BUCLD 35 Proceedings
To be published in 2011 by Cascadilla Press
Rights forms signed by all authors

Where does Verb Bias Come From? Experience with Particular Verbs Affects Online Sentence Processing

Zhenghan Qi, Sylvia Yuan, and Cynthia Fisher

1. Introduction

Language comprehension is fundamentally incremental. As sentences unfold, listeners or readers weigh multiple sources of information as each becomes available, to guide the interpretation of preceding elements in the sentence and to anticipate how the sentence will continue (e.g., Boland, Tanenhaus, & Garnsey, 1990; MacDonald, Pearlmutter, & Seidenberg, 1994; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). One powerful guide to incremental sentence interpretation is *verb bias*, knowledge of the probabilistic sentence-structural preferences of individual verbs (e.g., Garnsey et al., 1997; Trueswell & Kim, 1998). In this paper we explore the nature and acquisition of verb bias. In doing so we must begin to tease apart multiple potential sources of knowledge that are usually confounded (e.g., Snedeker & Trueswell, 2004; Willits, Sussman, & Amato, 2008). These include non-linguistic world knowledge about the plausibility of events, and linguistic knowledge about verb semantics and how verbs are distributed in sentences.

1.1. Verb bias guides sentence comprehension

To see the effects of verb bias, consider the case of the temporary ambiguity shown in (1). The verbs *warn* and *worry* can take direct objects or sentence complements, but *warn* more often takes a direct object, and *worry* more often takes a sentence complement. Listeners tend to analyze a noun phrase following *warn* as a direct object. This causes comprehension delays if that noun phrase turns out to be the subject of a sentence complement, as in (1a). Such "garden path" effects are reduced or eliminated if the verb more frequently occurs with a sentence complement (e.g., Garnsey et al., 1997). Thus, when reading or hearing sentence (1b), readers are less likely to experience difficulty, because they ex-

*The authors are affiliated with the University of Illinois, the University of California Berkeley, and the University of Illinois, respectively. We thank Jesse Snedeker for generously sharing her stimulus materials and for helpful suggestions in the design of this study. This research was supported by grants NIH HD 054448 and NSF BCS 0620257 to C. Fisher. Zhenghan Qi is the corresponding author, E-mail address: zqi2@illinois.edu.

pected a sentence complement to follow the verb *worried*.

(1) a. The referees warned the *spectators* would probably get too rowdy.
b. The bus driver worried the *passengers* were starting to get annoyed.

Children's parsing preferences are also guided by verb bias (e.g., Snedeker & Trueswell, 2004). Snedeker and Trueswell (2004) tracked 5-year-olds' eyes as they responded to instructions to act on toys. Critical instructions were globally ambiguous, as in (2): each contained a prepositional phrase that could be attached to the verb and given an instrument interpretation (e.g., using the feather to tickle), or attached to the noun and given a modifier interpretation (e.g., the frog that has the feather). Snedeker and Trueswell compared instrument-bias verbs, which often occurred with instruments in a norming study (e.g., *tickle*), modifier-bias verbs, which rarely did (e.g., *choose*), and equi-biased verbs, which fell between these extremes (e.g., *feel*). Children showed strong effects of verb bias: they more often used instruments when hearing instrument-bias verbs, and eye-movement analyses revealed that the effects of verb bias emerged quickly as children heard the noun phrase following *with* (e.g., *feather*).

(2) Tickle the frog with the feather.

These findings document the rapid use of verb bias in online sentence processing by children and adults. When they encounter a verb, native speakers retrieve frequency-sensitive information that they use to anticipate what kinds of phrases may follow that verb, and how those phrases should be interpreted.

1.2. What is verb bias, and where does it come from?

How are the structural biases of individual verbs established during acquisition? For example, what kinds of experiences might lead children to learn to expect an instrument prepositional phrase following *tickle* but not *choose*? As noted above, multiple information sources (not mutually exclusive) may contribute to verb-bias learning.

First, conceptual knowledge about events might directly affect online parsing, and serve as a primary source of verb bias. That is, upon encountering a verb, listeners might retrieve conceptual knowledge of the referent event, and use it to determine what kinds of event participants are plausible (e.g., Ferretti, McRae & Hatherell, 2001). This knowledge, in turn, could be derived from nonlinguistic *event distributional information*, via observation of events in the world. For example, we might treat *tickle* as an instrument-bias verb because we often observe tickling events involving instruments.

