

Sticking to what we know: Methodological limitations to generalizability

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Abstract:

The ultimate goal of research is to generate and test broad theories that account for a wide range of scenarios. Conclusions at this level, however, are only valid if they are based on heterogeneous data. This chapter reviews the limitations in child syntactic priming methodologies that do not allow generalization. Specifically, the set of structures that has been examined is small and most studies have tested priming effects using production tasks. The chapter concludes with an experiment that addresses both of these issues by using a comprehension methodology to investigate the priming of children's prepositional phrase attachment preferences.

1. Introduction

The ultimate aim of any research program should be to generate and test broad theories about the object of inquiry. In the case of the child syntactic priming literature, there are multiple examples of findings being used to create general theories about language learning. In this chapter, I argue that we are not yet able to make these types of broad claims because the available data is limited by several methodological factors including the structures investigated and the means of evaluating priming effects (i.e., production versus comprehension). In other words, we are guilty of quite often repeating the designs of previous studies and, therefore, sticking to what we know.

For example, prominent theories of the mechanisms underlying syntactic priming effects attribute them to implicit learning (Bock & Griffin, 2000; Chang et al., 2000, 2006; Hartsuiker et al., 2008). Historically, syntactic priming was first proposed to be the result of a boost in the transient activation of the primed structure (Bock, 1986; Pickering & Branigan, 1998). However, if priming were grounded in transient activation, priming effects should also be transient. This is not necessarily the case as long term priming effects – defined as priming lasting longer than a single trial – have been observed in adults in both their first language (e.g., Bock & Griffin, 2000; Kaschak, 2007; Kaschak et al., 2006, 2014) and their second (Nitschke, Kidd, & Serratrice, 2010), in typically developing children (Brandt, Nitschke, & Kidd, 2017; Branigan & Messenger, 2016; Huttenlocher, Vasilyeva, & Shimpi, 2004; Kidd, 2012b, 2012a; Messenger, 2021; Savage, Lieven, Theakston, & Tomasello, 2006; Vasilyeva, Huttenlocher, & Waterfall, 2006), and in children with

Specific Language Impairment (Garraffa, Coco, & Branigan, 2015). Though “long term” can be as short as across the length of 10 trials (Bock & Griffin, 2000), some studies demonstrate priming across a block of trials (Brandt et al., 2017; Huttenlocher et al., 2004; Kaschak, 2007; Kaschak et al., 2014, 2006; Messenger, 2021) and beyond the length of the first study session (Branigan & Messenger, 2016; Hesketh, Serratrice, & Ashworth, 2016; Kidd, 2012b; Savage et al., 2006; Serratrice, Hesketh, & Ashworth, 2015; Vasilyeva et al., 2006).

While there may be some doubt that priming across 10 trials or the length of an experiment constitutes long term effects, the studies that have observed priming beyond the study session can be safely classified as demonstrating the lasting effects of priming. Vasilyeva et al. (2006) demonstrated that priming effects persisted in preschool children up to a week after their final exposure. Specifically, they were interested in whether exposure to passives improved preschool children’s production and comprehension. Children (aged 3;4 – 5;0) participated in 10 story-reading sessions over the course of 2 weeks and were assigned to either a passive condition (i.e., greater than 50% of the sentences in the stories were passive) or an active condition that served as a control (i.e., all of the sentences were active). Children exposed to passives had better comprehension for this structure, even if they were tested a week after the final story-reading session. Also, they produced more passive sentences and these sentences were less error-filled than the control, active condition. Studies from Serratrice et al. (2015) and Hesketh et al. (2016) used similar designs to examine long term priming of direct versus indirect speech and coordination versus subordinate clauses respectively.

Savage et al. (2006) demonstrated that priming effects persisted for up to a month as long as the primed structure was reinforced a week after the experimental session. In this experiment, 4-year-olds primed with passives (e.g., *it got pushed by it*) were tested after varying lengths of

time. One group was tested twice: immediately and after a month. Another group was tested three times: immediately, after a week, and after a month. Additionally, the variability of the prime sentences was also manipulated such that some children were exposed to identical passive primes, while others were exposed to varied primes (using different verbs). Priming effects persisted for up to a month, but only for the children who received varied input reinforced by a test a week after priming. The fact that priming persisted over a week or more and was sensitive to varied input and reinforcement suggests that children learned from the passive primes in both studies and updated their linguistic representations accordingly. Similarly, Branigan & Messenger (2016) tested 3- to 4-year-old children's priming of the passive in two sessions held a week apart. Children produced more passives in the second session despite the fact that they were primed with both passives and actives in the first session. Additionally, children who were more likely to be primed in the first session had a higher rate of passive production in the second session.

All of these results are promising, but if we as researchers want to claim that priming is a learning mechanism, the evidence must not be tied to limited methodological choices. At the moment, there is not enough variability to be able to comfortably generalize this claim beyond the structures tested. For example, all of the long term priming studies described above used transitive events to prime either active or passive structures. Section 2 provides much more detail about the limited number of structures that have been examined in child priming studies, but briefly, there are not enough to validate such a broad claim. Strengthening this claim with additional data has the potential to have a large impact on the field; if priming is a form of implicit learning, there are potentially important implications for its role in language development and its use as an intervention tool (e.g., Vasilyeva et al., 2006). For further discussion of the idea that priming may be the result of implicit learning and the implications of this theory, see Chapter 4 in this volume.

Additionally, there is a real asymmetry between production and comprehension priming tasks in the developmental literature that reflects a similar, though less strong, asymmetry in adult syntactic priming studies (see Tooley & Traxler, 2010 for a review of the adult studies). Though parallels are often assumed between them, it is an open question whether or not production and comprehension priming are the result of the same mechanisms. The first direct comparison of production and comprehension priming effects in adults suggests that they may be the result of the same mechanism (Tooley & Bock, 2014), but this question requires further exploration and leaves open the possibility that priming in one domain develops before the other.

