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Building the mental timeline: Spatial representations of time in preschoolers

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Abstract

When reasoning about sequences of events, English-speaking adults often invoke a "mental timeline," stretching from left (past) to right (future). Although the direction of the timeline varies across cultures, linear representations of time are argued to be ubiquitous and primitive. On this hypothesis, we might predict that children should spontaneously invoke a timeline when reasoning about time. However, little is known about how the mental timeline develops. Here, we use a sticker placement task to test whether 3- to 6-year-olds spontaneously produce linear, spatial representations of time. We find that, while English-speakers under age five rarely adopt such representations spontaneously, a spatial prime increases the percentage of 4-year-olds producing linear, ordered representations from 36% to 76%, indicating that by this age, children can readily align the domains of space and time. Nevertheless, these representations often do not take on the conventionalized left-to-right orientation until age 5 or 6.

Keywords: time; space; metaphor; word learning; spatial representation

Introduction

What is the role of spatial metaphor in the formation of abstract concepts, like time? Understanding the nature of mental representations for time is one of the most historically challenging problems in western philosophy, and is now a contentious area of debate in modern cognitive psychology (e.g., Bottini & Casasanto, 2013). Most adults display strong a linear, spatial component in their conceptual understanding of time, often referred to as a "mental timeline" (for a review, Bonato et al., 2012). While some have argued that spatial representations of time are universal, the specifics of these associations vary considerably across cultures. This variability indicates that the formation of the mature mental timeline relies at least in part on learning and cultural transmission. However, the extent to which spatial representations of time are malleable – and the precise effects that cultural practices and spatial artifacts play in shaping them – is difficult to pin down in adult populations. For this reason, we sought here to test how children initially use space to represent time, before they have extensive exposure to cultural practices linking space and time in conventionalized ways. To do so, we ask 3- and 6-year-old children to perform a simple spatial task in which they graphically represent the temporal relations among familiar events (meals) and abstract temporal concepts (*yesterday*, *today*, and *tomorrow*).

In adult speakers of languages that are written from left-to-right, there is a strong association between leftward space and earlier or past events and between rightward space and later or future events, which has been taken as evidence for a "representation [of time] that is spatial in nature" (Bonato et al., 2012). However, the direction in which time is thought to "flow" varies across cultures, depending on the ways in which time and space are conveyed in language particular space-time metaphors, and on reading and writing direction (e.g., Bergen & Chan Lau, 2012; Boroditsky & Gaby, 2010). Furthermore, more variability in space-time mappings is seen along individuals who are illiterate or have less exposure to spatial artifacts for time (Bergen & Chan Lau, 2012). All of these findings indicate that learning temporal language, to read and write, and to use calendars have important effects on our spatial representations of time.

However, despite the cross-cultural variability in the direction of adults' space-time mappings, other features of the mental timeline seem to be pervasive, leading some researchers to posit that they may be innate. In particular, linearity is argued to be both ubiquitous. While some cultures have multiple spatial models of time, including, e.g., both linear and circular ones, it is extremely rare for any culture to lack any linear metaphor, and the few attested examples remain controversial (e.g., Sinha et al., 2011). Furthermore, infant studies suggest that at least one feature of the mental timeline – an association between spatial length and temporal duration – is present pre-linguistically (e.g., Casasanto et al, 2010; Srinivasan & Carey, 2010).

Current theoretical accounts of the relation between time and space have struggled to account for all of these findings (Winter et al., 2015). Particularly, it is unclear how and when more complex linear models of sequential and deictic (past/future) temporal relations emerge. Despite the cross-cultural variation, some have claimed that a single representational system accounts for both the infant length-duration association and the adult mapping of temporal sequence to spatial location, suggesting that linear representations of temporal structure may also be available from infancy (Bueti & Walsh, 2008). However, the evidence for a length-duration association does not alone prove that children have a spatial model of temporal sequence or deictic time. Strikingly little is known about the development of spatial representations for time between infancy and adulthood – the precise period over which most of the cultural tools posited to shape space-time representations are acquired by most English-speakers.

Here, we ask, first, if linear representations of temporal structure are present in early childhood, particularly in the years before children receive extensive exposure to cultural practices linking time and space in conventionalized ways, If so, we next ask whether those representations are like those of adults (e.g., left-to-right) and what role learning the formal calendar system plays in the acquisition of and developmental change in those representations.

