Children gradually construct spatial representations of temporal events

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Abstract

English-speaking adults often recruit a “mental timeline” to represent events from left-to-right, but its developmental origins are debated. Here, we test whether preschoolers prefer linear representations of events and whether they prefer culturally-conventional directions. English-speaking adults ($n=85$) and 3-to-5-year-olds ($n=513$; 50% female; ~47% white, ~35% Latinx, ~18% other) were told 3-step stories and asked to choose which of two image sequences best illustrated them. We found that 3- and 4-year-olds chose ordered over unordered sequences ($r_{3yo}=0.29$, $r_{4yo}=0.74$), but preferences between directions did not emerge until age 5 ($r_{5yo}=0.37$, $r_{adult}=0.91$). Together, these results show that children conceptualize time linearly early in development but gradually acquire directional preferences (e.g., for left-to-right).

Keywords: time; space; mental timeline; events; visual narrative

1. Introduction

Time and space are deeply interwoven in human experience and culture. For example, diverse societies use spatial artifacts to depict, measure, and track time. Languages often use the same words to refer to both time and space (e.g., a *long* nap and a *long* rope). When we read, our progress through a temporal narrative is contingent on our progress along a spatial path on the page. Multiple sources of evidence suggest that adults have implicit associations between locations in time and positions in space, e.g., associating leftward space with the past, and rightward space with the future (see Bonato et al., 2012, for a review; Casasanto & Bottini, 2014; Droit-Volet & Coull, 2015; Ishihara et al., 2008; Santiago et al., 2007). Based on evidence that the direction of this *mental timeline*, or MTL, differs cross-culturally (e.g., Bergen & Chan Lau, 2012; Fuhrman & Boroditsky, 2010; Nachshon, 1983; Ouellet et al., 2010; Tversky et al., 1991) some have argued that it is learned, and reflects differences in reading/writing direction and/or visual scanning habits (see Pitt & Casasanto, 2019, for discussion). Others have argued that humans begin life with an innate predisposition to conceptualize time according to a left-to-right (LR) MTL, and that cultural learning may optionally modify this default tendency (Bulf et al., 2016; Chatterjee, 2001; Chatterjee et al., 1999; Dehaene et al., 1993; Vicario et al., 2007). Some prior research with English-speaking children suggests that their preferences for LR representations of time do not arise until relatively late in development (e.g., Tillman et al., 2018). However, their methods may have been insufficiently sensitive to detect preferences in preschoolers (Autry et al., 2019). Here, we explored children's developing preferences for visual representations of time using a series of tasks that varied in difficulty, assessing both whether children prefer linear to non-linear representations and also whether they prefer particular spatial directions.

While the question of how the mental timeline is formed is fundamentally developmental, most previous studies of the MTL have been limited to adult populations. Many researchers argue that some type of MTL is universal in adults (Gell, 1992), consistent with the possibility that humans have an innate tendency to represent events linearly. However, cross-cultural comparisons showing reliable differences in the orientation and direction of the MTL suggest that these preferences are learned (e.g., Bergen & Chan Lau, 2012; Boroditsky & Gaby, 2010; Fuhrman & Boroditsky, 2010; Nachshon, 1983; Núñez & Sweetser, 2006; Ouellet et al., 2010). For example, while the LR MTL is robust in speakers of English and many other languages written using an LR orthography (Casasanto & Bottini, 2014; Droit-Volet & Coull, 2015; Ishihara et al., 2008; Santiago et al., 2007; for review, see Bonato et al., 2012), speakers of languages written from right-to-left (RL) often construe time from RL (Ouellet et al., 2010; Tversky et al., 1991). School-aged children also show cross-cultural differences: English-speaking elementary school children organize time-denoting stickers from LR (Tillman et al., 2018; Tversky et al., 1991), while Arabic-speaking children represent time from RL (Tversky et al., 1991).

These cross-cultural differences in the direction of adults' and schoolchildren's MTL are consistent with the possibility that humans are born without biases in how they represent time spatially, but acquire them gradually through experience. Many researchers argue that reading and writing experience shapes the MTL (see Pitt & Casasanto, 2019, for discussion). However, it is also possible that humans begin life with a predisposition to organize time into spatial sequences, perhaps even with directional biases, but that these biases are subject to later modification (e.g., resulting in alternative directional preferences in different cultures). For example, all infants could begin life with a bias toward representing time in an LR MTL, which is later either strengthened

or weakened by experience with cultural practices like reading (Bulf et al., 2016; De Hevia et al., 2012; Maass & Russo, 2003).

Other work, conducted in young infants, has hypothesized that some types of space-time mappings may be innate. For instance, infants show preferences for LR sequencing of information (Bulf et al., 2016). They have the ability to associate magnitudes from across dimensions such as duration, length, and number (e.g., de Hevia et al., 2014; Lourenco & Longo, 2010; Srinivasan & Carey, 2010). They also appear to associate magnitudes with locations in space (though the evidence for this in the case of temporal duration is mixed; Cheung & Lourenco, 2016; de Hevia et al., 2017; 2020). Critically, none of these studies provide evidence for organization of temporal sequences into spatial timelines. Still, evidence from other types of mappings involving space and number lend credence to this idea. These include reports that both infants and non-human animals associate “few” with the left and “many” with the right side of space (e.g., de Hevia et al., 2014; Rugani et al., 2017; but see also Cheung & Lourenco, 2016; de Hevia et al., 2017), that preschoolers spontaneously count objects from LR (Göbel et al., 2018; Shaki et al., 2012a),¹ that preschoolers demonstrate a leftward bias from the veridical center in line-bisection tasks (Chokron & De Agostini, 1995), and that preschoolers expect numbers to be organized from LR (Opfer, Thompson, & Furthong, 2010). While these studies do not test temporal cognition, researchers have argued that all of these phenomena result from the same evolutionarily-ancient hemispheric asymmetry in the brain, which should equivalently affect representations of time (Brooks et al., 2014; Chatterjee, 2001; Chatterjee et al., 1999; Rosen et al., 1987; Rugani et al., 2010, 2015;

¹ Interestingly, however, these biases in counting direction can be temporality switched after children observe adults reading a storybook aloud in the opposite direction (e.g., if an experimenter points from RL while reading to English-speaking children; Göbel et al., 2018), suggesting that reading-related factors can influence space-number mappings even in pre-literate children. Moreover, there is no evidence for a counting bias in illiterate adults (Shaki et al., 2012b).

Vallortigara, 2009; Vicario et al., 2007; but see Pitt & Casasanto, 2019, for evidence that the MTL and mental number-line are distinct).

