ABSTRACT

Title of thesis:	FAST MAPPING IN LINGUISTIC CONTEXT: PROCESSING AND COMPLEXITY EFFECTS
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Young children readily use syntactic cues for word learning in structurally-simple contexts (Naigles, 1990). However, developmental differences in children's language processing abilities might interfere with their access to syntactic cues when novel words are presented in structurally-challenging contexts. To understand the role of processing on syntactic bootstrapping, we used an eye-tracking paradigm to examine children's fast-mapping abilities in active (structurally-simple) and passive (structurally-complex) sentences. Actions after sentences indicated children were more successful mapping words in passive sentences when novel words were presented in NP2 ("*The seal will be quickly eaten by the blicket"*) than when novel words were presented in NP1 ("*The blicket will be quickly eaten by the seal*"), indicating presenting more prominent nouns in NP1 increases children's agent-first bias and sabotages interpretation of passives. Additionally, later recall data indicate children were less likely to remember new words when they were presented in structurally-challenging contexts.

FAST MAPPING IN LINGUISTIC CONTEXT: PROCESSING AND COMPLEXITY EFFECTS

by

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1. Introduction

Word learning is a foundational aspect of language development. At a basic level, learning the meaning of a new word requires pairing a sound with an appropriate referent, a skill known as *fast mapping*. While this task can sometimes be relatively straightforward, it is often complicated by competing referents in the environment. Nevertheless, children assign meanings to new words quite rapidly, and previous research has sought to define the mechanisms by which this is possible. One important source of information is the structure of the sentence in which a word occurs (Brown, 1957; Fisher, Gertner, Scott, & Yuan, 2010; Naigles, 1990). For example, the structures of the sentences, "He's sebbing" versus "Look, a seb!" provide cues to listeners that *seb* is an action in the former example and an object in the latter. Additionally, the morphological endings and function words in the sentence, "He's sebbing," provide sufficient information for the listener to know *seb* is a verb and the action is taking place in the present.

Critically, previous studies have assumed children make use of all structural cues that are available in their input. This assumption is often valid since most research focuses on fast mapping in the context of simple, active sentences (Bion, Borovsky, & Fernald, 2013; Campbell & Namy, 2003; Carey & Bartlett, 1978; Woodward, Markman, & Fitzsimmons, 1994). However, children often hear more syntactically complex sentences in the form of questions, multiple clauses, negation, and other sentences with non-canonical word order. Furthermore, previous research has found that these complex structures present notable processing challenges that lead to comprehension difficulties well into the school-aged years (Huang, Xiaobei, Xiangzhi, & Snedeker, 2013;

Trueswell, Sekerina, Hill, & Logrip, 1999). This raises the question of how children acquire the meanings of words when they occur in complex constructions. Are structural cues still informative under these circumstances? How is word learning impacted by children's processing abilities?

The present study will explore these questions by examining 5-year-olds' fast-mapping abilities when novel words occur in complex constructions like the passive. In the remainder of the Introduction, we will briefly outline some of the challenges inherent to word learning, describe how linguistic contexts may be used to overcome these challenges, propose two hypotheses about how children's processing abilities may affect use of syntactic bootstrapping, and outline a study that will use an eye-tracking paradigm to distinguish between them.

1.1 Challenges to word learning

Consider asking a toddler, "Where's the *remote?*" To identify the correct referent, she may scan the room and see a remote next to her favorite stuffed animal. However, even when only two objects are present in the immediate environment, the possible referents for "remote" are infinite. The speaker could be referring to a whole object (stuffed animal), its superordinate category (toy), one of its features (fluffy), or one of its parts (ear). Such indeterminacy of reference shapes nearly all word-learning environments (Quine, 1960). Nevertheless, children clearly overcome this kind of environmental ambiguity. By 16 months of age, they produce an average of 44 words, and by 24 months, this number jumps to an average of over 300 words (Fenson et al., 1994).

Critically, the precocity of children's early word learning raises the question of how they succeed at such a complex task. Previous research has found that when confronted with a novel word, young children demonstrate biases that limit the number of word meanings they consider plausible. Like adults, they tend to assume new words refer to whole objects, but not to parts or features of objects (Markman, 1990). Additionally, children are more likely to link a novel word to a novel object than to an object for which they already have a name, a constraint known as mutual exclusivity (Markman, 1990). Children also use social cues to identify the speaker's intended message. Even before infants are sensitive to the more subtle linguistic cues to word meanings, they are able use speakers' eye gaze to help identify a novel word's referent. At 16 months, infants meaningfully distinguish between referents associated with their own eye gaze and those of the speaker (Baldwin, 1991).

Clearly, word-learning biases and social cues are useful tools for overcoming basic challenges during word learning. However, these principles do not easily extend to all linguistic forms. Mutual exclusivity can hinder comprehension of synonymy and superordinate category relationships and whole-word biases must be overcome to learn relations, actions, movements, and properties of an object. Social cues are most helpful for word learning when the referent is a concrete object. Consequently, they provide minimal assistance to learning the meanings of verbs and adjectives. Furthermore, even within the category of nouns, social cues do not provide sufficient information to discriminate between more specific semantic-syntactic categories. For example, many languages distinguish count nouns, which have very rigid boundaries (e.g. cat, table, bottle), from mass nouns, which are less clearly individuated (e.g. rice, water, toothpaste). Similarly, among participants within an event, languages distinguish between agents that initiate an action (e.g., predator) from patients that are affected by the action (e.g., prey). Critically, the limitations of word learning biases and social cues for acquiring these distinctions suggest children must recruit additional sources of information to identify word meanings.

1.2 Syntactic bootstrapping

One important source of information that has received attention in prior research is children's use of syntactic cues, an ability commonly referred to as syntactic bootstrapping (Gleitman, 1990). Syntactic bootstrapping relies on the predictable relationship between the co-occurrence of words/morphemes within sentences and their meanings. Thus, language learners can use these cues to both identify word meanings as well as nuanced semantic/syntactic distinctions. For example, based on the preceding determiner, we know "a *blicket*" refers to a count noun while "some *blicket*" refers to a mass noun. Additionally, based on English's subject-verb-object (SVO) word order, children may learn to expect that the first noun phrase (NP1) in a sentence is typically the agent.