The development of temporal cognition in early childhood is complex and prolonged (for a review, see McCormack, 2014). If, at one extreme, all reasoning about time automatically invokes a spatial model of temporal structure, we might expect to see evidence of spontaneous linear associations between temporal events and spatial locations in all children who can represent and recall sequences of events or differentiate events in the past or future. These abilities arise long before children enter school, whereas, skills like reading and writing, knowledge of formal time-related language, and the ability to use calendars are acquired arduously over many years. Thus, if formation of the mental timeline depends entirely upon these latter factors, we may not expect to observe it in children until much later, likely after they enter school.

It is possible that children possess spatial representations of time that differ from those of adults. In adults, linear models of temporal structure are detailed, culture-specific, and spontaneously deployed. One hypothesis is that children initially possess a spatial model of time that is linear but does not yet have a specific, culture-dependent directionality. In this case, we might expect to see more variability and malleability in the spatial representations adopted by younger children than in those of older children and adults. A further possibility is that, even if children are able to make mappings between time and space early in development, they may not do so spontaneously, instead requiring external prompting to do so, until relevant cultural conventions are internalized.

While prior studies have investigated children's associations between space and time, each line of work is limited in its ability to resolve these questions. For example, children demonstrate a rudimentary ability to differentiate the times of past autobiographical events on an external, adult-specified spatial timeline around the age of 3 (Busby Grant & Suddendorf, 2009). The ability to differentiate future events spatially emerges later, but can still be observed in children as young as 4. Children's early competence with such tasks suggests that, at a minimum, their representations of time and space are readily aligned. Critically, however, while success on such tasks shows that, with adequate instruction, children *can* map time to space, it does not indicate that they do so by default. Furthermore, because the timelines are provided to children, these tasks do not allow assessment of variability in their spatial representations.

The most convincing demonstration that children may *spontaneously* represent time linearly, in the same direction in which their language is read and written, comes from a study by Barbara Tversky and colleagues (1991). The task was simple, and did not require children to interpret any preexisting spatial timeline or scale. Children simply placed stickers on paper to represent the relative positions of three temporal events. For example, the experimenter placed a sticker in the center of the page to represent "lunch," and the child placed two other stickers to represent "breakfast" and "dinner." Critically, children could place the stickers anywhere they chose: no spatial template was given and they were not told that the stickers should be arranged in an ordered line. Yet, remarkably, over 80% of kindergarteners, the youngest group in the study, placed the stickers in an ordered line. Beyond this, 70% of English-speakers between kindergarten and grade 5 placed the stickers in order from left-to-right, while only 30% of Hebrew-speakers (who read from right to left) did so.

While the study by Tversky et al. (1991) provides the strongest evidence thus far for the existence of a stable, conventionalized mental timeline in children, it has several limitations. First, because the youngest children in the study were already producing linear representations at a high rate, the questions of when and how this tendency develops, and particularly whether it depends on formal schooling and fluency with the calendar system, are left open. Secondly, although overt instructions on the task were not given, children always performed a spatial "warm-up" task with physical objects prior to the temporal tasks, which may have primed them to adopt horizontal spatial representations of time they might not have otherwise used. Finally, because all the items in this task were highly familiar daily events, it is unclear whether children's ability produce spatial representations of temporal relationships also extends to deictic time and/or to more abstract temporal concepts.

To investigate these questions, we conducted two experiments. In Experiment 1, we employed the Tversky et al. (1991) sticker task with a few variations. We tested a younger sample of children, beginning at age 3, both with and without a spatial "warm-up." Further, to test whether children can use space to represent the relationships among more abstract temporal concepts, we asked children to perform a version of the sticker task using deictic time words – *yesterday*, *today*, and *tomorrow*. Finally, to explore whether adopting adult-like left-to-right (LTR) spatial representations is related to overt knowledge of cultural conventions for timekeeping, we asked non-spatial questions to assess children's fluency with the calendar system, and, in Experiment 2, compared performance on the open-ended sticker task with one in which a calendar-like template was provided.

Methods

Participants

For Experiment 1, 181 children from the San Diego area were recruited, including 50 3-year-olds, 53 4-year-olds, 54 5-year-olds, and 24 6-year olds. In Experiment 2, 92 children have participated, including 27 3-year-olds, 25 4-year-olds, 24 5-year-olds, and 12 6-year-olds. Data collection is ongoing. An additional 12 children participated but were excluded from analysis due to failure to complete the task (7), being outside the age range of interest (3), experimenter error (1), and not speaking English as a primary language (1). Testing was conducted in local daycares, preschools, and museums. Consent was obtained from parents, and children received a small gift.