I propose that the need to be cautious in generalizing syntactic priming results to broader theories is the result of two major limitations in our current methodological choices: 1) the lack of variability in structures examined and 2) the relative lack of comprehension priming experiments (or, conversely, the focus on production priming). The remainder of this chapter addresses each of these limitations in turn, presenting evidence that they are biases that do indeed exist and suggesting potential explanations for why they both exist and persist. I present an ongoing child priming project of my own that addresses both of these concerns. Specifically, it utilizes an extremely uncommon syntactic structure in the child priming literature, a prepositional phrase attachment ambiguity, and tests priming in children's comprehension. I also briefly address two other areas where we see a lack of variability in child syntactic priming studies: the targeted age range and the languages being studied.

2. Lack of structural variability

First, I claim that there has been a distinct lack of variability in the selection of structures to be examined in child syntactic priming studies. As can be seen in Table 1, the vast majority of child priming studies have examined either transitive sentences in the form of active versus passive constructions (22 total: Allen, Haywood, Rajendran, & Branigan, 2011; Bencini & Valian, 2008; Bidgood, Pine, Rowland, & Ambridge, 2020; Branigan & McLean, 2016; Branigan & Messenger, 2016; Gámez & Shimpi, 2016; Gámez, Shimpi, Waterfall, & Huttenlocher, 2009; Gámez & Vasilyeva, 2015; Hopkins, Yuill, & Keller, 2016; Huttenlocher et al., 2004; Kidd, 2012; Manetti, 2013; Messenger, 2021; Messenger, Branigan, & McLean, 2011, 2012a; Messenger, Branigan, McLean, & Sorace, 2012b; Miller & Deevy, 2006; Savage, Lieven, Theakston, & Tomasello, 2003; Savage et al., 2006; Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007; Vasilyeva et al., 2006; Vasilyeva & Waterfall, 2012) or the dative alternation (9 total: Buckle, Lieven, & Theakston, 2017; Fazekas, Jessop, Pine, & Rowland, 2020; Goldwater, Tomlinson, Echols, & Love, 2011; Hopkins et al., 2016; Huttenlocher et al., 2004; Peter, Chang, Pine, Blything, & Rowland, 2015; Rowland, Chang, Ambridge, Pine, & Lieven, 2012; Shimpi et al., 2007; Thothathiri & Snedeker, 2008b). In total, only 10 structures have been examined across the last almost 20 years of child syntactic priming research.

Table 1.
Overview of structures tested in child syntactic priming studies.

Structure tested	Example	Age of children	Language	References
Transitive (active vs. passive)	<i>The dog chased the rabbit vs. The rabbit was chased by the dog</i>	3-, 4-, 5-, 6-, 7-, & 10-year-olds	English	Allen et al. (2011); Bencini & Valian (2008); Bidgood et al. (2020); Branigan & McLean (2016); Branigan & Messenger (2016); Gámez & Vasilyeva (2015); Hopkins, Yuill, & Keller (2016); Huttenlocher et al. (2004); Kidd (2012a, 2012b); Messsenger (2021); Messenger, Branigan, & McLean (2011, 2012a); Messenger et al.

				(2012b); Miller & Deevy (2006); Savage et al. (2003, 2006); Shimpi et al. (2007); Vasilyeva, Huttenlocher, & Waterfall (2006); Vasilyeva & Waterfall (2012)
			Italian	Manetti (2013)
			Russian	Vasilyeva, Huttenlocher, & Waterfall (2006)
			Spanish	Gámez et al. (2009); Gámez & Shimpi (2016)
Dative alternation	<i>The woman is reading the children a book</i> vs. <i>The woman is reading a book to the children</i>	3-, 4-, 5-, & 6-year-olds	English	Buckle et al. (2017); Fazekas et al. (2020); Goldwater et al. (2011); Hopkins, Yuill, & Keller (2016); Huttenlocher et al. (2004); Peter et al. (2015); Rowland et al. (2012); Shimpi et al. (2007); Thothathiri & Snedeker (2008b)
Prenominal vs. relative clause	<i>the blue book</i> vs. <i>the book that is blue</i>	4-, 7-, 8-, 11-, & 12-year-olds	Dutch	van Beijsterveldt & van Hell (2009)
			English	Branigan, McLean, & Jones (2005a)
			German	Foltz et al. (2015)
SVO- <i>ba</i> alternation	<i>little dog hug-tight</i> – <i>LE little cat</i> (SVO) vs. <i>little dog BA little cat hug-tight</i> – <i>LE</i> (SOV)	3-, 4-, 5-, & 6-year-olds	Mandarin Chinese	Hsu (2014a, 2014b, 2019)
Ambiguous RCs	<i>here is the-NOM/ACC woman that-NOM/ACC the-NOM/ACC girl hugs</i> (‘here is the woman that is hugging the girl’ vs. ‘here is the woman that the girl is hugging’)	6- & 9-year-olds	German	Brandt, Nitschke, & Kidd (2017)
Bare noun vs. Subject RC	<i>Il gatto</i> (‘the cat’) vs. <i>Il gatto che graffia il bambino</i> (‘The cat who scratches the child’)	4-, 5-, & 6-year-olds	Italian	Garraffa, Coco, & Branigan (2015)

Ambiguous PP-attachment	<i>La fille chatouille le bébé avec le pinceau</i> ('the girl is tickling [the baby with the brush]' vs. 'the girl is [tickling [the baby] with the brush])	5- & 6-year-olds	English	Qi, Yuan, & Fisher (2011)
			French	Havron et al. (2020)
Noun-verb homophones	<i>La petite ferme</i> ('the little farm' vs. the little one is closing')	18-month-olds, 2-, 3-, & 4-year-olds	French	Havron et al. (2021; 2021; 2019)
Coordinate vs. Subordinate clause	<i>Tom and him Mum walked to school and they saw a huge toy shop</i> vs. <i>As Tom and his Mum walked to school, they saw a huge toy shop</i>	5-year-olds	English	Hesketh et al. (2016)
Direct vs. Indirect speech	<i>The little girl said "I'm on my way home"</i> vs. <i>The little girl said that she was on her way home</i>	5-year-olds	English	Serratrice et al. (2015)