Empirical research supports the notion that children draw meaning from subtle syntactic differences in their linguistic input. For example, hearing "The rabbit is gorping the duck" led 2-year-olds to generate more looks to a transitive action (e.g. a rabbit pushing a duck) than an intransitive action (e.g. a rabbit and a duck swinging their arms) (Naigles, 1990). Previous studies have also found children recruit syntactic bootstrapping to distinguish between different classes of nouns (Bloom & Kelemen, 1995). In English, there are grammatical differences between mass nouns (e.g. ketchup) and count nouns (e.g. candles) that correspond to differences in perceptual features. When a question is posed in the frame, “Who has more______”, count nouns and mass nouns differ in morphological markers of plurality: count nouns are pluralized and mass nouns are not (Barner & Snedeker, 2005; Brown, 1957). Bloom and Kelemen (1995) explored how 4- and 5-year-olds interpret these subtle grammatical differences in the context of unfamiliar vocabulary. Children were presented with an array of five novel objects strung together and a novel word was introduced in either a plural count condition (“These are *fendles*. There are *fendles* over here.”), or a singular count condition (“This is a *fendle*. There is a *fendle* over here”). After being asked to, “Point to the *fendle”,* participants in the singular count condition were more likely to point to a collective picture (five novel objects strung together) than an individual picture (one novel object). Bloom and Kelemen (1995) argued these results demonstrate 4- and 5-year-olds sensitive to subtle syntactic cues to distinguish between count nouns and mass nouns.

Critically, prior research assumes that children make use of syntactic cues since they can accurately interpret the sentence context in the same way that adults do. This is a reasonable assumption when the novel word occurs in syntactically-simple sentences (Brown, 1957; Carey & Bartlett, 1978; Houston-Price, Plunkett, & Harris, 2005; Naigles, 1990; Namy & Waxman, 2000). For example, when children hear, “She is gorping,” they can infer that “*gorp*” is likely an action, based on their correct knowledge that “*She*” is an agent and the present progressive “*-ing*” marks an on-going action. However, not all input to children is syntactically simple. Since young children hear complex sentences in 12% of their parent’s speech (Huttenlocher et al., 2007), this raises the question of what children do when novel words occur in structurally-challenging contexts (e.g., multiple clauses or non-canonical word order)? Do children make use of syntactic cues under these circumstances? And if so, how is this affected by their biases and limitations during sentence processing?

1.3 Children's processing abilities

Previous research has found that when presented with a syntactically-complex sentence, children often generate different interpretations than adults. One systematic error that children make is to misinterpret temporarily ambiguous sentences based on early cues in the sentence and fail to revise misinterpretations, even after they are inconsistent with later cues in the sentence (Huang et al., 2013; Trueswell et al., 1999). For example, Huang et al. (2013) presented 5-year-olds with active and passive Mandarin sentences, which they then acted out using three objects (e.g. seal, shark, fish). Critical instructions varied the placement of the passive marker (BEI). Results indicated that children often misinterpreted passive sentences as active ones when BEI occurred *after* the expressed noun (e.g., Seal BEI it eat→ The seal is eaten by it). However, when BEI occurred *before* the expressed noun (e.g., It BEI seal eat → It is eaten by the seal), children interpreted passives more accurately. Huang et al. (2013) argued that when the expressed noun ("seal") occurred as NP1, children automatically interpreted it as an agent. They then failed to revise this misinterpretation, even after they heard the passive marker. In contrast, when the pronoun ("it") occurred as NP1, children did not initially know the referent, and thus did not automatically consider it the agent. This referential ambiguity allows them to interpret passive cue *without* having to revise an initial misinterpretation of the roles.

Critically, little is known about how these processing tendencies in children impact word learning. Do developmental differences in real-time processing abilities affect children's syntactic bootstrapping? One possibility is that processing abilities have little impact on word learning. While linguistic input to children may sometimes contain complex forms, it is largely dominated by simple, active sentences (Huttenlocher et al., 2007). Thus, children may learn to ignore input that they deem uninformative like passive sentences. Critically, if children engage in such a strategy, then they will have trouble learning novel words that are presented in complex syntax, but succeed in using linguistic context to map words in simple sentences. A second possibility is that children attempt syntactic bootstrapping from all possible input, but their ability to do so is affected by their processing abilities. If this is the case, children may successfully learn novel words when there are minimal processing requirements. However, they will experience more difficulty in the face of demanding processing requirements, such as situations where they would need to revise an initial misinterpretation.

1.4 The present study

Since previous word-learning research has focused on isolating word meanings in syntactically-simple sentences (Bion, Borovsky, & Fernald, 2013; Carey & Bartlett, 1978; Namy & Waxman, 2000), this question has yet to be addressed. To determine if processing abilities affect fast mapping, novel words must be presented in more complex syntactic frames. This experiment examined the accuracy of fast mapping in active and passives sentences in 5-year-old children. The passive construction is of particular interest because it is a later-acquired syntactic form that features a non-canonical word order (Messenger, Branigan, & McLean, 2012). The study unfolded over two phases.

During the familiarization phase, children were introduced to the relationship between three objects: one familiar object (e.g., seal) and two novel objects (see Figure 1). One of the novel objects was clearly a Likely Agent and the other was clearly a Likely Theme. For example, they saw a video of a large monster-like animal (Likely Agent) chasing a seal and a seal chasing a small, wimpy animal (Likely Theme). During the test phase, children's eye-movements to these objects were measured as they heard sentences like (1) and (2).

(1) Novel word NP2 a. active: The seal will be quickly eating the *blicket*.
b. passive: The seal will be quickly eaten by the *blicket*.

(2) Novel word NP1 a. active: The *blicket* will be quickly eating the seal.
b. passive: The *blicket* will be quickly eaten by the seal.

These critical sentences varied in both the syntactic structure of the construction (active vs. passive) and the position of the novel word (NP1 vs. NP2). Each critical sentence was followed by the statement, "Click on the *blicket*".