Procedure, Experiment 1

Calendar pre-test. Before the sticker task, all children answered several questions to assess their level of fluency with the calendar system: "This day is today, does [yesterday/tomorrow] come *before* today or *after* today?"; "Do you know the days of the week? Can you say them for me?"; "What day of the week is/was [today/tomorrow/yesterday]?" If children failed to list more than 3 days of the week, they were prompted, "The first day is Monday, do you know what comes next?" and so on, until failing to produce two consecutive days. If the child did not correctly name today's day of the week, they were told the the correct answer before being asked about tomorrow and yesterday. The order of each pair of yesterday and tomorrow questions was counterbalanced.

Sticker tasks. The sticker tasks used here were modeled on the task designed by Tversky et al. (1991). Half the children were assigned to a ***No prime*** condition and half to the ***Prime*** condition. First, a blank white (7x5 in) index card was placed in front of the child (C). In the ***No-prime*** condition, the experimenter (E) recited the following vignette: "Let's start! I want you to think about the times of the day we eat meals: breakfast, lunch, and dinner. I'm going to put a sticker down for *lunch* time, and I want you to put stickers down for *dinner* time and *breakfast* time. Here's where I'm putting the sticker for *lunch* time." E placed a red star sticker in the middle of the card. "Now you put a sticker down for *dinner* time…" E handed C a green sticker and paused while C placed it on the card. "…and another sticker down for *breakfast* time.." E handed C a blue sticker. After C placed the second sticker, E took the completed card and replaced it with a new blank card. For the second task, E began, "Great job! Now, I want you to think about the times when different days happen: yesterday, today, and tomorrow," and the task proceeded identically to the first, but used different colored stickers.

Prior to the first temporal task, children in the ***Prime*** condition also completed a spatial task, in which E placed three toy blocks – red, green, and yellow – in a horizontal line parallel to the top edge of the index card. E pointed to each block and asked: "What color is this?", C responded, and E proceeded to say "Good job! I'm going to put down a sticker down on the paper in the place of the green block, then I want you to put stickers down in the places of the red and yellow blocks," The task proceeded in the same manner as the others. The blocks were removed after the priming task was completed, and the next task began. The three tasks were always completed in the same order: Prime (if present), Meals, Days. The order in which the two stimuli were prompted in each task was counterbalanced.

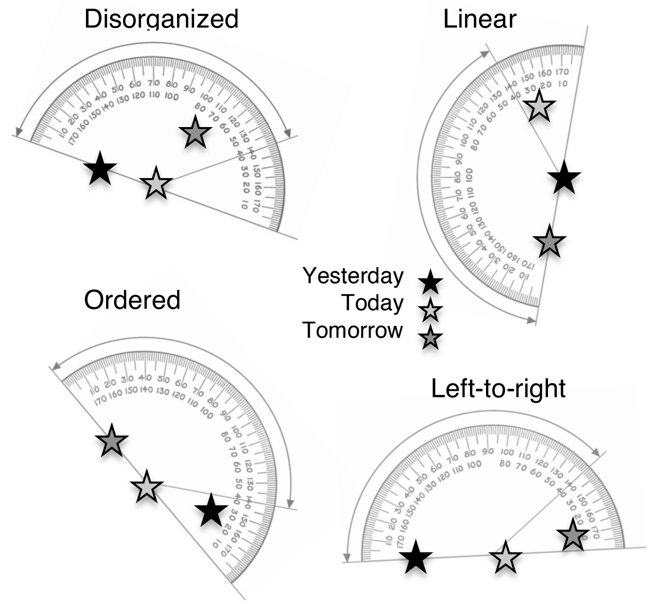

Figure 1. Example sticker arrangements from Experiment 1. See text for complete coding criteria. Protractors, not present during testing, show the angle, 140 deg, that must be exceeded for a child's sticker arrangement to qualify as "linear." Only one example per coding designation is shown, but many are possible under every designation but LTR.

Coding, Experiment 1.

