow." Previous studies have proposed two sources of information that children might use to acquire such words. According to the event mapping hypothesis, children might learn the meanings of time words by mapping them onto different events in their lives, such as through memory for past events (e.g., Friedman 2000, 2003) or conversations about future events (e.g., Hudson 2002, 2006; Zhang and Hudson 2018). In contrast, on a syntactic account, children might begin the acquisition of these words by leveraging the linguistic context (e.g., tense markings) in which they are embedded (e.g., Gillete et al. 1999; Gleitman 1990; Harner, 1976; Harner, 1980; Landau et al., 2009; Tillman et al. 2017; Williams et al. 2021).

We reasoned that if children learn the deictic status of words like "yesterday" and "tomorrow" solely by mapping them to events, then we should expect a delayed developmental trajectory for acquiring word meanings in the Hindi group, relative to the two English groups. In Hindi, because the same word "kal," is used for both yesterday and tomorrow, event mapping would predict the creation of conflicting associations between the word in both past and future events, potentially causing confusion in the child learner. Consequently, an event mapping view would predict that children in the English groups should acquire these words earlier than children learning Hindi. By contrast, if children rely more on syntactic cues like tense marking than on event mapping to learn deictic status, then Hindi learners should perform as well or possibly even better than English learners, since for "kal," these cues are necessary to disambiguate between reference to past and future events. Also, English children in the tense group might perform better than children in the no-tense group. Compatible with the latter hypothesis, we found that children in the Hindi group succeeded on the Two-Day Real Events task earlier than children in both English-speaking groups, and also that children in the English-tense group performed better than children in the no-tense group, and in particular for "yesterday," for which over morpho-syntactic tense cues are available.

Data from our study also revealed interesting differences in children's performance between the Two-Day Real Events, and One-Day Hypothetical Events tasks. Across tasks, both 4- and 5-year-olds performed better than 3-year-olds. While no clear differences in children's performance on the two tasks emerged within the English groups, Hindi learners performed better on the Two-Day Real Events relative to the One-Day Hypothetical Events task. It is important to note, however, that we do not see any significant interactions between age, task, and language group in our direct comparisons of these tasks, suggesting that the developmental trajectory underlying children's performance on these tasks may be more complicated. In general, comparisons to chance suggest that children begin to comprehend the meanings of these deictic time words sometime between 3 and 4 years of age, but continue to struggle when reasoning about hypothetical events at age 5.

Children's failures on the Hypothetical Events task in our study are compatible with findings of previous studies that require children to reason about hypothetical scenarios, which find later-learning of deictic time words, and reasoning about the past and future (e.g., Busby-Grant et al. 2009; McColgan and McCormack 2008; McCormack and Hanley 2011; Zhang and Hudson 2018). Moreover, this result is compatible with a separate study that we conducted in the United States, in which children as young as 3 succeeded on the Two-Day Real Events task but struggled on the One-Day Hypothetical Events Task (Maheshwari & Barner, *under review*). This result is potentially important, because many previous studies that test time concepts rely on tasks that describe hypothetical events on imaginary timelines, rather than events that actually occurred yesterday, last week, and so forth (e.g., Busby-Grant et al. 2009; Zhang and Hudson 2018). Consequently, it is possible that children's failures on these tasks reflect an inability to reason about hypothetical events as much as they indicate a failure to comprehend temporal concepts or language. In particular, such tasks may rely more on complex cognitive processes like conditional inference (e.g., Markovits et al. 2016), counterfactual reasoning (e.g., McCormack et al. 2018; Rafetseder et al. 2013), reasoning about possibilities (e.g., Turan-Küçük and Kibbe 2024; Leahy 2023), or executive function and metarepresentation (Hoerl and McCormack 2019; Redshaw 2014).

Although we find early comprehension of "kal" in Hindi-speaking children—compatible with the use of syntactic cues—could English-speaking children have also relied on event mapping? Two results suggest that, if they did, the impact of event mapping was not substantial. First, under such a scenario, we might expect that English-speaking children would outperform Hindi-speaking children, by drawing on two compatible sources of information—event mapping and syntax—rather than tense alone. Because we did not find such an advantage, our data suggest that if event mapping was used by English-speaking children, it played only a weak role. Second, we found that when English-speaking children lacked access to overt tense information, as in the no tense condition, 4-year-olds performed at chance for both "yesterday" and "tomorrow," suggesting they were unable to use event mapping (whereas children in the tense group performed better than chance for "yesterday"). Note that while English-speaking 5-year-olds began to show comprehension of both "yesterday" and "tomorrow" in the no-tense group, even this result is ambiguous, since it could reflect either event mapping or past experience hearing these words used in different morphosyntactic frames.