Table 1 speaks for itself: the structures that have been investigated in priming studies have been limited. Having acknowledged this shortfall, it is important to examine why researchers seem drawn to transitive sentences and the dative alternation as objects of inquiry for syntactic priming. There are two prime candidates for explanation. First, this structural preference may reflect the fact that researchers choose structures that young children have already acquired. As everyone that conducts research on child populations knows, study design must consider if children are capable of completing the task. Transitive and ditransitive actions are arguably relatively “easy” for young children to conceptualize, whereas other structures investigated in the adult priming literature might be difficult to depict (e.g., reduced relative clauses: Traxler & Tooley, 2008), especially for

the youngest age groups. Thus, despite evidence that passives may be acquired relatively late (Horgan, 1978), structures describing these two sets of actions are ideal candidates for child priming studies.

Alternatively, or perhaps additionally, this lack of variability in structural choices may be an artifact of the history of syntactic priming and child priming research. Many of the earliest studies that examined children's syntactic priming based their designs, whether explicitly or implicitly, on the foundational syntactic priming study: Bock 1986 (e.g., Huttenlocher et al., 2004; Savage et al., 2003). In this classic study, Bock (1986) established that passives and forms of the dative alternation could be primed in adults. Participants repeated sentences spoken by the experimenter (prime) and then described a picture (target). These picture descriptions were more likely to contain a passive structure when the prime was a passive (*The referee was punched by one of the fans*) than when the prime was active (*One of the fans punched the referee*), although passives were still only produced 20% of the time. Participants were also more likely to produce a dative matching the form of the previous sentence; double object datives (DO: *A rock star sold an undercover agent some cocaine*) were 22% more likely to be produced after another DO dative, and the production of prepositional object datives (PO: *A rock star sold some cocaine to an undercover agent*) increased by 23% when the prime was also a PO dative. Bock was the first to demonstrate syntactic priming, and the structures Bock examined have therefore become the benchmark for work that followed. When researchers decided to adapt the syntactic priming methodology for children, it was only natural that they turned to this influential study as a model for their own studies.

3. Lack of comprehension priming studies

Even in the adult syntactic priming literature, comprehension priming studies are somewhat rare (Arai, van Gompel, & Scheepers, 2007; Branigan, Pickering, & McLean, 2005b; Hutton & Kidd, 2011; LeDoux, Traxler, & Swaab, 2007; Nitschke, Serratrice, & Kidd, 2014; Scheepers & Crocker, 2004; Thothathiri & Snedeker, 2008a; Tooley & Bock, 2014; Traxler, 2008, 2014; see Tooley & Traxler, 2010 for a review), but this methodology is practically nonexistent in studies examining child priming. Table 2 summarizes the methodologies used by the studies cited in Table 1 and is broken down by the presentation of both the target and the prime. For example, a study in which an experimenter described a picture for the child and then the child described another picture would be classified as a comprehension-production study because the child comprehends the experimenter’s sentence (prime) and then produces their own sentence (target).

Table 2.
Summary of methodologies utilized in child syntactic priming studies.

<i>Prime Type</i>	<i>Target Type</i>	
	Production	Comprehension
Production	13	0
Comprehension	32	7

Of the studies cited in Table 1, fully 37 involve production of the target¹ (Allen et al., 2011; Bencini & Valian, 2008; Bidgood et al., 2020; Branigan & McLean, 2016; Branigan et al., 2005a; Branigan & Messenger, 2016; Buckle et al., 2017; Fazekas et al., 2020; Foltz et al., 2015; Gámez & Shimpi, 2016; Gámez et al., 2009; Gámez & Vasilyeva, 2015; Garraffa et al., 2015; Goldwater

¹ The production column under target type in Table 2 sums to a value larger than 30 because there were multiple studies in which children repeated prime sentences produced by the experimenter. I chose to count these as both comprehension and production primes because children had to comprehend the experimenter’s initial utterance, but also were forced to produce the sentence themselves.

et al., 2011; Hesketh et al., 2016; Hopkins et al., 2016; Hsu, 2014b, 2014a, 2019; Huttenlocher et al., 2004; Kidd, 2012a, 2012b; Manetti, 2013; Messenger, 2021; Messenger et al., 2011, 2012a, 2012b; Miller & Deevy, 2006; Peter et al., 2015; Rowland et al., 2012; Savage et al., 2003, 2006; Serratrice et al., 2015; Shimpi et al., 2007; van Beijsterveldt & van Hell, 2009; Vasilyeva et al., 2006; Vasilyeva & Waterfall, 2012). Compare this number to the 7 studies utilizing comprehension of the target (Brandt et al., 2017; Havron et al., 2020, 2021, 2021, 2019; Qi et al., 2011; Thothathiri & Snedeker, 2008b). In all 7 studies, children only interacted with the structures of interest via comprehension (i.e., comprehension-to-comprehension priming); there are no examples of production-to-comprehension priming!

Savage and colleagues (2003) were the first to adapt the syntactic priming paradigm for use with children, and they employed a production priming methodology. In their study, 3-, 4-, and 6-year-olds viewed a video of a transitive action that was described by the experimenter with either an active or passive sentence. Additionally, these sentences either had high overlap of lexical items (e.g., *It is pushing it* vs. *It got pushed by it*) or low overlap (e.g., *The digger pushed the bricks* vs. *The bricks got pushed by the digger*). Children either repeated the sentence produced by the experimenter (Experiment 1) or they did not (Experiment 2), and then were asked to describe a new transitive action. While children of all ages produced more passive sentences when there was high lexical overlap between the prime and the target, the 6-year-olds were the only ones to produce more primes when there was low lexical overlap. Thus, Savage et al. concluded that 3- and 4-year-olds were simply lexically primed, while 6-year-olds were both lexically and structurally primed and, therefore, have abstract representations of transitive constructions. This is only one example of the many studies that demonstrated priming via children's productions.

