Children spontaneously track temporal and causal relations within narratives

Katharine A. Tillman

Department of Psychology, The University of Texas at Austin

Nestor Tulagan

School of Education, University of California, Irvine

Jess Sullivan

Department of Psychology, Skidmore College

Corresponding author:

Katharine Tillman

ktillman@utexas.edu

Abstract

How do children understand the temporal and causal relations among events in a narrative? We explored the roles of (a) connectives like *before* and *because*, (b) chronology, and (c) world knowledge in supporting children's inferences about causal and temporal relations in narrative. We told 3- to 7-year-old children stories containing two events. We then unexpectedly asked them to retell the stories from memory, to test what they had encoded. Children attended to and recalled the causal and temporal relations from the stories. They were more likely to modify their retellings when the events in the story were not described chronologically, or when the causal relations were inconsistent with children's knowledge of the real world. These tendencies interacted with the specific connectives in the story and their positioning. These findings indicate that children as young as 3 spontaneously integrate their knowledge of connectives, sentence structure, and the world when processing narratives.

Keywords: cognitive development; language acquisition; temporal cognition; causal inference; narrative

Introduction

Imagine the following sequence of events unfolding during a baseball game: (1) the pitcher throws the ball; (2) the batter hits it; (3) an outfielder picks up the ball; (4) the outfielder throws it to first base; (5) the pitcher's team wins the game. Watching this, anyone can see that the ball was thrown before it was hit, and infer that the impact from the bat caused the ball to fly. Indeed, even 4-month-old infants draw this type of inference about physical causality from perceptual evidence (Cohen & Amsel, 1998). However, many of the causal relations that underlie the events in baseball cannot be perceived: understanding them requires knowing the rules of baseball. Why does the outfielder pick up the ball, and why do they throw it to first base (as opposed to third, or to the audience)? How does the act of throwing the ball end the game? To know that these events are causally related, one needs to know more than the causal relations between physical entities: one needs to understand the temporal and causal rules that structure a baseball game. One of the most powerful properties of language is its ability to convey temporal and causal information about events that are not ongoing, cannot be seen, or do not provide direct evidence of a cause. A narrative like, "The baseman caught the ball before the runner made it to base, and so the runner was out. Because there were already two outs and it was the final inning, the pitcher's team won," gives insight into the causal and temporal relations between events that can't be gleaned from perception alone. How do humans learn to extract this causal and temporal information from narratives? Here, we explore the linguistic cues that 3- to 7-year-old children use to interpret causal and temporal relations in language.

There are many sources of information that children might draw on to determine the causal and temporal relations between the events conveyed via language. Here, we focused on three such sources of information: (1) connectives like *because* and *before*, (2) the order of clauses and events

within sentences, and (3) the integration of linguistic information with world knowledge. To understand how these factors interact, consider the following sentences:

(1) The man ate chicken soup [and so; because; before; after] he got very sick.

(2) The man got very sick [and so; because; before; after] he ate chicken soup.

While the words used to describe the events (“ate chicken soup” and “got very sick”) are the same in both statements, the implied relations between these events differ according to the order of clauses in the sentences, the connectives that link them, and prior experiences with soup and illness. Below we discuss what is known about children’s use of these cues to infer causal and temporal relations.

Connectives

Sentences (1) and (2) are interpreted differently depending on their connectives. Given their power to efficiently convey information about event relations, and therefore to create coherent narratives, temporal and causal connectives are among the most frequent words in adult speech and text. By age 2.5, many American children produce connectives like *before* (produced by 40% of children), *after* (54%), *because* (49%), and *so* (38%; Frank et al., 2017). And, we know that 4- to 8-year-olds use these words causally: when they are asked to tell personal stories, ~80% of their uses of *because* (and 40% of uses of *and*) establish a causal relation between two clauses (Peterson & McCabe, 1991).

While, in adult language, connectives serve as a meaningful cue to temporal ordering and to causal relations, connectives do not have concrete referents in the world, the way that children’s earliest words, like *mama* and *apple*, do. Connectives are abstract and notoriously challenging for children to learn. Some studies suggest that children take years to converge on adult-like interpretations of causal and temporal language, and do not have mature meanings for temporal

terms like *before* and *after* until at least age 5 (e.g., Clark, 1971; Weist et al., 1991). It is also possible that the semantics of the connectives change over time. For example, by some accounts, *after* is initially interpreted by children to mean *before* (Clark, 1971). On the other hand, children's patterns of success and failure with sentences containing connectives also suggest that factors other than the semantics of the connectives themselves may be at play. These factors include the positions and grammatical roles of the connectives, whether the events in the sentence are described chronologically, and whether the events are arbitrarily related, causally linked, and/or familiar to the child (e.g., Amidon & Carey, 1972, Blything et al., 2015; Clark, 1971; Coker, 1978; French & Brown, 1977). We explored several of these factors concurrently in the present study.