During testing, the experimenter drew a small arrow on the back of each index card to indicate its orientation. Offline, the children's sticker arrangements were coded in three ways. The stickers were coded as **Linear** if the largest angle that they created that was under 180 deg. was at least 140 deg. (see Fig. 1). Stickers were coded as **Ordered** if, *in addition to being linear*, the child's two stickers were on opposite sides of the central (Experimenter's) sticker, creating a logical temporal sequence along any axis. Stickers were coded as **LTR** if, *in addition to being linear and ordered*, the axis of increase was left to right. Arrangements not reaching criteria for linearity were considered **Disorganized**. To index performance on the temporal tasks, children were awarded 0 points for Disorganized, 1 point for Linear, 2 points for Ordered, and 3 points for LTR arrangements, totaling 6 points across tasks.

Using responses to interview questions, we calculated an index of calendar knowledge for each child, in which she received 1 point for each correctly answered "What day is.." question and 1 point for each day of the week named in the correct sequence, for a total of 10 possible points.

Procedure, Experiment 2

Children in Experiment 2 answered a similar set of calendar questions as those in Experiment 1, but placed stickers on a pre-made, calendar-like template. The first questions were: "This day is today. Which day comes [before/after] today: tomorrow or yesterday?" The child was asked to recite the days of the week, then E placed a piece of paper with a horizontal sequence of 7 squares printed on it in front of the child. E said, "Look, these boxes are for the days of the week." E pointed to each box and said the associated day, following C's ordering (Sun-Sat or Mon-Sun). E then had C name each box, correcting if necessary. Next, E asked what day today was, and, after correcting C if necessary, asked her to point to "the box for today." If C was incorrect, E said "Nope, that box is for [day C picked]. Today is [correct day]. Can you find the box for [correct day]?" Regardless of whether C was correct, E then said "Look, I'm going to put a sticker in the box for today!" and placed a blue star in the correct box. C was then asked to put stickers in the boxes for tomorrow and yesterday. Finally, she was asked what day of the week each day was. The order of each pair of yesterday and tomorrow questions was counterbalanced. To the extent possible, testing was conducted on Tuesday-Friday, to avoid situations where "today" fell on the first or last box in the sequence.

Coding, Experiment 2. All arrangements in Exp. 2 were necessarily linear, but for the purposes of comparison to Exp. 1, were coded as **Ordered** for right-to-left orderings and **LTR** for left-to-right orderings.

Results

Experiment 1: Sticker arrangements, with and without spatial priming

To determine how frequently children adopted adult-like spatial representations of time, we calculated the proportion of children in each age group who arranged the stickers in accordance with criteria for Disorganized, Linear, Ordered, or Left-to-Right (LTR) arrangements (see Methods for criteria). A mixed-effects ANOVA of overall sticker task performance, including age group as the between-subjects variable and condition (prime vs. no prime) and item type (meals vs. days) as within-subjects variables, revealed main effects of age group and condition (F's>10, p's <0.001), and interactions between age and condition and between age and item type (F's > 3, p's < 0.05). Surprisingly, no main effect of item type (meals vs. days) was found. Here, except where noted, we report the results for days (*yesterday*, *today*, *tomorrow*). Proportions of children whose arrangements fell under each criterion are shown in Figure 2. Adult-like behavior increased dramatically over this time period, with a 4-fold change in the proportion of children producing LTR arrangements in the no-prime condition between age 3 (17%) and age 6 (73%).

To assess the impact of the spatial prime, we examined the interaction between age group and condition. Follow-up analyses on each age group in the days task revealed no effect of condition on the proportion of responses that were linear, ordered, or LTR in the 3-, 5-, or 6-year-olds. However, the prime dramatically increased the percentage of 4-year-old children who produced arrangements that were linear, from 56% to 95%; ordered, from 36% to 76%; and LTR, from 12% to 43% (t's>2.4, all p's < 0.05).