Amidst these findings that tense plays a more important role than event mapping in early learning—and in particular for learning deictic information—it is important to note that event mapping likely plays a significant role in later development. While grammatical tense communicates whether events occurred in the past or future, it cannot alone communicate, for example, that "yesterday" refers to the day before it is uttered, but not earlier, or that the German word "vorgestern" refers to the day before yesterday (see Williams et al. 2021). Previous studies—and in particular anecdotal reports from adults—suggest that this is a problem that many children struggle with, and that they often use "yesterday" to refer to events in the distant past (Ames 1946; Busby and Suddendorf 2005; Friedman 1990; Harner 1981, 1982; Nelson 1998; Tillman et al. 2017; Weist 1989). Given this, it's likely that children must use some form of event mapping to associate words like "yesterday" and "tomorrow" with distances of one day from the time of utterance. That said, it's also possible that this knowledge depends on other forms of learning, rather

than event mapping. For example, children might acquire a kind of "theory" in which they learn what constitutes a "day," how days are organized in recurring sequences, and perhaps even how they are individuated and ordered in artifacts like calendars. Exactly which sources of information children use to solve this problem, and the form that this knowledge initially takes, is currently not well understood. In sum, these results leave open how children use event mapping to learn remoteness information later in development, while providing strong evidence from both Hindi and English that syntactic cues play an important role in learning the deictic status of time words. Syntax may be especially important when other cues are not as readily available to the child learner, for example, when the events are hypothetical and not associated with memory traces (e.g., Friedman 2003; Hudson 2002; Hudson and Mayhew 2011), or when the same lexical item refers to both past and future events, as in Hindi.

Because the data reported in this study were collected in India, it remains possible that the developmental trajectory we report here is unique to this context. For instance, although details of her study are hard to glean, it appears that children in Harner's (1975) study understood "yesterday" and "tomorrow" earlier than English speakers in this study. This could be due to myriad factors, including differences in socioeconomic status, formal training, and parent interactions, which might in turn be related to differences in vocabulary learning, training with formal temporal symbols (e.g., clocks and calendars), and amount of exposure to English in children's day-to-day interactions and environment (given the multilingual nature of life in urban India). While it is unclear how Indian children compare to children in other cultures, our within-culture approach to comparing English and Hindi learners allows a relatively powerful assessment of the role that linguistic cues play in learning, since many of the cultural differences that exist between cultures like India and the United States are reduced or eliminated in our design.

In summary, we found evidence that Hindi learners acquired partial meanings of the deictic time words "yesterday" and "tomorrow" earlier, when asked about autobiographical events, relative to English learners in India, in support of the hypothesis that children rely chiefly on syntactic cues in language to infer the deictic status of time words like "yesterday" and "tomorrow." We also found evidence in favor of the hypothesis that tasks designed to test children's autobiographical experience of time might be a more sensitive measure of children's knowledge of specific time words. By testing children on two consecutive days, and across two languages in a non-Western culture, this project also highlights and addresses some limitations in the current literature. Future research on children's temporal cognition should devise new tasks and methods for testing children's conceptual knowledge of the past and future.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

De-identified data and materials are hosted on the Open Science Framework.

Endnotes

[1] Caregivers included individuals other than the target child and other children (e.g., mother, father, grandparents, teachers, and investigators). Note that when tense morpho-syntax could be used–as in the case of "yesterday"—caregivers did so most of the time (87.23% of the time). Meanwhile, children began using yesterday in tensed expressions at 52 months of age on average.

[2] We preregistered a sample of ninety 3- and 4-year-olds for this study. Due to limited access to 3-year-olds, we decided to include 5-year-olds in our sample. In addition to meeting our target *N* (30 per language group), adding 5-year-olds to the sample afforded a better understanding of the developmental trajectory underlying the acquisition of these deictic time words.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.