Chronology

Listeners may extract temporal and causal information from the order in which events are described, regardless of whether there is a connective present in the sentence. One sensible default assumption is that events are described chronologically, and thus that the events mentioned earlier within an utterance are also those that occur earlier. For example, the ordering of the sentences in the utterance “The man ate chicken soup. He got very sick” could imply that he ate the soup first, and that the soup was a possible cause of the illness. Narratives often describe events in the order in which they occur (Jakobson, 1965), and it is easier to determine how elements of a discourse are related to one another when the events are described chronologically (Bliss et al., 1998; Münte et al., 1998; Ye et al., 2012). However, English does not *require* that the order of clauses in sentences represent the chronology of events in the world. Sentences where the second clause represents an event that happened before the first are perfectly grammatical, as in (3) and (4).

(3) The man got very sick *after* he ate chicken soup.

(4) *Before* the man ate chicken soup, he got very sick.

While chronology and connectives are both useful in disambiguating the temporal ordering and causal relations in a narrative, and in many cases these cues align, they can also be contradictory, as in (3) and (4). Indeed, young children's errors interpreting sentences containing *before* and *after* often occur in cases where chronology and connectives provide contradictory cues to temporal and causal ordering (Clark, 1971; Pyykkönen & Järvikivi, 2012). This suggests that children may initially privilege order-of-mention (i.e., chronology) when determining the causal and temporal relations within an utterance (e.g., Blything et al., 2015; Clark, 1971). Neither clause order nor connectives, on their own, are sufficient to correctly establish the causal relations within a narrative. The listener must integrate both these cues, and this task may be made easier by using world knowledge.

World knowledge

In addition to explicit linguistic cues in a given narrative, children could (and should) use their prior knowledge about causal and temporal relations in the world to interpret sentences involving familiar events. For example, if a child knows that nourishing food can help make a sick person healthy, and/or that contaminated food can make a healthy person sick, they could use this information to help interpret the sentences in (1) - (4). Consistent with this idea, some studies have shown that, despite their early difficulty in resolving sentences containing *before* and *after* in unfamiliar or arbitrary contexts, 3- and 4-year-olds tend to comprehend and produce these terms appropriately when describing familiar sequences of events (Carni & French, 1984; French & Nelson, 1981). Children are more successful in reasoning about discourses that contain content they are knowledgeable about (Sullivan & Barner, 2016), including those containing causal connectives like *because* and *and so* (Sullivan et al., 2019). Nevertheless, a recent study that varied *both* world knowledge and clause order found that 3- and 4-year-olds used only order-of-mention

to judge which event came first in a two-clause sentence, regardless of whether the events followed a familiar or arbitrary sequence (Blything et al., 2015).

Limits of previous work

Although prior studies have examined children's use of connectives, clause chronology, and world knowledge to interpret complex sentences, there are several limitations to this prior work, which we sought to address in the present study. Most classic studies varied only one of these factors or co-varied them in ways that left the causes of developmental change unclear. Many prior studies also required children to perform complex tasks such as acting out events, potentially leading to failures unrelated to their linguistic abilities. Notably, one recent study avoided these issues by varying all three factors in a two-alternative forced-choice task (Blything et al., 2015). However, in this task, when listening to the sentences, children knew that their goal was to choose which event happened first, and therefore that they should pay close attention to linguistic cues relevant to resolving event relations. Thus, it is unclear whether they attend to any of these cues *spontaneously* when processing narratives (see Blything et al., 2015 for discussion). Moreover, this study (and most other prior studies) only tested comprehension of the temporal connectives *before* and *after*, and not causal connectives like *because* and *and so*. Finally, although prior work has compared children's processing of sentences where world knowledge is helpful vs. those where it is irrelevant (e.g., Blything et al., 2015; French & Brown, 1977), the strongest test of the role of world knowledge in shaping interpretation is when world knowledge *conflicts* with the other cues. The present study explicitly tests how children spontaneously process sentences whose literal meanings go *against* their understanding of the world, such as those that contain causally implausible relations, e.g., "It rained *because* the bunnies got very wet"?

The present study

We asked two primary questions about how children extract causal and temporal information from narratives. First, at what age do children begin to spontaneously track the temporal and causal relations between events in stories? Second, how do connectives, clause chronology, and world knowledge interact in children's processing and recollection of stories?

