Suggested Running Head: Cognitive control and the kindergarten-path effect

Children's (in)ability to recover from garden-paths in a verb-final language: Evidence for developing control in sentence processing

Youngon Choi and John C. Trueswell

Chung-Ang University University of Pennsylvania

In press. Journal of Experimental Child Psychology.

Please send correspondence to:

Youngon Choi
Department of Psychology
Chung-Ang University
221 Heukseok-dong, Dongjak-gu
Seoul, Korea 156-756
Tel: +82-2-820-5124
Email: yochoi@cau.ac.kr

Abstract

An eye-tracking study explored Korean speaking adults' and 4-5-year-olds' ability to recover from misinterpretations of temporarily ambiguous phrases during spoken language comprehension. Eye movement and action data indicated that children but not adults had difficulty recovering from these misinterpretations despite strong disambiguating evidence at the end of the sentence. These findings are notable for their striking similarities with findings from children parsing English; yet in those and other studies of English, children were found to be reluctant to use late-arriving syntactic evidence to override earlier verb-based cues to structure whereas here Korean children were reluctant to use late-arriving verb-based cues to override earlier syntactic evidence. The findings implicate a general cross-linguistic pattern for parsing development, in which late developing cognitive control abilities mediate the recovery from so-called 'garden-path' sentences. Children's limited cognitive control prevents them from inhibiting misinterpretations even when the disambiguating evidence comes from highly informative verb information.

Word count: 149 words

Keywords: sentence processing, parsing, ambiguity resolution, language development, executive function, cognitive control, Korean

Introduction

When children and adults interpret utterances, they appear to do so in 'real time', rapidly forming a hypothesis about the utterance's meaning as each word is perceived (see Pickering & van Gompel, 2006; Tanenhuas, 2007; Trueswell & Gleitman, 2007). The real-time nature of interpretation places specific processing demands on listeners. Because a listener cannot fully predict how a sentence will complete, the listener's belief about the meaning of a phrase may turn out to be incorrect with additional linguistic input; for adults, these temporary misinterpretations are just that, temporary (e.g., the speaker meant Mary, not Susan, when he said "she"). Adults are able to exert rapid control over their interpretive processes, e.g., to inhibit hypotheses proven wrong and promote hypotheses consistent with newer input. But what about children? In cognitive tasks, even children four to six years old have difficulty exerting control over 'pre-potent'/automatic responses (e.g., Davidson, Amso, Anderson & Diamond, 2006). Does this extend to real-time language comprehension? The initial evidence suggests perhaps so (e.g., Trueswell, Sekerina, Hill & Logrip, 1999; Weighall, 2008, see also Novick, Trueswell & Thompson-Schill, 2005). Yet, as discussed below, most of this evidence comes from a single language, English. The use of English raises many concerns, most notably because the grammar of any one particular language naturally forces some classes of linguistic evidence to appear earlier in a sentence than others, making it difficult to generalize to other language learners. We ask here about the development of sentence processing in another language, Korean, which runs its grammar essentially in the opposite direction of English. Will the same developmental patterns emerge? Or is there something specific about the ordering of linguistic information in English that drives what has thus far been learned about children's control over interpretive processes?

Developmental changes in executive function abilities, and 'cognitive control', are known to occur throughout childhood (Davidson et al., 2006; Diamond, Kirkham, & Amso, 2002; Müller, Zelazo, & Imrisek, 2005). Executive function (EF) refers to a set of cognitive processes that underlie goal-directed behaviors, including mental flexibility, planning, working memory, and inhibition (Hill, 2004; Huizinga, Dolan, & Molen, 2006; Miller & Cohen, 2001). EF is crucial in one's ability to control thoughts and actions in order to generate adapting behaviors to changing needs of the environment (Hill, 2004; Müller et al., 2005; Stuss & Knight, 2002). Preschool-aged children frequently show deficits in various cognitive control tasks involving these EF components, particularly inhibitory control (the ability to inhibit or select a representation under conditions of conflict, Zelazo, Müller, Frye, & Marcovitch, 2003). They often fail to adapt to the changing rules and tend to perseverate on one rule or dimension in the Dimensional Change Card Sorting Task (DCCST, Zelazo & Frye, 1998). And they perform poorly on tasks that tap into inhibitory control, such as the Go/No-Go task (Durston et al., 2002), the Stroop task (Zysset, Müller, Lohmann, & von Cramon, 2001), and other related tasks (Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002; Davidson et al., 2006; Sabbagh, Moses, & Shiverick, 2006). In fact, numerous studies have demonstrated that EF and inhibitory control do not fully develop until late adolescence (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001, Anderson, 2002; Diamond et al., 2002). This slow development has been linked to the protracted maturation of the associated brain regions, in particular, pre-frontal cortex (Huttenlocher & Dabholkar, 1997; see also Mazuka, Jincho, & Oishi, 2009).

Novick et al. (2005) has proposed that EF, in particular inhibitory control, plays an important role in language processing when the initial interpretation of a sentence is required to be inhibited in place of a later alternative interpretation. As mentioned above, revision of misinterpretations is a necessary consequence of the serial nature of linguistic input and the incremental nature of spoken language processing. That is, listeners evaluate incoming linguistic evidence in real time, assigning provisional syntactic and semantic analyses essentially on a word-by-word basis (e.g., Altmann & Kamide, 1999; Kjelgaard & Speer, 1999; Sedivy, Tanenhaus, Chambers & Carlson, 1999; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995). Sometimes however, these provisional analyses turn out to be incorrect, as evidenced by later information, resulting in processing difficulty. This has often been described as the garden-path phenomenon, in which the listener has been led down the proverbial garden-path by misleading evidence and must 'back up' to pursue a different path. For instance, consider what occurs when adults hear a sentence like (1).

(1) *Put the apple on the towel into the box.*

The first Prepositional Phrase (PP) *on the towel* is technically ambiguous; it could be a Destination phrase for the verb *put* (i.e., telling the listener where the apple should be put)[1] or a Modifier phrase for the Noun Phrase (NP) *the apple* (i.e., telling the listener more about the apple). Listeners tend to pursue initially a Destination interpretation when they first encounter the ambiguous phrase *on the towel*. When the sentence continues with an additional PP, such as "…*into the box,*" the 'morphosyntactic' information of *into* requires the new PP to be the Destination phrase, forcing the previous PP (*on the towel*) to be a Modifier of *the apple.* The initial (and in this case erroneous) parsing preference for the Destination analysis of *on the napkin* is due in large part to the strong syntactic and semantic expectations associated with *put:* it takes a Destination, typically in the form of a PP almost always occurring after a direct object Noun Phrase.

