

Learning the language of time: Children's acquisition of duration words

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Abstract

Before children acquire the precise definitions of time words, like *minute* and *hour*, how do they interpret them? And how are such proto-meanings acquired in development? Here we present three experiments, and assess children's early understanding of seven time words: *second*, *minute*, *hour*, *day*, *week*, *month*, and *year*. Our findings indicate that children first learn time words as a lexical class, then learn their ordinal relations, but initially have little to no knowledge of their relative durations. This understanding emerges late in development – many years after children first start using time words in speech – and in many children does not emerge until they have acquired formal definitions for the words.

Keywords: abstract word learning; time perception; language acquisition; number-line estimation

Introduction

Understanding the nature of time is a hard problem, not only for physicists and philosophers who debate its status in the universe, but especially for young children who are exposed to artifacts and linguistic representations of time from early in life. We rely on clocks, calendars, and words like *second*, *minute*, and *hour* to measure and keep track of time, and to coordinate our activities with others. Interestingly, although children begin using time words relatively early in life – by as young as 2- and 3-years of age, most do not receive formal instruction regarding the meanings of these words until much later, when they enter school. This raises the question of how children interpret these words prior to formal instruction, and how these words are initially related to their subjective experience of time, and the relative durations of events. In the present study, we explored this question, and asked what types of information children use to make sense of early time words, and thus how they begin to acquire their meanings in early development.

Duration words like *time*, *day*, and *year*, are among the most frequent nouns in English (Kucera and Francis, 1967). In addition to duration words, which we focus on in the present study, time is also conveyed through verb tense, through temporal adverbs such as *yesterday* and *tomorrow*, through spatiotemporal metaphor (e.g., “a long meeting”), and through the sequential structure of narrative itself. The rich and varied ways in which language encodes the dimension of time make it possible to reason and communicate about events that are not currently happening.

Despite this abundance of temporal language, acquiring the meanings of time words presents a considerable challenge to the early language learner. Time can neither be

seen nor heard. Unlike concrete nouns referring to whole objects that can be easily pointed out, and even more challenging abstract terms like color words (referring to properties of objects) and number words (referring to sets of objects), there is no static perceptual stimulus to which a duration word like *minute* refers. Word-learning principles such as “fast mapping” and mutual exclusivity, which describe useful strategies for learning the names of new objects or object properties in the context of familiar ones, do not easily apply. Rarely in everyday life (in the absence of clocks and timers) are there explicit perceptual markers denoting when events or specified temporal periods start and end, further complicating the task of figuring out the proper referents for time words.

Children are not typically taught the formal definitions of duration words (e.g., one minute equals sixty seconds) until they reach school age, but they begin hearing and even producing these words much earlier, albeit with very low accuracy. In child-directed speech, mothers of preschoolers use time words less often, but in a wider variety of contexts, than color and number words (Tare et al., 2008). While over 80% of children produce duration terms, including *minute(s)* and *hour(s)*, by age 5, only 22% of 5-year-olds reportedly use *hour(s)* appropriately (Grant and Suddendorf, 2011). Here we are interested in whether, during these years of inaccurate production, before learning the adult definitions (e.g., that an hour is 60 minutes), children acquire naive meanings based on other information, and, if so, what information they use to do so.

There are two broad sources of information children could use in forming intuitive definitions of duration words. One source is their capacity to perceive and represent the durations of experienced events, and the other is their linguistic input. Children's ability to use and combine information from these two sources leads to three possible hypotheses characterizing the extent of their early learning, each increasingly sophisticated.

By the first account, which we call the Nominal hypothesis, children rely upon linguistic input to construct a lexical category for time words, thus understanding only that *hour* and *minute* belong within a common class of words. Consistent with this, Shatz and colleagues (2010) observed that, when asked “how long” or “how much time” an event takes, a much higher proportion of preschool-aged children are able to respond appropriately (using a quantity word and a duration word) than are able to respond accurately (Shatz et al., 2010). Children apparently understand what kinds of words can answer a question

about time before they can map those words onto specific durations.