However, verbs do not simply refer to events; instead, they refer to construals of events. The same scene in the world can be described by multiple verbs with different meanings and structural preferences (Levin & Rappaport Hovav, 2005). For this reason, many have argued that word learning and sentence inter-

pretation depend on analyses of the linguistic contexts in which words appear (e.g., Gleitman, 1990; Trueswell & Gleitman, 2004). Such considerations suggest another possibility, that verb bias learning might be based on *linguistic distributional information* about how speakers use each verb in sentences. Thus, we might treat *tickle* as an instrument-bias verb because we often hear this verb in sentences with a verb-attached prepositional phrase that describes an instrument.

In natural language exposure, these information sources are nearly always confounded. For example, the verb *tickle* presumably occurs with instrument phrases in sentences because this verb highlights an event type in which it makes sense to use an instrument.

One way to disentangle these information-sources is to study the learning of artificial languages. Recent experiments have shown that fairly brief training creates verb-bias effects for newly-learned verbs (Wonnacott, Newport, & Tanenhaus, 2008; see also Amato & MacDonald, 2010). For example, Wonnacott et al. (2008) found that adults who were learning to produce and understand sentences in an artificial language encoded verb-specific constraints on word order that affected online sentence comprehension. These artificial-language-learning experiments all involved the simultaneous presentation of events as well as linguistic information. However, Wonnacott et al. took care that no covert semantic or event categories differentiated the verbs that selected different word orders in their experiment; therefore they argued that their verb-bias effects primarily reflected linguistic distributional learning.

Some of the strongest evidence for the independent role of linguistic distributional information in the verb lexicon comes from experiments in which 2-year-olds learn combinatorial facts about novel verbs before being shown any events at all (Arunachalam & Waxman, 2010; Yuan & Fisher, 2009). Yuan and Fisher (2009) showed 2-year-olds dialogues in which two women used a made-up verb in transitive (e.g., "Jane blicked the baby!") or intransitive sentences ("Jane blicked!"). In a later test, children's interpretations of the novel verb were influenced by the dialogue experience: those who had heard transitive dialogues looked longer at a two-participant event (as opposed to a one-participant event) than did those who had heard intransitive dialogues. These studies examined the learning of absolute subcategorization facts about novel verbs rather than probabilistic verb biases; nonetheless, these data show that toddlers can encode linguistic distributional facts about verbs, without situational knowledge.

Taken together, these results yield strong evidence that adults and children encode linguistic-distributional information about entirely new verbs, and that this information guides language comprehension.

Here we adopt a different tactic. Rather than establishing structural biases for unknown verbs, we provided children with additional experience with a set of familiar verbs in the laboratory, to determine whether simply listening to sentences could modify the biases of known verbs. We chose the eight equi-bias verbs from Snedeker and Trueswell's (2004) study (e.g., *point at, pinch*). Snedeker and Trueswell's data suggest that preschoolers know that these verbs can occur with both instrument and modifier prepositional phrases. If linguistic

distributional learning plays an independent role in the acquisition of verb bias, then new linguistic experience involving these verbs might reshape their biases.

One recent language production experiment suggests that the biases of familiar verbs can be modified in adults. Coyle and Kaschak (2008) asked participants to complete sentence stems containing dative verbs. In the biasing phase, the stems had object nouns that induced participants to produce double-object datives with one verb (e.g., *The teacher sent the student*) and prepositional datives with another (e.g., *The man handed the book*). At test, the stems to be completed ended at the verb (e.g., *The boy handed*), leaving it up to the participant which structure to use. Coyle and Kaschak found effects of the biasing phase on later productions: Participants produced more double-object sentences for the verb that they had produced in that structure in the biasing phase. Thus, adults encoded new information about the structural biases of known verbs when producing sentences, and this information biased later sentence production. Coyle and Kaschak's (2008) finding also suggests that the modification of familiar verbs bias derives from linguistic distributional information, because dative verbs such as *hand* describe essentially the same events whether they are used in double-object or prepositional dative sentences.

The present study built on these prior findings to explore the acquisition of verb bias in 5-year-old children. We ask whether brief experience listening to sentences containing familiar verbs can influence the structural biases of those verbs, thereby influencing incremental sentence comprehension.

