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BRIEF RESEARCH REPORT

Time after time: Factors influencing children's comprehension of *Before* and *After*

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Abstract

We investigated older children's (7–12 years) ability to comprehend *before* and *after* sentences. Results found that three factors that influence pre-school aged children's learning of these words continues to influence older children's comprehension. Specifically, children's accuracy is improved when the events can be naturally (vs. arbitrarily) ordered; when the clauses in the sentence iconically match (vs. mismatch) the order of the events in the world; and when sentences use *before* (vs. *after*). The first two factors are argued to directly facilitate the building of mental models while the last one does so indirectly because of patterns of input usage.

Keywords: Temporal Comprehension; Before/After; Later Language Development

Introduction

By age 5 years, children can act-out a pair of events in the correct sequence, guided by the words *before* and *after* (E. V. Clark, 1971). Nevertheless, even 12-year-olds have persistent difficulties correctly interpreting such sentences (Pyykkönen & Järvikivi, 2012). This study examines if there is continuity in this domain by investigating if the factors that influence young children's interpretation of temporal connectives persist in influencing the performance of older children.

Previous investigations of children's comprehension of *before* and *after* have argued for three distinct elements influencing children's learning of these terms (Blything & Cain, 2016; Blything et al., 2015; E. V. Clark, 1971; DeRuiter et al., 2018; Pyykkönen & Järvikivi, 2012; Pyykkönen et al., 2003). The first is the real-world connection between the described events. Some events are naturally ordered in the world: brushing your teeth comes before going to bed; eating dessert comes after eating vegetables. Other events can be reasonably sequenced in either order, such as going to the park and going to the zoo. Early studies (e.g., French & Brown, 1977) found that preschool-aged children could only successfully interpret *before* and *after* with naturally-ordered events. However, in principle, children do not need to understand the temporal connectives at all to correctly sequence naturally-ordered event pairs, and many researchers have simply avoided them

for that reason. More recently, Blything et al. (2015) tested 3- to 7-year-olds using both naturally- and arbitrarily-ordered events and found that children successfully interpreted the temporal sequences of *before* and *after* with both event types. However, Pyykkönen et al. (2003) found that event naturalness helped 8- to 12-year-olds in what appeared to be a more difficult test of temporal connectives.

A second element influencing both acquisition and processing is the iconicity of the ordering between the sentential clauses and the events themselves. For example, in the sentence, *The dog went upstairs before the cat came home*, the dog's action not only precedes the cat's action in the world, but the clause describing it precedes it in the sentence: there is an iconic mapping between the ordering in the world and the linguistic description. Non-iconic sentences have a mismatch between the word order and the ordering in the world (e.g., *Before the cat came home, the dog went upstairs*). Iconicity is a persistent factor in children's interpretation of *before* and *after,* with higher accuracy rates found for iconic ordering among children starting in preschool (E. V. Clark, 1971; DeRuiter et al., 2018) and extending to 7-year-old (Blything & Cain, 2016; Blything et al., 2015) and even 12-year-old children (Pyykkönen & Järvikivi, 2012; Pyykkönen et al., 2003). The dominant explanation for why iconic orders are easier is that they facilitate building a mental model of the events (cf. Gernsbacher, 1990; Zwaan & Radvansky, 1998). Children begin to build models as they listen to the sentence, and the iconic match between what they hear first and what they should order first helps them create a stable mental model. Moreover, iconicity is not only favored by children: iconic orders for *before/after* sentences were more frequent than non-iconic orders in an adult corpus study (Diessel, 2008), and differential ERP patterns were observed in adults for iconic and non-iconic orders (Münte et al., 1998).