Given this relative paucity of direct evidence for an MTL in developmental populations, the present study took a step in this direction by testing 3- to 5-year-old preschoolers. This age group provides a good entry point to this question because, if an MTL is present in infants, then evidence of an MTL of some form should be found in older children as well. Consequently, though the presence of an MTL in this group would leave open a role for early learning, the absence of an MTL would provide important evidence against innateness. Further, this age group is interesting because it reflects the period during which children in North America typically begin to receive exposure to reading and writing.² Although preschoolers' ability to read and write is typically limited, many receive exposure to structured spatial input that could potentially influence the MTL. For example, text in books and visual scanning habits by caretakers may provide important visual cues (Göbel et al., 2018; Patro et al., 2016). Finding evidence of a mental timeline in preschoolers would be an important step toward determining the nature of environmental input (if any) required to shape it.

Previous studies have reported that, while elementary-school aged children demonstrate biases favoring culturally-conventional linear representations of time, preschoolers do not, suggesting that these preferences are learned, rather than innate. Such studies have asked children to construct spatial representations of events by placing items on timelines (Friedman, 1990; Hudson & Mayhew, 2011; Tillman et al., 2017), placing stickers on blank paper (Tillman et al., 2018; Tversky et al., 1991), sorting picture cards (Bornens, 1990; Fivush & Mandler, 1985), or

² In general, according to standard kindergarten curricula (e.g., Common Core in the United States). The age at which children begin writing varies across individuals, schools, countries, and cultures.

drawing (Dobel, Diesendruck, & Bolte, 2007). For example, in one study, researchers asked 4-year-olds to arrange stickers representing events, and found that a large majority failed to produce any type of linear arrangement (Tillman et al., 2018). Moreover, the children who did produce a line failed to demonstrate an LR bias. Nonetheless, these studies leave open the possibility that 4-year-olds associate time with linear spatial arrangements, but are simply unable to generate those sequences themselves (see Autry et al., 2019 for discussion). In other words, it is possible that the tasks that have been used to assess the MTL in older children, and which are impossible for infants, are also too difficult for preschoolers, and thus failed to detect evidence of linear representations and/or LR biases in preschoolers.

To summarize, infants readily associate temporal and spatial magnitudes (e.g., de Hevia et al., 2014) and they can learn a pattern of shapes that are shown one at a time in a line from LR (Bulf et al., 2007). Many English-speaking preschoolers spatially represent colors shown one at a time in an LR line (Autry et al., 2019), and demonstrate LR biases on a variety of tasks involving spatial representations of other abstract domains, such as number. However, when explicitly asked to represent different points in *time*, preschoolers (unlike older children and adults) do not systematically organize them in lines with an isomorphism between position in space and event order, and they do not show evidence of an LR bias (Tillman et al., 2018). This collection of results leaves open whether the different elements of the MTL (such as linearity and direction) might represent innate defaults vs learned conventions.

Figure 1. Example stimuli. On the first trial, participants heard the story “First there was an egg. Then the egg cracked. And a baby chick popped out!” In the Horizontal condition, they chose between cards showing (A) left-to-right and (B) right-to-left sequences of images.

To address this, we tested a large sample of preschoolers ($n = 514$ across three experiments) on a new task that greatly reduced demand on children. We asked them to express a preference in a two-alternative forced-choice task, rather than requiring them to construct lines on their own. Preschoolers and adult controls were told brief stories describing three-step event sequences and then asked to choose which of two spatial depictions of each story was “better.” In Experiment 1, we tested whether children have directional preferences by asking them to choose between LR, RL, top-to-bottom (TB), and bottom-to-top (BT) representations of events (see Fig 1). In Experiment 2, we tested if children were sensitive to whether the order of the images matched that of the events they depicted, by asking them to choose between ordered and unordered sequences. In Experiment 3, we replicated Experiments 1 and 2 using a modified procedure including additional scaffolding to aid children’s comprehension of the task. Finally, we conducted a parent

survey to explore the relationship between children's early literacy skills and their performance on the space-time task.

As we will show, our effort to simplify our methods was successful. We found that even 3-year-olds have a preference for ordered over unordered sequences (Experiment 3). Nevertheless, despite this evidence that they were able to comprehend the task, children under age 5 did not demonstrate directional preferences in any of our experiments, suggesting that although children have an early predisposition to conceive of time according to spatial sequences, they do not have a preference for LR (or any other spatial configuration) before the age of 5.

2. Experiment 1

In Experiment 1, we tested whether adults and children have preferences between different spatial sequences (e.g., LR vs. RL) after hearing a story.

2.1 Methods

2.1.1 Participants. A total of 271 participants were included in Experiment 1, including 62 3-year-olds ($M_{\text{age}} = 3;6$, range 3;0 – 4;0), 63 4-year-olds ($M_{\text{age}} = 4;6$, range 4;0 – 5;0), 61 5-year-olds ($M_{\text{age}} = 5;5$, range 5;0 – 6;0), and 85 adult controls (at least 18 years of age). 44% of child participants were girls. Children were recruited from museums and daycares in an urban area on the west coast of the United States. The sample was drawn from a local population with the following demographic characteristics: 33% white, 45% Hispanic/Latino, 9.7% Asian, 5.1% Black/African American, 0.6% American Indian/Native American. Adults were workers on Amazon Mechanical Turk living in the United States; information on race and gender were not collected. An additional 23 children were tested but excluded from all analyses because they were outside the target age range ($n = 11$), English was not their primary language ($n = 2$), they spoke a second language with a non-LR orthography ($n = 4$), they failed to complete the task ($n = 2$),

clerical error ($n = 3$), or developmental delay ($n = 1$). Five adults were excluded from analysis due to speaking a language with non-LR orthography ($n = 2$) and lack of attention to the task, as indexed by failing a “catch” trial ($n = 3$). All participants spoke English as their primary language, and none spoke a secondary language with non-LR orthography. Adults and parents of children provided informed consent to participate. Children were awarded a small prize, and adults were compensated \$1 for a task that took approximately 5 minutes to complete.

2.1.2 Stimuli. We composed eight stories, each describing a three-step temporal event that was intended to be familiar to children in the target age range. Four cards were created to match each story. Each card showed three images that represented the steps in the story in consecutive order from a particular direction: either left-to-right (LR), right-to-left (RL), top-to-bottom (TB) or bottom-to-top (BT). For an example, see Fig 1. All stimuli are shown in Appendix Table 1.