To answer these questions, we told children two-clause stories describing causal and temporal relationships (e.g., "The cat walked away *because* the dog barked"). These sentences were presented in the context of a picture-matching task that children could solve simply by attending to a single word such as *cat*. Critically, the relations between events in each story were irrelevant to the task at hand, and participants did not know their knowledge of the stories would be tested. However, after children completed the picture identification, we unexpectedly asked them to retell the story that went with each picture, to discover what they spontaneously recalled about the causal and temporal relations between events. We measured how frequently children's retellings reflected attention to connectives [*and so* and *because* in Experiment 1; *before* and *after* in Experiment 2], world knowledge [Exp. 1], and clause chronology [Exp. 2].

Experiment 1

Methods

Participants. One-hundred-thirty-nine monolingual English-speaking 3- to 7-year-olds participated ($M_{\text{age}} = 5;5$; range = 3;1 - 7;11). Children were pseudo-randomly assigned to one of three conditions: the *because* condition ($n = 59$), *and so* condition ($n = 54$), or baseline condition ($n = 26$).

Materials. We constructed eight sentence frames containing two independent clauses that could be connected with a causal connective, e.g., "The cat walked away [because/and so] the dog barked." Between-subjects, we manipulated which connective linked the two clauses: children

therefore either heard eight stories containing *and so* or eight stories containing *because* (see Table 1 for three examples). Within those eight stories, two were causally implausible (e.g., “The kids got very cold *and so* it started to snow”) and the remaining six were plausible. Pictures were created to match the sentence frames. None of the pictures depicted the causal relations within the story. All study stimuli and scripts used by research assistants during testing can be accessed at <https://osf.io/ajkr9/>.

Table 1. Example stimuli.

Picture	Prime	Plausible?	
		“And so”	“Because”
The man ate chicken soup [and so/because] he got very sick.	●	●
It rained [and so/because] the rabbits got very wet.	●
The daddy was late for work [and so/because] the bus broke down.		●

Procedure. The experimental setup is illustrated in Figure 1. Experimental sessions were audio-recorded for later transcription. Sessions consisted of three phrases: Warm-Up, Priming, and Test. In the Warm-Up phase, children were asked open-ended questions about events in their lives, e.g., “Can you tell me what you did on your last birthday?”, in order to get them producing full

sentences. In the Priming phase, the researcher placed the eight pictures on the table and told the child that they were pages that had fallen out of a storybook. The researcher then asked the child to listen as they told the stories, and to point to the picture that matched each story. Critically, individual words from the story, e.g., *bus*, were sufficient to complete this task, rendering the causal and temporal relations within the stories task-irrelevant. In rare cases, the child selected an incorrect picture, and the researcher corrected them. Each picture was turned over once it had been chosen. Participants were randomly assigned to hear the stories in one of four orders. After children heard all eight stories and identified the matching pictures, the Test phase began. In the Test phase, the experimenter showed the pictures one-at-a-time in randomized order and asked, “Can you tell me what happened in this story?”

Children in the baseline condition did not experience Priming – they were simply shown the images once in the Test (after Warm-up) and asked to describe them.

Figure 1. Experimental setup.

Coding and Analyses. Here, we use “prime” to refer to the words that children heard during the Priming phase. We use “retelling” to refer to the child’s retelling of what they heard. We use “story” as a neutral term to refer to the conceptual contents of the narrative within either the prime or retelling.

Research assistants, blind to condition and hypotheses, coded a transcription of the child’s retellings. Stories produced by the same child were never coded in sequence, so that a child’s retelling of one story could not influence the coding of their retelling of another. To classify clauses in the retellings, coders were provided with a list of all 16 events from the eight stories, and the coders were asked to identify if any of those events occurred in the child’s retelling. Children were not required to repeat the events verbatim, and coders were instructed to count an event from the prime as present if it was consistent with the original story, even if the precise wording differed substantially. For example, “The man got there slowly” would be coded as a match for the event “The daddy was late for work.” Coders recorded any connectives used by the child, which event in their retelling was the *first event*, i.e., the one that preceded/caused the other in their retelling, and whether the chain of events they described was plausible. The full instruction guide provided to coders is available at <https://osf.io/ajkr9/>.

After data were coded, we compared children’s retellings to the primes they had heard, asking which elements of the prime were preserved and which elements were changed. In particular, we asked whether children preserved the ordering of the events, e.g., regardless of which clause each event appeared in, if the “eating soup” event was the cause in the prime, did the child also produce a retelling in which the soup event was the cause? We also asked whether children preserved the ordering of the clauses, e.g., if the prime contained a cause in the 1st clause

and an effect in the 2nd, did the child’s retelling also place the cause in the 1st clause and the effect in the 2nd? Examples are shown in Table 2.