Evidence for these conclusions comes from eye movement studies of spoken language processing, in which listeners act upon objects in response to spoken instructions (c.f., Tanenhaus et al., 1995, and Trueswell & Tanenhaus, 2005 for a review). This method, often referred to as the ‘visual world’ paradigm, provides a moment-by-moment record of listeners’ real-time interpretive commitments by recording their eye fixations on (ir)relevant objects as they listen to each instruction. Listeners’ eye position tends to be closely time-locked with the speech they hear (e.g., they will typically fixate an apple 0-200 ms after hearing the word ‘apple’, see Tanenhaus et al., 1995). Tanenhaus et al. (1995) also found that eye position could capture listeners’ temporary consideration and revision of garden-path sentences. While hearing *Put the apple on the towel…* as adults viewed a scene containing an apple on a towel, an empty towel, a pencil on a plate, and an empty box, they showed an increased tendency to look over at the empty towel (a potential Destination for the *putting* action) as they heard the word *towel*. Such increased fixation tendency was not observed when listeners heard unambiguous sentences such as *Put the apple <u>that’s</u> on the towel….* Further, upon hearing *into the box* after *Put the apple on the towel*, listeners tended to show some general confusion, looking around more as compared to the unambiguous sentences. Yet adults ultimately arrived at the correct interpretation, moving the apple into the box in most cases.[2]

As noted by Novick et al. (2005), these language processing conditions are quite similar to those found in EF tasks: listeners must use newly arriving information to inhibit a representation (based on an early input) that is 'pre-potent', i.e., a familiar analysis given past experience with similar input. Adults have developed the ability to modulate and inhibit early arriving constraints when later countervailing evidence is encountered, and thus are able to recover from temporary mis-analyses (e.g., considering *on the towel* as the verb's Destination).

Slow development of EF predicts that children with limited cognitive control abilities would not deal well with these parsing conditions, which require inhibiting an initial pre-potent interpretation. In fact, comprehension studies that have used sentences like (1) have found that 4-5-year-old children, as compared to adults and older children, have much greater difficulty revising their initial parsing choice, i.e., they often cannot recover from a garden-path (hence named 'the kindergarten-path effect', Trueswell et al., 1999; see also Hurewitz, Brown-Schmidt, Thorpe, Gleitman & Trueswell, 2000; Kidd & Bavin, 2005; Weighall, 2008). These studies also used the visual world eye-tracking paradigm and observed that when children heard an instruction with a temporary ambiguity, '*Put the frog on the napkin into the box'*, their early eye fixation patterns resembled those of adults[3], indicating real-time commitment to the Destination analysis. Among the four different objects in the scene [a frog on a napkin (Target), a frog on a towel (Competitor), an empty napkin (Incorrect Destination), and an empty box (Correct Destination)], there were significantly more looks to the Competitor and to the Incorrect Destination as compared to the unambiguous condition (*Put the frog that's on the napkin into the box*). However, unlike adults, children's ultimate interpretations (as revealed by their actions on the toy animals) were often consistent with this initial Destination analysis rather than the Modifier analysis; on over 60% of temporarily ambiguous trials, children made errors, such as moving a frog first to the Incorrect Destination (the empty napkin) and then to the Correct Destination (the empty box). Children made very few errors (5%) with unambiguous items. Strikingly, all errors for temporarily ambiguous instructions involved moving an object to the Incorrect Destination, suggesting that they were honoring the Destination analysis of *on the napkin.* Also, the Competitor animal was as likely to be involved in their actions as the Target animal, indicative of their failure to re-consider *on the napkin* as a noun Modifier after encountering the second PP. Together, these data suggest that children formed an initial Destination interpretation of the ambiguous phrase based on the verb *put* and had difficulty revising this commitment even after encountering countervailing linguistic information, with this difficulty perhaps being due to their immature cognitive control abilities.

However, it is also possible that children's interpretation errors may be arising for other reasons. In particular, they may reflect developmental changes in children's reliance on particular sources of information to structure the input. Many studies with children (ages 3-5 years or younger), using a wide range of linguistic material, suggest that their parsing system is organized and operates in a way similar to the mature parsing system, i.e., it engages in rapid real-time parsing and referential interpretation and can weigh validity and reliability of evidence probabilistically, even in the face of ambiguity (Arnold, Brown-Schmidt, & Trueswell, 2007; Epley, Morewedge & Keysar, 2004; Nadig & Sedivy, 2002; Sekerina, Stromswold & Hestvik, 2004; Thothathiri & Snedeker, 2008). Yet, these studies also reveal changes over developmental time in information use. For instance, some studies suggest that children may disproportionately rely on verb information over extra-sentential contextual information when resolving structural ambiguities, perhaps due to the higher reliability of verbs to predict structure (Trueswell & Gleitman, 2004, 2007; Snedeker & Trueswell, 2004; Snedeker & Yuan, 2008). Snedeker & Trueswell (2004) compared children's use of verb cues and contextual cues to resolve the meaning of globally ambiguous sentences such as 'Tickle the frog with the feather" in which "with the feather" could be an instrument of the verb "tickle" or a Modifier of the noun "frog". Five-year-old children's interpretation choices showed great sensitivity to the type of verb used in the sentence (consider "Choose the frog…"), whereas manipulations of the context to support one interpretation over the other showed no effects, even for verbs that were neutral with regard to their semantic/syntactic preferences for instrument phrases. Adults in contrast showed good use of these contextual cues to inform their interpretive commitments.

Such disproportionate reliance on verb information may be pertinent to the acquisition order of various cues in which more reliable cues to structure are discovered and acquired earlier (Bates & MacWhinney, 1987; Snedeker & Yuan, 2008). Therefore, the information that regularly predicts syntactic structure more reliably, such as verb-specific information (Boland & Cutler, 1996), become employed first developmentally and dominate the child's early parsing processes (Trueswell & Gleitman, 2004, 2007).

