How fast are children on the "inside"? Real-time processing of spatial prepositions

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To what extent do children use their representations of spatial relations during real-time language processing? Fluent speech is fleeting: child comprehenders hear upward of three words every second (Chermak & Schneiderman, 1985) and must use the limited attentional and memory resources available to them to integrate this ever-changing signal into a coherent sentence representation on the fly. Spatial prepositions such as *inside* and *near* present a particularly interesting case: by their nature, they require making inferences about the kinds of objects that can participate in specific spatial relationships. A ball is only *inside* a cup by virtue of the cup's geometric properties (i.e. it affords containment); by contrast, the same ball can be *near* another object regardless of its geometric properties. Can children use their knowledge of the spatial constraints on specific prepositions to predict upcoming reference objects?

Little is known about how children process spatial prepositions in real-time. Chambers et al., (2002) presented the first evidence that adults use the non-linguistic information provided by the properties of objects in their context to constrain their referential interpretations when processing spatial prepositions. For example, adults hearing "Put the ball *inside* the…" will look to potential containers before they are explicitly told what the target object is. While children as young as 28 months have been shown to understand the meanings of spatial prepositions in offline tasks (Meintis et al., 2002), and much older children have been shown to use prepositions to determine reference when speech is slowed down (Christou et al., 2021), it remains unclear whether young children make predictions on the basis of spatial information, or indeed on the basis of closed-class words at all (though see Özge et al., 2019 for evidence that children make use of case markers to predict upcoming arguments).

We tested whether children's real-time processing of spatial prepositions is adult-like and follows the general rule of predictive processing that holds for open-class terms, or whether children ignore the potentially-informative clues provided by their understanding of spatial prepositions. 4 year-olds (N=13) were introduced to a puppet who told them how to play with sets of her favorite toys. The puppet appeared behind a sloped display that always featured a container toy (e.g. a cup), a non-container distractor toy (e.g. a ball), and a smaller non-container toy to be moved initially (e.g. small grapes, see Figure 1). On each trial, the puppet labeled the objects, then hid behind the display while pre-recorded sentences were played in her voice. On critical trials (N=10), the first sentence was an instruction to pick up the small, close toy. The next sentence was the critical utterance, and told children where to put the small toy using a spatial preposition that required a container or specifically did not allow one (e.g. "Now put them *inside/near* my favorite cup!"). A third utterance ensured that the non-container toy was also mentioned on each trial. As children participated and manipulated the objects, their gaze to each item was tracked with Tobii Pro 2 eye-tracking glasses (Tobii Pro, 2014).

As seen in Figure 2, children showed anticipatory looks to the container upon hearing "inside" but not "near." An analysis was conducted on the preregistered time window after the onset of the preposition ("inside/near") and before the container noun (e.g. "cup"). A mixed effects regression model with random intercepts for subjects and items and random slopes for items found a reliable effect of preposition in this time window (β=.953, SE=.25, z=3.89, p<.001). This result is predicted by an account wherein children process spatial prepositions in real-time, and are able to incorporate information about the referential scene and object affordances into their model of the sentence as it unfolds. Future work will determine whether the spatial configuration of objects is what is accessed by children to evaluate spatial affordances on the fly (e.g. by turning containers upside-down), and will test for further distinctions within the spatial relation system, such as whether children distinguish between relations that are more "core" or primitive vs. complex, non-canonical relations. The present finding, however, marks an important first step in determining the extent to which children's system for encoding spatial relations interacts with the parser in real-time.

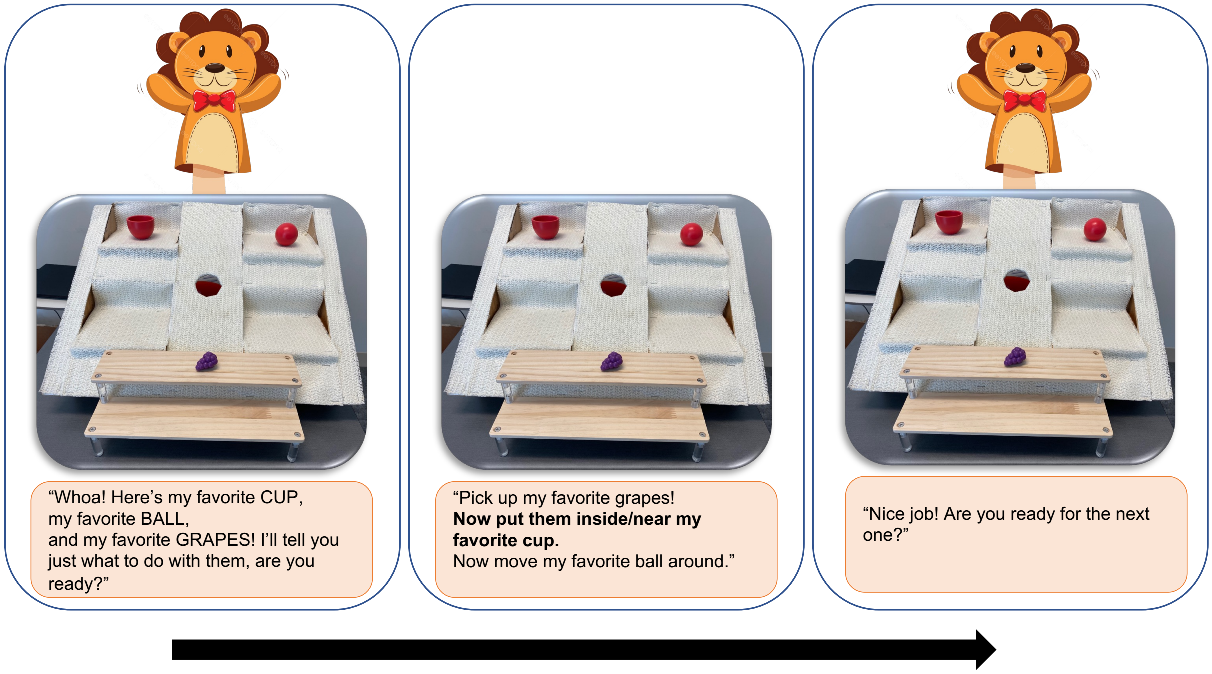

Figure 1: Example trial sequence. Each trial was set-up with a Container (Cup, top left), Distractor (Ball, top right) and Moved object (Grapes, center platform). Left/right location of container and distractor objects were counter-balanced across trials, as was item order. During the middle panel, the puppet is hidden behind the display. Filler trials (N=10) looked identical to target trials but did not contain an explicit preposition manipulation and ensured that the container was not always the first goal location.

Figure 2: Children's looks to container (cup), out of total looks to container vs. competitor (ball) during critical sentences. Vertical lines indicate average onsets of preposition, adjective phrase and noun. Children look to the container directly following the preposition onset, but, critically, before noun phrase is heard.

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