2. The current study

In an initial study phase, 5-year-olds watched training dialogues in which two women used familiar equi-bias verbs to talk about unseen events. Each verb appeared in sentences containing structurally ambiguous *with* prepositional phrases. The discourse context and noun phrase choices in the dialogues were designed to strongly bias children toward either modifier or instrument interpretations of the prepositional phrases (see Methods below). Each child heard four modifier and four instrument training dialogues containing different verbs.

In the subsequent test phase, children responded to sentence instructions that included ambiguous *with* prepositional phrases (e.g. "Point at the pig with the flower") by moving toys in a display while a central camera recorded their eye-movements. We analyzed children's actions and eye-movements as the sentences unfolded to determine whether their interpretations of the ambiguous *with* phrases were affected by whether they had heard the verb in an instrument- or in a modifier-training dialogue during the initial study phase.

If this brief language experience can modify children's verb biases, then children should retrieve the new verb-bias information encoded during the training dialogue when they encounter the same verb in the test phase. As a result, they should be more likely to consider a modifier interpretation of an ambiguous *with* phrase when encountering modifier-trained verbs, and an instrument interpretation when encountering instrument-trained verbs. This pattern would be

consistent with the hypothesis that linguistic-distributional information contributes to verb-bias learning. On the other hand, it might be that this brief language experience has no effect on the perceived structural biases of familiar verbs. This pattern might imply that verb bias learning requires support from event-distributional information.

2.1. Methods

2.1.1. Participants

Sixty-four 5-year-olds (mean 60 months, range 51-70.4 months; 32 boys, 32 girls) participated. Sixteen additional children were eliminated from analysis, because they declined to participate (6), were inattentive (3), contributed too few codable trials (5; see Coding below), or showed evidence of misunderstanding the study phase dialogues (2; see Procedure below).

2.1.2. Materials

The materials included two types of dialogue videos (Instrument-training and Modifier-training dialogues) used in the study phase, and prerecorded instructions accompanied by an appropriate set of toys for the test phase. The verbs in the dialogues and the critical instructions were the 8 equi-bias target verbs [*point at, turn over, throw, scratch, pinch, feel, blow on,* and *drag*] from Snedeker and Trueswell (2004).

For the study phase, for each target verb we created 2 short videos showing two women talking about unseen events (16 experimental dialogues). Each dialogue contained 4 critical sentences with structurally ambiguous *with* phrases, with discourse context and noun-phrase choices strongly promoting either modifier or instrument interpretation of the *with* phrases. For example, (3) shows the instrument- and modifier-training dialogues for the verb "point." In the Instrument-training dialogue (3a), the question "What did Tim use…" and the prepositional phrase objects "red pencil" and "magic sword" implied an instrument interpretation of the *with* phrases. In the Modifier-training dialogue (3b), the question "Which tiger…" and the prepositional phrase objects "sharp teeth" and "large paws" implied a modifier interpretation. We also created 2 filler dialogues that did not contain a target verb or *with* phrases.

(3a) ***Instrument-training dialogue***
A: "Do you remember that story about the tiger? What did Tim use to point at the tiger?"
B: "He pointed at the tiger with the red pencil."
A: "Right, he pointed at the tiger with the red pencil. Hmm. If I were him, I would point at the tiger with the magic sword."
B: "Wow! You wanna point at the tiger with the magic sword! How exciting!"
(3b) ***Modifier-training dialogue***
A: "Do you remember that story about the tiger? Which tiger did Tim point at?"

B: “He pointed at the tiger with the large paws.”
A: “Right, he pointed at the tiger with the large paws. Hmm. If I were him, I would point at the tiger with the sharp teeth.”
B: “Wow! You wanna point at the tiger with the sharp teeth! How exciting!”