2.1.3 Conditions. Participants were randomly assigned to three conditions: Horizontal, Vertical, or Perpendicular. In the Horizontal condition, participants ($n = 21$ 3-year-olds, 22 4-year-olds, 21 5-year-olds, 29 adults) were asked to choose between cards that depicted stories either from LR or RL (See Figure 1; Appendix Fig. 1). In the Vertical condition, participants ($n = 20$ 3-year-olds, 20 4-year-olds, 20 5-year-olds, 29 adults) were asked to choose between cards that depicted stories from TB and BT (Appendix Fig. 1). In the Perpendicular condition ($n = 21$ 3-year-olds, 21 4-year-olds, 20 5-year-olds, 27 adults), participants were asked to choose between images arranged from LR and TB. This last condition was included to assess whether a preference between the horizontal and vertical axes might emerge at a different point in development than preferences within an axis (e.g., for LR vs. RL in the Horizontal axis). For example cards showing all directions, see Appendix Figure 1.

2.1.4 Procedure for children. The experimenter (seated next to the child) introduced the task, saying “We’re going to play a picture game together. Every time we play, I’m going to tell you a story, and you’re going to pick the card that matches the story. Each card shows three pictures of things that happened in the story, and you’re going to pick the one that has them all in the right order, just how they happened in the story.” Next, on each of eight trials, the experimenter recited the story. For example, on the first trial, the child heard the Egg story: “First there was an egg. Then the egg cracked. And a baby chick popped out!” As shown in Figure 1 (Horizontal condition), the experimenter then simultaneously placed two cards on the table, and asked, “Which card shows that story? Which one is *better*? Is it *this one* [point to card] or *this one* [point to card]?” After the child pointed to their choice, the cards were removed, and the next trial began.

The two cards were placed side-by-side in the Vertical and Perpendicular conditions, but were positioned one above the other in the Horizontal condition.³ The positioning of the two cards, including the location of the more conventionally-ordered choice, was counterbalanced across subjects and items, in two trial orders, one of which was the reverse of the other. Every child heard the Egg story first (see Figure 1). Half the children heard the remaining stories in the order listed in Appendix Table 1, and half heard them in the reverse order.

2.1.3 Procedure for adults. Adults ($n = 85$) completed a computerized version of the task, created using Qualtrics and posted as a HIT on Amazon Mechanical Turk. On each trial, the participant read the story, then clicked an arrow to advance to the next screen, which showed the two “cards” (squares) outlined in black arranged in the same positions as they were for children, and the test question (“Which card shows that story? Which one is *better*?”). The participant clicked a radio button below the card they thought was better, and then clicked an arrow to advance to the next

³ When horizontal cards were placed side-by-side in pilot testing, having all six images aligned in a row across the two cards appeared confusing for children.

trial. The two trial orders were the same as those used in the children's procedure, except that two additional "catch trials" were included after test trials 3 and 6. In these cases, one of the two options contained a non-chronological sequence, e.g., the Watermelon story arranged from LR vs. an unordered horizontal sequence which showed (from LR) sliced watermelon, eaten watermelon slices, and then an intact watermelon. Adults who failed either of these trials ($n = 3$) were excluded due to suspected inattention to the task. After finishing the task, participants answered a series of questions about their language exposure.

2.1.4 Parent survey. A subset of parents of 4-year-olds in Experiment 1 ($n = 16$) completed a survey about their child's emergent literacy skills and an adaptation of the Children's Title Checklist, a previously-used measure of print exposure in children (Senechal et al., 1996, 1998). Survey data were also collected in Experiments 2 and 3. Further description of the survey and its results are described in the section on Experiment 3.

2.2 Results

2.2.1 Direction preferences in adults.

To assess direction preferences in adults, we calculated the percentage of trials, out of 8, on which each participant chose the card with each direction. We found robust direction preferences in all three conditions. The median percentage of trials on which adults chose LR cards was 100%, 95% CI [100%-100%] in the Horizontal condition (LR vs. RL) and 87.5% [75%-100%] in the Perpendicular condition (LR vs. TB). In the Vertical condition (TB vs. BT), adults chose the TB card on a median 100% [100%-100%] of trials. In all subsequent analyses, we considered these adult-preferred directions to be the "conventional" choices, and the contrasting directions to be "unconventional" choices. The distribution of conventional choices among adults across conditions is shown in Fig. 2, right column.

Figure 2. Frequency of preferences for conventional visual representations of time in Experiments 1 and 2. In Experiment 1 (top row), participants chose between two ordered, linear sequences with different directionalities. In Experiment 2 (bottom row), children chose between ordered sequences and scrambled (i.e., unordered) sequences. Adults were not tested in Experiment 2. Red solid lines represent medians. Dotted lines represent chance.

2.2.2 Direction preferences in children.

To analyze children's data, we conducted a mixed-effects logistic regression, which modeled the likelihood of choosing the conventional direction as a function of the child's age (as a continuous, scaled variable), and condition (Horizontal, Vertical, or Perpendicular). In this model, and in all subsequent models discussed in Exp. 1-3, we also included an interaction term and a random intercept for subjects. Age was a significant predictor which improved the fit of the model, $\beta = 0.31$, $p = 0.02$; $\chi^2(1) = 8.3$, $p = 0.004$, when compared to a reduced model that did not

include this predictor. However, we did not find a significant effect of condition, and this factor did not improve the model, $\chi^2(2) = 1.8, p = 0.41$. Therefore, although children's choices became overall more conventional over time, this first analysis did not find a difference between the development of LR and TB preferences.

While these analyses indicate that children's preferences for conventional representations of events increased with age, they don't establish when such preferences first emerge. To explore this, we examined each age group separately. As shown in Figure 2, neither 3-year-olds' nor 4-year-olds' performance differed from chance: the median percentage of trials on which children from both groups chose the conventional direction was 50% [50% – 50%], one-sample sign tests, both $s < 16, p's > 0.6$. However, the median percentage of trials on which 5-year-olds chose conventional directions was 62% [50%-75%], greater than chance guessing would predict, one-sample sign test, $s = 32, p = 0.02$. This suggests that directional preferences in this task did not emerge in most children until after age 5.