This may explain why preschool children appeared to fail to revise their initial sentence interpretation. It is possible that children in these studies were not necessarily unable to revise the initial choice but were instead reluctant to use morphosyntactic evidence from a preposition (*into…*) to override what they know about a common verb (*put*). When hypotheses generated from different information sources compete, children may lean more towards those that are suggested by a more reliable information source on syntax (i.e., verb information) than others (i.e., morphosyntactic information) (similar to the idea presented in MacWhinney, Pleh, & Bates, 1985). It is possible then that children's difficulty with revising the temporarily ambiguous items reflect an information-reliability difference in the child's parsing system. Under this view, as children gain more experience with their language, they become attuned to exceptional parsing circumstances that require re-evaluation of cue validity and become better able to evaluate a diverse set of evidence to determine sentence structure and meaning.

With English data, both accounts outlined above, immature cognitive control and differences in children's information use, are equally plausible. In English, verb-specific lexical information tends to arise early in a sentence relative to other information. In fact the verb appears first in the type of instructions (i.e., imperative sentences) used in these visual world studies. This early access to verb information in English sentences makes it hard to determine whether 5-year-olds' verb-consistent interpretation patterns were because a verb-based representation was formed early and thus became a hypothesis that needed to be inhibited in favor of a later formed representation, or because children were reluctant to override a verb-generated analysis with that indicated by less predictive morphosyntactic information. Languages such as Korean, however, would permit us to pull apart these two possibilities. As we discuss below, Korean, a head-final language, offers an exceptionally strong test of the generality of children's failure to inhibit earlier interpretations as opposed to their reliance on particular information such as verb-specific lexical constraints.

Because of its head-final nature (Baker, 2001), the order by which information arrives to the ear in Korean is, to a first approximation, often opposite to that of English. For example compare (2) and its Korean equivalent in (3).

(2) **Put** the toy in the box.

(3) sangca-***ey*** cangnankam-ul **nehu-sey-yo.**
Box-***Loc*** toy-Acc **Put**-Hon-SE
"Put the toy in the box."

Verbs appear sentence/clause finally in Korean (Kim, 1999) whereas verb information tends to arise much earlier in a sentence in English. What this means in the present context is that verb information, which is used to guide parsing commitments in English, instead is used to confirm and elaborate sentence parses in Korean (and as we discuss below, sometimes disambiguate parses). Case markers (-*ey* and –*ul* above) in principle serve as cues to the structure of the input, and as such guide processing.

Adult sentence processing studies support the idea that adult listeners and readers of head-final languages such as Korean (or Japanese) parse sentences incrementally just as head-initial language listeners do and thus do not await the verb to determine the sentence meaning/structure (Kamide, Altmann, & Haywood, 2003; Kamide & Mitchell, 1999; Konieczny, Hemforth, Scheepers, & Strube, 1997; see Mazuka & Nagai, 1995 for detailed proposals). Listeners/readers of head-final languages tend to begin projecting the structure of an upcoming sentence as soon as they gain access to structure-relevant evidence such as morphosyntactic information from case markers (Kamide & Mitchell, 1999) or argument structure information concerning the number and type of noun phrases (e.g., Aoshima, Phillips, & Weinberg, 2004; Kamide, Altmann, & Haywood, 2003). As this evidence suggests, we believe that both Korean adults *as well as* children incrementally parse sentences, starting to build their interpretations in real-time as soon as they encounter linguistic evidence.

Korean PP-attachment ambiguity and parsing pattern predictions

Like English (and all other natural languages for that matter), Korean contains temporary syntactic ambiguity. For instance, even the simple sentence in (3) above contains a temporary ambiguity, which is illustrated below in (4a) and (4b).

(4) (a)	*naypkhin-**ey***	*kaykwuli-lul*	*nohu-sey-yo* (PP as a Verb argument)
	napkin-Loc	frog-Acc	put-Hon-SE
	napkin –on	frog	put
	"**Put** the frog on the napkin."		

(b)	*naypkhin-**ey***	*kaykwuli-lul*	*cipu-sey-yo* (PP as a Noun Modifier)
	napkin-Gen	frog-Acc	pick up-Hon-SE
	napkin –on	frog	pick up
	"**Pick up** the frog on the napkin."		

When the Post-positional Phrase (PP), *naypkhin-ey*, appears prior to a noun phrase *kaykwuli-lul* as in (4a-b), it remains ambiguous until the verb arrives because it can be interpreted either as a Modifier or as a Destination phrase, depending on the verb[4]. The case marker *–ey* here can be either a Locative marker, a Genitive marker, or a reduced form of a full relative *-ey issnun* (that is on/in-). When a verb requires a Destination phrase (*put* in 4a), *naypkhin-ey* serves as the Destination of *put* indicating where the frog should be placed. Here, the marker *–ey* is used as a Locative, indicating a Destination. By contrast, if the verb is *pick up* as in (4b), no Destination phrase is allowed and *naypkhin-ey* becomes the Modifier of the following noun, specifying the target referent as 'the frog that is on the napkin, not the one on the book.' The marker *–ey*, in this case, is either a reduced form of a full relative, *–ey issnun*, or a Genitive *–uy* (although spelled differently, this marker is pronounced the same as Locative -*ey*). Thus, the phrase, *naypkhin-ey kaykwuli-lul* (we will use *napkin-on frog-Acc* to refer to these hereafter), in (4a-b) is temporarily ambiguous until the verb becomes available.

Theories of initial parsing preferences almost uniformly predict that such a temporary ambiguity would be resolved toward a Destination interpretation. That is, listeners should initially interpret *napkin-on frog-Acc* as two separate arguments (the napkin is a Destination that the frog will be going to). For instance, Minimal Attachment theory (Frazier, 1987) predicts listeners have a preference against complex noun phrases, like the sort required if *napkin-on frog-Acc* was treated as a single noun phrase with *napkin-on* serving as a Modifier of *frog-ACC*. Other parsing theories, which instead emphasize the frequency of syntactic alternatives (e.g., constraint-based parsing theories of MacDonald, Perlmutter & Seidenberg, 1994; Trueswell & Tanenhaus, 1994), make the same prediction, but for a different reason: the ambiguous marker *–ey* is much more commonly used as a Locative (Destination) than a Genitive (Modifier) in the child-directed linguistic input. In a prior corpus analysis and two sentence-completion experiments, we have found a strong tendency for the Destination use of these PPs. An analysis of a corpus of Korean Child-Directed speech identified 115 occurrences of this type of phrase with -*ey*, of which 108 were marking a Destination, and only seven cases where the phrases were modifying the following noun phrase.[5] This tendency for the Destination interpretation was also observed in written and auditory sentence-completion studies.[6]

Thus, there is a strong expectation that Korean listeners will have a bias to initially interpret *napkin-on* as a Destination phrase for an upcoming verb. Ending the sentence with the verb *put* would confirm this interpretation. However, ending it with *pick up* does not confirm this analysis, and instead forces the Modifier interpretation (e.g., the frog that's on the napkin). Thus, the sentence involving *put* (4a above) should be an easy sentence for Korean children to understand whereas the one involving pick up (4b) should not: it should cause a garden-path.