For the test phase, we recorded 8 critical sentences and 24 filler sentences; all were taken from the materials of Snedeker and Trueswell (2004). Each critical sentence contained a target verb followed by an ambiguous *with* phrase (e.g., “Point at the pig with the flower”). As shown in Figure 1, each test sentence was accompanied by a set of toys: a Target Animal with a small replica of the target instrument (e.g., a pig holding a flower), a Distracter Animal that had a small replica of the distracter instrument (e.g., an elephant holding a crayon), a Target Instrument (e.g., a large flower) and a Distracter Instrument (e.g., a large crayon). These toys made available both modifier and instrument interpretations of the *with* phrase. That is, to return to our example, the display contained a large flower with which to point at the pig, and a pig that had a flower. These trials thus represented the one-referent condition of Snedeker and Trueswell’s experiment. In their two-referent condition, the distracter and target animals were of the same kind (e.g. two pigs holding different mini-instruments). We chose the one-referent condition for our experiment so that we could use the same materials in a planned version for adults: Snedeker and Trueswell found that adults overwhelmingly interpreted ambiguous prepositional phrases as modifiers in the two-referent context with equi-bias verbs.

2.1.3. Procedure

In the study phase, children watched 10 dialogues (the 2 fillers and 8 of the experimental dialogues) presented on a laptop. After each dialogue, the experimenter asked the child to repeat the last sentence of the dialogue (“What did she just say?”, while pointing at the last speaker), and gave the child a sticker. The experimenter then repeated the last sentence whether or not the child repeated it correctly. This was done to ensure that children attended to the dialogues, and to assess their comprehension of the dialogue sentences.

During the test phase, children sat in front of an inclined podium with a shelf in each quadrant on which toys could be placed and a central camera that recorded the children’s eye-movements. Another camera behind the children recorded their actions. The recorded instructions were played from a laptop through external speakers. Children were told that they would play a game involving following instructions. At the start of each trial, the experimenter placed the toys in each quadrant of the podium, introducing each by name. The mini-instruments attached to each animal were introduced as separate objects (e.g., “Here’s a crayon, a pig, a flower, another flower, an elephant, and another crayon”). After naming the objects in this manner twice, the experimenter played the pre-recorded instructions for the trial. Each trial began with an instruction to look at the camera, followed by two other pre-recorded instructions. In critical

trials the first instruction was the critical sentence and the second was a filler sentence. Each child received 4 critical and 5 filler trials. This procedure is same as that described by Snedeker and Trueswell (2004).

1A. Study phase **1B. Test phase**

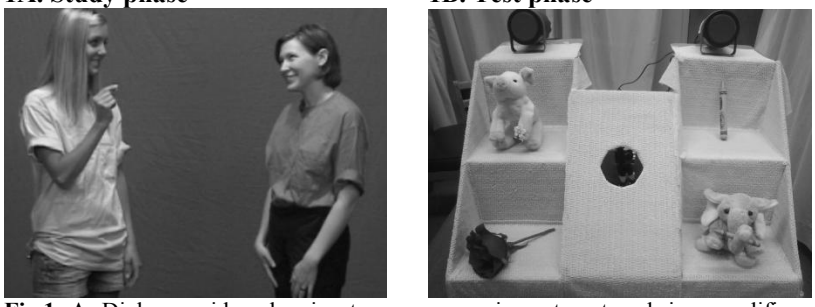


Fig.1. A. Dialogue video showing two women using a target verb in a modifier- or instrument-bias context; B. Toy layout for the sentence "Point at the pig with the flower."

2.1.4. Design

The 8 equi-bias verbs were divided into two lists. The lists were combined such that each child heard instrument-training dialogues for 4 verbs and modifier-training dialogues for the other 4, intermixed with filler dialogues in a quasi-random order. Each verb was presented in a modifier-training dialogue to half of the children, and an instrument-training dialogue to the other half. In the test phase, children received only 4 critical test trials – each child was tested either on the verbs they had heard in instrument-training dialogues, or on the verbs they had heard in modifier-training dialogues.

2.1.5. Coding

Trained coders categorized children's actions as: Instrument actions (the child performed the action on the target animal using the target instrument), Modifier actions (the child performed the action on the target animal using her hand), and Mini-instrument actions (the child used the mini-instrument attached to the target animal to carry out the action). Ten trials coded as Mini-instrument actions were removed from the eye-movement analyses (as in Snedeker & Trueswell, 2004). Two additional trials were excluded from analysis because the action was performed on the distracter animal (1) or the child blocked the coder's view of the target quadrant (1).