2.3 Discussion

The results of Experiment 1 indicate that most children begin to express conventional direction preferences on this task, along both the horizontal and vertical axes, around 5 years of age, similar to prior findings using a production task (Tillman et al., 2018). However, there are two potential problems with this study. First, although Experiment 1 suggests that 3- and 4-year-old children don't have strong directional preferences on this task, it leaves open whether they prefer ordered sequences over unordered ones. All of the images used in Experiment 1 were in sequential order with respect to the narrative, despite sometimes violating conventional adult-preferred directionality. Second, the failures of younger children on this task, while compatible with a lack of preference, are also consistent with a failure to understand the task. We reasoned that if

the task is understandable to 3- and 4-year-old children but they simply lack directional preferences, then they may succeed on a version of the task that probes a preference for ordered vs. unordered spatial representations of events, even while failing to prefer specific directionalities. In Experiment 2 we explored this possibility by asking children to choose between ordered sequences of images and unordered, “scrambled” sequences (e.g., an LR sequence of an egg, a baby chick, and then a cracked egg, which we called the “scrambled egg” condition). If children prefer ordered over scrambled sequences, this would suggest both that they can organize time spatially and that they understand the task, but that they simply don’t yet have directional preferences.

3. Experiment 2

The purpose of Experiment 2 was to explore whether children prefer linear representations of sequential temporal events to representations in which the events are depicted out of order. We assessed both whether children prefer LR images to scrambled horizontal sequences and whether they prefer TB images to scrambled vertical sequences. Finding equal preference for both LR and TB over scrambled images would provide evidence that children have a linear representation of time, but no clear LR bias. A stronger preference for LR over scrambled images than TB vs. scrambled would provide evidence both for linear representations and for a potential LR bias. Finally, a lack of preference for either LR or TB vs. scrambled images would suggest both a lack of linearity and a lack of directional bias.

3.1 Methods.

3.1.1 Participants. There were 126 participants in Experiment 2, including 40 3-year-olds ($M_{\text{age}} = 3.5$, range 3 – 4 years), 46 4-year-olds ($M_{\text{age}} = 4.5$, range 4 – 5 years), and 40 5-year-olds (M_{age}

= 5.4 years, range 5 – 6 years). They were randomly assigned to one of two conditions, with 20 3-year-olds, 23 4-year-olds, and 20 5-year-olds in each. 55% of participants were girls. Children were recruited from museums and daycares on the west coast of the United States ($n = 79$) and of Canada ($n = 47$) areas. Demographics of the US population were the same as those reported in Experiment 1. The Canadian sample was drawn from two small cities with the following (combined) demographic makeup: 90% white, 5% First Nations/aboriginal, 4% Asian, 1% Black, <1% Hispanic/Latino. An additional 15 children were tested but excluded due to being outside the target age range ($n = 4$), not speaking English as their primary language ($n = 6$), speaking a second language with a non-LR orthography ($n = 3$), experimenter error ($n = 1$), or clerical error ($n = 1$).

3.1.2 Materials and procedures were identical to those used in the Horizontal and Vertical conditions of Experiment 1, except that each RL card was replaced with a Scrambled Horizontal card (see Appendix Figure 1E), and each BT card was replaced with a Scrambled Vertical card (Appendix Fig. 1F). Thus in the Horizontal Scrambled condition children compared a LR card to an unordered sequence that was oriented horizontally, and in the Vertical Scrambled condition children compared a TB card to an unordered sequence that was oriented vertically.

3.2 Results

We conducted a mixed-effects logistic regression modeling the likelihood of choosing the ordered image as a function of the child's age (as a continuous, scaled variable) and condition (Horizontal Scrambled or Vertical Scrambled). As in Experiment 1, we found that age was a significant predictor improving the fit of the model, $\beta = 0.36$, $p = 0.003$; $\chi^2(1) = 26.3$, $p < 0.001$, but that condition did not improve model fit, $\beta = -0.17$, $p = 0.3$; $\chi^2(1) = 1.2$, $p = 0.3$. Thus, as before, although older children were more likely to choose ordered sequences than were younger children, we found no evidence that children performed better for LR than for TB. As shown in

Fig. 2 (bottom row), when we examined individual age groups, we found that 5-year-olds were much more likely to choose ordered images than chance would predict, median = 75% [62%-88%], one-sample sign test, $s = 29$, $p < 0.001$. In contrast, the median percentage of ordered image selections was 50% in both the 3- and 4-year-old groups (95% CI for 3-year-olds, [50%-62%]; for 4-year-olds [50%-75%]), which was not different from chance, one-sample sign tests, both $s < 16$, both $p > 0.3$.

3.3 Discussion

The results of Experiment 2 indicate that children begin showing a preference for images representing temporal events in sequential order in this task around age 5. The median proportions of 3- and 4-year-olds preferring conventional (Exp. 1) and ordered (Exp. 2) cards were both 50%, consistent with the possibility that many children may have been randomly guessing in both tasks.

Relative to prior tasks, which have typically required the use of complex timelines or the creation of visual representations of time by the child (e.g., Busby Grant & Suddendorf, 2009; Friedman, 2000, 2002; Friedman & Kemp, 1998; Hudson & Mayhew, 2011; Tillman et al., 2017; Tillman & Barner, 2015; Tversky et al., 1991), the two-alternative forced choice task used in Experiments 1 and 2 imposed relatively low response demands. Still, this method may have posed other challenges. In particular, it is possible that some 3- and 4-year-olds had difficulty remembering the story, interpreting the individual pictures, or connecting the pictures to the steps in the stories they had heard (see Cohn, 2020, for discussion). If so, these difficulties could have prevented us from detecting the presence of direction or orientation biases.

We reasoned that, in order to succeed at the task, the child must mentally create an isomorphism between the temporal order of the events in the story and the spatial positions of the images on the card. Although one obstacle to this is understanding how time and space are related,

another challenge is identifying which images on the cards correspond to which events. For example, if the child did not understand that the picture of the cracked egg on the card corresponds to the egg cracking event in the story, they might fail to situate it in the middle of the story. They might therefore be unable to use this knowledge to situate the corresponding image in the middle of the spatial sequence. If so, the child might fail the task regardless of their preferences for how time should be spatially represented.

To address this, unlike in Experiments 1 and 2, where the pictures were only presented at test, in Experiment 3 they were also presented during the story-telling phase as each event was described. The images were shown one at a time in the center of the screen. This created an alignment between the events in the story and the pictures, without presenting the pictures in any spatial arrangement relative to one another. Furthermore, children were asked to repeat back each story to the experimenter (in their own words) prior to the test phase, to ensure that they had heard and encoded it.

4. Experiment 3

In Experiment 3, we repeated all five conditions from the previous experiments with this modified procedure designed to further reduce task difficulty.