Table 2. Coded retellings of the prime “The daddy was late for work *because* the bus broke down.”

Child’s retelling	Preserved order:	
	Events?	Clauses?
The daddy was late for work <i>because</i> the bus broke down	yes	yes
The bus broke down <i>and so</i> the daddy was late for work	yes	no
The daddy was late for work <i>and so</i> the bus broke down	no	yes
The bus broke down <i>because</i> the daddy was late for work	no	no

Results

Throughout the results, the original sentence the child heard to describe each picture during the matching game is referred to as the “prime” and the child’s response, when later asked what happened, is referred to as the “retelling.”

Data Management. We decided *a priori* to analyze only retellings that contained at least two clauses, so that they could be assessed for preservation of the event relations in the story.

Our initial intention was to compare children in the baseline condition to children in the *because* and *and so* conditions, to assess the impact of the primes on children’s retellings, and ensure that the causal and temporal relations that children described couldn’t be explained by the

content of the images. Consistent with this, only 20 out of 208 retellings in the baseline condition contained at least two clauses. This suggested that the two-clause retellings provided by children in our critical conditions were the results of children's memories of the primes, not the visual content of the picture. Given the paucity of two-clause responses in the baseline condition, we do not consider it further.

Considering the retellings from the two prime conditions, we next excluded single-clause responses, because it was not possible to assess children's knowledge of the causal relationships between events when only one event was described. Unsurprisingly, excluding single-clause responses led to the disproportionate exclusion of younger children's retellings. We cannot be certain whether younger children's higher tendency to produce single-clause retellings was a limitation on production, e.g., they encoded the content of the prime but failed to retell it, or comprehension, e.g., they retold everything they remembered about the prime. The data from Blything et al. (2015) suggest this could be due to memory limitations.

Nonetheless, we retained over 50 retellings for each age group: 51 retellings for 3-year-olds; 113 retellings for 4-year-olds; 131 retellings for 5-year-olds; 140 retellings for 6-year-olds; 155 retellings for 7-year-olds. The final dataset included 590 retellings from 101 participants ranging in age from 3;2–7;11 [$M_{age} = 5;10$].

Analyses. All analyses were conducted in JMP using the GLMM add-in; in all models, we included subject as a random effect, and data were treated as binomial. We first asked whether children preserved the causal ordering of the events from the prime. In other words, if the [eating soup] event caused the [getting sick] event in the prime, did it also do so in the child's retelling? We found that this was the case in the vast majority, 78.3%, of children's retellings. Children were more likely to preserve the causal ordering of the events in the story as they got older, ($B = .42$, SE

= .11, $p = .0003$), and more likely to do so for stories containing *and so* than *because*, ($B = .35$, $SE = .14$, $p = .016$), but there was no interaction of age and connective ($B = .097$, $SE = .11$, $p = .39$).

We next asked whether children preserved the causal relations between the *clauses* in the prime. In other words, if the events in the first clause caused the events in the second clause (i.e., the events were described in chronological order), was this also the case in the retelling? We found that this was the case on 84.4% of retellings. Children's likelihood of preserving the causal relations between clauses did not increase with age ($B = .21$, $SE = .16$, $p = .18$), but was higher for stories containing *and so* than *because*, ($B = .66$, $SE = .20$, $p = .0013$); again, there was no interaction of age and connective ($B = -.06$, $SE = .16$, $p = .71$).

We next coded each retelling according to whether it preserved (a) both the event and clause order from the prime, (b) the event order only, (c) the clause order only, or (d) neither (see Table 2 for examples). To begin, we focused only on the plausible stories: those for which the events in the prime were ordered in a causally sensible way. We found that 3-year-olds preserved both elements of the story 43% of the time. Three-year-olds' retellings that didn't preserve both elements were more likely to preserve only the clause order (43%) than only the event order (3%; this is only 1 child). In contrast, 79% of 4-year-olds' retellings preserved both elements, and this percentage was similarly high for all older age groups. As shown in Figure 2A, unlike 3-year-olds, older children who did not preserve both elements of the prime were more likely to preserve event order than clause order.

Figure 2. Children's preservation of event order and clause order from (A) plausible and (B) implausible primes in Experiment 1, arranged by age.

Finally, we asked whether children incorporated world knowledge into their retellings. If children simply parroted back the primes' contents, they should have been just as likely to preserve

the causal relations between events when those relations were implausible as when they were plausible.