A final element that influences children's comprehension of temporal connectives is the specific words themselves: temporal orders that are conveyed using the connective *after* tend to be more difficult for children to understand than those that are conveyed with *before* (E. V. Clark, 1971; DeRuiter et al., 2018; Pyykkönen & Järvikivi, 2012; Pyykkönen et al., 2003). DeRuiter et al. (2021) attributed this effect to differing patterns of use in children's input. They examined dense corpora of two parent-child dyads and found that while *before* and *after* appeared at similar rates overall, *before* was used more consistently to order two full clauses (*before the girl went outside, she ate a donut).* The connective *after* was more frequently used than *before* in non-temporal contexts (e.g., *look after*) and for ordering nominal events (e.g., *after dinner*). Given that all of the experimental studies used sentences with two full clauses, these corpus results suggest that children are more likely to have encountered that particular type of sentence with the connective *before* than *after*. However, one notable exception to *before* being easier for children found no effect of connective on accuracy, at least by age 7 years (Blything & Cain, 2016).

Overall, the existing literature paints a clear picture of what influences preschool-aged children's ability to succeed with *before/after:* they benefit from naturally-ordered events, iconically presented in the sentence, using the connective *before*[1]. However, the picture

[1]An additional factor that may contribute to children's comprehension is the order of the clauses: *before* and *after* create subordinate clauses which can be placed either before or after the main clause of the sentence. Moreover, H H. Clark and E. V. Clark (1968) found that both clause order and iconicity of events and clauses influenced ease of processing among a range of temporal sentences. However, for sentences containing just *before* and *after*, there is a general confound between the ordering of the main and subordinate clauses and the interaction between connective type and iconicity making it quite difficult to disentangle the potential

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becomes more complicated when older children are considered. Blything and colleagues (Blything & Cain, 2016; Blything et al., 2015) found strong success in accuracy in children by the age of 7 years regardless of the naturalness of the event ordering or the connective, while Pyykkönen and colleagues (Pyykkönen & Järvikivi, 2012; Pyykkönen et al., 2003) found that children as old as 12 years had ongoing difficulties and their accuracy was influenced by both naturalness of event ordering and connective. Even for iconicity, which both studies found to be a helpful cue, Blything and colleagues (Blything & Cain, 2016; Blything et al., 2015) argue that it is tempered by an interaction between the syntactic position of the connectives and the memory demands of creating mental models. They note that *before* creates iconic interpretations when it appears in the middle of a sentence (X *before* Y) and non-iconic interpretations when it appears at the beginning (*before* Y, X); the reverse is true for *after*. Thus, significant working memory demands on building the model only arise for non-iconic *before,* because only in that case has the listener been signaled that they must remember the first event so that they can order it after an event yet to come. When *after* is in initial position, it is iconic, allowing one to simply begin building the model. Encountering *after* in medial position is non-iconic, but it does not impose significant working memory demands on the model-building because it appears immediately before the second event. In support of their position, Blything and Cain (2016) found that children's working memory significantly improved the fit of their model predicting children's accuracy and reaction times for iconic and non-iconic *before/after* sentences. However, DeRuiter et al. (2018) did not find that children's working memory predicted slightly younger children's accuracy above and beyond the influence of iconicity and connective.

Several differences across the studies make it difficult to determine why such different results have been obtained. One major difference is the language of testing. Most studies, including those by Blything and colleagues, tested children learning English as their native language. By contrast, Pyykkönen and colleagues tested children learning Finnish. While Finnish has similarities to English in how these temporal connectives are used, it is distinctly possible that there are other linguistic features of Finnish which may make the task more difficult in that language. Another notable difference between studies is the method of presentation and response. Pyykkönen and colleagues examined children as old as 12 years, and tested them in an ecologically valid way for children in school, using written sentences and asking them to mark their responses with pencil and paper. However, requiring children to read and write may have created a cognitive load that interfered with their ability to interpret these temporal connectives. By contrast, Blything and colleagues presented their 3- to 7-year-old participants with fully animated clips of each event to be ordered. This type of presentation may have facilitated children's ability to display their understanding, but it might also have increased the memory demands of the task as children had to remember what happened in each short video.

The current study aims to resolve the question of whether the same factors that influence accuracy in young children – naturalness of ordering, iconicity of presentation, and connective – continue to impact children learning English into the school years. We tested a broad age range from 7 – 12 years that encompasses the oldest ages tested by Blything and colleagues through the oldest children tested by Pyykkönen and colleagues. Our method was modeled most closely on that of DeRuiter et al. (2018): children were

independent effects of clause ordering. We have therefore put aside the issue of main and subordinate clauses within the experiment, but will return to it in the general discussion.