Eye-movement data were coded frame by frame from video. Coders first marked the onset of each critical sentence, then recorded where the child was looking from the onset of the critical sentence until 3.5 seconds later, by which time most children had carried out an action (average critical sentence length was 2.1 s). We coded looks to the four quadrants of the podium, away, and to the central camera. Frames were coded as missing if the child's eyes were hid-

den. Four trials with fewer than 1/3 of frames coded as fixations to a quadrant of the podium were removed from analysis. Coding reliability was assessed for 16 children and yielded agreement on 96% of coded video frames.

2.2. Results and discussion

2.2.1. Offline behavior measures

We first asked whether children's actions reflected the dialogue manipulation. The overall mean proportion of instrument actions was 0.55, which is similar to the mean proportion of instrument actions for equi-bias verbs in Snedeker and Trueswell's (2004) data. Children also tended to enact more instrument actions for instrument-trained (M = 0.61, SE = 0.06) than for modifier-trained verbs (M = 0.49, SE = 0.06). This effect was in the right direction to indicate an influence of the dialogues, but was not significant (F (1, 62) = 2.12, p = .15). Each verb appeared only four times in its dialogue; evidently this manipulation was too slight to substantially alter children's offline interpretations of sentences.

2.2.2. Online eye-movement measures

We next asked whether children's eye movements showed effects of the training dialogues as the sentences unfolded. For verbs trained in instrument dialogues, children should more often consider an instrument interpretation, and therefore look longer at instruments. For verbs trained in modifier dialogues, in contrast, children should look less at instruments, and more at the animals.

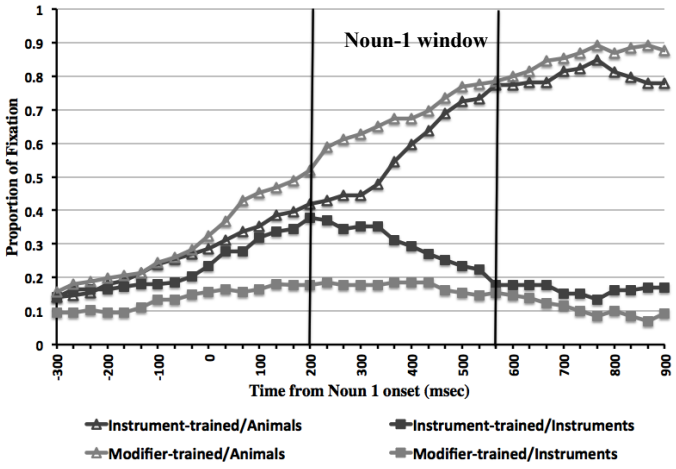
Fig. 2 plots eye fixations in two critical analysis windows. Figure 2A shows fixations as children heard the direct object noun (Noun-1, "pig" in "Point at the pig with the flower"), and Figure 2B shows fixations as children heard the prepositional phrase object noun (Noun-2, "flower" in the same example). The zero-point of each plot's time scale is aligned with the onset of the relevant noun.

Fig. 2A shows the proportion of fixations to animals (either target or distracter) and instruments (target or distracter) in the Noun-1 window. We analyzed looks to animals and instruments rather than only to the target animal and target instrument in the Noun-1 window because at this point (1) children have not yet heard the target instrument name, and (2) as the animal name unfolded during the Noun-1 window, the search for the target animal involves increased attention to both animals. Thus we reasoned that a composite measure of fixations to animals and instruments might be sensitive to early training effects. As Fig. 2A shows, during the Noun-1 window, looks toward animals became dominant more quickly in sentences with modifier-trained rather than instrument-trained verbs. Children who heard instrument-trained verbs distributed their attention more equally between animals and instruments. Following Snedeker and Trueswell (2004), we conducted statistical analyses in a 367-ms time window starting 200 msec after Noun-1 onset[†]. Children looked reliably more to animals

[†] Analysis windows were offset by 200 msec to allow time to program an eye movement.

when they heard modifier- rather than instrument-trained verbs (F (1, 62) = 4.17, p < .05), and reliably more to instruments when they heard instrument- rather than modifier-trained verbs (F (1, 62) = 5.20, p < .05).