In order to assess the variability of children's spatial representations of time, we next analyzed the directionality

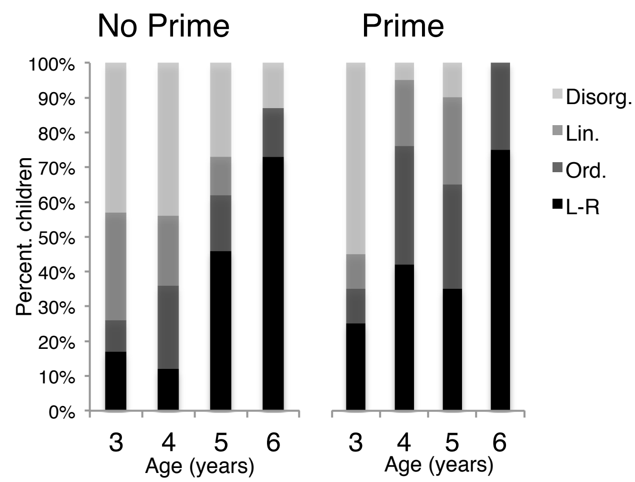

Figure 2. *Sticker arrangements for days*. Percentage of children in the prime and no prime conditions of Exp. 1 who arranged stickers representing "yesterday," "today", and "tomorrow" according to each criterion. Disorg.= disorganized, Lin.= linear, Ord. = ordered, L-R = left-to-right.

of children's ordered responses in the no-prime condition. Due to the small number of ordered arrangements by 3-year-olds, we combined the 3- and 4-year-old groups. Interestingly, without a prime, this younger group of children was equally likely to produce right-to-left (RTL) as LTR arrangements (47% each). In contrast, among children who produced ordered arrangements, 5-year-olds produced LTR arrangements 67% of the time, as compared with 27% RTL, and the 6-year-olds produced LTR arrangements 80% of the time, with 20% RTL. Notably, use of the vertical axis was extremely rare in all age groups.

Experiment 1: Calendar knowledge questions.

As shown in Figure 3, we calculated the proportion of children in each age group who correctly answered the questions "What day is today/yesterday/tomorrow]?" and the proportion of children who listed all seven days of the week in order (with or without prompting). As expected, on each question, a significant improvement in performance with increasing age was observed. It is interesting to note, however, that only 65% of 6-year-olds correctly identified the current day of the week.

Finally, we found that indices of overall sticker-task performance and calendar knowledge (see Methods) were moderately correlated, R=0.32. After centering and scaling each index, and also including condition and interactions in models of sticker task performance for each age group, linear regression analyses revealed no effect of calendar knowledge (t's<1.3, p's>0.07).

Experiment 2, sticker task with calendar template. In Experiment 2, children performed the yesterday/tomorrow sticker task on an adult-designated linear calendar template. To assess the effectiveness of this template, we calculated the proportion of children who adopted Ordered and Left-to-right arrangements for yesterday, today, and tomorrow (Fig. 4). Again, we observed a significant effect of age on

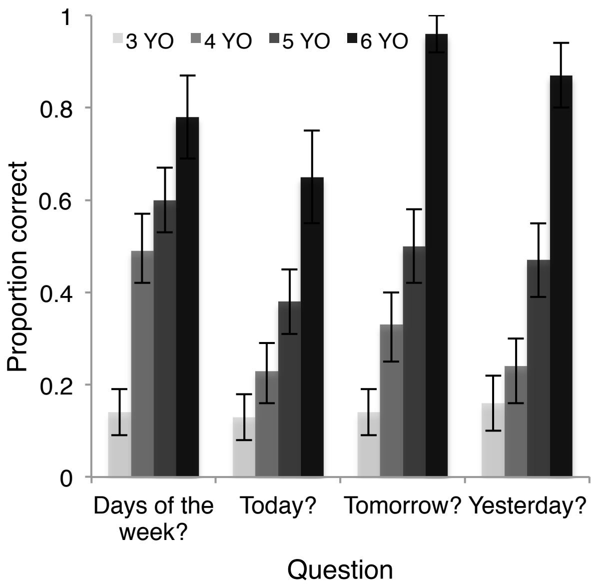

Figure 3. Calendar knowledge. Proportion of children who correctly named: all 7 days of the week in order, today's day of the week, tomorrow's and yesterday's days of the week (given today's).

performance. Next, we compared the performance of children in Exp. 2 with those in Exp. 1 (see Fig 4). As in Exp. 1, we saw no effect in the 3-year-old group, who were unlikely to produce ordered arrangements, or the 6-year-old group, who usually made adult-like LTR arrangements in every case, all *t*'s<1, *p*'s>0.3. The 4-year-old group performed significantly better with the calendar prime than those without a prime in Exp. 1, t(38)=2.2, *p*=0.03, but no differently from those who received the block prime in Exp. 1, *t(*42)=-0.2, *p*=0.8. 5-year-olds, however, performed significantly better with the calendar prime in Exp. 2 than with the block prime in Exp. 1 (*t*(33)=4.0, *p*<0.001.