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presented with sentences auditorily over headphones, eliminating the need for children to be able to read; the events were represented by individual still images which were more vivid than the written word but did not require the memory demands of a movie. And finally, we included all three factors in a within-subjects design, allowing us to determine how they may interact with each other across this age range.

Method

Participants

Sixty-five 7- to 12-year-old native English-speaking children completed the protocol (between 10 and 12 children for each annual age bin). An additional child was tested, but their data were excluded because parents reported that the child was diagnosed with autism. The mean ages of the 7-, 8-, 9-, 10-, 11-, and 12-year-old groups was 7.4, 8.5, 9.4, 10.4, 11.5, and 12.4 years, respectively. Thirty-one were female, 34 male, and 0 nonbinary. Most participants were White (n=55), with the remaining identifying as Asian-American (n=3), Black/African-American (n=2), or biracial White and Black/African-American (n=5). Parents reported no history of speech-language or hearing challenges.

Materials and Procedure

Children were tested in a fully repeated measures 2x2x2 design with two stimulus sentences per condition, resulting in 16 trials, which were randomized across participants. The three factors were iconicity (iconic/non-iconic), naturalness (natural/arbitrary), and temporal connective (*before/after*). All sentences contained two fully tensed clauses. Table 1 displays the sentences in each condition. On each trial, a unique RMS-equalized sentence digitally recorded by a Midland American English-speaking woman in a sound-attenuated room was presented auditorily. At the same time, two colorful cartoon images (e.g., publicly available clipart), one showing each of the described events, were displayed on a 24-inch Dell monitor. After each sentence ended, children were prompted to select one image with the question, "which event happened first?" uttered by the same speaker who recorded the sentences. The side on which the pictures were presented was randomized. As an example, Figure 1 displays the images used for one of the sentences used in the Iconic/Natural/Before condition. Children were instructed to press the left-most button on an E-Prime Serial Response Box if they thought the left-hand image reflected the correct answer and the right-most button if the right-hand image reflected the correct answer. To ensure the children understood the button-press task, they were presented with several practice trials that were not directly related to the test trials.

Recruitment took place at a local science museum, and testing took place in a quiet lab within the museum. Stimulus presentation was controlled with E-Prime v. 2.0 (Psychology Software Tools, 2007) on a Dell Optiplex 790 desktop computer. Auditory stimuli were presented at a comfortable level over binaural Audiotechnica headphones (model 8TH-770COM). Children were not provided feedback but were given praise and encouragement after each test trial. All testing procedures were approved by the local institutional review board. Caregivers provided verbal permission and children provided verbal assent to participate. As is customary in museum laboratory settings, participants were not compensated. Data were analyzed in SPSS v. 28.

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Table 1. Test Sentences for each Condition

Condition	Sentence Stimuli
Before/Natural/Iconic	The girl blew out the candles before she ate the cake
	Tiger put on his socks before he put on his shoes
Before/Natural/Non-iconic	Before the boy picked the flower, he planted the seed
	Before the girl opened the door, she unlocked it with a key
Before/Arbitrary/Iconic	The boy painted a flower before he drew a house
	The girl jumped before she clapped
Before/ Arbitrary /Non-iconic	Before the boy went down the slide, he played on the swingset
	Before the girl walked to the park, she walked to the store
After/Natural/Iconic	After the boy ate his vegetables, his mom gave him dessert
	After the girl came home, she watched TV
After/Natural/Non-iconic	The boy went to bed after he brushed his teeth
	The girl drove in the car after she put on her seatbelt
After/ Arbitrary /Iconic	After the boy swam in the river, he walked in the woods
	After the girl did a cartwheel, she did a summersault
After/ Arbitrary /Non-iconic	The boy rode in the car after he rode on a bike
	The girl opened a window after she sat on a chair

Figure 1. Images displayed for one of the sentences in the Iconic/Natural/Before condition, "The girl blew out the candles before she at the cake." The image on the left reflects the correct response to "What happened first?" and the right-hand image is the foil.