2A. Direct Object Noun (Noun 1) Region



2B. Prepositional Phrase Object Noun (Noun 2) Region

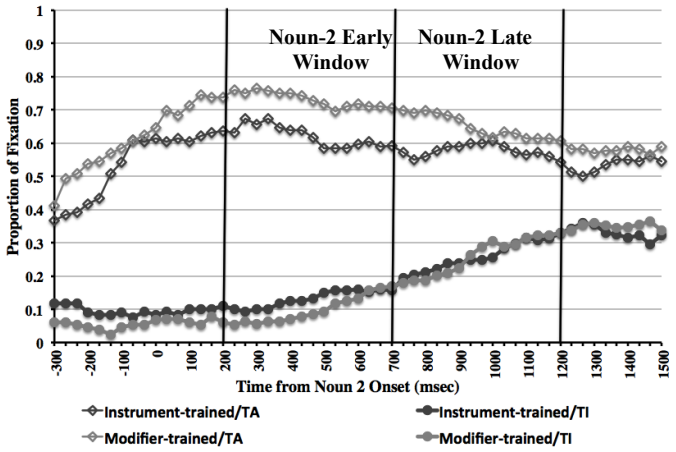


Fig.2. Proportion of fixation to objects, time-locked at the onset of the direct object noun (**A**) and the prepositional phrase object noun (**B**). The dark grey lines represent test trials containing instrument-trained verbs. The light grey lines represent test trials containing modifier-trained verbs. TA: target animal; TI: target instrument.

No training effect emerged before the Noun-1 region. Analyses of fixations in a window beginning 200 msec after verb onset and ending 200 msec after Noun-1 onset revealed no effect of training on fixations to animals or instruments (F's < 1.6, p's > .2).

Fig. 2B shows the proportion of fixations to the target animal and target instrument in the Noun-2 window. Following Snedeker and Trueswell (2004), we divided the 1-s period beginning 200 msec after Noun-2 onset into two 500-msec analysis windows, the Early and Late Noun-2 windows shown in Fig. 2B. In the Early Noun-2 window, we found a marginal effect of training on looks to the target animal (F (1, 62) = 3.42, p = .07). Children tended to look more at the target animal in trials with a modifier- rather than an instrument-trained verb. The training dialogues did not affect children's fixations to the target instrument in either the Early or Late Noun-2 window (F's < 1, p's > .5).

Why did the training effect appear so early? The early effect of training in the Noun-1 region, as children heard the target animal's name but before they encountered the ambiguous *with* phrase, and its rapid decay in the Noun-2 region, raised questions about whether this early effect depended on the *with* phrase at all. Did children anticipate instruments for instrument-trained verbs as soon as they heard the verb, even before they heard a *with* phrase? Or might this early effect be carried by later trials within the experiment, if children learned to anticipate a *with* phrase as the experiment progressed? Filler sentences did not contain ambiguous *with* phrases, but the provision of many such sentences in the dialogue videos may have drawn children's attention to them.

Fig. 3A. Noun-1 Window **Fig. 3B. Early Noun-2 Window**

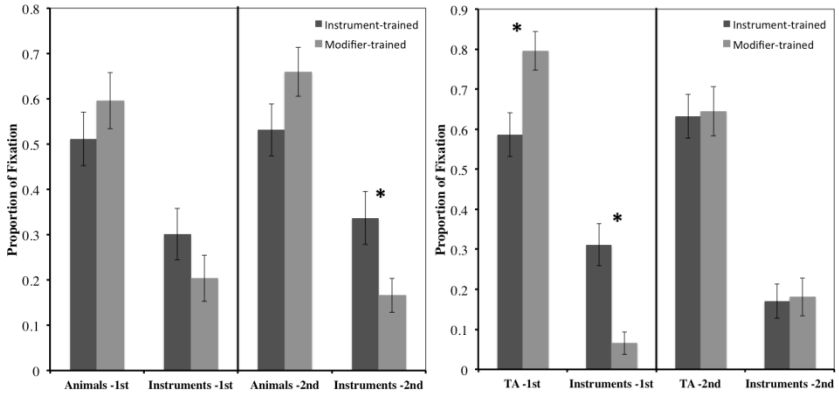


Fig.3. Mean (SE) proportion of fixations to animals and instruments in the Noun-1 window (**A**) and fixations to the target animal (TA) and instruments in the Early Noun-2 windows (**B**). The left side of each figure plots the first half of the test trials and the right side plots the second half.

