Children's spontaneous inferences about time and causality in narrative

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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

During a baseball game, the following sequence of events unfolds: (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 baseman'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 et al., 1998). However, many of the event relations cannot be perceived, and understanding them requires knowledge of the rules of baseball. Therefore, a novice without this prior knowledge will need help to understand how the events are causally related. 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 don't 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, and the baseman's team won," gives insight into the causal and temporal relations between events that can't be gleaned from perception alone. 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 in a story. Here, we focused on (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 events (eating soup and getting sick) are the same across all these statements, the implied relations between these events differ as a function of 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 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" (40%), "after" (54%), "because" (49%), and "so" (38%; Wordbank, 2016). Children's use of these words is not random: when 4- to 8-year-olds are asked to tell personal stories, ~80% of their uses of *because* (and only 40% of uses of *and*) establish a causal relation between two clauses (Peterson & McCabe, 1991). Such connectives serve as useful cues to the causal structure of narratives (although, of course, it is possible to make causal and temporal inferences about sentences in the absence of these connectives).

While connectives could serve as a meaningful cue to temporal ordering and to causal relations between events, these words are fundamentally abstract, and therefore challenging. Some studies suggest that children require several 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 to mean *before* (Clark, 1971). Nevertheless, children's patterns of success and failure with sentences containing connectives suggest that factors other than 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, Davies, & Cain, 2015; Clark, 1971; Coker, 1978; French & Brown, 1977). We explored many of these factors concurrently in the present study.

Chronology Listeners may extract temporal and causal information from the order in which events are described, whether or not there is a connective present in the sentence. For example, the ordering of the sentences in the utterance "The man ate chicken soup. He got very sick" could lead both to the inference that he ate the soup first, and that the soup was the cause of the illness. Most narratives describe events in the order in which they occur (Jakobson, 1966), and it is easier to compute discourse coherence when this is the case (Bliss, McCabe, & Miranda, 1998; Münte, Schlitz, & Kutas, 1998). One sensible default assumption is that events are described chronologically, and thus that the events mentioned earlier within a single sentence also occur earlier.

However, importantly, English does not *require* that the order of clauses in sentences represents the chronology of events in the world. Sentences where the second clause represents an event that happened before the first are perfectly legal, e.g., "The man got very sick *after* he ate chicken soup." 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 the example above, and in the sentence "*Before* the man ate chicken soup, he got very sick." Indeed, young children's errors interpreting sentences containing *before* and *after* often occur in these situations, suggesting that they may initially privilege order-of-mention as a cue to meaning (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 information about them both, and this task may be made easier by using world knowledge.

World knowledge In addition to the explicit linguistic cues present in a given narrative, children could (and should!) use their prior knowledge about causal/temporal relations in the world to interpret sentences involving familiar events. For example, in sentences 1-2, prior knowledge of soup and illness might help to resolve the causality in each sentence, if the child knows that soup can help make a sick person healthy, and/or that contaminated food can make a healthy person sick. Consistent with the idea that children rely on world knowledge in early narrative comprehension, 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). More generally, previous work has shown that children are more successful in reasoning about discourses that contain content that they are knowledgeable about (Sullivan & Barner, 2016). 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 order, and world knowledge to interpret complex sentences, there are several limitations to this prior work. 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 more 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. Therefore, 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*. 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), it remains unclear how children process sentences whose 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"[1]? We sought to address these limitations in the present study.

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/causal relations between events in stories? Second, how do connectives, clause order, and world knowledge interact in children's processing and recollection of stories?

To answer these questions, we told children 2-clause stories describing causal and temporal relationships (e.g., "The cat walked away because the dog barked"). These sentences were heard in the context of a picture-matching

[1]If preceded by the sentence "How do you know it rained?", the utterance "it rained because the bunnies got wet" is sensible, and represents epistemic causal reasoning. Here, we focus only on cases of physical causal reasoning.

task that children could solve simply by attending to a single word such as "cat." Critically, while children listened to each story, the relations between events were irrelevant to their task, and they did not know their knowledge of them would be tested. However, after children had completed this task, we unexpectedly asked them to retell the story that went with each picture, to discover what they spontaneously recalled about the 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 order [Exp. 2].