Second, children might learn the ordinal relations among time words. This requires an additional inference: duration words vary along a common scale. Linguistic input could also be used to support this level of understanding. For instance, if a child hears an adult utterance such as, “We’re leaving for the zoo in an hour, so you only have ten minutes to finish eating lunch,” without knowing the precise definitions of either duration word, he could still use the linguistic context to conclude that an hour must be longer than a minute, if he understands that both those words denote amounts of time. By the Ordinal hypothesis, beyond simply learning that time words share a nominal class, children also learn the ordinal relationships among their list of known time words, e.g., year > month > week > day > hour > minute > second.

Third, children might learn the approximate ratios between the durations encoded by time words. How could this most knowledge be acquired before explicit instruction on time words? The Ratio hypothesis relies on duration perception, as understanding of relative temporal magnitudes requires that duration words be associated with nonverbal representations of duration. By the Ordinal account, above, a child will know only that a minute is ‘bigger’ than a second, but by the Ratio account, he would also know approximately how much bigger than a second a minute is (a ratio of 60:1).

We experience duration, thus children might be able to map this dimension onto language. Experimental work has shown that even nonverbal animals use temporal information to guide behaviors such as seeking food or avoiding shocks that come at predictable intervals. The human mind must have means of representing elapsed time, and many cognitive models have been proposed describing the operation of mental clocks and pacemakers. By four months, babies habituate to the temporal pattern of a flashing visual stimulus, and react when a flash is omitted at a prescribed time, revealing a very early sensitivity to elapsed duration (Columbo & Richman, 2002). Basic psychophysical tasks have also measured the precision with which adults and children can estimate and compare the durations of auditory and visual stimuli, usually on the order of milliseconds or seconds. Although temporal sensitivity does not reach adult levels until around age 8, even the youngest children tested are able to discriminate stimuli on the basis of duration (Droit-Volet et al., 2004).

If the duration representations are available to children, how would the mapping between duration and language be formed? Perhaps a child hearing adult speech about time may associate unfamiliar duration words with the familiar events they describe or in whose context they are uttered, resulting in associative mappings between duration words and perceived temporal magnitudes. Evidence that children have knowledge of the durations of familiar events that they are not currently experiencing (and which extend beyond a few seconds in temporal extent) comes from a study by

William Friedman (1990). Friedman first taught children that a spatial array of nine boxes, much like a number-line, represented duration, from a very short time (the leftmost box) to a very long time (the rightmost box). He then had children indicate how long familiar events, such as drinking a glass of milk or watching a cartoon show, took, by placing a cube in the appropriate box. Four-year-old children correctly ranked-ordered the activities by duration, and by 5 years their mean placements on the 9-point scale were well-correlated with adult-estimated durations of the activities. Friedman’s tasks did not utilize any conventional duration terms such as *minute* or *hour*. Our Experiment 3 asks whether children are able to use a number-line paradigm to estimate the durations represented by conventional time terms as well as by familiar events.

Few prior studies of language acquisition have assessed children’s early comprehension of time words. Such studies probe what children know about time words before they can produce them accurately, for instance by requiring a forced choice. In Shatz et al. (2010)’s Study 2, children were introduced to a puppet “from far away” who “didn’t know very much,” and were asked show him which of two pictures represented an activity taking a specific amount of time, such as 10 minutes. Five-year-olds performed above chance overall, and 6-year-olds were near 70% correct. This study suggests that 5-year-olds have a rudimentary understanding of the meanings of duration words and how they relate to familiar activities. However, the results are difficult to interpret because each prompt combined duration words, number words, and events. Children could succeed (or fail) at the task based on their level of understanding in any of these three areas. Though Shatz et al. interpreted their results as favoring a lexical domain hypothesis, they do not rule out the possibility that children may rely on quantitative representations of duration as well.