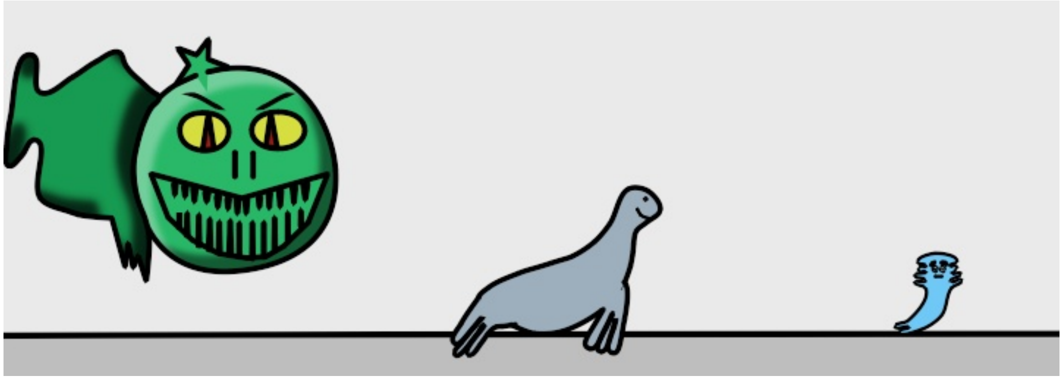

Figure 1. An example three item set, including the Likely Agent (left), the Expressed Noun (center), and the Likely Theme (right).

Our primary measure is how accurately children pair novel words with their intended referents. In 1a and 2b, the *blicket* is the Likely Theme, and in 1b and 2a, the *blicket* is the Likely Agent. If children only attend to syntactically-simple constructions and ignore complex ones, then they will correctly map the meanings of novel words when they occur in active sentences (e.g. 1a and 2a) but have substantial difficulty when they occur in passive sentences (e.g. 1b and 2b). This pattern will hold irrespective of the position of the novel word. If, however, children attempt to use all available input, but their limited ability to revise initial interpretations affects their syntactic bootstrapping, then they will again succeed in learning novel words in active sentences. However, their performance with passives will vary depending on whether or not they need to revise a bias to interpret NP1 as an agent. Based on the findings from Huang et al., (2013), it is likely that children will correctly map novel words when they occur in NP1 position, but will have more difficulty when they occur in NP2 position.

2. Methods

2.1 Subjects

This research was conducted through the Language and Cognition Lab at the University of Maryland, College Park. A total of 39 five-year-old children (M = 5;4, SD = 3 months, range = 5;0-5;11) were recruited from schools in the Washington D.C. metro area and randomly assigned to each condition (n = 20 in the Novel NP1 condition, n = 19 in the Novel NP2 condition). This age is of particular interest because 5-year-olds are skillful word learners (Fenson et al., 1994), yet they demonstrate processing limitations when presented with temporarily-ambiguous sentences (Huang et al., 2013; Trueswell et al., 1999). Consent was obtained from the school directors to collect data in their building and distribute consent forms to interested parents. Each school received a donation of school supplies or books as a thank you for participating. Demographic information was collected through parent surveys, and only monolingual speakers of

English with typically-developing language skills and no history of hearing loss were included in the study.

2.2 Procedure

The whole study involved three tasks: fast-mapping, recall, and expressive vocabulary. All three tasks were completed in roughly 30 minutes for each participant. Participants first saw the fast-mapping task, and were seated in front of a 17-inch computer monitor. An EyeLink 1000 remote desktop eye-tracker was mounted under the monitor. Each trial involved two phases. During the familiarization phase, participants saw a short animation involving three objects acting upon each other. Each animation ended with the three objects in resting position on the screen. During the test phase, participants heard a critical sentence describing the objects. They were then asked to click on one of the objects. After participants selected one of the objects, the current trial was over and a new one began.

After participants completed the fast-mapping task, they were then presented with the recall task as a measure of memory of word meanings after initial fast mapping. During the recall task, participants were asked to answer questions about the objects they saw in the previous stage of the experiment. For each of the twelve critical three-item sets (e.g. seal, large monster-like animal, small unthreatening animal), the two novel objects were printed onto cardstock and laminated. The two novel objects for each critical item were presented to the child simultaneously, and the child was asked, "*Which one is the blicket?"* Children were then asked to point to the correct picture to indicate their response, and their accuracy scores were measured.

After the recall task, children were presented with the receptive vocabulary measure to explore the relationship between syntactic processing and lexical development. This task was adapted from the Peabody Picture Vocabulary Test, Fourth Edition (PPVT-4) (Dunn & Dunn, 2007). Two sections of the PPVT-4 were administered rather than the entire test to allow all tasks (eye-tracking, recall, and receptive vocabulary) to be completed in one session. Twenty PPVT-4 items were presented in total: ten from Section 4 (starting point for 5-year-olds) and ten from Section 10 (starting point for 11- and 12-year-olds). Section 4 was selected because most 5-year-olds can complete it successfully. However, Section 10 was chosen to improve the sensitivity of the task; it is challenging enough that some, but not all, children demonstrated low levels of accuracy.

2.3 Materials

During the eye-tracking task, each trial included a three-item set of objects: an Expressed Noun, a Likely Agent, and a Likely Theme (see Figure 1). The Expressed Noun was a familiar object (e.g. seal) and the Likely Agent and Likely Theme were both novel objects. During the familiarization phase, the meaning of these two unfamiliar objects was demonstrated by their relationship to the familiar object. An animation displayed the Likely Agent acting upon the Expressed Noun (e.g. large, monster-like animal chasing the seal) and the Expressed Noun acting upon Likely Theme (e.g. seal eating the small, unthreatening animal). This relationship was also reflected in the objects' size; Likely Agents were larger than Expressed Nouns, while Likely Themes were smaller than Expressed Nouns. Appendix A provides images of all critical items.

During the test phase, participants were presented with still images of the three objects while pre-recorded speech stimuli referring to these objects were played. Half of the participants heard sentences that featured the novel word in NP2 position (1a and 1b) and half of the participants heard sentences that featured the novel word in NP1 position (2a and 2b). Each critical sentence included a two-syllable novel word selected from the ARC nonword database (Rastle, Harrington, & Coltheart, 2002). Appendix B provides phonetic transcriptions of all novel words. Each participant saw a total of 12 critical trials. Six additional filler trials were also randomly presented to mitigate participant fatigue. Filler trials recruited familiar words in active sentences (e.g. "*The sheep will be slowly eating the grass. Click on the grass.*").