Experiment 1

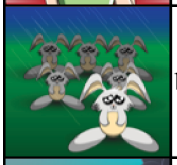
Method (Exp. 1)

Participants 139 monolingual English-speaking 3- to 7-year-olds participated. Children were pseudo-randomly assigned to one of 3 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 connected by a causal connective, e.g., "The cat walked away [because/and so] the dog barked." Children heard 8 stories containing either *and so* or *because* (see Table 1 for three examples). Within those 8 stories, 2 were causally implausible (e.g., "The kids got very cold *and so* it started to snow") and the remaining 6 were plausible. Pictures were created to match the sentence frames. None of the pictures depicted the entirety of the story (see Table 1).

Procedure 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 8 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 8 stories and identified the matching pictures, the Test phase began. In the test phase, the experimenter showed the pictures one-at-a-time in random order and asked, "*Can you tell me what happened in this story?*"

Table 1: Example stimuli.

Picture	Story	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.		●

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. By comparing these descriptions to those of children in the *because* and *and so* conditions, we were able to assess the impact of the stories.[2]

Coding and Analyses A research assistant, 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 8 stories. Children were not required to repeat the events verbatim. 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 the meaning of the sentence, and whether the chain of events they described was plausible.

After data were coded, we compared children's retellings to the stories they had heard, asking which elements of the story 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

[2]Only 20 out of 208 retellings in the baseline condition contained at least two clauses. This suggests that the two-clause retellings provided by children in the critical conditions were the result of children's memories of the stories, not the visual content of the pictures. We do not consider the baseline data further.

in the story, 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 story 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 daddy was late for work *because* the bus broke down.'

Child's retelling	Preserved order:	
	Events?	Clauses?
The daddy was late for work *because* the bus broke down	yes	yes
The bus broke down *and so* the daddy was late for work	yes	no
The daddy was late for work *and so* the bus broke down	no	yes
The bus broke down *because* the daddy was late for work	no	no

Results (Exp. 1)

Throughout the results, the original sentence the child heard to describe each picture during the matching game is referred to as the 'story' 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 2 clauses, so that they could be assessed for preservation of the event relations in the story. Unsurprisingly, excluding single-clause responses led to the disproportionate exclusion of younger children's retellings[3]. However, we retained over 50 retellings for each age group: 3YO: 51 trials remained; 4YO: 113 trials remained; 5YO: 131 trials remained; 6YO: 140 trials remained; 7YO: 155 trials remained. The final dataset included 590 retellings from 101 participants ranging in age from 3;2–7;11 [M_{age} = 5;10].

Analyses We first asked whether children preserved the causal ordering of the events from the story. In other words, if the [eating soup] event caused the [getting sick] event in the story, 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 = .06, SE = .01, p < .0001), and more likely to do so for stories containing *and so* than *because*, (B = .05, SE = .02, p = .003), but there was no interaction (B = .003, SE = .01, p = .81). We next asked whether children preserved the causal relations between the *clauses* in the story. 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 also increased with age (B = .02, SE = .01, p = .0495), and was higher for stories containing *and so* than *because*, (B = .07, SE = .01, p <.0001); again, there was no interaction (B = -.008, SE = .01, p = .46).

We also asked how likely children who preserved one element of the story were to preserve the other element. To do this, we coded each retelling according to whether it preserved both the event and clause order from the story, the event order only, the clause order only, or neither (see Table 2 for examples). We found that 3-year-olds preserved both elements of the story 36% 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 (6%; though note that this is a relatively small n). In contrast, 71% of 4-year-olds' retellings preserved both elements, and this percentage was similarly high for all older age groups. As shown in Figure 1, unlike 3-year-olds, older children who did not preserve both elements of the story were more likely to preserve event order than clause order.

Finally, we asked whether children incorporated world knowledge into their retellings. If children simply parroted back the stories' 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×plausibility interaction, we found an effect of plausibility (B = -.18, E = .02, p <.0001), an effect of age (B = .06, SE = .01, p <.0001) an effect of connective (B = .06, SE = .02, p = .002), but no interaction (p = .22). This suggests that children *did* spontaneously process the causal relations between events, even though the task they

[3]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 story but failed to retell it, or comprehension, e.g., they retold everything they remembered about the story. The data from Blything et al. (2015) suggests this could be due to memory limitations.

were performing while listening to the stories did not require them to do so. As shown in Figure 1B, when the story 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. 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."