Here we present three experiments designed to assess whether children understand time words at the Nominal, Ordinal, or Ratio level. Experiment 1 uses a forced-choice procedure to ask whether children can make time quantity comparisons on the basis of duration words alone (Nominal hypothesis predicts failure, Ordinal and Ratio hypotheses predict success). Experiment 2 introduces number words into the forced-choice, asking whether children can combine their knowledge of time words with their understanding of number (only Ratio hypothesis predicts success on critical trials). Experiment 3 uses number-line estimation to assess children’s ability to map time words and events onto a spatial scale representing duration, providing data that can be analyzed both by ordinality (testing the Ordinal hypothesis) and by relative distance (testing the Ratio hypothesis). Finally, we assess children’s explicit knowledge of the formal definitions of duration words, and use this as a predictor of their number-line estimation performance.

Materials and Methods

Participants

For Experiment 1, we recruited 89 children from the San Diego area, including 25 3-year-olds, 26 4-year-olds, 20 5-

year-olds, and 18 6-year olds. For Experiment 2, 85 children participated, including 25 4-year-olds, 22 5-year-olds, 22 6-year-olds, and 16 7-year-olds. Fifty-two children participated in Experiment 3, including 22 5-year-olds, 17 6-year-olds, and 13 7-year-olds. 36 young adults (Mean age = 20.6 years) also participated in Experiment 3. An additional 16 children also participated but were excluded from analysis due to failure to complete the task (8), failure to comprehend the task (4), being outside the age range of interest (3), and experimenter error (1).

Procedure, Experiments 1 and 2: Forced-choice

Two action figures, Farmer Brown and Captain Blue, were placed on a table in front of the child. On each trial, the experimenter read a short scenario such as, “Farmer Brown [jumped] for [a minute]. Captain Blue [jumped] for [an hour].” This was followed by a two-alternative forced choice, “Who [jumped] more, [Farmer Brown or Captain Blue]?” If the child was reluctant to give a verbal response, she was encouraged to point to the character that did the action more. Procedures for Experiment 2 were identical to those of Experiment 1, but the time words were modified by number words. For example, “Farmer Brown [jumped] for [two] [minutes]. Captain Blue [jumped] for [three] [hours].” Each child completed a total of 26 trials in the Experiment 1, or 30 trials in Experiment 2.

Trials and coding, Experiment 1. Children completed two blocks of thirteen duration comparisons involving seven time words: *second*, *minute*, *hour*, *day*, *week*, *month*, and *year*. The comparisons tested were: week vs. month, day vs. week, month vs. year, hour vs. day, day vs. month, week vs. year, minute vs. hour, second vs. minute, hour vs. week, day vs. year, minute vs. day, second vs. hour, and second vs. day. Six action verbs, all of which were high-frequency words denoting activities that could be done for variable lengths of time, were used: *jumped*, *slept*, *cried*, *played*, *danced*, and *talked*. Within each block, trials were conducted in quasi-random order. Verbs were randomly assigned to duration comparisons, with the stipulation that the same verb was never used in two consecutive trials. Trials were counterbalanced with respect to whether the larger duration word came first, which character represented the correct answer, and which character was prompted first. Half the participants received one item-order, and the other half received the reverse order. For analysis, the child’s response on each trial was coded as correct (1) or incorrect(0). These numbers were then converted into proportions correct.

Trials and coding, Experiment 2. Trials in Experiment 2 included the same six verbs from Experiment 1. However, only five time-word comparisons were used in Experiment 2: minute vs. hour, week vs. year, day vs. year, day vs. week, and second vs. hour. For each of those five time-word pairs, 7 different types of number-word comparisons were made (Table 1). One trial included no numbers (identical to Experiment 1), 3 included “small” numbers (2 and/or 3), and 3 three included “big” numbers (6 and/or 9). Each comparison was designated Same, Congruent, or

Incongruent, depending on whether the larger number word was paired with the larger time word (see Table 1). All 30 trials were conducted in quasi-random order. Half the participants received one item-order while the other half received the reverse order.