All sentences were recorded by a female native speaker of American English in a sound-attenuated room. Instructions featured natural, child-friendly prosody with stress on content words. Audio stimuli were analyzed using Audacity (Audacity 2.0.3, 2013), audio-editing software, to ensure active and passive sentences are ambiguous prior to the past participle and there were not acoustic cues before the onset of the verb.

3. Results

3.1 Action data

In the fast-mapping task, we first examined the accuracy with which children clicked on the correct image during filler trials to affirm the task was appropriate for 5-year-olds. Participants responded highly accurately to filler trials (M = 97.35%, SD = 16%, range = 66.67%-100%). This suggests that children understood the task, and any low accuracy scores observed were the result of differences in condition.

Turning to the critical trials, our primary dependent measure is participants' accuracy scores across conditions (see Figure 2). A trial was deemed correct if the child selected the most plausible referent of the novel word. The correct response for the Novel NP2 Active and Novel NP1 Passive conditions is the Likely Theme, and for the Novel NP2 Passive and Novel NP1 Active conditions is the Likely Agent. These data were analyzed using a 2 x 2 ANOVA with one repeated measure where syntactic construction (active v. passive) is a within-subjects variable and novel word position (NP1 v. NP2) is a between-subjects variable. This analysis revealed a main effect of construction (*F* (1,38) = 11.38 p<.01) as well as an interaction between construction and novel word position (*F* (1,38) = 20.35, p<.01). Planned comparisons within the level of novel word position confirmed children in the Novel NP1 group were more accurate in interpreting the novel word when it was presented in an active sentence than a passive sentence (*F* (1,19) = 39.006, p < .01). Critically, children in the Novel NP2 group showed no difference in accuracy interpreting the novel word when it was presented in active and passive sentences (*F* (1, 18) = .53, p = .48). There was no additional main effect of novel word position, (*F* (1,38) = .99, p = .33). These results suggest that children's processing abilities *do* affect their use of syntactic cues for fast mapping.

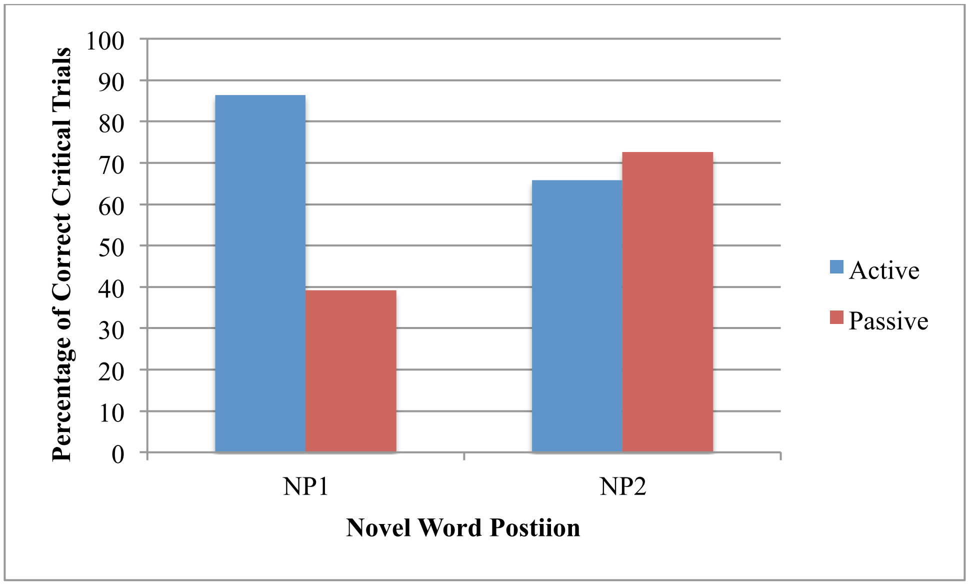

Figure 2. The accuracy of children's fast-mapping accuracy by condition.

Within each condition, participants' accuracy scores were also compared to selection based on chance. Since there were two novel objects possible for each trial, we set this value to 50%. This analysis revealed above chance selection in Novel NP1 Active condition (t(19) = 9.65, p < .001), Novel NP2 Active condition (t(18) = 2.65, p = .01), and Novel NP2 Passive condition (t(18) = 3.35, p < .01). However, these analyses found that participants' interpretation in the Novel NP1 Passive condition did not exceed chance (t(19) = -1.42, p = .17).

3.2 Eye-movement data

Children's eye movements as they heard the critical sentences provided additional information about how their interpretations were constructed. Eye-movement data were examined to determine children's sensitivity to the morphological cues on the verb (i.e., present progressive in the active trials and past participle in the passive trials). These data provide converging evidence of whether (1) children were interpreting syntactically complex constructions and (2) their ability to do so was impacted by processing limitations. We conducted an analysis of fixations after the onset of the verb, which was the point at which active and passive sentences disambiguated. The disambiguation time period was shifted 200 msec to account for the time it takes to generate an eye movement (Martin, Shao, & Boff, 1993).

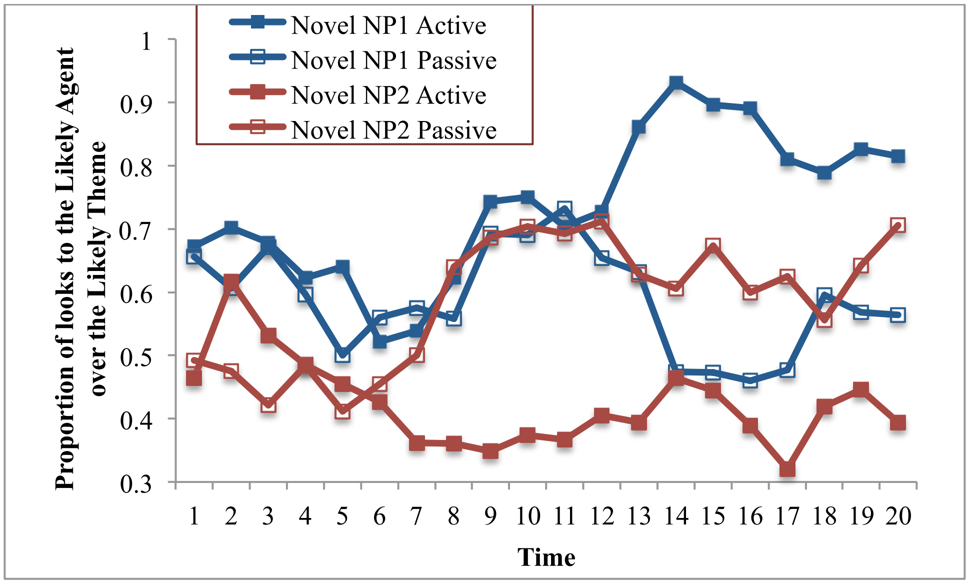

Figure 3. The time course of the proportion of looks to the Likely Agent. Time is plotted in incremements of 200 msec, and begins after the onset of the verb (disambiguation).