On the face of it however, simple sentences like *Pick up the frog on the napkin* and *Put the frog on the napkin* should be easy for Korean children to understand. What children know about these common verbs should tell them what to do with the phrase *on the napkin*. Indeed, if children disproportionately rely on verb information to determine structural interpretations (as the 'change-in-information use' account predicts), then Korean children should show little difficulty parsing these sentences. According to this view, despite the fact that the verb becomes accessible later than other sources in Korean, young Korean children would be more willing to override their initial case-marker (morphosyntactic) based interpretation with those proposed by a verb because verbs are a highly reliable source of sentence structure. As a result, their interpretations should tend to be more consistent with verb than case-marking information, predicting that both *pick up* and *put* sentences would be unlikely to elicit errors.

Yet, the cognitive control account makes a strong prediction contrary to this intuition. Because the *pick up* sentence (4b) above requires revision, children, but not adults, should make errors when they hear *pick up,* and produce non-adult actions consistent with *napkin-on* being the verb's Destination phrase. They ought to, for instance, move the frog over to another napkin, rather than raising it in the air. In contrast, the *put* version is not expected to flummox Korean children because ending the sentence this way is consistent with the initial interpretation. Under this account, although Korean children know the meanings of these verbs, cognitive control limitations sometimes prevent using this knowledge to override an initial parsing choice.

Experiment: Korean-speaking Adults & Five-year-olds

To test these predictions, the current experiment examined how Korean adults and 4-5-year-old children parse these temporarily ambiguous sentences described above ending either with the verb *put* or *pick up*, using the visual world eye-tracking paradigm.

Method

Participants

Sixteen adult native speakers of Korean (Female = 13) and 16 children between 4;0 and 5;4 (mean = 4;9, Female = 10) participated in the study. Adult participants were recruited via a subject participant pool at Ajou University (Suwon, Korea) and they received course credit for their participation. All participating children were monolingual Korean speakers, recruited from preschools in Suwon, Korea. The experimenter visited the preschools and tested children individually in an unoccupied room at their schools. Three additional children who participated were excluded from the analysis because they failed to understand the task.

Procedure

An experimental procedure similar to Snedeker and Trueswell (2004) was used. Each participant sat in front of a podium with four shelves roughly at each quadrant and a hole at the center (and a smiley face sticker just beneath the hole), behind which a digital camera was placed to record participants' eye-gaze (see Figure 1). Another digital camera recorded the location of the props and the participants' actions as they acted out the sentence. At the beginning of each trial, the experimenter laid out the props and labeled each one to familiarize the participant with the names for objects (e.g., this is (a) frog, (a) napkin, (a) box, etc.). Then, pre-recorded instructions were played from a computer and participants were asked to carry out the action with the objects based on their interpretation of the instruction. All instructions were recorded by a female native Korean speaker. The experimental session began with two practice trials followed by 26 test trials (12 target and 14 filler trials), with each trial consisting of 3-4 instructions. Children were told that they were going to play games with many toys and a computer would ask them to do certain things with the toys. Children were praised upon completion of their actions, regardless of the accuracy of their responses. If the child refused to respond or asked what to do, the sentence was played again, but the eye movements were always coded from the initial presentation of the sentence unless 1) the first play was interrupted by the child her/himself (e.g., started talking to the experimenter), 2) interruption by others (e.g., teachers or peers). These sorts of interruptions occurred only for a small number of trials. Participants were told to begin their action after the command was over. If the participant initiated action before the instruction was over, s/he was reminded to wait until the instruction was complete.

Materials and Design

A total of 12 target items were constructed, beginning with an ambiguous Post-positional Phrase (PP) and ending either with the Modifier-bias verb 'pick up (*cipuseyyo*)' (*Pickup* trials) or the Destination-bias verb 'put (*nohuseyyo*)' (*Put* trials). Each of these items could appear in one of four experimental conditions: Ambiguous-*pickup*; Unambiguous-*pickup*; Ambiguous-*put*; and Unambiguous-*put* (see below (5a-d) and Appendix I for the full list of materials). As Figure 1 shows, each target scene was always in a two-referent context and contained the following objects: the Target referent (e.g., a frog on a napkin), a Competitor referent (e.g., a frog in a bowl), a Destination (e.g., an empty napkin), and an Unrelated (Other) object (e.g., a giraffe in a basket).

(5) (a) *naypkhin-**ey*** *kaykwuli-lul* *cipu-sey-yo* (Ambiguous-*pickup*)
napkin-Loc frog-Acc pickup-Hon-SE
napkin –on frog pick up
"Pick up the frog on the napkin."

(b) *naypkhin-ey-**iss-nun*** *kaykwuli-lul* *cipu-sey-yo* (Unambiguous-*pickup*)
napkin-Loc-**be-Rel** frog-Acc pickup-Hon-SE
napkin-on-is-that frog pick up
"Pick up the frog **that is** on the napkin."

(c) *naypkhin-**ey*** *kaykwuli-lul* *nohu-sey-yo* (Ambiguous-*put)*
napkin-Loc frog-Acc put-Hon-SE
napkin –on frog put
"Put the frog on the napkin."

<u>Example of a visual scene for (5a-c):</u>
a frog on a napkin (Target), a frog in a bowl (Competitor),
an empty napkin (Destination), a giraffe in a basket (Other)

(d) Instruction same as (c) above; only the scenes differed. (Unambiguous-*put*)

<u>Example of a visual scene for (5d):</u>
a frog on a plate (Target)*, a frog in a bowl (Target)*,
an empty napkin (Destination), a giraffe in a basket (Other)
* Note that no frog on a napkin was present.