4.1 Methods.

4.1.1 Participants.

Given the relative success of 5-year-olds in Experiments 1 and 2, here we focused on 3- and 4-year-olds. A total of 202 participants were included in Experiment 3, including 101 3-year-olds ($M_{\text{age}} = 3;6$, range 3;0 – 4;0 years) and 101 4-year-olds ($M_{\text{age}} = 4;6$, range 4;0 – 4;11 years). 54% of participants were girls. Children were randomly assigned to one of five conditions: Horizontal (20 3-year-olds and 20 4-year-olds), Vertical (21 3-year-olds and 20 4-year-olds),

Perpendicular (20 3-year-olds and 21 4-year-olds), Scrambled Horizontal (20 3-year-olds and 20 4-year-olds), or Scrambled Vertical (20 3-year-olds and 20 4-year-olds). Children were recruited from daycares and museums in the western United States ($n = 127$) and Canada ($n = 75$), with the same demographics reported in Experiments 1 and 2. An additional 12 children were excluded from analysis because they were outside the target age range ($n = 1$), English was not their primary language ($n = 2$), they failed to complete the task ($n = 2$), or had completed a prior version of the experiment ($n = 7$).

4.1.2 Procedures and materials.

As shown in Table 1, procedures in Experiment 3 were similar to those in Experiments 1 and 2, except that children viewed images on a computer screen during the story-telling phase of each trial rather than after the story. At the start of the session, the experimenter said, “Every time we play, I’m going to show you a story on the computer, and you’re going to pick the card that matches the story.” On each trial, while reading the three steps of the story, the experimenter presented the image corresponding to each step. The pictures were shown sequentially in the center of the screen. For example, while hearing, “First, there was an egg” the child was presented with the picture of the whole egg (see Table 1). Then, while saying “Then, the egg cracked,” the experimenter advanced the slide to show the cracked egg (replacing the previous image in the same location). She advanced to slide again to show the hatching egg while reciting the final “...and a baby chick came out!”

Next, also unlike in Experiments 1 and 2, the experimenter asked the child to repeat back the story they had just heard, to help ensure that children had processed the story. The experimenter asked, “Now, can you tell me what happened in that story?,” and prompted the child with “and then what happened?” if necessary. If the child did not accurately repeat all three steps, the

experimenter re-iterated them. Children were not shown the images again during this story-repetition phase. To avoid penalizing younger children for shyness, those who did not repeat back the story on every trial were not excluded, nor were trials in which children did not repeat the story without assistance. Below we report analyses that examine whether such children differed from those who were able to repeat the story.

The test phase was identical to Experiments 1 and 2. Two cards were placed on the table and the child was asked to select the one that best showed the story.

Table 1. Design of Experiments 1 and 2 vs. Experiment 3

Exp.	Story		Repeat	Test
1 & 2	“First there was an egg, then the egg cracked, and a baby chick came out.”		N/A	<p>“Which one shows that story? Which is better?”</p> <div> </div>
3	<p>“First there was an egg...”</p>	<p>“Then the egg cracked...”</p>	<p>“And a baby chick came out!”</p>	<p>“Now can you tell me what happened in that story?”</p> <p>“Which one shows that story? Which is better?”</p> <div> </div>

4.1.3 Parent survey. Some of the participating children’s parents ($n = 79$ in Experiment 3) also completed a survey on their children’s emergent literacy and print exposure. Parents indicated whether their child attended preschool, and answered eight yes-or-no questions about their child’s reading and writing skills. Questions included whether their child was able to identify or write *some* letters, identify or write *all* letters, read or write their own name, and read or write at least five other words. Each child was given a writing score of 0-4 and a reading score of 0-4, based on

their parent's responses. Secondly, to assess children's print exposure in the home, the parent completed an adaptation of the Children's Title Checklist (CTC; Sénéchal et al, 1996; see Appendix). The CTC is a list containing 40 popular children's book titles (e.g., *Where the Wild Things Are*) and 20 foils which were not real titles (e.g., *Three Cheers for Gloria*). Parents were instructed to indicate each title they were familiar with (whether or not they had read the book) by checking a box next to the title. Each child was later assigned a print exposure score equivalent to their parent's number of hits minus false alarms.

4.2 Results

4.2.1 Story repetition. Prior to completing the test phase, children in Experiment 3 were asked to repeat the story back in their own words, with the goal of helping them to encode it in memory. Children repeated the whole story back accurately on 77% of trials, including 63% of trials for 3-year-olds and 90% of trials for 4-year-olds. Unsurprisingly, the number of trials on which children repeated back the story on the first try was correlated with their age, $r = 0.5$, $p < 0.001$. Nevertheless, when this factor was included in a logistic regression model along with age and condition, it was unrelated to performance in the card selection task, $\beta = 0.1$, $p = 0.15$; $\chi^2(1) = 2.1$, $p = 0.15$. Given this, all data were retained for the following analyses, regardless of whether the child repeated back the story independently on a given trial.

4.2.2 Scrambled conditions. Data from the two "scrambled" conditions (i.e., comparisons of ordered vs. unordered cards) were analyzed in the same fashion as data from Experiment 2. We modeled the likelihood of choosing the ordered image as a function of age (as a continuous, scaled variable) and condition (Horizontal Scrambled or Vertical Scrambled) using a mixed-effects logistic regression. Age significantly improved the fit of the model, $\beta = 0.26$, $p = 0.1$; $\chi^2(1) = 15.8$, $p < 0.001$, and there was an interaction of age and condition, $\beta = 0.51$, $p = 0.04$; $\chi^2(1) = 4.4$, $p =$

0.04. Older children were more likely to choose ordered images, and, unexpectedly, the preference for ordered over scrambled images was more pronounced in the Vertical Scrambled condition (TB vs. Scrambled) than in the Horizontal Scrambled condition (LR vs. Scrambled).

The frequency distributions of responses in Experiment 3 are shown in Figure 3, with the Scrambled conditions represented in the rightward two columns. We found that the median percentage of trials in which 3-year-olds chose the ordered card was 62% [50%-62%] in the Horizontal Scrambled condition. Unlike our finding in Experiment 2, this was significantly greater than chance, one-sample sign-test, $s = 12$, $p = 0.003$. However, the median percentage among 3-year-olds was only 50% [38%-61%] in the Vertical Scrambled condition, which was not different from chance, $s = 3$, $p = 0.5$. The median percentage of trials in which 4-year-olds chose the ordered card was also 62% [52%-99%] in the Horizontal Scrambled condition and 94% [64%-100%] in the Scrambled Vertical condition. Again, unlike our findings of Experiment 2, 4-year-olds performed better than chance in both conditions, s 's > 13 , p 's < 0.001 . Our finding that 4-year-olds showed a stronger preference for ordered images in the Vertical Scrambled condition than the Horizontal Scrambled condition was unexpected. While this finding does not support the hypothesis that the LR axis is uniquely privileged, we have no theoretical explanation for why space-time mappings along the vertical axis would be stronger in children this age.