Across all four conditions, eye-movement data are consistent with action data from the fast-mapping task. Eye-movement data vary by condition and are sensitive to differences in action data accuracy. Figure 3 illustrates the time course of proportion of looks to the Likely Agent. In both the Novel NP1 and the Novel NP2 conditions, children's looks to the Likely Agent in active sentences diverge from their looks to the Likely Agent in passive sentences, which demonstrates they *can* interpret syntactically complex constructions and are sensitive to the morphological cues of the sentence that disambiguate conditions. However, the time at which conditions diverge differs between conditions. The separation between looks to the Likely Agent in active and passive sentences occurs at around 2200 msec in the Novel NP1 condition and at around 1000 msec in the Novel NP2 condition, which indicates the placement of nouns in critical sentences affected children's access to syntactic cues. Critically, these syntactic cues are identical in the Novel NP1 and Novel NP2 conditions (present progressive and past participle). Thus, children's eye-movements indicate presenting the novel word in NP1 position required higher processing demands than presenting the novel word in NP2 position. This pattern is consistent with children's accuracy with the previous fast-mapping task; when children had less success with the previous offline fast-mapping task (Novel NP1 condition), they also were slower to look to the correct referent.

3.3 Recall task

Children's accuracy in the fast-mapping task was compared to their accuracy with the subsequent recall task in order to (1) measure how well children remember their responses and (2) determine if their ability to remember their response is impacted by whether or not they correctly interpreted the sentence. We conducted two 2 x 2 ANOVAs to determine the likelihood that participants' click responses match their recall responses. A recall response was considered a match if it was the same as the fast-mapping response, regardless of whether or not the response was initially correct.

First, we analyzed the likelihood of matching fast-mapping and recall responses when fast-mapping response was *incorrect* (see Figure 4). That is, when children initially misinterpreted the sentence, these data convey the likelihood that they also selected the incorrect referent in the recall task. Within the Novel NP1 condition, children were more likely to match their initial response to the recall task in passive sentences (M = 92%) than active sentences (M = 55%), and within the Novel NP2 condition, children were more likely to match their initial response to the recall task in active sentences (M = 90%) than in passive sentences (M = 60%). Critically, in order to match their initial response in the Novel NP1 Passive and Novel NP2 Active conditions, children needed to select the Likely Agent, but in the Novel NP1 Active and Novel NP2 Passive conditions, children needed to select the Likely Theme. Thus, when children initially misinterpreted a sentence, they were more likely to again select the incorrect object if it was the Likely Agent. Results from the 2 x 2 ANOVA revealed an interaction between construction and novel word position (*F* (1,19) = 5.67, p = .02), indicating that when children initially misinterpret a sentence, their ability to remember the object they wrongly selected is impacted by condition. There was no main effect of construction (*F* (1, 19) = .06, p = .80) or novel word position (*F* (1, 19) = .02, p = .89).

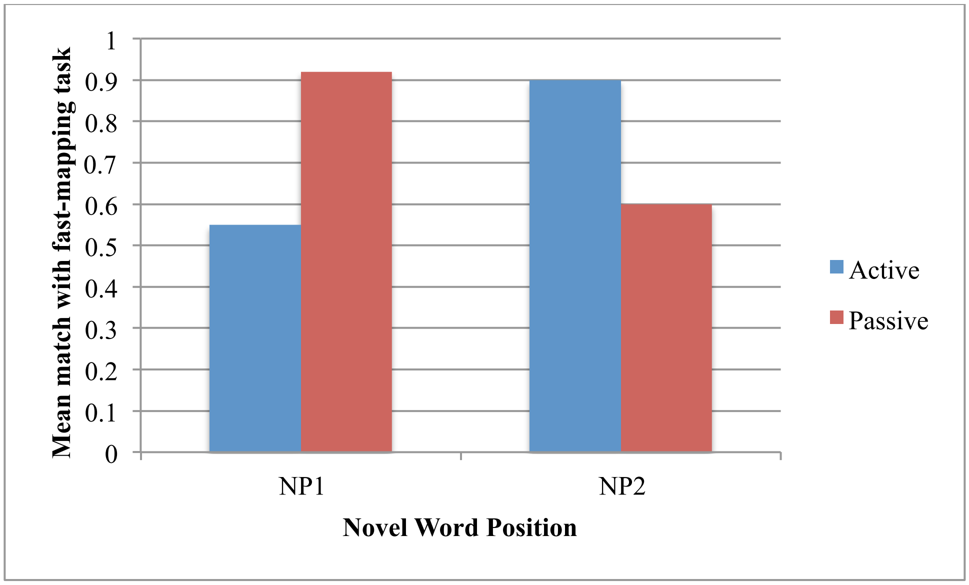

Figure 4. Mean match of recall task and fast-mapping task, when fast-mapping selection was *inaccurate.*

Second, we analyzed the likelihood of matching fast-mapping and recall responses when fast-mapping response was *correct* (see Figure 5). Within the Novel NP1 group, children were more likely to remember their response to active sentences (M = 93.92%) than to passive sentences (M = 46.57%), and within the Novel NP2 group, children were more likely to remember their response to passive sentences (M = 78.70%)

than to active sentences (M = 65.74%). Results from the 2 x 2 ANOVA revealed an interaction between construction and novel word position (*F* (1,19) = 11.16, p < .01), indicating that even when children are able to successfully interpret a sentence, their ability to remember the object they correctly selected is affected by the initial processing challenges they faced. There was no main effect of construction (*F* (1,19) = 3.63, p = .06) or novel word position (*F* (1, 19) = .09, p = .76).