Table 1: Experiment 2 trial types

Number comparison	Number size	Example
No numbers	None	a minute vs an hour
Same	Small	2 minutes vs 2 hours
	Big	6 minutes vs 6 hours
Congruent	Small	2 minutes vs 3 hours
	Big	6 minutes vs 9 hours
Incongruent	Small	3 minutes vs 2 hours
	Big	9 minutes vs 6 hours

Procedures, Experiment 3: Number-line estimation

Participants were given a sheet of 8.5’x11’ paper with four horizontal, 17-cm lines printed in a vertical column down the center of the page. Each line had circles on both endpoints and no other markings. Children were told that the top line was a number-line going from 0 to 100. “Each number has its own place on the line,” said the experimenter. “You’re going to show me where certain numbers go on the number-line. Look, 0 goes here [experimenter draws vertical mark at left endpoint] and 100 goes here [experimenter marks right endpoint].” For each of four number stimuli (see Table 2), the experimenter instructed the child, “The [first] number is [4]. Can you show me where [4] goes? Can you draw a line with the [blue] pencil?” The first line was intended to give a baseline measure of children’s ability to perform an estimation task using a number-line. For each of the next three tasks, the line represented duration rather than numerical quantity. This was explained to the participants as follows: “Now, this line is different. It shows how much time things take to do. It goes from a very short amount of time to a very long amount of time. Each amount of time has its own place on the line, and the further you go over here [gesturing along the line], the more time something takes. You’re going to show me how long certain things take to do on the line. Something very short, like blinking your eyes, goes here [experimenter marks left endpoint]. Something very long, like the time from waking up in the morning to going to bed at night, goes here [experimenter marks right endpoint]. For each stimulus (see Table 2), the child was instructed to think about how long the activity takes to do and to mark the line accordingly. Participants were reminded that each subsequent line represented duration and what the endpoints represented (blinking eyes, morning to night) in between the remaining tasks and if confused.

Trials and coding, Experiment 3.

Stimuli for Experiment 3 are shown in Table 2. Each participant estimated number on the first line, familiar event durations on the second, conventional time word durations

on the third, and combinations of time words and number on the fourth. Within each line, half the participants received the four stimuli in the order shown in Table 2, while the other half received the reverse order. As in Experiments 1 and 2, participants were presented with time word stimuli (lines 3 and 4) in the context of events that could take variable amounts of time, e.g. “[jumping] for a minute.”

Table 2: Experiment 3 Number-line stimuli

Number	Event	Time word	Num + time
4	Watching movie	Hour	2 hours
45	Washing hands	Second	6 hours
18	Trip to zoo	Minute	9 min
61	Eating lunch	Day	3 min

Explicit knowledge. Following completion of the four number-line tasks, the participant was asked 3 follow-up questions: how minutes are in an hour, how many hours are in a day, and how many seconds are in a minute. Responses were coded as either correct (1) or incorrect (0), and were converted to proportions correct.

Estimation. To analyze the number-line data, we measured the distance (in cm, to the nearest tenth) from the left endpoint of the line to the intersection of the number-line with each of the participant’s pencil marks. Marks falling exactly on the left endpoint were recorded as 0.1 cm (to avoid divide-by-zero errors) and those falling exactly on the right were recorded as 17.0 cm. To assess knowledge of relative durations, we computed ratios between each pair stimuli (e.g., min/sec, hour/sec, hour/min, day/sec, day/min, day/hour). Children’s estimation performance was assessed by comparing their distances and ratios with corresponding means from the adult participant group. We focus on the results from the time word numberline task, which most directly bear on the Ordinal and Ratio hypotheses.

Ordinality. Responses to each trial were also coded for ordinality. To do this, each of the four stimuli for each line was rank-ordered by increasing magnitude or duration. In the case of line 2, the correct (adult-estimated) rank order was: 1. washing your hands, 2. eating lunch, 3. watching a movie, 4. going on a trip to the zoo. The participant’s marks were also ranked by increasing distance from zero. For each estimated item which fell in the correct rank, the participant was awarded a 1, for each incorrectly ranked item, the participant was given a 0, which were converted into proportions correct for each child and each age group.