In a model predicting preservation of the causal relations between events from age, connective, plausibility, and a connective $\times$ plausibility interaction, we found an effect of plausibility ($B = 1.19$, $SE = .11$, $p < .0001$), an effect of age ($B = .48$, $SE = .14$, $p = .0008$) an effect of connective ($B = .44$, $SE = .18$, $p = .019$), but no interaction ($B = .05$, $SE = .11$, $p = .66$). This suggests that children *did* spontaneously process the causal relations between events, even though the task they were performing while listening to the primes did not require them to do so. As shown in Figure 2B, when the prime was causally implausible, only 12.5% of 3-year-olds' retellings preserved both their event and clause order, and this percentage remained below 50% until children reached age 7. Children across ages also rarely retained the event ordering alone, when the events that had been initially described had been causally implausible. These findings indicate that children revised implausible stories such that the causal relations between the events were more plausible. For example, a child who heard that the bus broke down because the daddy was late to work might say "Daddy was late for work because the bus broke down."

Discussion

Experiment 1 had three main findings. First, the majority of children over age 3 preserved both the event ordering and clause ordering of the prime in their retellings, even though they did not know they would be asked to recall any elements of the prime. Second, when children *didn't* preserve both elements of the prime, they typically preserved the causal relations between events in the primes they heard. Specifically, if Event A was the cause of Event B in the prime, children told stories in which Event A was the cause, regardless of which clause they placed Event A in within their retelling. Third, children didn't simply parrot back the stories presented within the

primes, but appeared to spontaneously process the causal relations within them: children were less likely to preserve the causal relations when the primes had contained *because* than they were when the primes contained *and so*. This would not be expected if children simply memorized the words they heard during the Priming phase. Further, children were less likely to preserve the causal relations that had been presented in the prime stories if they were implausible. In the latter cases, children tended to revise the story in their retelling so that it would make sense given world knowledge.

Importantly, in Experiment 1, the connective always came between the two clauses, creating a confound: for primes containing *and so*, events were described chronologically, and for primes containing *because*, they were not. Therefore it is unclear whether children were better at retelling *and so* stories because they had better comprehension of *and so*, or because they had an easier time encoding or retelling chronological stories. However, it was not possible to completely disentangle the roles of connective and chronology in Exp. 1, because sentences like “*And so* the daddy was late for work, the bus broke down” are ungrammatical.

In Experiment 2, we tested the roles of connective and chronology separately, by using the temporal connectives *before* and *after*. This is because, in Experiment 2, we were able to manipulate the placement of both connectives in the sentence, e.g., “The bus broke down *before* the daddy was late for work” vs “*Before* the bus broke down, the daddy was late for work.”

Experiment 2

Method

Participants. Eighty-one monolingual, English-speaking 4- to 5-year-olds ($M_{age} = 4;11$; range = 4;0–5;11) completed the experiment. This range was selected on the basis of prior literature

demonstrating that children’s ability to resolve sentences containing *before* and *after* improves dramatically during this age range (Clark, 1971; Blything et al., 2015). Children were pseudo-randomly assigned to one of four conditions: *before*-chronological ($n = 16$), *before*-reverse ($n = 25$), *after*-chronological ($n = 24$), and *after*-reverse ($n = 16$).

Table 3. Conditions in Experiment 2.

Condition	Example primes
<i>before</i> -chronological	The daddy was late for work <i>before</i> the bus broke down
<i>before</i> -reverse	<i>Before</i> the daddy was late to work, the bus broke down
<i>after</i> -chronological	<i>After</i> the daddy was late for work, the bus broke down
<i>after</i> -reverse	The daddy was late for work <i>after</i> the bus broke down

Materials and Procedures. The procedure was identical to Experiment 1, with two exceptions: Children (1) heard the connectives *before* or *after*, and (2) either heard the connective at the start of the prime or between the two clauses. As demonstrated in Table 3, this manipulation allowed us to ask whether children struggled more to preserve the content from the primes when the prime presented events in reverse order, such that the second event was introduced in the first clause.

Results

Data Management. As in Experiment 1, we only considered retellings that included at least two clauses. We retained a substantial number of retellings in each condition: *before*-chronological ($n = 91$), *before*-reverse ($n = 114$), *after*-chronological ($n = 123$), and *after*-reverse ($n = 46$), and our

final sample retained a total of 374 retellings from 72 participants ranging in age from 4;2-5;11 ($M_{\text{age}} = 4;11$).

Analyses. As in Experiment 1, we were interested in whether children's retellings preserved the event order and clause order of the primes they heard. Overall, 57% of children's retellings in Experiment 2 preserved the ordering of the events in the prime (i.e., which of the two events came first), and 69% preserved the ordering of the clauses in the prime (i.e., whether the story within the prime was told chronologically).