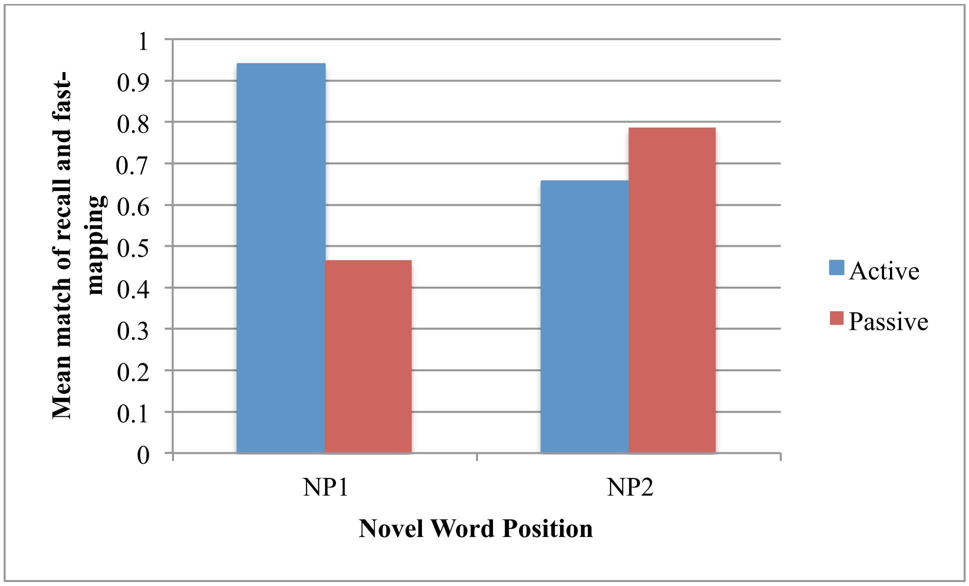

Figure 5. Mean match of recall task and fast-mapping task, when fast-mapping selection was *accurate.*

3.4 Vocabulary

Group-level analyses of accuracy on the receptive vocabulary measure revealed a mean of 58.06% (SD = 17.04%, range = 20%-90%). We also compared participants' receptive vocabulary skills with their accuracy in the fast-mapping task. There were no significant correlations between children's action accuracy for active sentences and their performance on our receptive vocabulary measure (r = .08, n = 31, p = .67), nor was there a significant correlation between children's action accuracy for passive sentences and their receptive vocabulary score (r = .12, n = 31, p = .52).

4. Discussion

The present study explored whether children benefit from syntactic bootstrapping for complex constructions during fast mapping. We found that children attempt to make use of all available linguistic input, but the success with which they access these cues varies based on the position of nouns in the sentence. When children heard a novel word in NP1 position, they were more successful identifying the correct referent in active sentences than passive sentences. However, when children heard a novel word in NP2 position, there was no effect of construction. Children's eye-movements demonstrated the same effects, and were sensitive to differences in fast-mapping accuracy. The effects of children's processing limitations extended to our delayed recall task, where children's ability to remember the object they previously identified as the correct referent varied by condition. We found no significant correlations between our receptive vocabulary measure and fast-mapping accuracy.

Although these results support our prediction that children's processing abilities affect their use of syntactic cues for word learning, the direction of the main effects do not support the prediction that presenting the novel word in NP1 position will lead to higher accuracy scores. Our original hypothesis is supported by prior research (Huang et al., 2013), which demonstrated passive sentences that have referential ambiguity in NP1 (i.e. a pronoun) are easier to interpret than passive sentences that feature a familiar noun in NP1. However, current results indicate children do not process novel words in the same way that they process pronouns; when we presented a novel word (*blicket*) in NP1, children had more trouble than when we presented a familiar word (*seal*).

In the remainder of this Discussion, we will first focus on possible reasons for why current results differ from prior findings on children's comprehension of passives. Second, we will describe what children's eye movement data reveal about how they process passive sentences. Third, we will discuss the implications of children's processing limitations on their ability to remember new words. Fourth, we will consider the clinical implications of these results.

4.1 The effect of NP1 prominence on the agent-first bias in passives

While we are finding effects of processing, it's in a direction that was not predicted by previous results. Recall that previous findings revealed differences in NP1s can change listeners' expectations for ambiguous role assignments. Huang et al. (2013) argued that referential ambiguity in NP1 lessens the agent-first bias, and thus improves interpretation of passive sentences. However, the results of the current study provide conflicting evidence for this argument. When we presented novel words in NP1, which created temporary referential ambiguity, children's action data were *less* accurate than when we presented a familiar word in NP1. If referential ambiguity in NP1 lessens the agent-first bias, then children's action data would have been *more* accurate when NP1 included a novel word. Our data demonstrate that children process passives differently when "blicket" occupies NP1 than when "seal" occupies NP1, but what is driving these differences?

Here we will consider two hypotheses of how an agent-first bias may have led to the patterns observed in our results. One hypothesis is that children simply ignored the sentences we presented and selected the object that was most interesting to them. This is plausible because we designed Likely Agents to be larger in size and to appear more menacing. The nature of these stimuli might have captured children's attention at the expense of the audio stimuli. If this hypothesis is correct, then we would expect children to always select the Likely Agent, regardless of condition. This account would correctly explain why children selected the Likely Agent in the Novel NP1 Active and Novel NP2 Passive conditions. However, it would fail to explain why children selected the Likely Theme in the Novel NP2 Active condition, and selected the Likely Theme and Likely Agent equally often in the Novel NP1 Passive condition. Thus, our data indicate children were not significantly distracted by an agent bias, and their actions varied based manipulation of independent variables.

A second hypothesis for why current patterns are different from prior findings may lay in our use of novel words. Unlike prior work that relied on familiar words (e.g., "it" in Huang et al., 2013), the current study examined interpretation of novel words. A novel word like "*blicket"* is more prominent than "*seal"* because it is new and unfamiliar to the discourse. Critically, children are sensitive to differences in word-level prominence early on. Before their third birthday, children demonstrate a preference to assign pronouns as the most prominent noun in prior discourse context (Song & Fisher, 2007). Song and Fisher (2007) presented 2.5-year-olds with stories in which one character was made to be more prominent. The final sentence of the story featured a pronoun, and during the pronoun time region children looked more to the prominent character than the less-prominent character. The authors argued that children used discourse prominence to determine the correct referent for the pronoun. This suggests prominent referents capture children's attention more than less prominent referents, because the features of prominent referents are retained and are more available to be paired with a pronoun.