Results and Discussion

We began with three alternative hypotheses for how to characterize children’s early knowledge of duration words prior to learning their definitions. The Nominal hypothesis is that children simply understand that durations words belong to a common lexical category, the Ordinal hypothesis is that children have knowledge of the ordinal relations among the words within this category, and the Ratio hypothesis is that children have knowledge both of the

ordinal relations and of the relative lengths of the durations to which the words refer. Of these three possibilities, only the Ratio hypothesis requires that children form associations between duration words and nonverbal representations of duration.

Experiment 1

The primary goal of Experiment 1 was to distinguish between Nominal and Ordinal/Ratio understanding of time words, by asking whether children are able to compare two lengths of time strictly on the basis of the conventional duration terms used to describe them. In order to succeed at this two-alternative forced choice task, children must possess some understanding of the ordinal relations among the various time words. Unlike in prior forced-choice studies of time word comprehension (Shatz et al., 2010), here participants could not rely on their knowledge of number or of familiar events in order to succeed. Measuring overall accuracy in Experiment 1, we found that while our youngest group of participants, the 3-year-olds, did not perform better than 50% accuracy, as predicted by chance ($M \pm SEM = 0.48 \pm 0.02$ $p = 0.2$, n.s.), the 4-, 5-, and 6-year-old groups all performed significantly better than chance ($M \pm SEM$, respectively, $= 0.57 \pm 0.02$; 0.67 ± 0.04 ; 0.81 ± 0.03 , all p ’s < 0.005). Furthermore, each age group performed significantly better than each younger group (all p ’s < 0.05). While the question of whether 3-year-olds have nominal understanding of some or all of the terms is left open, these data reject the possibility that children 4 years and older know only that time words belong to a common category. It is also noteworthy that our oldest age group, the 6-year-olds, while performing quite well, were not at ceiling, despite the simplicity of the task and the likelihood that this sample had already received some formal instruction on duration words.

We were also interested in possible comparison effects or time-word effects in the data, as these may provide important clues into the order in which duration words are acquired. We hypothesized that, if these words are truly associated with durations, we might observe patterns such as greater accuracy on comparisons between more distant terms (sec. vs. day $>$ sec. vs. min.), or greater success on comparisons involving shorter, and thus easier-to-represent durations, such as second and minute, than comparisons involving longer terms, such as month and year, which may be harder to represent nonverbally. Though a mixed logistic regression predicting the probability of making the correct choice as a function of the participant’s age and the time-word comparison type did find significant effects of each (Age: $\chi^2(3) = 142.7$, $p < 0.001$, TrialType: $\chi^2(13) = 59.0$, $p < 0.001$), as well as an interaction between them ($\chi^2(36) = 71.2$, $p < 0.001$), there was no evidence indicating that the relative durations encoded by the two words being compared were driving the effect. Furthermore, collapsing the data across all comparisons involving each time word so as to compare overall accuracy for each word revealed no differences in performance ($F(6,595) = 1.2$, $p = 0.3$, n.s.). As accuracy improved from age group to age group, it improved across the board, with equal improvement on each

tested word, as would be expected if these words are being learned as a set, with performance on each word being limited by overall understanding of the ordinal relations among the words in the list, without direct associations between each individual term and duration per se (consistent with the Ordinal, rather than the Ratio hypothesis).