Results

Figure 2 displays mean accuracy for each condition as a function of age group. A repeated measures ANOVA with three within-subject factors (Connective, Naturalness, Iconicity) and one between-subjects factor (age group) revealed that accuracy was better for the *before* connective than *after*, $F(1,59)=59.651$, $p<.001$, $\eta^2p=.503$. Similarly, accuracy was better for natural than arbitrary temporal orders, $F(1,59)=33.306$, $p=.038$, $\eta^2p=.361$, and for iconic than non-iconic temporal structures, $F(1,59)=4.530$, $p<.001$, $\eta^2p=.071$. There was no main effect of age group ($p=.467$), nor did age group interact with any of the temporal sentence structure variables, reflecting that accuracy did not change

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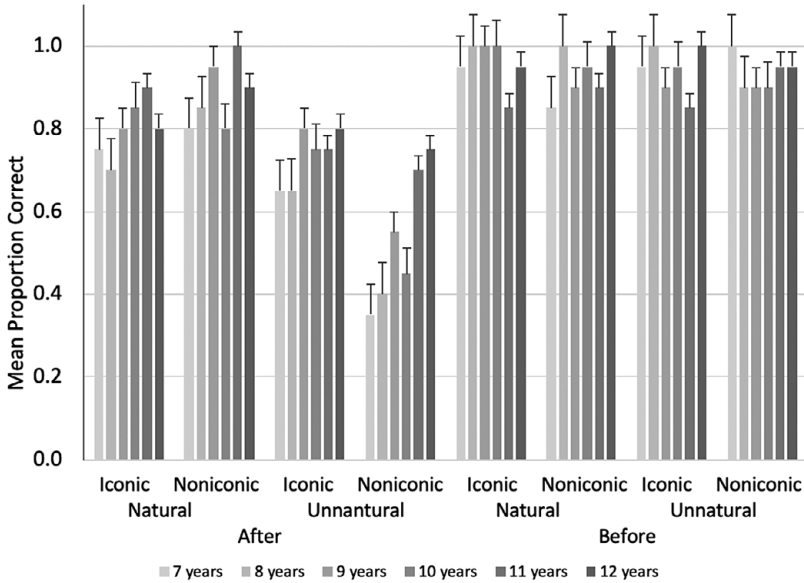

Figure 2. Mean proportion correct (+ standard error) for each condition as a function of age group.

significantly across the elementary to early-teenage range in this sample. Naturalness interacted with Connective, $F(1,59)=22.601$, $p<.001$, $\eta^2p=.277$, which resulted from accuracy for *before* being high regardless of Naturalness (≥ 0.92), but accuracy for *after* being higher when the sentences followed a natural (0.85) rather than arbitrary temporal order (0.62). Naturalness also interacted with Iconicity, $F(1,59)=13.776$, $p<.001$, $\eta^2p=.189$, reflecting that accuracy was poorer with an arbitrary temporal order, particularly when the order in which events occur in the sentence was mismatched with how they occur in the real world (non-iconic). Finally, there was a three-way interaction among Connective, Naturalness, and Iconicity $F(1,59)=13.285$, $p<.001$, $\eta^2p=.184$. Sentences using *before* were consistently perceived accurately ($\geq .92$) regardless of their iconicity or naturalness. In contrast, sentences using *after* were less accurate than those with *before,* particularly when they had an arbitrary and non-iconic temporal order (0.52).

Discussion

The goal of this study was to examine the persistence of three temporal elements in guiding children's temporal interpretation. The results revealed that for 7- to 12-year-olds the ability to accurately order two events is influenced by the naturalness of the ordering, the iconicity of the temporal structure, and the specific connective used. While all three factors were significant predictors of children's accuracy on their own, there was a notable interaction among the three: children of all ages were significantly less accurate when the sentences contained an arbitrary ordering of events expressed in a non-iconic manner using the connective *after*.