Next, we asked whether children's retellings were predicted by (a) the connective in the prime (*before* vs. *after*) and (b) whether the prime they heard was told chronologically (i.e., the first event was described in the first clause). To do so, we constructed a model predicting children's rates of preserving the event ordering in their retellings, i.e., whether the same event occurred first in both the prime and the retelling. As predictors, we included the connective (*before* or *after*), the chronology of the prime (chronological vs. reverse, see Table 2), the interaction of connective and chronology, and the child's age (continuous). We found a significant effect of age ($B = .69$, $SE = .14$, $p = .02$), a significant effect of chronology ($B = .66$, $SE = .14$, $p < .0001$), but no effect of connective ($B = -.14$, $SE = .14$, $p = .31$) or interaction of connective and chronology ($B = -.28$, $SE = .14$, $p = .052$).

Figure 3. Children's preservation of event order and clause order in their retellings of chronological and reverse-chronological primes containing *before* and *after*

Next, we predicted children's rates of preserving the *clause* ordering in their retellings, using the same model described above. Here, the only effect we found was of chronology: participants were less likely to preserve the ordering of the clauses in their retellings when that ordering did not mirror the order of events in the story ($B = 2.1$, $SE = .34$, $p < .0001$). This means that children rearranged their retellings such that the events were described chronologically, regardless of which connective was in the prime.

Post-hoc analyses testing for an effect of plausibility revealed no effect above and beyond that of chronology. This may be because, unlike "implausible" sentences in Experiment 1 that were causally impossible (e.g., "It rained because the bunnies got wet."), the "implausible" sentences in Experiment 2 were merely temporally unlikely (e.g., "It rained after the bunnies got wet.")

As in Experiment 1, we also coded whether each retelling preserved both event and clause order, event order only, clause order only, or neither. As shown in Figure 3, children's retellings of stories presented within chronological primes usually preserved both event order and clause order, and this was especially true when the chronological primes contained *before* (75.8% of retellings). Strikingly, for reverse-chronological primes containing *before*, more than half (54.3%) of children's retellings retained neither the event ordering nor the clause ordering from the prime (Figure 3). This points to a strong role for chronology in shaping children's expectations about the temporal ordering of events.

Discussion

The results of Experiment 2 showed that children's ability to retell stories they had heard varied not only by the specific connective used in the prime, but also by where the connective was placed (i.e., before the first or the second clause) and thus whether the events were described in chronological order. Our finding that the chronology of the prime shaped children's preservation of both the event and clause ordering is consistent with those reported by Blything and colleagues (Blything et al., 2015). In their study, children also heard sentences that varied in both the connective used and its position in the sentence, but the children were aware that they needed to attend to the event relations in the sentences to choose the event that happened first. By using a production task, we provide additional support for Blything and colleagues' proposal that children's early difficulties with non-chronological sentences are related to limitations in memory. Importantly, as we show, when children retold these stories, they often not only included a change in clause order (i.e., they heard non-chronological stories but told chronological ones), but also changed the ordering of the events within the stories, thereby altering their meaning.

General Discussion

Language is powerful because it allows us to represent and communicate causal and temporal relationships that are not ongoing, perceptible, or possible in the real world. The abstract nature of temporal and causal language and the complexity of narratives pose challenges to child language learners. We explored the cues children use to make inferences about causal and temporal relationships in narratives. We primed children with two-clause stories that included causal (Exp. 1) and temporal (Exp. 2) connectives. Importantly, this was done during a picture-matching game that did not require children to process the causal and temporal relations in order to succeed. Afterward, we asked them to retell the stories, and we analyzed what information about the stories they spontaneously retained. Our primary finding is that, by 3 to 4 years of age, children robustly retold stories with the same causal and temporal relations they had heard. This finding indicates that young children attended to and retained temporal and causal relations from language even when these relations were task-irrelevant. Moreover, children of all ages were sensitive to the temporal and causal relations that exist across clauses. In Experiment 1, regardless of the specific events described, if a child heard a prime in which a causal event occurred in the first clause, they likely retold a story with the same clause structure.

Beyond this, our findings showed that children were not simply acting as noisy tape recorders: they spontaneously *restructured* their input in their retellings. For example, children in Experiment 1 restructured their retellings so that their retellings would be causally plausible, even when the prime they had heard presented a causally implausible story (e.g., that the bus broke down *because* the daddy was late for work). In Experiment 2, where we were able to disambiguate the relative roles of connective (e.g., *after* vs. *before*) and chronology (e.g., whether the order of

the clauses within the prime matched the order in which the events occurred), children were also less likely to retain clause and event ordering when the stories they heard were not chronological.