Comparatively, priming of comprehension behaviors has seldom been attempted and usually it is the chosen methodology only because production priming is not appropriate for addressing the experimental question. As noted above, there are less than ten studies that examine comprehension priming in children. The first, Vasilyeva et al. (2006), is summarized in Section 1. In short, production and comprehension of passives in 3- to 5-year-olds was primed up to a week after last exposure to the prime sentences. Thothathiri and Snedeker's (2008b) work has been particularly influential; they were explicitly interested in the effects of syntactic priming on children's real time comprehension, so a comprehension methodology was required. In this study, 3- and 4-year-olds were instructed to interact with the objects in a visual scene using either a double object (DO) or prepositional object (PO) dative structure. In the targets, the form of the noun phrase following the verb induced a temporary argument structure ambiguity (DO: *Give the **bird** the dog bone*; PO: *Give the **bird** house to the sheep*). An animate NP (e.g., *bird*) is compatible with the DO structure, while an inanimate NP (e.g., *bird house*) is compatible with the PO structure. Both within and across verbs, children primed with DO datives looked more toward the animate recipient (e.g., *bird*, compatible with the DO structure) than the inanimate theme (e.g., *bird house*, compatible with the PO structure) during the ambiguous region. Also, this effect was reversible; children primed with PO datives looked more toward inanimate themes than animate recipients. These results demonstrate that children as young as 3 utilize the structure of a previous utterance to inform their processing of an upcoming utterance and, in turn, their interpretation of temporarily ambiguous NPs.

Similarly, Brandt and colleagues (2017) were interested in a structure requiring a non-linguistic context for disambiguation: children's interpretation of ambiguous German relative clauses. German feminine and neuter nouns do not have distinct forms for nominative and

accusative case, so transitive relative clauses are ambiguous when they contain only nouns of this type, see (1).

- (1)² Hier ist die Frau, die das Mädchen umarmt.
here is the-NOM/ACC woman that-NOM/ACC the-NOM/ACC girl hugs
'here is the woman that is hugging the girl'
'here is the woman that the girl is hugging'

Given the need for non-linguistic context to disambiguate these sentences, investigating children's interpretation of them also necessitated an examination of comprehension behaviors. Were a child to produce a sentence with the same linear order as (1), it would be impossible to determine which interpretation they intended. However, this intent is revealed by using comprehension as the independent variable. In their picture matching task, Brandt and colleagues primed 6- and 9-year-olds with object relative clause interpretations, which were disambiguated by the picture options. Both pictures portrayed both the agent and the patient, but only one depicted the correct relative clause verb. On target trials, children were asked to select between pictures of each of the possible meanings of the ambiguous relative clause. Though 6-year-olds were not primed, 9-year-olds selected the object relative clause interpretation significantly more often than their baseline rate both immediately after priming and in a post-test block. Thus, there is evidence that syntactic priming influences children's comprehension of subsequent utterances. Two other comprehension priming studies (Havron et al., 2020; Qi et al., 2011) are discussed in more detail in Section 4 as they are directly relevant for the experiment presented there.

The genesis of the preference for production priming studies is less easy to identify than the repetitive use of particular structures. Again, it may simply be the result of the choice to reflect adult studies in the design of child studies. As there is a relative lack of comprehension priming studies in the adult literature, perhaps it is unsurprising that there are even fewer studies

² Example 9 from Brandt et al. (2017)

investigating comprehension priming in children. Additionally, it is arguably more difficult to measure comprehension effects in children, particularly when the structure of interest is not ambiguous. Brandt et al.'s (2017) offline picture selection task is only possible because German relative clauses are ambiguous. Thothathiri and Snedeker (2008b) employed more complicated online measures, visual world eye tracking, because datives are linguistically disambiguated within the utterance. In this case, a picture selection task would have only revealed whether or not children understood the sentences, not if their initial interpretations were shaped by the previous sentence. Traditional measures of adult online comprehension such as self-paced reading and eye tracking during reading are not available for developmental studies because children at the age that these studies target are either not literate or are not yet reliable readers. Nonetheless, the comprehension priming studies summarized above are proof that it is possible to address questions related to comprehension in children with clever study design.

4. Addressing both concerns: PP-attachment priming study

Having laid out the several factors leading to the lack of diversity in the available syntactic priming data, I move on to present one experiment of an in-progress research program that explicitly addresses some of these limitations; the preliminary study presented here examines children's syntactic priming in relation to a structure found only twice in Table 1 using a comprehension priming methodology. In particular, it focuses on an underexplored structure in child syntactic priming: globally ambiguous sentences that arise from a prepositional phrase

attachment ambiguity. Broadly, globally ambiguous sentences arise when two different syntactic structures generate an identical linear word order. The ambiguous relative clauses in German from Brandt et al. (2017) are one example of such sentences.

The current study explores an ambiguity that arises from ambiguous prepositional phrase (PP)-attachment in English. Sentences like *The boy saw the girl with the binoculars* are globally ambiguous because the PP *with the binoculars* could either attach at the verb phrase level (i.e., the boy used the binoculars to see the girl: [VP[VP saw the girl][PP with the binoculars]]) or at the noun phrase level (i.e., the girl possessed the binoculars: [VP saw [NP the girl with the binoculars]]). The interpretation of these PP-attachment ambiguities, and therefore the underlying syntactic structure, has been shown to be primed in adults' comprehension (Boudewyn, Zirnstein, Swaab, & Traxler, 2014; Branigan et al., 2005b). For example, in a picture selection task (Branigan et al., 2005b), participants were 18% more likely to select the VP attachment interpretation when they had been primed with that same interpretation.