Figure 3. The proportions of preschoolers who chose conventional linear representations of time in Experiment 3. The “conventional” choice was LR in the Horizontal Scrambled, Horizontal, and Perpendicular conditions and TB in the Vertical Scrambled and Vertical conditions. Red vertical lines indicate medians. Dotted lines indicate chance.

4.2.3 Ordered conditions. So far we have shown that, with the methodological changes introduced in Experiment 3, preschoolers often demonstrated preferences for ordered over unordered sequences of images. This result indicates that children of this age were able to understand the task. Next, we considered data from the three conditions in which *both* cards showed ordered sequences to test whether they had direction preferences. A mixed-effects logistic regression modeled the likelihood of choosing the conventional direction as a function of age (continuous and scaled) and condition (Horizontal, Vertical, or Perpendicular). Only the interaction between factors was significant, $\beta = 0.5$, $p = 0.04$; $2(2) = 6.3$, $p = 0.04$. As shown in Fig. 3, and replicating our results in Experiment 1, the median percentages of conventional choices made by 3-year-olds in the Horizontal, Vertical, and Perpendicular conditions were all exactly 50%, 95% CIs, respectively [38%-50%]; [43%-62%]; [27%-50%], consistent with chance responding, one-sample sign tests, horizontal, $s = 5$, $p = 0.77$; vertical, $s = 7$, $p = 1$; perpendicular, $s = 3$, $p = 0.15$. The median percentage of conventional choices made by 4-year-olds in the Vertical condition was 44% [27%-50%]⁴, and, in both other conditions, 50%, 95% CI [39%-73%] in the Horizontal condition, [38%-70%] in the Perpendicular condition. Again, none were significantly different from chance (Horizontal, $s = 8$, $p = 0.79$; Vertical, $s = 5$, $p = 0.3$; Perpendicular $s = 10$, $p = 1$). Thus, although the methodological changes in Experiment 3 helped children to differentiate ordered from unordered sequences, they did not affect children's ambivalence regarding the directionality of ordered sequences. This pattern suggests that our previous failures to find directional preferences were not simply due to failures to comprehend the task, and is more consistent with the hypothesis that such preferences emerge robustly only after the age of 5.

⁴ Although this percentage did not significantly differ from 50%, a preference for BT images over TB among 4-year-olds images was also found in Tillman et al., 2018. This result is consistent with the possibility that some young children represent time along a sagittal axis, in which time flows away from the body, rather than down from the top of the page.

4.2.4 Ordered conditions vs. Scrambled conditions.

In order to test whether the preference of 3- and 4-year-olds for ordered sequences was indeed stronger than their apparently random preferences for specific directions, we conducted an analysis that directly compared performance on these tasks. To do so, we compared children's performance on the ordered conditions (Horizontal, Vertical, and Perpendicular) that required comparisons between two ordered sequences, and the Scrambled conditions (Horizontal Scrambled and Vertical Scrambled) requiring comparisons between one ordered and one scrambled sequence. We modeled the likelihood of choosing the conventional image as a function of age (as a continuous, scaled variable) and comparison type (ordered condition vs. scrambled condition; collapsed across condition within each type). We found that age significantly improved the model, $\beta = 0.47, p < 0.001$; $2(1) = 10.3, p = 0.001$, as did comparison type, $\beta = -0.75, p < 0.001$; $\chi^2(1) = 25.8, p < 0.001$, and there was a significant interaction between these factors, $\beta = -0.40, p = 0.005$; $\chi^2(1) = 7.8, p = 0.005$. Thus, children were more likely to choose conventionally-ordered cards over unordered cards than over unconventionally-ordered ones, and this difference increased with age.

4.2.5 Parent survey. Prior studies argue that direction-specific mappings between time and space in children and adults are a result of reading and writing experience (e.g., Autry et al., 2019; Bergen & Chan Lau, 2012). Our finding that robust preferences for conventionally-ordered representations of time only emerged around that age when children enter school is consistent with this possibility. To provide a slightly stronger test of this, we next asked how children's responses were related to their parents' report of their early literacy and print exposure. Because surveys were only available from a subset of parents ($n = 98$ across studies; see Appendix Table 2),⁵ we collapsed across all conditions and experiments for which we had any parent-report data. The results of this analysis

⁵ Parents of children tested in daycares or preschools were not available to complete the survey.

should therefore be interpreted with caution. Examining the relationship between children's likelihood of preferring conventional representations of events and these literacy measures, we found a significant correlation of task performance with writing scores, $r = 0.26$, $p = 0.01$, but not with reading scores, $r = 0.18$, $p = 0.07$, or print-exposure scores, $r = -0.06$, $p = 0.6$. When all of these factors were included in a linear regression also including comparison type (ordered vs. scrambled conditions), only comparison type, $\beta = 0.17$, $p = 0.002$, and writing scores, $\beta = 0.06$, $p = 0.04$, were significant predictors of children's performance on the picture-selection task, model $F(5, 89) = 3.5$, adjusted $R^2 = 0.12$, $p = 0.006$. However, as expected, several literacy factors were themselves correlated, including reading and writing scores, $r = 0.63$, $p < 0.01$, and writing scores and age, $r = 0.57$, $p = 0.01$.

4.3 Discussion

With additional scaffolding to support children's comprehension of the task, we detected modest preferences for ordered horizontal sequences in both 3- and 4-year-olds, and a strong preference for ordered vertical sequences in 4-year-olds. These methodological changes led to improvements in preschoolers' performance in the "scrambled" conditions (relative to Exp. 2), and showed that preschoolers were not simply responding randomly due to incomprehension of the task. However, they did not appear to affect children's directional preferences. Unlike most 5-year-olds and nearly all adults (Exp. 1), most younger children did not demonstrate preferences for LR over either RL or TB representations of events, nor for TB over BT representations. Because this was true *despite* their demonstrated sensitivity to the ordering of images in the scrambled conditions, particularly in 4-year-olds, the overall pattern of results is consistent with the hypothesis that most English-speaking children do not develop direction preferences for spatial representations of temporal events before the age of 5.