To examine these questions, we conducted separate analyses of the first and second halves of the test session. Fig. 3 shows children's fixations in the first and second halves of the experiment, in the Noun-1 and Early Noun-2 windows. Fig. 3A shows again that children tended to look more at instruments in the Noun-1 window when they heard instrument- rather than modifier-trained verbs; however, this effect did not become reliable until the second half of the experiment. Children looked reliably more at instruments in trials with instrument-

rather than modifier-trained verbs in the second half of the experiment (F (1, 62) = 6.03, $p < .05$) but not in the first half (F (1, 62) = 1.59, $p = .21$). In contrast, as shown in Fig. 3B, the Early Noun-2 region exhibited a strong training effect in the first but not the second half of the test phase. In the first half of the experiment, as they listened to the noun following *with*, children looked reliably more at the target animal in trials with modifier- rather than instrument-trained verbs (F (1, 62) = 8.82, $p < .01$) and looked reliably more at instruments[‡] in trials with instrument- rather than modifier-trained verbs (F (1, 62) = 4.91, $p < .05$). These effects in the Early Noun-2 window disappeared in the second half of the experiment (F's < 1). Finally, although not shown in Fig. 3, we also observed a training effect on looks to the target animal in the Late Noun-2 window; this effect appeared in the first half of the experiment (F (1, 62) = 5.74, $p < .05$) and disappeared in the second half ($F < 1$).

This pattern suggests that the training effect we observed in children's eye movements depended on the ambiguous *with* phrases in the test sentences. In the first half of the trials, reliable effects of training emerged as children heard the object of prepositional phrase. In the second half of the trials, after hearing some test trials including *with* phrases, the effect of training shifted earlier in the trial.

3. Discussion

Our findings show that brief exposure to sentences was sufficient to modify the structural biases of familiar verbs. All children heard both instrument and modifier dialogues in the study phase. Their consideration of instrument versus modifier interpretations of *with* phrases in the test phase depended on which verbs appeared in the test sentences – those they had heard in instrument or in modifier dialogues. Thus, during the study phase, children attached to each verb information about its occurrence with instrument vs. modifier phrases. At test, children retrieved this combinatorial information when they encountered the same verbs again. As a result, our dialogue manipulation influenced children's online processing of sentences with ambiguous *with* phrases.

These findings have consequences for theories about the acquisition of verb bias. Evidence that new linguistic experience involving known verbs can reshape their structural biases is consistent with the hypothesis that linguistic distributional learning plays an independent role in the acquisition of verb bias.

Can we strongly conclude that these training effects primarily reflected linguistic-distributional rather than event-distributional knowledge? In the dialogue manipulation, we presented sentences but not events; thus children had linguistic experience to work with. However, although the events described by the dialogue sentences were not visually depicted, the linguistic descriptions conveyed event information. For example, upon hearing "point at the tiger with the magic

---

‡ This effect was not reliable in the Early Noun-2 window in analyses of the target instrument alone, but only in analyses of the composite measure of fixations to either instrument.

sword" in a context demanding an instrument interpretation, children presumably generated a mental representation of the event described. Thus the dialogues simultaneously gave children information about (1) the likelihood that an instrument would be used in a pointing event, (2) the likelihood that an instrument would be mentioned in "point at" sentence, and (3) the likelihood that a verb-attached *with* prepositional phrase co-occurs with this verb. The first of these three is event-distributional information, although linguistically conveyed in our case; the latter two are both forms of linguistic distributional information.

The difficulty of disentangling event and linguistic distributional information follows from the nature of linguistic communication. When we identify a verb, we activate a complex of syntactic, semantic, and conceptual knowledge. This includes information about the possible syntactic complements of the verb, the participants involved in the event, and the mapping between the two (e.g., Carlson & Tanenhaus, 1988). In adults, presentation of a verb causes readers or listeners to activate detailed information about the participant-roles that are filled by that verb's arguments (e.g, Boland, 2005; Ferretti et al., 2001).

One aspect of our current findings provides initial evidence that learning about the co-occurrence of a *with* phrase with each verb in the training phase played a critical role in our task. In the first half of the test phase, we found effects of dialogue training only after the onset of the prepositional phrase object; later in the experiment, the effects of dialogue training shifted earlier in the course of the sentence. We argued that this pattern suggested that the training effects were elicited by the ambiguous *with* phrases in the test sentences. Thus children may have learned during the dialogue phase how to interpret a *with* phrase in sentences containing each verb, not simply whether the events referred to by each verb were plausibly enacted with an instrument.