For Unambiguous-*pickup* trials, the optional Relativizer (*issnun*) was added as in (5b). The Relativizer appears immediately after *naypkhin-ey*, modifying the upcoming NP *frog*, and thus *napkin-on* cannot be taken as a Destination phrase. Unambiguous-*put* variants of each target trial were constructed by presenting the ambiguous instruction (*napkin-on frog-Acc put*) in a visual context that made the Modifier interpretation of the PP impossible as described in (5d) above. For instance, for the instruction, *napkin-on frog-Acc put*, the scene contained a frog on a plate, a frog in a bowl, an empty napkin, and a giraffe in a basket, instead of including a frog on a napkin. Thus, although the Unambiguous-*put* construction was still technically ambiguous, the Modifier interpretation was not possible given the context.

Four experimental lists were constructed such that within a given list, 12 target trials (three in each condition) were interspersed with 14 filler trials, which consisted only of filler instructions (e.g., “Squeeze the cow” or “Cover the apple with the napkin”). The twelve target trials within each list involved different sets of objects (i.e., no objects were repeated, except for the occasional plate or bowl). Each trial (including both target and filler trials) began with the instruction that brought the participant to the center fixation point (i.e., “Look at the smiley face”), followed by three to four commands. The first of these was the target sentence in target trials and the rest were filler instructions. Therefore, children heard 12 target sentences and 66 distractor sentences in total (including filler instructions from both target and filler trials). All critical sentences were the first instructions after the fixation was centered.

Using a Latin square procedure, the 12 target sentences were rotated through the four conditions across four presentation lists, and each participant was assigned to one of the four lists. Thus, the Verb and Ambiguity were manipulated within participant. The filler trials were constructed to include two types of instructions that resemble *put* and *pick up* instructions respectively: 1) to elicit a transfer type of action (e.g., an object is transferred to a different location such as a candy from a jar into a bowl), and 2) to elicit direct actions on an object itself (e.g., tickling an animal toy or shaking an object). Thirty-two filler sentences were designed to elicit the transfer type action, and 33 to elicit direct action on the object type. One distractor sentence involved both the transfer and the direct action elicitation (i.e., “Move the turtle into the jar and shake it”). Forty two different verbs were used with filler instructions. About half the time, filler trial scenes mimicked the target trial scenes, containing two referents and at least one empty platform or container-type object. The instructions were 2.5 to 6 seconds long: the target instructions for Ambiguous-*pickup*, Ambiguous-*put*, & Unambiguous-*put* conditions were on average 2.7 seconds long while the Unambiguous-*pickup* instructions were about 3.4 seconds long (longer because of the additional element, the Relativizer).

Coding

Eye movements were coded according to Snedeker and Trueswell (2004). A trained coder, blind to experimental conditions, examined the videotape of the participant’s face, viewing it frame by frame (33 ms for each frame) from the onset of the target utterance to the onset of the following instruction. The coder noted the onset of the target sentences and the onset of each change in gaze and the location of the subsequent gaze. The eye gaze data collected using this method is comparable to data collected from a head-mounted eyetracker (Snedeker & Trueswell, 2004) and this method has the added benefit of not requiring the child to wear a cumbersome eye-tracking visor (see Trueswell, 2008, for a discussion of various child eye-tracking methods). A second coder (the first author) separately coded the onset of each word/phrase using the PRAAT program (Boersma & Weenink, 2004) by viewing waveforms and spectrograms of each target sound file. Onsets were then aligned with eye video onsets. Location of gaze was coded as being in one of the quadrants (i.e., upper left, upper right, lower left, and lower right), at the center, or away from the display (e.g., looks to the experimenter or to the camera). If the participant's eyes were closed or not visible, the frame was coded as track loss. Trials on which track loss occurred over 40% of the time were excluded from the analysis (3.2% of all trials in the child data but none such trials in the adult data). Reliability over the coding was established by having a second coder fully re-code the data of three randomly selected subjects, and by having a third coder resolve disagreements. The direction of eye-gaze coded by the two coders agreed for 90.5% of the coded frames, where disagreement was defined as any instance where coders disagreed for more than one video frame. From the children's data, 16 trials (four in Ambiguous-*pickup*; two in Ambiguous-*put*; eight in Unambiguous-*put*) were excluded from further analysis due to experimental errors.

Action responses were coded from the scene video and were categorized into three groups: (1) VP action: these include all the actions that clearly showed the post-positional phrase (PP) to be the Destination phrase for the verb (e.g., moving either the target or the competitor animal/object into a container/platform object), (2) NP action: actions on the target animal/object itself, indicating the PP as a Modifier of the NP (e.g., grabbing and holding the target animal). In this group, the PP was interpreted as a Modifier for the following noun phrase. (3) Other action: all other types of actions that belong to neither of the first two categories. In children's action responses, we also included those actions that clearly indicated that the PP was a verb argument even though it was not interpreted as a Destination. For instance, an instrumental action such as using the Destination object as an instrument to move the target/competitor was also coded into the VP action category.

Results and Discussion

Eye-gaze patterns from onset of verb

The central question of interest here is whether Korean children also show difficulty with revising their initial parsing as compared to adults. To assess this, we examined looks to the Destination object (the empty napkin) upon hearing the sentence-final verb: *pickup* or *put.* Looks to the Destination object can be taken as evidence for listeners' consideration of the Destination analysis of the PP (e.g., Spivey et al., 2002). It is expected that Korean-speaking adults will use their knowledge of the verb *pickup* to block consideration of the Destination parse, showing far fewer looks to the Destination object in Ambiguous-*pickup* sentences as compared to Ambiguous-*put* sentences, with the size of this effect being almost identical to unambiguous versions of these sentences (Unambiguous-*pickup* and Unambiguous-*put* respectively). By comparison, if immature cognitive control was the underlying factor of the child's parsing errors, Korean-speaking children are expected to show difficulty using their knowledge of *pickup* to prohibit consideration of the Destination interpretation: Ambiguous-*put* and Ambiguous-*pickup* sentences should both produce looks to the Destination object; only unambiguous items should show a large difference, such that Unambiguous-*pickup* sentences should produce few looks to the Destination object as compared to Unambiguous-*put*. If, on the other hand, the previously observed failure of children to revise had more to do with their reliance on verb information over other information, then Korean children are expected to show little to no difficulty in parsing these ambiguous sentences: their looks to the Destination object should be blocked upon hearing *pick up*, similar to adults.