Experiment 2

Experiment 2 assessed children's ability to integrate their knowledge of number with their understanding of time words, pitting the Ordinal and Ratio hypotheses against one another by probing the specificity of children's knowledge of the relative lengths of time referred to by conventional duration terms. In Congruent trials (e.g., 3 hours vs. 2 minutes), the numbers provide an additional cue to the correct answer. Even a child with no idea how long either an hour or a minute is might still choose correctly, based solely on his understanding of 3 vs. 2, thus improving overall performance on Congruent relative to Same/No Number trials. We expect the children with the least precise understanding of time words to show the greatest increase in performance in Congruent relative to Same trials. However, in Incongruent trials (e.g., 2 hours vs. 3 minutes), basing the choice on number alone would lead the child to make the wrong choice. While a qualitative understanding that an hour is more time than a minute is sufficient to succeed in the Same or Congruent trials, only a quantitative understanding will suffice on Incongruent trials. Making the correct choice requires sufficient understanding of the relative durations encoded by time words to realize that their ratio far exceeds that of the number words, 3:2. Knowing the order of the time words alone is insufficient, so the Ordinal hypothesis predicts lower performance on Incongruent trials. Only the Ratio hypothesis, in which time words are mapped onto representations of duration, predicts equal success on Incongruent and Same trials.

Overall accuracy in Experiment 2 was similar to that found in Experiment 1 for those age groups represented in both. All groups performed significantly above chance. Proportions correct ($M \pm SEM$) for the 4-, 5-, 6-, and 7-year-olds groups, respectively, were 0.55 ± 0.02 , 0.71 ± 0.03 , 0.81 ± 0.04 , 0.97 ± 0.02 . The critical comparison between Same, Congruent, and Incongruent trials is shown in Figure 2. Data were collapsed across time-word comparison types and number sizes, as neither was a significant predictor of children's performance in Experiment 2. Performance in the Same number case was not significantly different from that in the No Number case.

While the 4-year-old group was both helped by number word congruency and hindered by incongruency, as predicted by the Ordinal hypothesis, the 7-year-olds were near ceiling on the task in all conditions, with no cost to incongruency or benefit to congruency, as predicted by the Ratio hypothesis. The intermediate age groups show different patterns, with the 5-year-olds showing a cost of incongruency and no benefit to congruency, and the 6-year-

olds showing no cost to incongruency and a benefit to congruency. Strikingly, these results suggest that there are children who know both that 3 is greater than 2 and that an hour greater than a minute, but fail to accurately compare 3 minutes with 2 hours.

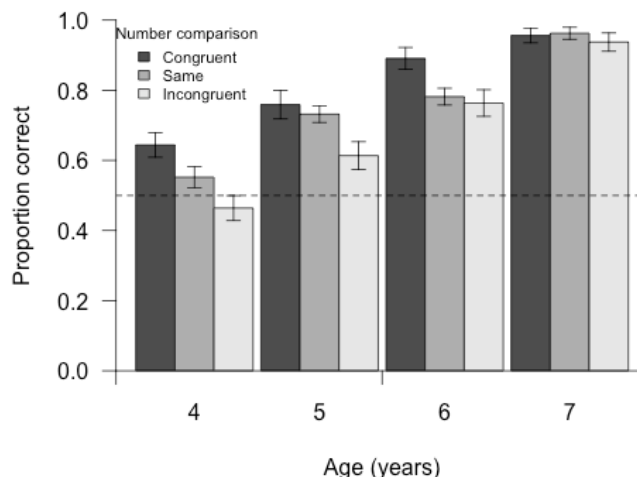


Figure 1: Effect of congruency of time word comparisons and number word comparisons in Experiment 2.

Taken together, the results of Experiments 1 and 2 suggest that children learn duration words as a lexical class, and they begin to learn the ordinal structure of that class by age 4, prior to mapping them onto nonverbal representations of duration. Further, children do not have a full understanding of how these words encode relative duration, consistent with the Ratio hypothesis, until at least the age of 7, after they've encountered time words in school. One possibility is that children do not map these words onto specific durations until they learn their definitions. Another possibility is that younger children do associate these words with durations, perhaps relying on their experience hearing them used in relation to familiar events to make these associations, but these representations are imprecise, not easily combined with number knowledge.