Prior studies have also explored how world knowledge impacts children's production and comprehension of sentences containing connectives, often by comparing cases where the ordering of events was arbitrary to cases where the order followed a familiar sequence (e.g., the steps involved in a trip to the grocery store) and/or were causally related, finding mixed results (Blything et al., 2015; Carni & French, 1984). Here, we showed that while children's retellings were strongly influenced by world knowledge when the sentences they heard violated real-world causal relations (Exp. 1), this factor did not reach significance when sentences merely violated a more likely real-world temporal ordering (Exp. 2, see also Blything et al., 2015).

Why might children struggle more to encode and reproduce stories in which events are not described chronologically? One possibility, discussed by Blything and colleagues (2015), is that these narratives have particularly high memory and information processing demands (i.e., because children must retain both clauses in mind while mentally "re-organizing" them to arrive at the correct interpretation of the sentence). Consistent with this possibility, the researchers found that stronger working memory skills were predictive of better performance on a task that required children to indicate which of two events happened first, after hearing either a chronological or reverse-chronological sentence.

It is also possible that children's difficulties with reverse-chronological sentences are related to early limitations in their temporal or causal reasoning skills. For instance, preschoolers have more difficulty with causal and counterfactual reasoning tasks that require them to reason from effects to causes (i.e., reverse-chronologically) than from causes to effects (i.e., chronologically, e.g., Erb & Sobel, 2014; Hong et al., 2005). Children under around age 5 tend to

struggle with tasks in which they receive information about events in an order that is inconsistent with the order in which those events actually occur, regardless of whether these tasks are specifically designed to test children's comprehension of terms like *before* and *after* (see Hoerl & McCormack, 2019 for discussion). By age 4 children are able to sort cards to indicate the sequential order of familiar events, but they remain unable to accurately reverse the order until age 5 (Friedman, 1990). Within the temporal reasoning literature, such failures are sometimes described as being limitations on temporal perspective-taking, the ability to mentally project oneself forward and backward along a "mental timeline" to adopt multiple points of view. This inability to reverse sequential temporal representations is a possible source of children's difficulty with comprehension of *before* and *after* in contexts where there is a mismatch between the order in which events are mentioned and the order in which they occurred.

Indeed, several prior studies have found correlations between children's comprehension of *before* and *after* and children's reasoning about the order of events, when these two skills were assessed separately (McCormack & Hanley, 2011; Trosborg, 1982; Weist et al., 1991, 1997, 1999). Such correlations held even after the effects of age were controlled for, suggesting that specific developments in temporal language acquisition and temporal reasoning are linked during the preschool period. It is not possible to surmise from these correlational studies whether language or cognition leads the way for improved performance in the other domain. However, authors of these studies argue that their results likely show an effect of temporal reasoning skill on language acquisition (not vice-versa), supporting the suggestion that children's prolonged difficulty with *before* and *after* may be due to an inability to flexibly represent the relationships between events. This topic should be addressed further in future research.

In conclusion, the present findings indicate that, from early in language acquisition, children process narratives in sophisticated ways, spontaneously integrating their knowledge of connectives, sentence structure, and the world.

References

- Amidon, A., & Carey, P. (1972). Why five-year-olds cannot understand before and after. *Journal of Verbal Learning and Verbal Behavior*, 11(4), 417–423. [https://doi.org/10.1016/S0022-5371\(72\)80022-7](https://doi.org/10.1016/S0022-5371(72)80022-7)
- Bliss, L. S., McCabe, A., & Miranda, A. E. (1998). Narrative assessment profile: Discourse analysis for school-age children. *Journal of Communication Disorders*, 31(4), 347–363. [https://doi.org/10.1016/S0021-9924\(98\)00009-4](https://doi.org/10.1016/S0021-9924(98)00009-4)
- Blything, L. P., Davies, R., & Cain, K. (2015). Young Children’s Comprehension of Temporal Relations in Complex Sentences: The Influence of Memory on Performance. *Child Development*, 86(6), 1922–1934. <https://doi.org/10.1111/cdev.12412>
- Carni, E., & French, L. A. (1984). The acquisition of before and after reconsidered: What develops? *Journal of Experimental Child Psychology*, 37(2), 394–403. [https://doi.org/10.1016/0022-0965\(84\)90011-0](https://doi.org/10.1016/0022-0965(84)90011-0)
- Clark, E. V. (1971). On the acquisition of the meaning of before and after. *Journal of Verbal Learning and Verbal Behavior*, 10(3), 266–275. [https://doi.org/10.1016/S0022-5371\(71\)80054-3](https://doi.org/10.1016/S0022-5371(71)80054-3)
- Cohen, L. B., & Amsel, G. (1998). Precursors to infants’ perception of the causality of a simple event. *Infant Behavior and Development*, 21(4), 713–731. [https://doi.org/10.1016/S0163-6383\(98\)90040-6](https://doi.org/10.1016/S0163-6383(98)90040-6)
- Coker, P. L. (1978). Syntactic and semantic factors in the acquisition of before and after*. *Journal of Child Language*, 5(2), 261–277. <https://doi.org/10.1017/S0305000900007467>
- Erb, C. D., & Sobel, D. M. (2014). The development of diagnostic reasoning about uncertain events between ages 4–7. *PloS One*, 9(3), e92285.

- Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2017). Wordbank: An open repository for developmental vocabulary data. *Journal of Child Language*, 44(3), 677–694. <https://doi.org/10.1017/S0305000916000209>
- French, L. A., & Brown, A. L. (1977). Comprehension of before and after in logical and arbitrary sequences. *Journal of Child Language*, 4(2), 247–256.
<https://doi.org/10.1017/S0305000900001641>
- French, L. A., & Nelson, K. (1981). *Temporal Knowledge Expressed in Preschoolers' Descriptions of Familiar Activities*. <https://eric.ed.gov/?id=ED209930>
- Friedman, W. J. (1990). Children's Representations of the Pattern of Daily Activities. *Child Development*, 61(5), 1399–1412. <https://doi.org/10.1111/j.1467-8624.1990.tb02870.x>
- Hoerl, C., & McCormack, T. (2019). Thinking in and about time: A dual systems perspective on temporal cognition. *Behavioral and Brain Sciences*, 42, e244.
<https://doi.org/10.1017/S0140525X18002157>
- Hong, L., Chijun, Z., Xuemei, G., Shan, G., & Chongde, L. (2005). The influence of complexity and reasoning direction on children's causal reasoning. *Cognitive Development*, 20(1), 87–101. <https://doi.org/10.1016/j.cogdev.2004.11.001>
- Jakobson, R. (1965). Quest for the Essence of Language. *Diogenes*, 13(51), 21–37.
<https://doi.org/10.1177/039219216501305103>
- McCormack, T., & Hanley, M. (2011). Children's reasoning about the temporal order of past and future events. *Cognitive Development*, 26(4), 299–314.
<https://doi.org/10.1016/j.cogdev.2011.10.001>
- Münte, T. F., Schiltz, K., & Kutas, M. (1998). When temporal terms belie conceptual order. *Nature*, 395(6697), 71–73. <https://doi.org/10.1038/25731>

- Peterson, C., & McCabe, A. (1991). On the Threshold of the Storyrealm: Semantic Versus Pragmatic Use of Connectives in Narratives. *Merrill-Palmer Quarterly*, 37(3), 445–464.
- Pyykkönen, P., & Järvikivi, J. (2012). Children and situation models of multiple events. *Developmental Psychology*, 48(2), 521.
- Sullivan, J., & Barner, D. (2016). Discourse bootstrapping: Preschoolers use linguistic discourse to learn new words. *Developmental Science*, 19(1), 63–75.
<https://doi.org/10.1111/desc.12289>
- Sullivan, J., Boucher, J., Kiefer, R. J., Williams, K., & Barner, D. (2019). Discourse Coherence as a Cue to Reference in Word Learning: Evidence for Discourse Bootstrapping. *Cognitive Science*, 43(1), e12702. <https://doi.org/10.1111/cogs.12702>
- Trosborg, A. (1982). Children's comprehension of 'before' and 'after' reinvestigated*. *Journal of Child Language*, 9(2), 381–402. <https://doi.org/10.1017/S0305000900004773>
- Weist, R. M., Atanassova, M., Wysocka, H., & Pawlak, A. (1999). Spatial and temporal systems in child language and thought: A cross-linguistic study. *First Language*, 19(57), 267–308.
- Weist, R. M., Lyytinen, P., Wysocka, J., & Atanassova, M. (1997). The interaction of language and thought in children's language acquisition: A crosslinguistic study. *Journal of Child Language*, 24(1), 81–121.
- Weist, R. M., Wysocka, H., & Lyytinen, P. (1991). A cross-linguistic perspective on the development of temporal systems*. *Journal of Child Language*, 18(1), 67–92.
<https://doi.org/10.1017/S0305000900013301>
- Ye, Z., Kutas, M., George, M. S., Sereno, M. I., Ling, F., & Münte, T. F. (2012). Rearranging the world: Neural network supporting the processing of temporal connectives. *NeuroImage*,

59(4), 3662–3667.