Discussion

The purpose of this study was to investigate children's initial spatial representations of time. We focused this investigation on several questions. First, are linear representations of time produced spontaneously by children, in the years before they have extensive exposure to cultural practices linking space and time in conventionalized ways? Second, if linear representations are of time are produced by children, are they like those of adults (e.g., left-to-right for English-speakers)? Lastly, what role does knowledge of the formal calendar system play in guiding adult-like spatial representations of time?

In Experiment 1, 3- to 6-year-old children placed stickers representing mealtimes (breakfast, lunch, dinner) and days (yesterday, today, tomorrow) on blank index cards. We found that, without any instruction on what type of spatial arrangement they should use and no spatial priming, only 26% of English-speaking 3-year-olds and 36% of 4-year-olds produced ordered, linear representations of time. In contrast, a much higher proportion of 5-year-olds, 70%,

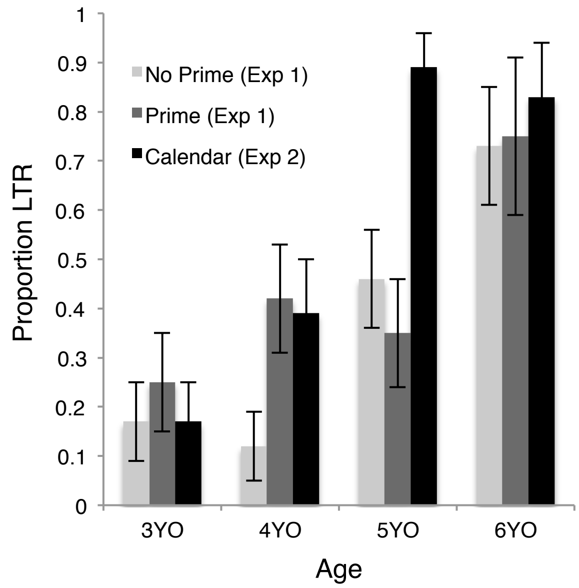

Figure 4. Proportion of children who arranged stickers representing 'yesterday', 'today', and 'tomorrow' in an ordered line from left to right. In the Prime condition, prior to completing the temporal items, children first used stickers to represent the spatial positions of physical objects. In the Calendar condition (Exp 2), children placed their stickers on linear template representing the days of the week.

spontaneously represented temporal order linearly, and 83% of six-year-olds did so. These findings suggest that "automatic" activation of a linear schema for time does not arise in most children until at least age 5.

Experiment 1 also revealed that inducing younger children to adopt spatial representations of time can be remarkably simple, indicating that many children can readily make mappings between these domains before they begin to do so spontaneously. Prior to completing the temporal representation tasks, children in a spatial priming condition also used stickers to represent the spatial positions of three physical objects arranged in a horizontal line. After experiencing this spatial prime, the number of 4-year-olds who produced linear, ordered, and left-to-right representations of time increased dramatically, with 76% adopting ordered arrangements. However, despite the remarkable efficacy of spatial priming in 4-year-olds, this type of priming was of no benefit to children who were younger or older. Three-year-olds rarely produced linear representations of time in either condition, and, though such representations became increasingly common in 5- and 6-year-olds, these children were just as likely to produce them without a prime, also indicating that it is around this point in development that children begin to internalize spatial models of temporal sequence.

These findings confirm and extend previous work showing that kindergarteners produce spatial representations of time that are consistent with their reading and writing direction (Tversky et al., 1991). While, in that study, participants always performed a spatial "warm-up" task directly prior to the temporal tasks, here we show that, in their age group, the ability to spatialize sequential time does not depend on spatial priming. Furthermore, by expanding this line of work to include preschoolers, we were able to better characterize the developmental trajectory of this phenomenon, showing that children who have no yet entered school are much less likely to produce conventional spatial representations of time. While Tversky and colleagues examined only children's ability to depict the relations among highly familiar events, we show that children are also able to spatially represent the relations among abstract deictic time words. Surprisingly, despite other evidence that preschoolers' use of terms like *yesterday* and *tomorrow* is often inaccurate (Grant & Suddendorf, 2011), we found no evidence that children's ability to represent the relations between these concepts spatially is less developed than their ability to do so with events. This suggests that knowledge of the relative ordering of deictic time words may precede acquisition of their fully adult-like meanings – a pattern that has also been observed for duration words (Tillman & Barner, 2015).