A limitation of the forced-choice methodology employed in the first two experiments is that each trial probed knowledge of two different duration words, conflating the participant's knowledge of them which may have precluded finding differences in the acquisition of individual words. To further probe children's ability to estimate the durations encoded by individual time words, and to obtain a more precise measure of participants' ability to rank-order a set of time words, we used the number-line method in Experiment 3. This also allowed us to compare children's ability to estimate the durations of familiar events and conventional time words, and to ask whether overt knowledge of the definitions of the duration words predicted better duration estimation performance.

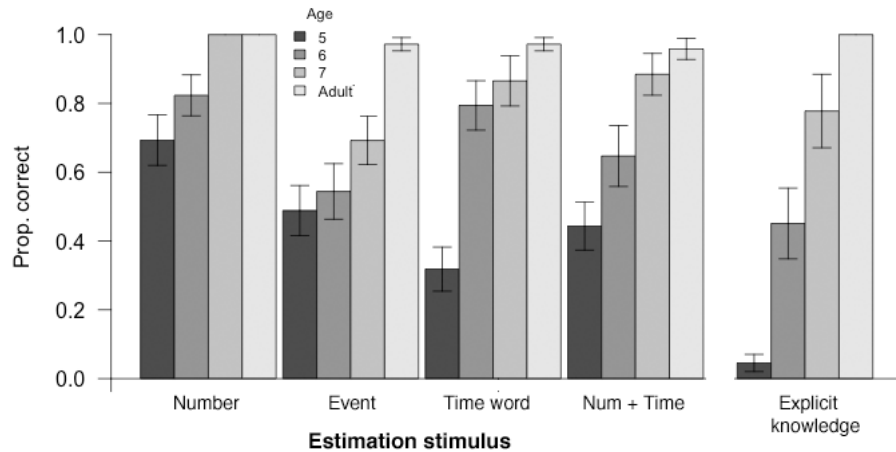


Figure 2: Proportion of ordinal estimates in Experiment 3 and proportion of correct definitions of duration words

Experiment 3

Estimation data were analyzed in terms of their distance from 0 along the line representing elapsed duration. Overall time word estimation performance for the three age groups was assessed by plotting each child participant's estimated duration ratios (see Methods) as a function of adults' mean ratios and fitting the data for each age group with a linear model. The closer the slope of that line approximates 1, the more adult-like the estimation. Slopes for the 5, 6, and 7-year-old groups, respectively, were 0.14, 0.57, and 0.86. These data confirm that children have essentially no quantitative understanding of the relative durations encoded by these words at the age of 5 (despite their above-chance performance in Experiments 1 and 2), but obtain this understanding in the early school years.

Results from the ordinality measure (see Methods) are shown in Figure 2, alongside results from the follow-up questions testing overt knowledge of the duration words definitions. Comparing time word and event estimation, the five-year-olds perform better with familiar events, lending moderate support to the idea that young children extract duration information from familiar activities and use that knowledge to aid them in learning duration words, via associative mappings. By six, however, children are estimating better overall with conventional time words than without. The probability of successfully rank-ordering the 4 time words is correlated with having explicit knowledge of their definitions. Almost no 5-year-olds but most 7-year-olds know these definitions. Sorting the 6-year-old data according to whether each child knows the formal definitions of the words reveals that those who know them perform like 7-year-olds while those who do not perform like 5-year-olds, highlighting the importance of this factor.

An intriguing possibility is that learning duration words not only improves our ability to estimate the lengths of events described in those terms, but also provides a useful cognitive framework for encoding and estimating the durations of perceived events in general. However, by this account we expect explicit knowledge of time words to

improve performance on duration estimation in both the Event and Time word tasks. However, while we find that accuracy on the follow-up questions (e.g., How many seconds are in a minute?), when added to a model including age group, was a significant predictor of children's proportions of ordinal responses in the time word task, it did not account for additional variance in event estimation performance.

In conclusion, the three experiments presented here suggest that, prior to acquiring their adult definitions, children learn the nominal category of time words as well as the ordinal structure of that category. However, we find no evidence that children map these terms onto precise representations of duration until after they learn their formal definitions.

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