Similarly, in the present study, children's attention to prominent referents enhanced their agent-first bias. Agents are inherently more prominent since they tend to be larger in size, animate, and likely actors in an event (Dowty, 1991). Thus, it is logical for children to demonstrate a stronger bias towards assigning the first-mentioned noun as the agent when it is more prominent than when it is less prominent. This increased agent-first bias had distinct impacts on children's comprehension of different constructions. It led to exceedingly accurate interpretations when the more prominent noun was presented first in an active construction. However, children struggled when the more prominent noun was presented first in a passive construction, when a stronger agent-first bias sabotaged interpretation.

4.2 Relationship between processing, learning, and recall

The current study had two additional measures of children's performance in the task. First, children's eye-movements were measured as they listened to critical sentences during the fast-mapping task. The results of children's eye-movement data provide converging support for their action data. In both the Novel NP1 condition and the Novel NP2 condition, there was a point at which the proportion of looks to the Likely Agent in active sentences diverged from the proportion of looks to the Likely Agent in passive sentences. This demonstrates children are sensitive to the morphological cues (present progressive in the active trials and past participle in the passive trials) that disambiguate critical sentences. Critically, children's processing limitations impacted their access to these cues. Children were slower to look to the correct referent in the Novel NP1 condition (2200 msec) than the Novel NP2 condition (1000 msec), which suggests presenting the novel word in NP1 position increases processing demands. These results indicate children's offline actions and online eye-movements are representative of the same underlying processes, because both eye-tracking data and fast-mapping accuracy data revealed the Novel NP1 condition was most challenging.

Second, children were presented with a delayed recall task after they had completed the fast-mapping task. We conducted an analysis of the likelihood of matching the initial fast-mapping response with the later recall response to determine if children were more likely to remember their response when it was correct. The pattern of results differed when children initially misinterpreted a sentence and when they initially interpreted a sentence correctly. When children initially misinterpreted the sentence and chose the incorrect object, their selections for the recall task were mediated by object salience. If children wrongly selected the Likely Agent in the fast-mapping task, they were more likely to remember their response because Likely Agents are more visually salient. However, when children wrongly selected the Likely Theme, they were less likely to remember their response and their responses were near chance. Critically, even when children initially interpreted the sentence correctly and succeeded with the fast-mapping task, they still demonstrated more challenges recalling the word when sentences required revision. That is, sentences that posed higher processing demands interfered with children's ability to remember the correct referent for the novel word to which they were introduced in the fast-mapping task.

4.3 Clinical implications of the current results

Finally, the current data have several clinical implications. Previous research has shown that rates and outcomes of word learning are highly variable across children. At 16 months, the highest 10% of children understand 321 words and the lowest 10% of children understand 92, and this disparity becomes larger with age (Fenson et al., 1994). Isolating factors that affect this achievement gap is important for designing effective intervention programs and for providing useful information to parents. Critically, while we know that differences in the linguistic input to which children are exposed affect long-term language outcomes (Hoff-Ginsberg, 1990; Huttenlocher et al., 2007; Rowe, 2012), less is known about the immediate effects of differences in linguistic input. How are children using the input they are given on a moment-to-moment basis? Our results demonstrate that children *do* engage in syntactic bootstrapping for complex input, and if children are able to interpret a syntactic frame, they are more likely to retain semantic information about the word. However, if they struggle to comprehend the sentence in which a word is presented, they are unlikely to be able to recall the word. Brief exposure to a novel word in a fast-mapping task is only supportive of word learning when the structural features of the sentence are within the child's syntactic repertoire. Based on these findings, it would be interesting to isolate the effect of specific characteristics of prominence in future studies. For example, future studies could investigate if differences in acoustic prominence cause similar effects on children's agent-first bias, or if discourse prominence is more salient.

4.4 Conclusion

In conclusion, this study examined children's use of syntactic bootstrapping for fast-mapping and word learning in passive and active sentences. We considered two hypotheses to explain how children's processing abilities affect this use of syntactic cues for fast mapping. It is possible that (1) children simply ignore grammatical forms that are too complex or (2) children attempt to make use of all linguistic input available to them, but struggle with increased processing and syntactic complexity. Our current results support the second hypothesis. Children can successfully interpret syntactically complex constructions, but their processing abilities affect their use of syntactic cues for fast mapping. When novel words are more prominent, this increases the agent-first bias. Critically, this agent-first bias facilitates comprehension of sentences where NP1 is an agent (actives) but hinders comprehension of sentences where this initial interpretation will need to be revised with subsequent morphological cues (passives).