The results are consistent with the cognitive control account. Figure 2A summarizes the proportion of time[7] adults spent looking at the Destination object in five time windows: (1. PP) from the onset of the PP until the onset of the NP, (2. NP) from the onset of NP until the onset of the verb, (3. VP) from the onset of the verb until the offset of the verb, (4. Post-VP1) a one-second time window immediately after the offset of the verb, and (5. Post-VP2) a second one-second time window following the previous time window.[8] Our particular focus will be given to three windows (VP, Post-VP1, & Post-VP2), which is relevant to test our predictions. Hearing the verb *put* triggered increased looks to the Destination object for adults in both the Ambiguous-*put* and Unambiguous-*put* conditions (see Figure 2A). No such looks were observed when adults heard *pickup* (Ambiguous-*pickup* and Unambiguous-*pickup*). In contrast, the child eye movement patterns (see Figure 2B) showed increased looks to the Destination object both in the Ambiguous-*put* and the Ambiguous-*pickup* condition. Unambiguous items showed effects similar to adults, such that Unambiguous-*put* showed increased looks to the Destination, but Unambiguous-*pickup* did not.

In order to assess these patterns statistically, we fit the data for children and adults separately within each of the three time windows, using a multi-level mixed linear model that treated the experimental factors of Ambiguity (Ambiguous vs. Unambiguous) and Verb (*pickup* vs. *put*) as fixed effects, with crossed random intercepts for Subjects and Items (Baayen, Davidson & Bates, 2008; Jaeger, 2008). Because proportions were used, the data were first transformed using an empirical-logit function (Barr, 2008; Jaeger, 2008).[9]

The beta coefficients for the models based on the adult data appear in Table 1. Ambiguity is a small but reliably negative predictor of looks to the Destination object in the VP window, indicating that as compared to Ambiguous items, Unambiguous items drove down looks to the Destination. However, this predictor interacts with the Verb predictor: only Unambiguous-*pickup* items drive down the Destination object fixation (see Figure 2A). In the next two time windows (Post-VP1, Post-VP2) we see a very different pattern. Verb is a strong reliable positive predictor of Destination object looks: hearing *put* produces the Destination object fixations whereas hearing *pickup* does not (see Figure 2A). This effect interacts with Ambiguity such that Unambiguous items produce reliably larger effects of Verb than Ambiguous items, though the effect is small.

Table 2 summarizes the model results for the child data. No reliable predictors of the Destination fixations appear in the VP window. However, in the next region, children, unlike adults, show no influence of the Verb on looks to the Destination, and instead show an influence of Ambiguity and its interaction with Verb. This interaction supports the crucial observation that all conditions with the exception of Unambiguous-*pickup* are showing elevated looks to the Destination Object (see Figure 2B). This interaction persists into the next time window (Post-VP2).

Tests for developmental changes (children vs. adults) were performed by modeling the entire data set (both child and adult data) in one model for each time window (see Table 3). The crucial result is the existence of a strong interaction between the Verb and Age Group predictors. This interaction reflects the fact that the effect of Verb in Post-VP1 and Post-VP2 is present in adults but does not exist in children, indicating that the children were having difficulty using verb information to modulate looks to the Destination object.

Action patterns

An inspection of the actions children gave in response to these spoken instructions offer perhaps the most striking demonstration that they had difficulty using verb information to revise initial parsing choices. As predicted, children produced non-adult (erroneous) actions on the majority (54%) of the trials in the Ambiguous-*pickup* condition but not in the other three conditions (see Table 4). Most of these errors involved the use of the Destination object (VP Actions), with the two most typical VP Actions illustrated in Figure 3: Children either moved an object/animal to the Destination object, or used the Destination object as an instrument to pick up the object/animal. Both action types are consistent with an interpretation of the PP as an argument of the verb (VP attachment). As expected, children's dominant response in each of the three other conditions matched that of adults, whose actions were largely flawless (see Table 4).

In order to statistically model child and adult actions we excluded all 'Other' actions, and calculated the proportion of VP actions out of all NP and VP actions (see Figure 4). These action data were fit to multi-level mixed linear models using the same methods as those used for eye gaze data. Table 5 presents the three models: (1) for adults, (2) for children and (3) for adults and children combined. Not surprisingly, the best fitting model for adults is one in which the Verb is the only reliable predictor, showing a strong positive effect: *put* produces VP actions and *pickup* does not. Ambiguity is not a predictor because adults responded to the Ambiguous sentences as if they were Unambiguous. In contrast, the best fitting model of the child actions is one that has both Verb and Ambiguity as reliable predictors. Moreover, the interaction between Verb and Ambiguity is also a reliable predictor. Finally, in the model that combines the child and adult data, the expected developmental patterns are observed, including a reliable three way interaction between Verb, Ambiguity and Group.

Are all children alike? To examine whether the observed errors in the Ambiguous-*pickup* condition were driven by certain individual children, the distribution of error responses was examined among children. The majority of children committed one or more errors in the Ambiguous-*pickup* condition, showing that the results were not driven by a few individual children: five children committed errors more than 75% of the time (age range: 4;0 —5;1) and five between 25% and 75% (age range: 4;2 —5;3). However, there were six children who did not make any errors in the Ambiguous-*pickup* condition, which also show that children in this age range are beginning to show greater control of their parsing abilities – an issue we return to in the General Discussion.

Which frog did they act on? Recall that English speaking children in the Trueswell et al. (1999) study were at chance when selecting the Target or Competitor object to act upon, suggesting they didn't realize that *on the napkin* could be a Modifier (English-speaking adults almost always pick the Target). A similar pattern was observed here for *pickup* instructions. Adults always acted on the Target (100% of the time) regardless of whether the phrase was temporarily ambiguous or not. Children in contrast showed some confusion about which object to act on for temporarily ambiguous instructions. Out of NP and VP actions, they used the Target 64% of the time and the Competitor 32%. For Unambiguous instructions, they acted on the Target 81% of the time and the Competitor only 6%. This pattern suggests that children sometimes failed to realize that the temporarily ambiguous PP could be a Modifier telling them which object to act upon (see Appendix II and III).

Put trials, if parsed correctly as Destinations, are referentially ambiguous – e.g., either frog could be acted upon. As expected, Korean-speaking adults showed this referential pattern, but also showed a pragmatic effect of preferring to move the Competitor (e.g., the frog currently not on a napkin) over to the Destination (e.g., the empty napkin). In particular, adults acted on the Competitor (71%) more than the Target (29%). Children also acted similarly but with less of a preference for the Competitor (48%) as compared to the Target (39%), with one clever child using both the Target and Competitor in their action (a type of action observed with some English-speaking children). We refer the reader to Appendix III for a detailed breakdown of all action types.