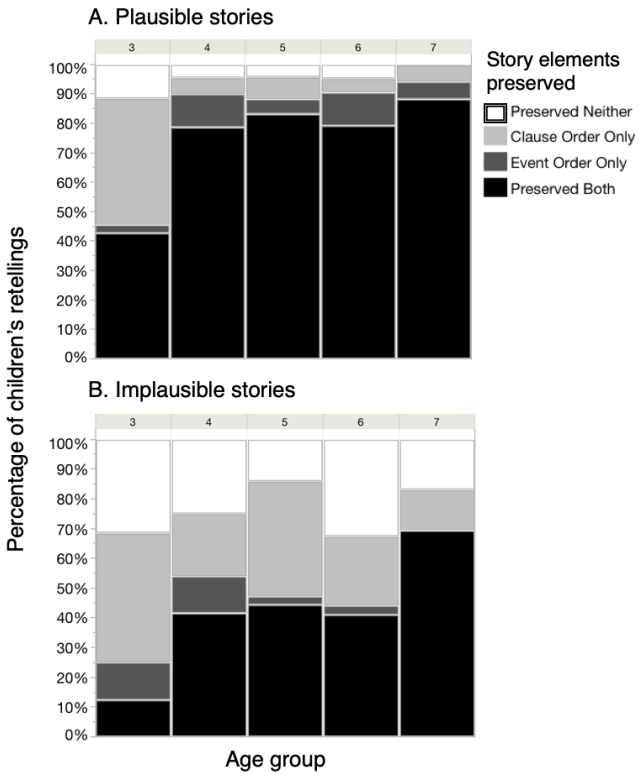


Figure 1: Children's preservation of event order and clause order for (A) plausible and (B) implausible stories in Experiment 1

Discussion (Exp. 1)

Exp. 1 had three main findings. First, the majority of children over age 3 preserved both the event ordering and clause ordering of the story in their retellings. Second, when children *didn't* preserve both elements of the story, they typically preserved the causal relations between *events* in the stories they heard. Specifically, if Event A was the cause of Event B, children retold stories in which Event A was the cause, regardless of which clause they placed Event A in. Third, children didn't simply parrot back the stories, but appeared to spontaneously process the causal relations within them. Thus, children were less likely to preserve the causal relations within stories containing *because* than *and so*, which would not be expected if children simply memorized the stories, and they were less likely to preserve the causal relations if they were implausible. In the latter cases, they tended to revise the story 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 *and so* stories, events were described chronologically, and for *because* stories, 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 and/or retelling chronological stories. In Exp. 2, we tested the roles of connective and chronology separately, by using the temporal connectives *before* and *after*. Unlike in Experiment 1, we were able to manipulate the placement of both connectives in the sentence[4], 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 (Exp. 2)

Participants Eighty-one monolingual, English-speaking 4- to 5-year-olds (M_{age} = 4;11; range = 4;2–5;11) completed the experiment[5]. Children were pseudo-randomly assigned to one of 4 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 story
before-chronological	The daddy was late for work *before* the bus broke down
before-reverse	*Before* the daddy was late to work, the bus broke down
after-chronological	*After* the daddy was late for work, the bus broke down
after-reverse	The daddy was late for work *after* the bus broke down

[4] This was not possible for all items in Exp. 1, because sentences like "*And so* the daddy was late for work, the bus broke down" are ungrammatical.

[5] 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).

Materials and Procedures were identical to those in Exp. 1, with two exceptions: Children (1) heard the connectives *before* or *after*, and (2) either heard the connective at the start of the story or between the two clauses. As demonstrated in Table 3, this manipulation allowed us to ask whether children struggled more to preserve stories in which the order of the events was reversed, such that the second event was introduced in the first clause.