While the syntax of these structures is ambiguous, lexical biases driven by individual verbs can affect the interpretation of these sentences. Arguably, some verbs prefer the VP attachment interpretation (e.g., hit, tickle), some prefer the NP attachment interpretation (e.g., choose, look at), and some are equi-biased between the two interpretations (e.g., feel, turn over). Snedeker and Trueswell (2004) examined how these verb biases affected adults' and 5-year-old children's interpretation of globally ambiguous sentences of this type. They were presented a visual scene containing an object that could be used as an instrument and a noun phrase referent holding that same object and were instructed to perform some action, e.g., "Tickle the frog with the feather" in the context of a feather and a frog holding a feather. Both age groups were sensitive to verb biases in their interpretation of these structures; instrument actions were more likely after verbs biased

toward VP attachments, less likely after verbs biased toward NP attachments, and equally likely after equi-biased verbs. Verb biases were determined with a sentence completion task in which adults were given sentences up to the point of the preposition (e.g., “Grover pinches the teddy bear with...”). The eight best examples of each bias that were known by children were selected for the experiment (average bias toward the instrument interpretation: VP attachment = 97%; NP attachment = 12%; equi-biased = 52%).

Only two previous studies have explored whether or not children’s attachment preferences can be primed. The first, Qi et al. (2011) tested the priming of 5-year-olds’ interpretations of these ambiguous structures. They used a design paralleling that of Snedeker and Trueswell (2004), except that the eye tracking and action phase was preceded by a study phase consisting of a dialogue video. In this dialogue, children heard two women talking about occurrences using the structurally ambiguous *with* phrases except these sentences were disambiguated by the context. One group watched a dialogue that biased the instrument interpretation (VP attachment) while another watched one that biased the modifier interpretation (NP attachment). The results were mixed; in terms of their behavior, children performed an instrument action on 55% of the trials regardless of which dialogue they watched. Similarly, there were only effects of training in some of the analyses of the eye tracking data. Thus, this study is somewhat inconclusive in terms of the ability to prime English-speaking children’s interpretation of these globally ambiguous sentences.

A recent study from Havron and colleagues (2020) examined this same ambiguity in 5- to 6-year-old children acquiring French using a comprehension-to-comprehension priming methodology. Parallel to the English translation, French sentences using the preposition *avec* (‘with’) are ambiguous between a VP- and NP attachment interpretation, see (2).

- (2) La fille chatouille le bébé avec le pinceau
the girl tickle-3SING the baby with the brush

“the girl is tickling the baby with the brush”

In this tablet-based experiment, adults and children had to pick the picture that matched a sentence produced by a cartoon girl named Mandy. They were assigned to one of three groups: VP attachment primes, NP attachment primes, or alternating primes. On prime trials, there was only one correct picture on the tablet, while on target trials, the two pictures that participants had to choose between represented the two possible interpretations of the sentence. Both adults and children were successfully primed and the amount of priming was determined by the proportion of structures in their input. The groups primed solely with NP attachment interpretations showed greater priming effects (i.e., a larger proportion of NP attachment interpretation target picture selections) than the groups primed with alternating interpretations. While Havron and colleagues recognize the effect of verb bias – and ran a control to measure the biases of the verbs used in this study – this bias was not explicitly manipulated. They note that the verbs were not equi-biased as all but one were biased toward the VP attachment interpretation (10/11).

In both French and English, the word order of these PP-attachment ambiguities does not reflect the underlying syntactic structure. Thus, the study presented here employs similar logic to Havron et al. (2020) in that comprehension priming is used to determine which interpretation the child is assigning to the ambiguous target sentence. Unlike Havron and colleagues, this study was designed with the specific intention to examine the priming of equi-biased verbs. Thus, the present study explores whether 5-year-olds’ interpretations of sentences with PP-attachment ambiguities and equi-biased verbs can be primed in both directions; that is, towards the VP attachment interpretation following VP attachment primes and towards the NP attachment interpretation following NP attachment primes.

Participants

Thirty-two English-speaking children (mean age = 5;7, range: 4;5 – 6;7) participated in this study and were randomly assigned to one of two priming groups: they received either exclusively VP attachment (N = 16; mean age = 5;7, range: 4;5 – 6;4) or exclusively NP attachment primes (N = 16; mean age = 5;7, range: 5;0 – 6;7). An additional 16 children (mean age = 5;4, range: 4;2 – 6;2) participated in a control task. These children were recruited via a partnership between the Living Lab at the University of Michigan (<https://sites.lsa.umich.edu/livinglab/>) and the Ann Arbor Hands-On Museum (AAHOM, <https://www.aahom.org/>). The UM Living Lab is a collection of developmental researchers that have set-up and maintained mutually beneficial community partnerships. These partnerships are designed to both make a pool of child participants available to researchers as well as to bring science outreach and research to the public. All of the children were AAHOM visitors and participated in a dedicated Living Lab space in the museum.

Materials

The experiment consisted of 16 sentences. All sentences contained a PP-attachment ambiguity that rendered them globally ambiguous with two possible underlying syntactic structures that correspond to two unique interpretations, see (3).

(3) The elephant blows on the monkey with the fan.

In (2), the PP *with the fan* has two possible attachment sites: 1) attached to the verb phrase (VP) as a description of how the action is performed (i.e., the PP describes the instrument of the action),

as in (4), or 2) attached to the direct object noun phrase (NP) as a description of the animal (i.e., the PP modifies the NP), as in (5).

(4) *VP attachment / Instrument interpretation*

- a. [VP [VP blows on the monkey] [PP with the fan]]
- b. The elephant uses the fan to blow on the monkey.

(5) *NP attachment / Modifier interpretation*

- a. [VP blows on [NP the monkey with the fan]
- b. The elephant blows on a monkey that is holding a fan.