General Discussion

The central finding of the current study is that Korean-speaking children show substantial difficulty recovering from garden-path sentences, even though the disambiguating evidence at the end of the sentence was a verb. Eye-gaze patterns demonstrated that unlike adults, Korean-speaking children had considerable difficulty using their knowledge of *pick up* to block consideration of the initial Destination interpretation of *napkin-on*: Sentences ending with *pick up* and sentences ending with *put* both produced increased looks to the Destination object. Only sentences that contained an unambiguous NP Modifier allowed children to block fixating the Destination object. Moreover, children's actions indicated a failure to fully recover from this garden-path on a sizeable proportion of the trials; children frequently performed non-adult actions, which typically involved the Destination object. Their actions suggest that they interpreted the ambiguous PP as an argument of the verb, assigning it an Instrument or a Destination role.

As discussed in the introduction, numerous parsing studies of English show that children rely heavily on verb information to guide parsing commitments for ambiguous phrases, frequently failing to use disambiguating evidence to override their initial parse (e.g., Hurewitz et al., 2000; Trueswell et al., 1999; Weighall, 2008). The present data from Korean are consistent with the cognitive control account that these parsing preferences are not a reflection of a general dispreference to override verb information, but rather a reflection of developing cognitive control abilities. Across both languages, children in the same age range are showing a strong preference for early-arriving cues to sentence structure over late-arriving ones, especially when these cues conflict. Critically, verb information was the early-arriving cue in one language (English) but the late-arriving cue in the other language (Korean). Cross-linguistically, the resulting parsing preferences prioritized the temporal order of the cue rather than the kind of cue. In contrast, adults in both languages are able to use late arriving cues to structure so as to dynamically revise their interpretation and parse of the sentence (older children, age 8, also show this ability to revise; Trueswell et al, 1999; Weighall, 2008). The observed developmental difference in parsing patterns is expected if general cognitive control/executive function abilities play a central role in garden-path recovery. Consistent with this account, Novick and colleagues have recently demonstrated that a patient with a focal lesion to Left Inferior Frontal Gyrus (LIFG) in the prefrontal cortex shows deficits in cognitive control tasks and garden-path recovery (Novick, Kan, Trueswell & Thompson-Schill, in press). Strikingly, this patient's language deficits appear largely limited to revising ambiguity, be it lexical or syntactic. Taken together, it appears that the observed revision difficulty in sentence parsing among children speaking English and Korean is associated with their developing cognitive control abilities.

The results of the present study suggest that we have taken a snapshot of children transitioning from child-like to adult-like cognitive control and garden-path recovery abilities. However, it should be noted that the current data does not completely rule out another possibility. The pattern of our results could have arisen from cross-linguistic variability in cue validity and the differential treatment of these cues by children within each language. It is possible that in Korean, due to its head-final nature, morphosyntactic case-marking information (or noun morphology) may carry more predictive power compared to the type of morphosyntactic information in head-initial languages such as English, and thus affects the child's parsing processes differently. Hence, Korean children perhaps were more willing to rely on case-marking morphosyntax contingencies than the verb as compared to English children. This issue can be addressed by examining the effect of the order of information presentation in a sentence within each language, for example, delaying the verb information to the end of the sentence in English (e.g., "*The frog on the napkin into the box ...put*!") or presenting the verb information prior to morphosyntactic information in Korean (e.g., "*Pick up!.. napkin-on frog-acc.*"). If the revision difficulty observed in both Korean and English children were mainly due to their difficulty in inhibiting an initial representation, it is expected that children will not be as prone to committing to erroneous interpretations when the presentation of biasing information such as verb or case-marker information is delayed. In fact, preliminary results of our follow-up research on this appear to confirm this prediction. Both English and Korean children are less prone to commit to interpretation errors when the verb in English and the case-marking information in Korean are presented later in the sentence (Choi & Trueswell, in preparation).

In addition, it would be important to directly test the relationship between language processing and cognitive control abilities to find further support for the cognitive control difficulty account. For instance, it should be examined whether individual differences in cognitive control predict individual differences in the ability to revise garden-path sentences in both languages. We are currently investigating this relationship by obtaining various measures of executive functions to further illuminate which cognitive process(es) underlying EF is pertinent to language processing abilities. Again, the preliminary results seem to point to the general information processing deficit account, though a larger sample of data is being collected to confirm these findings.

Similarly, to further confirm the generality of our findings, additional studies need to be done to test the child's parsing abilities involving a broader set of linguistic materials beyond the limited set of items we used in our study (one pair of verbs, *put* versus *pick up*).

Universal Constraint-based Parser

The results from English and Korean, when viewed in this way, suggest a striking commonality (and an expected symmetry) in child parsing cross-linguistically. As such, they indicate that executive function and cognitive control abilities should be integrated into current theories of sentence processing. Although we expect it would be possible to integrate such mechanisms into most theories, we have argued elsewhere that control mechanisms of this sort more naturally fit into constraint-based parsing accounts and that the evidence to date supports such a view (Novick et al., 2005). Indeed, the work conducted thus far on ambiguity resolution abilities in children and adults is most consistent with a system that is highly sensitive to morpho-syntactic/lexical-syntactic regularities. Children appear to be greedily collecting statistical regularities regarding the syntactic environments within which lexical items can appear. The present findings are consistent with this general view, and point out that morphemes are the contingency that children are relying quite heavily on (whether it be derived from verbs, prepositions, case-markers, tense/aspect markers, etc.).

However, as suggested here, late developing executive function / cognitive control abilities interact with structural processing in significant ways; under situations when cues to structure conflict, the serial nature of the input causes learners with natural deficits in cognitive control to disproportionately rely on earlier arising cues to structure rather than later arising cues.

Closing Remarks

The results of our study suggest general difficulty for children when recovering from garden-path sentences. It appears that young children (regardless of the language they are learning) disproportionately rely on early-arriving constraints on structure to resolve ambiguity, whereas post-ambiguity constraints exert less influence even when they are highly informative. Such a pattern is expected cross-linguistically under constraint-based accounts of language development that incorporate notions of executive function and/or cognitive control.