5. General Discussion

We explored the development of mental associations between time and space by asking whether preschoolers prefer spatial representations of temporal events that have a conventional linear structure over those that do not. As in previous studies, we found that English-speaking adults strongly preferred spatial representations of events that were sequentially ordered across the horizontal axis from left-to-right (LR), consistent with their reading and writing direction. We also found that most 5-year-old children preferred depictions of events ordered from LR to those ordered right-to-left (RL). However, directional preferences were not unique to the LR direction: both adults and 5-year-olds also preferred top-to-bottom (TB) representations of events to bottom-to-top (BT) ones. We found that children under age 5 required more scaffolding to ensure that they comprehended the task. When this was given, even 3- and 4-year-olds demonstrated preferences for sequential images to images that were out-of-order with respect to the narrative. This result suggests that children acquire a predisposition to order events into spatial sequences early in development, leaving open the possibility that humans may have an innate tendency toward representing time linearly. Nonetheless, unlike adults and older children, 3- and 4-year-olds did *not* display conventional directional preferences when choosing between two ordered sequences. These findings suggest that specific directional associations between temporal narratives and spatial positions (e.g., an LR bias) are not innate, but are learned gradually during childhood.

Our findings are consistent with past work showing that although elementary-school children and adults have culture-specific biases in the way they spatially represent temporal events (e.g., Bergen & Chan Lau, 2012; Fuhrman & Boroditsky, 2010; Nachshon, 1983; Ouellet et al., 2010; Tillman et al., 2018; Tversky et al., 1991), most preschoolers do not (Tillman et al., 2018; but see Autry et al., 2019). Due to concerns that the difficulty of prior tasks may have led to

underestimation of children's knowledge, here we designed a series of increasingly simple tasks. Unlike prior tasks, these did not require children to use a complex timeline (Busby Grant & Suddendorf, 2009; Friedman, 2000, 2002; Friedman & Kemp, 1998; Hudson & Mayhew, 2011; Tillman et al., 2017; Tillman & Barner, 2015), to produce symbolic, spatial representations of time (Tillman et al., 2018; Tversky et al., 1991), or to interpret sequential images and create their own narratives to describe them (e.g., Berman, 1988; Bulf et al., 2016; Poulsen et al., 1979; Trabasso & Nickels, 1992; Trabasso & Stein, 1994; Zampini et al., 2013, 2017). Instead, this task provided the child with the temporally organized narrative (a verbal story), and the spatial stimuli (sequences of images organized in lines). In the case of Experiment 3, we also provided a demonstration of which part of the event each image was meant to represent (i.e., simultaneous presentation of each image with the relevant part of the story, prior to test). Moreover, the child needed only to point to a card to respond to the test questions. Using these methods, we found evidence that direction preferences do not emerge until around the time that North American children begin their formal education in kindergarten. Suggesting that this was not simply a result of overall task difficulty, we found that preschoolers were able to distinguish representations of time that were well-ordered with respect to the verbal narrative from ones that were not.

There is debate over whether the MTL is entirely learned, or if it might be the result of a biologically-determined tendency to represent time in a linear spatial fashion. The present findings fail to support accounts on which humans have an innate bias to represent time specifically from LR (e.g., Bulf et al., 2016; Chatterjee et al., 1999; Dehaene et al., 1993; Vicario et al., 2007; see Pitt & Casasanto, 2019, for discussion). Given that the youngest children we tested were 3 years old, it is possible that their preferences for linear representations of time (over unordered ones) were learned, albeit at an earlier point in development than are direction preferences. However,

these data also leave open the possibility that children's preference for ordered sequences, particularly along the horizontal axis, might be innate.

The present findings also suggest that a preference for linear representations of time is present at an earlier age than some previous work demonstrates. For example, in a prior study, researchers asked 4-year-olds to place stickers on paper to represent the relative locations of temporal events like breakfast, lunch, and dinner. When they did not provide any spatial priming, not only did a large majority fail to show a preference for LR to RL representations of time (consistent with the present results), most children also did not produce ordered linear arrangements at all (Tillman et al., 2018). This contrasts with the present finding that even some 3-year-olds demonstrated a preference for ordered to unordered sequences in a two-alternative forced-choice task. Thus, while task difficulty cannot account for the lack of directional preferences in the current study, the need to produce linear representations of temporal events in prior studies may indeed have made them less sensitive to some aspects of children's knowledge.

Still, it remains possible that even the present results underestimate children's early knowledge. In contrast to both the findings of the sticker-placement task and the present results, another recent study argues that 3-year-olds have an LR-specific MTL. In their Color Card task, Autry and colleagues (2019) asked children to place cards on a table one at a time as the corresponding colors appeared sequentially on a computer screen. They found that preschoolers made LR arrangements more frequently than chance. The Color Card task made no reference to abstract time words or task-external temporal events. As discussed above, we do not believe children had any global difficulty with the stimuli in the present task that could account for this discrepancy in results. Another possibility is that the Color Card task required a fundamentally

different type of temporal cognition.⁶ A recent theory of temporal cognitive development makes a distinction between temporal *updating*, an evolutionarily-ancient ability to keep track of perceptual changes in the environment as they unfold, and temporal *reasoning* about the ordering of events (Hoerl & McCormack, 2019). Temporal reasoning, which emerges around age 4 or 5, is thought to be required when the events under consideration are not ongoing or if there is a mismatch between the order information is received and the order events occur (Hoerl & McCormack, 2019). Paralleling this distinction, the Color Card task required children to spatially represent an ongoing perceptual sequence, while our card selection task required them to consider event sequences that were not ongoing.⁷ Thus it is possible the Color Card task required only temporal updating, but our task required the later-developing temporal reasoning. Use of the updating system might also help explain why even 7-month-olds show a direction bias when implicitly learning sequences of shapes (Bulf et al., 2016). It is possible that the development of the MTL might help support the transition from reliance only on updating to mature temporal reasoning. This hypothesis could be explored in future research.

Although studies have come to different conclusions about the onset of the MTL, they provide convergent evidence that it develops gradually across the preschool and early school years. Across studies, school-aged children consistently prefer culturally-conventional directions (e.g., Autry et al., 2019; Tillman et al., 2018; Tversky et al., 1991), while preschoolers' performance is

⁶ A third, less interesting, possibility is that the difference in the reported frequency of LR mappings among preschoolers across studies is simply due to differences in the amount of data that were excluded, which was much larger in the study by Autry and colleagues (2019) than in the present study. It is also possible that the bias toward creating LR arrangements in the Color Card task was related to handedness: given that nearly all participants were right-handed, it may simply have been most efficient to place each subsequent card to the right of the previous one.