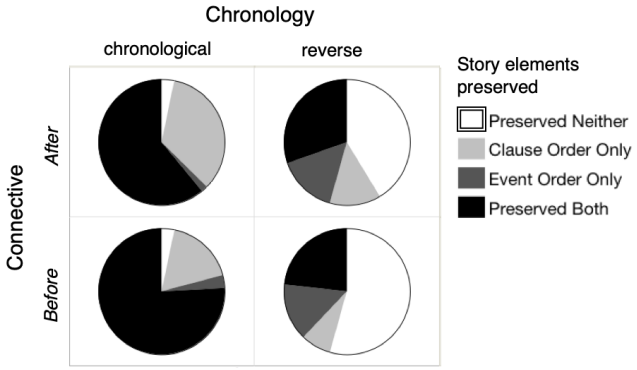


Figure 2: Children's preservation of event order and clause order in their retellings of chronological and non-chronological stories containing *before* and *after*

Results (Exp. 2)

As in Experiment 1, we were interested in whether children's retellings preserved the event order and clause order of the stories they heard. Overall, 56.7% of children's retellings in Experiment 2 preserved the ordering of the events in the story (i.e., which of the two events came first), and 68.9% preserved the ordering of the clauses in the story (e.g., whether the story was told chronologically). Next, we asked whether children's retellings were predicted by (a) the connective in the story (*before* vs. *after*) or (b) whether the story they heard was told chronologically (i.e., the first event was described in the first clause). To do so, we first 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 story and the retelling. As predictors, we included the connective (*before* or *after*) in the story, the chronology of the story (chronological vs. reverse, see Table 3), age, and their interaction. We found a significant effect of age (B = .13, SE = .06, p = .02), a significant effect of chronology (B = .144, SE = .03, p < .0001), and a significant interaction of connective and chronology (B = .05, SE = .03, p = .047). Specifically, for chronological stories, participants preserved the event ordering significantly more often for *before* sentences (79.1%) than for *after* sentences (62.6%; B = .41, SE = .16, p = .01). For reverse-chronology stories, there was no effect of connective: participants preserved the event ordering less than half of the time for *before* (45.7%) and for *after* (37.9%; B = -.16, SE = .18, p = .37).

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 = -1.71, SE = .18, p < .0001). They preferentially arranged their retellings such that the events were described chronologically, regardless of which connective was in the story. 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 Exp. 1 that were causally impossible (e.g., "It rained because the bunnies got wet."), the "implausible" sentences in Exp. 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 2, children's retellings of chronological stories usually preserved both event order and clause order, and this was especially true for chronological stories containing *before* (75.8% of retellings). Strikingly, more than half (54.3%) of children's retellings of reversed-order stories containing *before* retained neither the event ordering nor the clause ordering from the story (Fig. 2). This points to a strong role for chronology in shaping children's expectations about the temporal ordering of events.

Discussion (Exp 2).

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 story, 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 there was a significant interaction between connective and chronology, and that 4- to 5-year-old children's retellings were most accurate in the *before*-chronological condition, are consistent with those Blything and colleagues (2015). In their study, children also heard sentences that varied in both the connective used and its position in the sentence, but were aware that they needed to attend to the event relations in the sentences to choose the event that happened first. Here, we show that children's processing and recall of narrative is affected by both of these factors even when they are not aware that they will be tested, and the relations between events was irrelevant to the task they were performing. Moreover, 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, children's retellings of these stories often not only changed the clause order (i.e., they heard non-chronological stories but told chronological ones), they also changed the ordering of the events within the stories, thereby changing their meaning.

General Discussion

Language is powerful because it allows us to represent and communicate causal and temporal relationships that are not ongoing, perceptible, and/or possible in the real world. The abstract nature of temporal and causal language, and the complexity of narratives, pose challenges to child learners. We explored the cues children use to make inferences about causal and temporal relationships in narratives. We told children 2-clause stories which 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. Afterward, we asked them to retell the stories, to examine what information about the narratives 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 in language even when these relations were task-irrelevant.

We had several additional findings. First, children 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 story in which a causal event occurred in the first clause, they likely retold a story where that was the case. Beyond this, our findings showed that children were not simply acting as noisy tape recorders: they spontaneously *restructured* their input in their retellings, and were more likely to do so for causally implausible stories than for causally plausible stories. In Experiment 2, we found that they were also less likely to retain clause and event ordering when the stories they heard were not chronological, and their likelihood of doing this was affected by the connective they heard. Specifically, when they heard sentences that were not chronological, and began with *before*, children most often produced chronological retellings describing the opposite temporal relations between events, indicating that such sentences are particularly challenging for children.

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. 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 it simply impacted the likelihood of events following a particular temporal sequence (Exp 2, see also Blything et al., 2015).

Together, these 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.

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