Future experiments will explicitly test whether the training effect found here required the encoding of information about the co-occurrence of each verb with a *with* phrase in the dialogues. For example, in the study phase, children might hear "point at the tiger using the red pencil" in instrument-training dialogues, and "point at the tiger that has the large paws" in modifier-training dialogues. They would then encounter these verbs in the same critical sentences used here, with ambiguous *with* phrases. These modified dialogues use different syntactic structures to describe the same events described by the dialogues in the current experiment. This manipulation permits a further uncoupling of linguistic- and event-distributional learning. If the training effects found here are reduced or eliminated by this syntactic difference between the dialogue and test sentences, then this would provide stronger evidence of an independent role for linguistic-distributional learning in the acquisition of verb bias.

In our experiment, children attached to each verb new information about its probability of occurrence with an instrument or modifier *with* phrase. They later retrieved that information when they encountered the same verb again, and used it to guide ambiguity resolution. This task provides us with a new tool to investigate the kinds of experiences that lead to the creation of verb bias. Our future experiments will further disentangle the effects of (linguistically-conveyed)

event-distributional information and linguistic-distributional information.

References

Amato, Michael & MacDonald, Maryellen (2010). Sentence processing in an artificial language: Learning and using combinatorial constraints. *Cognition, 116*, 143-148.

Arunachalam, Sudha, & Waxman, Sandra (2010). Meaning from syntax: Evidence from 2-year-olds. *Cognition*, *114*, 442-446.

Boland, Julie (2005). Visual arguments. *Cognition, 95*, 237–274.

Boland, Julie, Tanenhaus, Michael, & Garnsey, Susan (1990). Evidence for the immediate use of verb control information in sentence processing. *Journal of Memory and Language*, *29*, 413-432.

Carlson, Greg, & Tanenhaus, Michael. (1988). Thematic roles and language comprehension. *Syntax and semantics*, *21*, 263-288.

Coyle, Jacqueline & Kaschak, Michael (2008). Patterns of experience with verbs affect long-term cumulative structural priming. *Psychonomic bulletin & review, 15*, 967-970.

Ferretti, Todd, McRae, Ken, & Hatherell, Andrea. (2001). Integrating verbs, situation schemas, and thematic role concepts. *Journal of Memory and Language*, *44*, 516-547.

Garnsey, Susan, Pearlmutter, Neal, Myers, Elizabeth, & Lotocky, Melanie (1997). The contributions of verb bias and plausibility to the comprehension of temporarily ambiguous sentences. *Journal of Memory and Language*, *37*, 58-93.

Gleitman, Lila (1990). The structural sources of verb meaning. *Language Acquisition, 1*, 3-55.

Levin, Beth, & Rappaport Hovav, Malka (2005). *Argument realization*. New York, NY: Cambridge University Press.

MacDonald, Maryellen, Pearlmutter, Neal, & Seidenberg, Mark (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review*, *101*, 676-703.

Snedeker, Jesse, & Trueswell, John (2004). The developing constraints on parsing decisions: The role of lexical-biases and referential scenes in child and adult sentence processing. *Cognitive Psychology*, *49*, 238-299.

Tanenhaus, Michael, Spivey-Knowlton, Michael, Eberhard, Kathleen, & Sedivy, Julie (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*, 1632.

Trueswell, John & Gleitman, Lila (2004). Children's eye movements during listening: Developmental evidence for a constraint-based theory of sentence processing. In J.M. Henderson & F. Ferreira, (Eds.), *The interface of language, vision, and action: Eye movements and the visual world* (pp. 319-346). New York: Psychology Press.

Willits, John, Sussman, Rachel Shirley, & Amato, Michael (2008). Event knowledge vs. verb knowledge. In *Proceedings of the 30th Annual Conference of the Cognitive Science Society* (pp. 2227–2232).

Wonnacott, Elizabeth, Newport, Elissa, & Tanenhaus, Michael (2008). Acquiring and processing verb argument structure: Distributional learning in a miniature language. *Cognitive Psychology*, *56*, 165-209.

Yuan, Sylvia, & Fisher, Cynthia (2009). Really? She blicked the baby? *Psychological Science*, *20*, 619-626.