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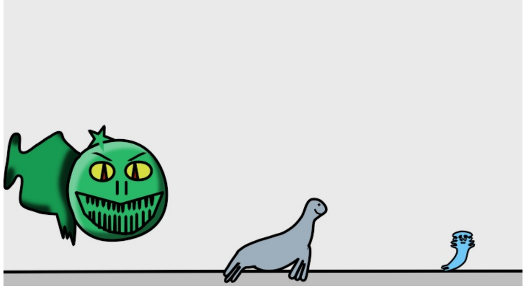
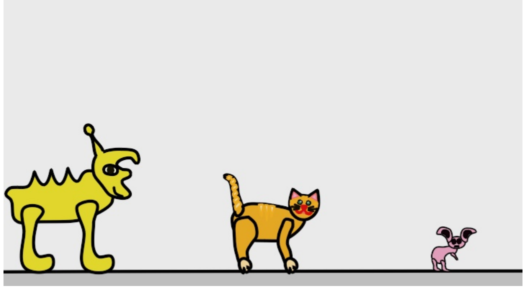
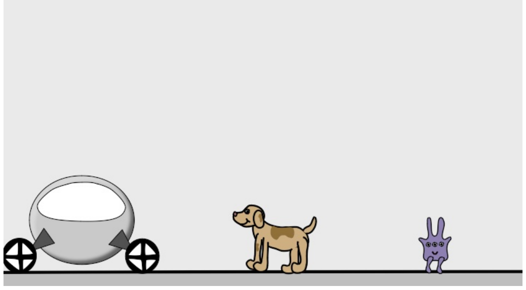
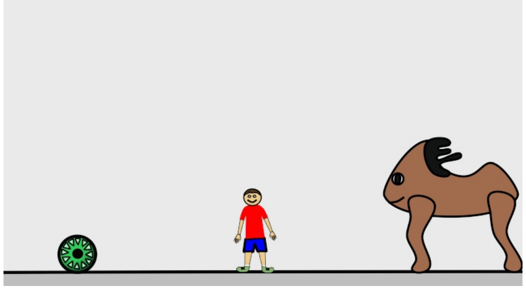
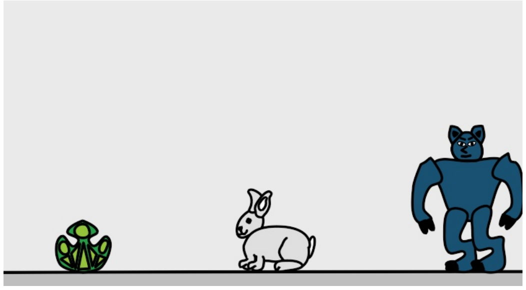
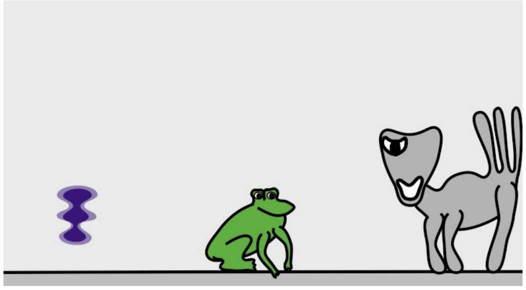
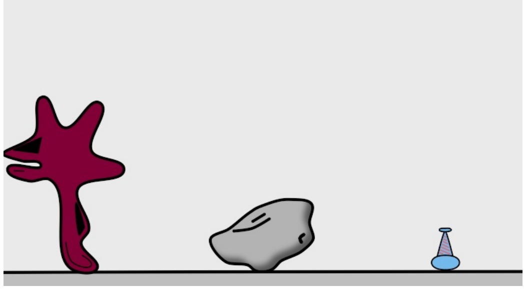
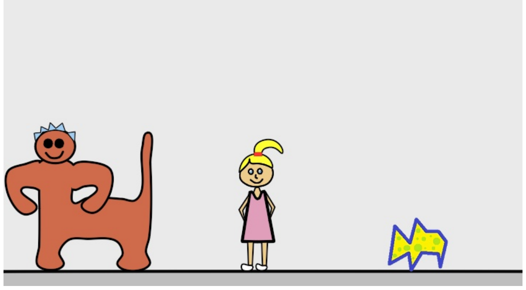
Appendix A
List of Critical Items

Expressed Noun: Seal Action: Eat 	Expressed Noun: Cat Action: Scare 
Expressed Noun: Dog Action: Chase 	Expressed Noun: Boy Action: Kick 
Expressed Noun: Rabbit Action: Eat 	Expressed Noun: Frog Action: Catch 

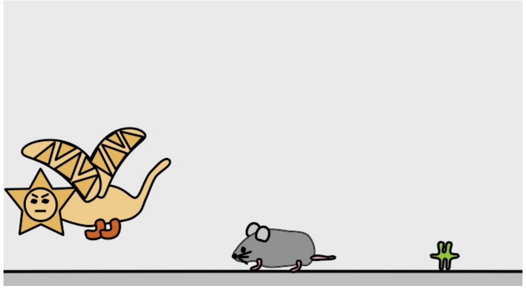
Expressed Noun: Rock
Action: Smash



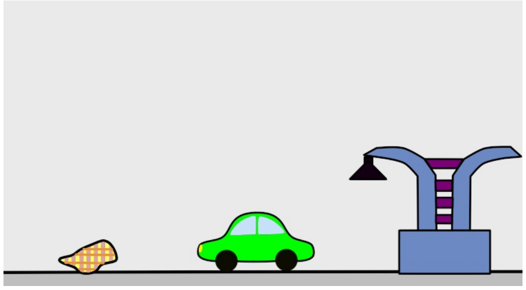
Expressed Noun: Girl
Action: Lift



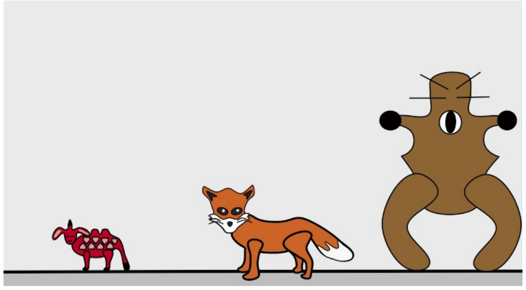
Expressed Noun: Mouse
Action: Grab



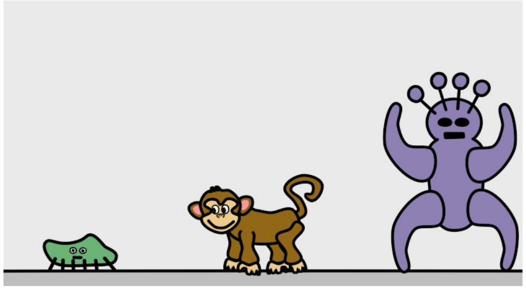
Expressed Noun: Car
Action: Squish



Expressed Noun: Fox
Action: Chase



Expressed Noun: Monkey
Action: Scare



Appendix B
Orthographic and Phonetic Transcriptions of Novel Words

Orthographic Transcription	IPA Transcription
Nedoke	/nidok/
Coopa	/kupə/
Hantil	/hæntɪl/
Daylon	/delən/
Tayvak	/tevæk/
Chowvag	/tʃæwvæg/
Vaychip	/vetʃɪp/
Noytoff	/nɔjtaf/
Bellwer	/bɛlwɚ/
Furpin	/fɚpɪn/
Leepo	/lipo/
Blicket	/blɪkɛt/