While sentences of this type are globally ambiguous because both structures are possible, individual verbs demonstrate biases toward one interpretation; verbs like *choose* and *look at* are biased toward NP attachment or a modifier interpretation, while verbs like *clean* and *tickle* are biased toward PP attachment or an instrument interpretation. We know that children are highly susceptible to these verb biases (Snedeker & Trueswell, 2004), so this study focuses on verbs deemed equi-biased, i.e., equally likely to occur with either attachment site / interpretation. In particular, I used the 8 verbs categorized as equi-biased by Snedeker and Trueswell (2004): scratch, throw, pinch, feel, drag, turn over, blow on, and point at.

For each equi-biased verb, a set of two sentences or trials – one each for prime and target – was constructed. These trials were paired such that verbs were repeated across prime and target trials. Adults often demonstrate a lexical boost in their priming behavior (e.g., Branigan et al., 2000; Cleland & Pickering, 2003; Hartsuiker et al., 2008; Pickering & Branigan, 1998); priming is stronger when there is lexical repetition across the prime and the target. There is some inconsistent evidence that children are also subject to a lexical boost (Branigan & McLean, 2016; van Beijsterveldt & van Hell, 2009 vs. Peter et al., 2015; Rowland et al., 2012), so such repetition was included in the current task to maximize the likelihood that children would be primed.

For each of the 16 sentences, a picture unambiguously portraying each of the interpretations was designed and combined on a single letter sized piece of paper divided down

the middle (Figure 1A). These pictures provided the options for the picture selection portion of the task (i.e., the target trials).

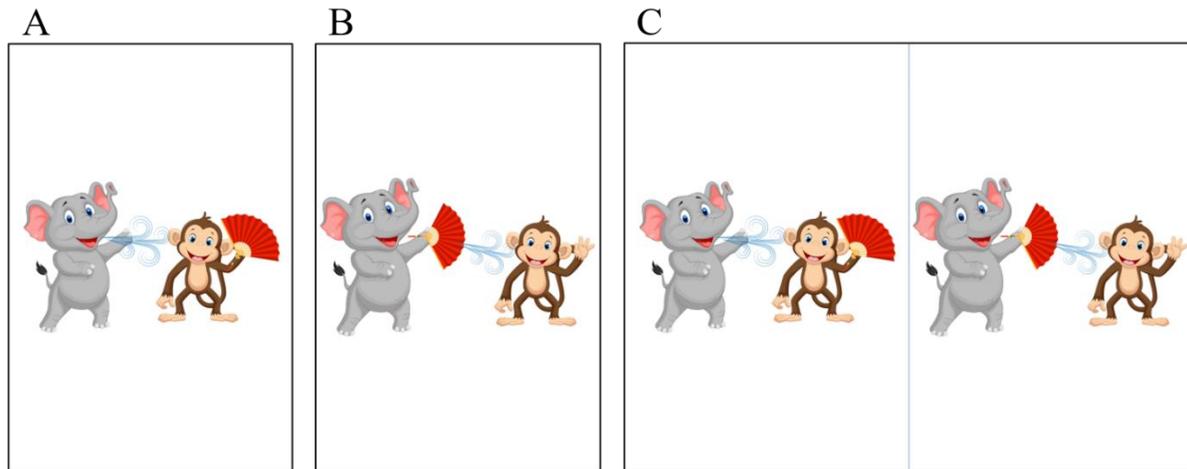


Figure 1. These pictures are all associated with sentence (1): *The elephant blows on the monkey with the fan*. A: Example prime picture with the NP attachment / modifier interpretation. B: Example prime picture with the VP attachment / instrument interpretation. C: Example paired target pictures. The image on the left depicts the NP attachment / modifier interpretation (i.e., the monkey possesses the fan, same as A), while the image on the right depicts the VP attachment / instrument interpretation (i.e., the elephant is using the fan, same as B).

Prime trials consisted of a single picture representing one of the two possible interpretations (Figures 1B and 1C). Thus, the picture provided the context to disambiguate the meaning of the PP-attachment ambiguity, and prime pictures were unambiguous.

Procedure

The 5-year-olds played a picture-matching task with Mr. Monkey (a puppet controlled by the experimenter). The goal of this game was to select the picture that matched the sentence, and there were two roles in this game: one that produced the sentence (the producer) and one that selected the matching picture (the matcher). The child and the puppet took turns producing a globally ambiguous sentence like (1) while alternating roles. Each round consisted of a prime trial

and a target trial each of which had an associated globally ambiguous sentence utilizing the same equi-biased verb. An example of a prime / target pair is given in (5).

- (5) a. *Prime*: The elephant blows on the monkey with the fan.
b. *Target*: The cow blows on the horse with the straw.

For the prime sentences, the child was the producer and the puppet was the matcher. Children were presented a single picture unambiguously depicting one of the two possible interpretations, and the experimenter named the two animals and provided the verb (e.g., “This picture is about blowing on”). Children were then prompted to describe the picture using a sentence like (4a). To ensure that children produced sentences of this type, a practice trial preceded the experimental trials in which the experimenter demonstrated this sentence structure using another equi-biased verb not used in the main experiment (*The leopard surprised the horse with the balloons*) and made the child repeat it. On subsequent experimental trials, children were coached to use these globally ambiguous sentences if they attempted to describe the picture using an alternative structure. The intended interpretation of the prime was manipulated between participants, so children were randomly assigned to one of two priming groups: VP attachment / instrument interpretation (see Figure 1C) or NP attachment / modifier interpretation (see Figure 1B). On target trials, the roles reversed: the puppet described a picture using the same globally ambiguous sentence structure and the child chose the picture that matched the sentence from the two possible interpretations (see Figure 1A). A small occluding wall was placed between the child and the puppet space so that the puppet could not see the picture that the child was describing and vice versa.