Beyond the age-related increase in the frequency of children's linear representations of time, we also observed developmental changes in the types of linear representations children produced. Unlike older children, the majority of whom produced adult-like left-to-right arrangements, younger children were no more likely to depict time as proceeding from left-to-right as from right-to-left. This early variability aligns with the results of cross-cultural studies of adults showing that illiteracy and lack of exposure to spatial artifacts for timekeeping are associated with higher variability in space-time associations. Moreover, the presence of linear and logical but writing-direction-inconsistent time-space mappings in children is consistent with the hypothesis that a more generalized spatial model of time may be in place before children have fully internalized cultural conventions. Notably, however, even the youngest children used the horizontal axis nearly exclusively. The extent of children's bias toward arranging items horizontally is being examined in more detail in ongoing studies attempting to prime children to use the vertical axis instead.

When the effect of age was controlled for, children who displayed higher semantic knowledge of the calendar system outside a spatial context (e.g., those who could recite the days of the week without error) were no more likely to produce adult-like spatial representations of time. However, when children were provided an explicit calendar-like template on which to perform the sticker task in Experiment 2, we saw a large increase in adult-like behavior among 5-year-olds. This suggests that the use of such spatial artifacts may play a role in solidifying left-to-right representations among children of this age. This structural scaffolding conferred no particular benefit outside of this developmental window, however. It had no impact on the low performance of 3-year-olds or on the high performance of 6-year-olds, and it was no more effective than simple spatial priming for 4-year-olds. Though rote knowledge of the calendar system alone does not lead to conventionalized space-time mappings, a baseline level of semantic knowledge is likely required to render spatial artifacts like calendars comprehensible to children.

In conclusion, our findings suggest that, while preschoolers do not often spontaneously produce linear representations of time, many are able to map temporal sequence to linear space, and can be easily primed to do so as early as age 4. The refinement and conventionalization of children's spatial representations of time, however, continues into the school years.

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References

Bergen, B. K., & Lau, T. T. C. (2012). Writing direction affects how people map space onto time. *Frontiers in psychology*, *3*.

Bonato, M., Zorzi, M., & Umiltà, C. (2012). When time is space: evidence for a mental time line. *Neuroscience & Biobehavioral Reviews*, *36*(10), 2257-2273.

Boroditsky, L., & Gaby, A. (2010). Remembrances of times east absolute spatial representations of time in an Australian aboriginal community. *Psychological Science*, *21*(11), 1635-1639.

Bottini, R., & Casasanto, D. (2013). Space and time in the child's mind: metaphoric or ATOMic?. *Frontiers in psychology*, *4*.

Bueti, D., & Walsh, V. (2009). The parietal cortex and the representation of time, space, number and other magnitudes. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *364*(1525), 1831-1840.

Busby Grant, J., & Suddendorf, T. (2011). Production of temporal terms by 3-, 4-, and 5-year-old children. *Early Childhood Research Quarterly*, *26*(1), 87-95.

Casasanto, D., Fotakopoulou, O., & Boroditsky, L. (2010). Space and time in the child's mind: Evidence for a cross-dimensional asymmetry. *Cognitive Science*, *34*(3), 387-405.

McCormack, T. (2014). The development of temporal cognition. In R. Lerner, L. Liber, U. Mueller (Eds.), *Handbook of Child Psychology and Developmental Science, Volume Two, Cognitive Processes*, 7th Edition

Sinha, C., Silva Sinha, V., Zinken, J., & Sampaio, W. (2011). When time is not space: the social and linguistic construction of time intervals and temporal event relations in an Amazonian culture. Language and Cognition, 3, 137e169.

Srinivasan, M., & Carey, S. (2010). The long and the short of it: on the nature and origin of functional overlap between representations of space and time. *Cognition*, *116*(2), 217-241.

Tillman, K. A. & Barner, D (2015). Learning the language of time: Children's acquisition of duration words. *Cognitive Psychology, 78*, 57-77.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*(4), 515-557.

Winter, B., Marghetis, T., & Matlock, T. (2015). Of magnitudes and metaphors: Explaining cognitive interactions between space, time, and number. *Cortex*, *64*, 209-224.