⁷ In the sticker-placement task, children were also required to consider temporal items in an order that didn't match their actual ordering, by placing two event-denoting stickers relative to one representing an intermediate time (Tillman et al., 2018; Tversky et al., 1991).

weaker and more variable. Further, the MTL does not emerge at the same age in every child, as indicated by several bimodal distributions across our experiments (see Figures 2 and 3). Why might some children develop directional space-time mappings prior to entering school? While these data should be interpreted with caution, preliminary findings from our parent survey suggest that precocious development of the MTL may be linked to earlier writing skills.⁸ Autry and colleagues (2019) also found a correlation between children's comprehension of print and their production of LR representations, further suggesting that literacy is linked to the development of the MTL.

To summarize, we have presented data from 3 experiments demonstrating a protracted developmental trajectory in children's acquisition of adult-like preferences for visual representations of events. Beginning at age 3, children were able to associate progress in time with relative order in space, but only after the images had been unveiled one at a time as the relevant elements of an accompanying story were told. However, conventional direction preferences do not emerge in most children until the age of 5, when there is typically a substantial increase in children's exposure to spatial artifacts for time and explicit instruction in reading. Finally, even at that age, children's preferences for culturally conventional spatial representations of time remained far weaker than those of adults and were not limited to the LR direction.

⁸ Note that, while we did not find an effect of preschool attendance in this analysis, there is variation (across preschools, elementary schools, and cultures) in when children begin to receive explicit instruction on writing.

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Appendix

Stimuli

Appendix Table 1: Event stories

Event	<i>First..</i>	<i>Then..</i>	<i>And..</i>	Images (LR)		
Egg	there was an egg	the egg cracked	a baby chick came out!
Ice Cream	there was an ice-cream	it started melting	it was all gone!
Drawing	someone started drawing a stem	they added blue petals	it was a flower!
Caterpillar	there was a caterpillar	it made a cocoon	it turned into a butterfly!
Baby	a baby was born	he started growing	he was a big kid!
Apple	there was an apple	someone took a bite	they ate it all!
Rose	a rose started growing	it opened	it got big and pink!
Watermelon	there was a watermelon	we cut it all up	everyone ate it!

Appendix Figure 1: *Example picture cards*. The three images on each card depict the three stages in the Egg story (see Table 1). Cards used in Experiments 1 and 3: **(A)** LR, left-to-right, **(B)** RL, right-to-left, **(C)** TB, top-to-bottom, and **(D)** BT, bottom-to-top. Additional cards used only in Experiments 2 and 3: **(E)** Scrambled Horizontal and **(F)** Scrambled Vertical.

Parent survey

Parents of a subset of participants completed the survey below. The Children's Title Checklist was adapted from the original used by Senegal and colleagues (1996, 1998) such that 11 real titles that were recognized by less than 30% of parents in their 1998 study were replaced by more recent, popular titles aimed at children in the age range of our subjects (e.g., *The Rainbow Fish*; *Rosie Revere, Engineer*). All real children's book titles are checked below for reference, but were not indicated on the survey parents received. A breakdown of the participants and average scores on each measure is shown in Appendix Table 1.

Appendix Table 2: Participants whose parents completed the survey, and mean scores across parents.

Condition	<i>n</i>	Age, years <i>M</i> (sd)	Writing score, 0-4 <i>M</i> (sd)	Reading score, 0-4 <i>M</i> (sd)	CTC <i>M</i> _{hits-FA} (sd)
horizontal	2	4.3 (0.3)	2 (0)	2.5 (0.7)	9.5 (3.5)
vertical	9	4.7 (0.3)	1.7 (1.4)	2.4 (1.1)	11.2 (7.9)
mixed	15	4.2 (0.4)	1.4 (1.4)	2.0 (1.3)	12.4 (5.7)
scrambled horizontal	38	4.0 (0.6)	1.2 (1.0)	2.0 (0.9)	12.9 (6.1)
scrambled vertical	34	4.0 (0.6)	1.3 (1.1)	1.8 (1.1)	11.9 (6.1)
Total	98	4.1 (0.6)	1.3 (1.1)	2.0 (1.0)	12.2 (6.1)

1.1 Parent survey:

Part 1: Circle each that is true of your child:

Attends
school/preschool

Recognizes some
letters

Writes some
letters

Reads his/her
name

Writes his/her
name

If so, grade/year:

Recognizes all
letters

Writes all letters

Reads 5 or more
words

Writes 5 or more
words

Part 2: Children's Title Checklist

*This list contains some names of children's storybooks and some unrelated titles. Put a check in the box beside the name of any children's book that you **recognize** - you do not have to have read the book - but please do not guess!*

Just Me and My Dad	X	Don't Let the Pigeon Drive the Bus!	X	Terry Toad	
Wonderful Pigs of Jullian Jigs	X	Love You Forever	X	I Want My Hat Back	X
What Do I Hear Now?		Franklin in the Dark*	X	Where the Wild Things Are	X
The Polar Express	X	Press Here	X	The Book with No Pictures	X
Go Dog Go	X	Tracy Ticks		Eleanor and the Magic Bag	
The Runaway Bunny	X	I Hear a Knock at My Window		Rachel's Real Dilemma	
Green Eggs and Ham	X	Big Old Trucks		Alexander and the Terrible, Horrible, No Good, Very Bad Day	X

Mortimer	X	Jelly Belly	X	Saggy Baggy Elephant	X
Zack's House		The Poky Little Puppy	X	Snowflakes Are Falling	
The Toy Truck		Goodnight Moon	X	Those Darn Squirrels!	X
The Rainbow Fish	X	How Steven Found a Pet		Harry the Dirty Dog	X
Flotsam	X	A Pocket for Corduroy	X	Tootle	X
Hello Morning, Hello Day		The Paper Boat's Trip		Winter Fun on Snowy Days	
Kimberly's Horse		Bears on Wheels	X	Alligator Pie	X
Scruffy the Tugboat	X	Velveteen Rabbit	X	Matthew and the Midnight Tow Truck	X
How Wishes Come True		The Very Hungry Caterpillar	X	Amelia Bedelia	X
The Snowy Day	X	Stellaluna	X	Thomas' Snow Suit	X
Murmel, Murmel, Murmel	X	Worry No Longer		Martha Rabbit's Family	
Red is Best	X	Three Cheers for Gloria		Clarissa's Patch	
Franklin in the Dark*	X	My Friend is Sad	X	Rosie Revere, Engineer	X

*This title was listed twice in error. Parents were awarded 2 points for correctly identifying it both times.

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