Previous research demonstrated that 5-year-old children accepted both the instrument and modifier interpretations (Zimmer, 2017), but did not indicate children’s baseline preference for one structure over the other. Although the current study focuses on supposedly equi-biased verbs, this categorization was based on adult preferences (Snedeker & Trueswell, 2004) and does not

guarantee that children share this approximately equal baseline preference. To address this issue, a smaller group of children (N=13) participated in a control condition. In this control condition, children only responded to prompts from the puppet and did not produce any sentences themselves. The 8 ambiguous target trials from the experimental conditions were each preceded by 2 unambiguous filler trials with a different structure and verb than the targets for a total of 32 items. Examples of filler items included collective actions (e.g., *The frog and the rabbit eat the bread*, Figure 2) and ditransitives (e.g., *The cow gives the balloons to the horse*). These sets of 3 (2 filler sentences + 1 ambiguous target) were quasi-randomized for each participant.

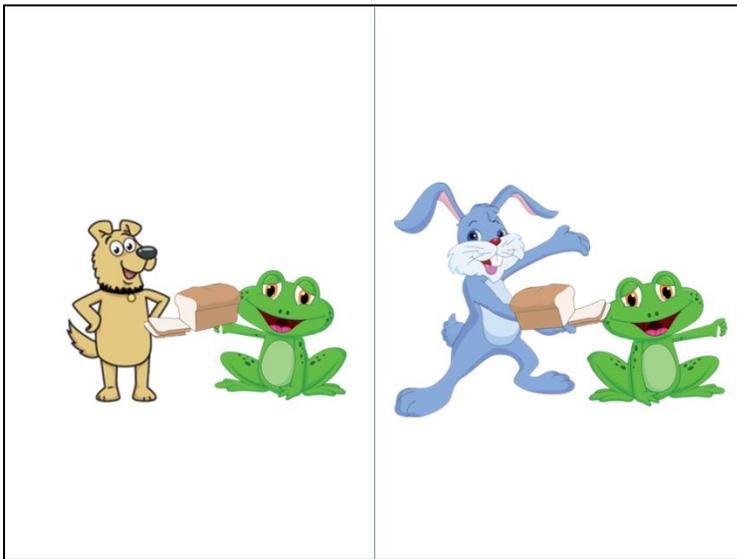


Figure 2. Example paired target pictures associated with the collective action filler trial, *The frog and the rabbit eat the bread*.

Results

Control group

Overall, children in the control group chose the instrument interpretation (i.e., VP attachment) in 81% of trials. Of the 16 participants, 6 exclusively selected this interpretation (8/8 trials, 100%), 3

selected it 7 times (7/8 trials, 87.5%), 3 selected it 6 times (6/8, 75%), and only 4 selected it approximately half the time as predicted by the classification of the verbs as equi-biased (4/8 or 5/8, 50% or 62.5%). In other words, 75% of the children in the control group selected the instrument interpretation in at least 75% of trials. Clearly, the 8 verbs used in this study actually have a strong bias toward an instrument interpretation for 5-year-olds. Thus, 81% will be used as the baseline level of instrument interpretation selection for the purposes of analyzing the priming data.

Experimental groups

Given the strong preference for the instrument interpretation in the control group, the analysis of the priming groups will be in terms of selections of the instrument interpretation during the testing phase (i.e., how often children selected the picture corresponding to the instrument interpretation). Children in the instrument interpretation priming group selected the instrument interpretation 94% of the time during the test phase ($SE = 2.3\%$). Conversely, children in the modifier interpretation group only selected the instrument interpretation 68% of the time ($SE = 4.6\%$) for a difference of approximately 26%, which is a large effect (Cohen's $d = 1.26$, 95% confidence interval = 0.47 – 2.05).

To test for priming, a logistic mixed effect model testing the effect of prime group (sum coded: instrument primes = 1, modifier primes = -1), centered age, and their interaction on the likelihood of selecting the instrument interpretation. Participant and verb identity, which was confounded with trial number, were the random effects. The maximal random effect structure that converged was used (Barr, Levy, Scheepers, & Tily, 2013), which included random intercepts for participant and verb identity and a random slope for prime group for verb identity. There were

significant effects of prime group ($\beta = 0.72$, $SE = 0.18$, $p < 0.001$) and age ($\beta = 0.52$, $SE = 0.26$, $p < 0.05$). Participants in the instrument priming group were more likely to select the instrument interpretation; thus, children demonstrated priming in this experiment. Also, older children – regardless of priming group – selected the instrument interpretation more often.

As an additional test of priming, independent t -tests compared each prime interpretation group to the baseline of 81% instrument picture selections collected from the control group. A Bonferroni correction was used to correct the p -value for multiple comparisons. While the instrument interpretation group selected the instrument picture significantly more often than the baseline (difference = 12%; $t = 3.82$, $df = 15$, $p < 0.001$), the modifier interpretation group selected the instrument picture less often than the baseline only marginally (difference = 13%; $t = -2.06$, $df = 15$, $p = 0.06$). For the instrument interpretation group, this effect is large (Cohen's $d = 0.95$, 95% confidence interval = $-0.17 - 2.08$). Despite being only marginally significant for the modifier interpretation group, it is a medium effect (Cohen's $d = -0.51$, 95% confidence interval = $-1.60 - 0.57$). Thus, although the instrument interpretation is the more frequent structure (VP attachment), these results suggest that the significant effect of priming group in the mixed effect model was largely driven by children's preferences for the instrument interpretation being strengthened by exposure to instrument primes. Clearly there were no ceiling effects in spite of the high baseline preference for the instrument interpretation.

Discussion

The present experiment suggests that, like Havron et al. (2020), English-speaking children's PP-attachment preferences can be primed using a comprehension priming methodology.

In this picture matching task, children between the ages of 4 and 6 produced sentences with ambiguous PP-attachments that were associated visually with either a VP attachment / instrument or an NP attachment / modifier interpretation. Then, children comprehended another one of these sentences and chose the picture that matched the structure that they assign to it. The selection rate for the instrument interpretation varied based on which structure children were exposed to. The baseline comparison analysis suggested that this result was largely driven by the group primed with VP attachment; that group selected the instrument interpretation significantly above the baseline rate, but children primed with NP attachment did not reliably select the instrument interpretation below the baseline rate. This experiment responded to both the need to diversify the structures that are examined in child syntactic priming studies and the need to increase the number of comprehension priming studies.