These results are consistent with what has been previously found for younger children acquiring English (Blything & Cain, 2016; Blything et al., 2015; E. V. Clark, 1971; DeRuiter et al., 2018; French & Brown, 1977), as well as similarly-aged children using a

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somewhat different method acquiring Finnish (Pyykkönen & Järvikivi, 2012; Pyykkönen et al., 2003). They stand first of all, therefore, as an important replication of existing results in this field (cf. Nosek et al., 2022). They do, however, differ somewhat from Blything and colleagues (Blything & Cain, 2016; Blything et al., 2015) who found that only iconicity was a reliably persistent factor in 7-year-olds.

We speculate that the reason that the Blything group's results differed from our results (as well as those of other researchers) has to do with the fact that they provided children with particularly robust support for the events. Both Blything studies noted above presented children with animated videos depicting the events to be ordered, while the current study (similar to DeRuiter et al., 2018) used still pictures; Pyykkönen and colleagues (Pyykkönen & Järvikivi, 2012; Pyykkönen et al., 2003) provided no pictorial support at all. It seems possible that more detailed event representations facilitate children's ability to incorporate them into a mental model. Thus, the differing results across studies actually provide support for the core argument in Blything and Cain (2016): the fundamental process behind interpreting *before/after* sentences involves sequencing events within a mental model. Anything that makes it easier to create the appropriate mental model will improve accuracy and processing.

The elements examined in this study facilitate model building in different ways. Events which are naturally ordered are conceptually easier to sequence in a model than arbitrarily-ordered events because one can draw on rich background knowledge. We speculate that providing richer representations of the events – as with animated movies – offers a similar conceptual advantage. Compared to non-iconic orders, an iconic mapping between the events in a sentence and the ordering in which the events should be sequenced in the model allows for more straightforward model building. However, the advantage for *before* over *after* does not have any obvious conceptual or processing reason to facilitate model-building. To explain the difference between the connectives, we appeal to the explanation offered in DeRuiter et al. (2021): the input data for the two connectives are different.

DeRuiter et al. (2021) conducted an analysis on *before/after* usage in the dense corpora of two child-parent dyads. We verified their main findings by conducting a similar corpus analysis that drew on the full set of American English-speaking children in the CHILDES database (MacWhinney, 2000). We extracted all the tokens of *before* and *after* from mothers (N=3997) and children (N=1065). Like DeRuiter et al. (2021) we found that the two connectives were used at very similar rates overall; but also, like them, we found that *after* was more likely to be used in non-temporal constructions than *before.* Moreover, even within sentences that were temporally ordering two events, *after* was more likely than *before* to refer to one of those events in a nominal form (e.g., *before bed, after supper).* Nominal events provide evidence for how to use the connectives to sequence events, but they look quite different from the kinds of sentences involving two full clauses used in the current and all previous studies. In addition, parallel to the corpus work of Diessel (2008), we found that both parents and children were more likely to place the event with the connective (whether the event was expressed in a full clause or as a nominal form) second. We note that this ordering places the main clause first more often, which may facilitate processing of the temporal ordering (cf. H. H. Clark & E. V. Clark, 1968). Interestingly, however, the preference for beginning with the main clause was far stronger for sentences containing *before*, where that order preserved iconicity than for sentences containing *after,* where an initial main clause creates a non-iconic interpretation. One additional phenomenon worth noting (which was not discussed in detail in DeRuiter et al., 2021) is that the present moment was often used as one of the times being sequenced, particularly

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for the connective *before: before now; did you ever do that before?* These utterances suggest that in typical usage, one common anchor point for creating temporal sequences in a model is the here-and-now. These results constitute another replication (again, see Nosek et al., 2022). In combination with DeRuiter et al. (2021), these usage results suggest that *after* is less consistently used to signal temporal sequencing and further, that the types of sentences used in these studies do not represent the most common ways that children use or hear events and time being sequenced.

In conclusion, the results of the current study show that even into the middle-school years, children's ability to interpret *before* and *after* is influenced by the same range of factors that influence younger children. Moreover, all of these factors are plausibly related to the process of constructing a mental model of the sequence of events.

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Competing interest. The Authors declare none.

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