I am currently conducting several follow-up studies that are investigating other methods of disambiguating the intended meaning of the prime and the effect of priming on verbs that are either instrument- or modifier-biased (instrument: *brush, clean, hit, tickle, poke, bop, cover, feed*; modifier: *choose, sing to, look at, listen to, yell at, find, talk to, hug*). In the present study, the intended interpretation of the prime was disambiguated by the single picture presented to the child to describe. Thus, these results may not reflect priming of the underlying syntactic structure (i.e., the attachment site of the PP), but rather priming of the interpretation independent of abstract structure.³ One way to distinguish between these two possibilities is to examine if / how priming is affected by prime sentences that are themselves unambiguous. Studies are in progress that use unambiguous prime sentences that either maintain the same basic underlying syntactic structures

³ The mechanism of this kind of priming could perhaps be explained by priming of the general visual scene, which includes the placement of the animals and the item and how these actors interact with one another. For example, in VP-attachment pictures, the inanimate item (e.g., the fan in (5)) is centered between the two animals, while in the NP-attachment pictures, it is closer to the patient animal.

as the ambiguous sentences used in this study (e.g., instrument: *The elephant blows on him with the fan*, modifier: *The elephant blows on the one with the fan*)⁴ or do not (instrument: *The elephant blows on the monkey by using the fan*, modifier: *The elephant blows on the monkey that has the fan*). Any priming effects following these latter sentences cannot be the result of *syntactic* priming, because the syntax of the prime and target sentences differs. Thus, comparing the results of these 3 types of primes could help differentiate if the priming effects in the current study are the result of syntactic priming, interpretation priming, or a combination of the two.

Another line of related research is examining whether priming can help children overcome the attachment biases associated with individual verbs. The current study employed verbs that were (supposedly) equi-biased to allow for priming in either direction. Despite the fact that adults do not display a strong attachment preference for this set of verbs, children demonstrated a fairly strong preference for VP attachment / instrument interpretations in the control study. Given this bias, it is possible that it would be more difficult to prime children away from VP attachment. On the other hand, if NP attachment is more novel and surprising, this may lead to greater learning and therefore stronger priming effects (see Jaeger & Snider, 2013 for a similar argument about adult priming effects). Thus, I am in the process of conducting parallel experiments that use this comprehension priming methodology to investigate priming against verb biases. For example, the verb *tickle* is biased toward VP attachment; children prefer to interpret the sentence *The lion tickles the zebra with the duster* as the lion using the duster to tickle the lion. Similarly, the verb *hug* is biased toward NP attachment, and the sentence *The rabbit hugs the pig with the blanket* is interpreted as the pig holding or wearing the blanket. While these same biases exist in adults, they

⁴ Thanks to Jesse Snedeker for suggesting this manipulation.

are stronger in children (Snedeker & Trueswell, 2004). Therefore, these follow-up studies address the question: can children’s attachment preferences be primed despite these strong biases?

5. Additional limitations

In addition to the two major limitations identified above – i.e., lack of structural variability and lack of comprehension priming – there are two more limitations that the distribution of studies in Table 1 helps bring to light: 1) a lack of variability in the ages of the children under study, and 2) a lack of variability in the languages of study. A quick scan of Table 1 makes it obvious that most studies examine children between the ages of four and six. There are a few exceptions that test either younger (e.g., Bencini & Valian, 2008; Havron et al., in press; Hsu, 2014a) or older children (e.g., Allen et al., 2011; van Beijsterveldt & van Hell, 2009). Crucially, the studies examining older children are usually interested in “atypical” populations (e.g., children with ASD: Allen et al., 2011; deaf children: van Beijsterveldt & van Hell, 2009). In terms of younger children, most studies examine children no younger than two or three, but Havron et al. (2021) were able to test 18-month-olds’ interpretation of French noun-verb homophones using a habituation method, although they did not find evidence for priming. Comprehension priming methodologies in particular seem suited for examining younger children’s abilities as they often involve the selection of a single picture from two alternatives; such a design is ideal for a preferential looking experiment.

Additionally, most of the studies reported in Table 1 were conducted in English or other Indo-European languages, with the one exception being the series of studies conducted on priming of the SVO-*ba* alternation in Mandarin Chinese (Hsu, 2014b, 2014a, 2019). Both of these are

variables requiring further exploration in future structural priming studies. Obviously, the experiment presented in Section 4 does not address these issues, as it was conducted with 5-year-olds and in English, but I hope to design studies in the future that push these limitations as well.

6. Conclusions

In this chapter, I have argued that there are two major roadblocks to our ability to develop general theories using data from the syntactic priming of children: 1) the lack of variability in structures examined and 2) the relative lack of comprehension priming experiments. A review of child priming studies revealed that the vast majority of studies examined either transitive (i.e., active vs. passive) or ditransitive (i.e., the dative alternation) structures. Although it is difficult to know the locus of this phenomenon, I suggested that it may be a historical artifact due to the fact that many studies are modeled after Bock's famous 1986 paper. Therefore, these studies overwhelmingly use production tasks as a measure of priming. Even though this parallels the relative lack of comprehension priming studies in the adult literature, it is important to further investigate comprehension to better understand the nature of priming. My own work provided an example of the prescribed course of action by testing for syntactic priming effects in structures not typically used in developmental studies and by contributing to the number of studies examining comprehension. In fact, Tooley and Traxler (2010) make similar recommendations in their review of adult comprehension priming studies and suggest that they are needed in the effort to build a parsimonious model of syntactic priming. Completing this work in parallel with children can only

bolster our understanding of structural priming as a phenomenon and better understand the connections between adult and child priming. Finally, we must continue expanding the type and number of languages under study and examine children across a wider span of ages.

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