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Acknowledgments

This research was supported by NIH Grant R01-HD37507 (awarded to John Trueswell and Lila Gleitman). We thank David January, Allison Wessel, Alon Hafri and other lab members at the University of Pennsylvania for their help in coding the data and their valuable comments. We thank Dr. Young-jin. Kim and Dr. Kwangill Choi at Ajou University, and the director Doyun Lee at Rainbow Child Care in Korea for their help in data collection. We are also grateful to Emily Trueswell for the illustrations found in this paper.

Appendix I. Materials used in the Experiment

Auditory stimuli (PP-NP)	Visual Stimuli	
	*Inside parentheses indicates scenes for Unambiguous-*put* condition.	
1. 수건에 (있는) 코끼리를	elephant/towel (tray)	towel
towel-[e] (that's) elephant-acc	puppy/box	elephant/book
2. 접시에 (있는) 사슴을	deer/box	deer/plate (basket)
plate-[e] (that's) deer-acc	plate	cow/bowl
3. 냅킨에 (있는)오렌지를	banana/basket	orange/plate
napkin-[e] (that's) orange-acc	orange/napkin (bowl)	napkin
4. 쟁반에 (있는) 생쥐를	mouse/tray (plate)	tray
tray-[e] (that's) mouse-acc	zebra/cup	mouse/towel
5. 쟁반에 (있는) 크레용을	crayon/tray (cup)	tray
tray-[e] (that's) crayon-acc	notebook/box	crayon/towel
6. 수건에 (있는) 기린을	towel	alligator/basket
towel-[e] (that's) giraffe-acc	giraffe/bowl	giraffe/towel (box)
7. 종이에 (있는) 고양이를	cat/paper	paper
paper-[e] (that's) cat-acc	frog/pot	cat/tray
8. 접시에 (있는) 사탕을	candy/box	candy/plate (tray)
plate-[e] (that's) candy-acc	plate	cookie/jar
9. 냅킨에 (있는) 시계를	mirror/bowl	clock/magazine
napkin-[e] (that's) clock-acc	clock/napkin (basket)	napkin
10. 수건에 (있는) 포도를	grapes/basket	grapes/towel (plate)
towel-[e] (that's) grape-acc	towel	strawberry/jar
11. 냅킨에 (있는) 상어를	starfish/bowl	shark/book
napkin-[e] (that's) shark-acc	napkin	shark/napkin (box)
12. 그릇에 (있는) 돌고래를	bowl	toothbrush/cup
bowl-[e] (that's) dolphin-acc	dolphin/cup	dolphin/bowl (basket)

Appendix II. Summary of detailed breakdown of Adult action responses.

		Object Grabbed	Type of Platform (e.g., a napkin) Used in Action				
Verb	**Ambiguity**		**Empty**	**Under-Target**	**Other**	**None***	***Total***
Pickup	**Ambiguous**	Target	.	.	.	**48(100%)**	48(100%)
		Competitor	.	.	.	.	.
		Both	.	.	.	.	.
		Other	.	.	.	.	.
		Total	*0(0%)*	*0(0%)*	*0(0%)*	*48(100%)*	*48(100%)*
	Unambiguous	Target	.	.	.	**48(100%)**	48(100%)
		Competitor	.	.	.	.	.
		Both	.	.	.	.	.
		Other	.	.	.	.	.
		Total	*0(0%)*	*0(0%)*	*0(0%)*	*48(100%)*	*48(100%)*
Put	**Ambiguous**	Target	**13(27%)**	**1(2%)**	.	.	14(29%)
		Competitor	**34(71%)**	**.**	.	.	34(71%)
		Both	.	.	.	.	.
		Other	.	.	.	.	.
		Total	*47(98%)*	*1(2%)*	*0(0%)*	*0(0%)*	*48(100%)*
	Unambiguous	Target (either)	**48(98%)**	.	.(2%)	.	48(100%)
		Both	.	.	.	.	.
		Other	.	.	.	.	.
		Total	*48(98%)*	*0(0%)*	*0(2%)*	*0(0%)*	*48(100%)*

* "None" means that no platform was used in the action, indicating a picking-up action, i.e., picking up an object and holding it in one's hand. "Empty" refers to the empty platform, i.e., the possible Destination (the empty napkin). "Under-Target" refers to the platform under the Target object (e.g., the napkin under the frog).

Appendix III. Summary of detailed breakdown of Child action responses.

Verb	Ambiguity	Object Grabbed	Type of Platform (e.g., Napkin) Used in Action				
			Empty	Under-Target	Other	None*	*Total*
Pickup	**Ambiguous**	Target	**6(14%)**	**1(2%)**	1(2%)	20(46%)	28(64%)
		Competitor	**9(21%)**	.	.	5(11%)	14(32%)
		Both	.	.	.	.	.
		Other	.	.	1(2%)	1(2%)	2(4%)
		Total	*15(35%)*	*1(2%)*	*2(4%)*	*26(59%)*	*44(100%)*
	Unambiguous	Target	.	.	.	39(81%)	39(81%)
		Competitor	.	.	.	3(6%)	3(6%)
		Both	.	.	.	1(2%)	1(2%)
		Other	1(2%)	1(2%)	1(2%)	2(4%)	.(10%)
		Total	*1(2%)*	*1(2%)*	*1(2%)*	*45(93%)*	*48(99%)*
Put	**Ambiguous**	Target	**12(26%)**	**1(2%)**	3(7%)	2(4%)	18(39%)
		Competitor	**16(35%)**	**6(13%)**	.	.	22(48%)
		Both	1(2%)	.	.	.	1(2%)
		Other	.	4(9%)	1(2%)	.	5(11%)
		Total	*29(63%)*	*11(24%)*	*4(9%)*	*2(4%)*	*46(100%)*
	Unambiguous	Target (either)	32(80%)	1(3%)	1(3%)	.	34(86%)
		Both	3(8%)	.	.	.	3(8%)
		Other	.	2(5%)	1(3%)	.	3(8%)
		Total	*35(88%)*	*3(8%)*	*2(6%)*	*0(0%)*	*40(102%)*

* “None” means that no platform was used in the action, indicating a picking-up action, i.e., picking up an object and holding it in one’s hand. “Empty” refers to the empty platform, i.e., the possible Destination (the empty napkin). “Under-Target” refers to the platform under the Target object (e.g., the napkin under the frog).

Figures & Tables

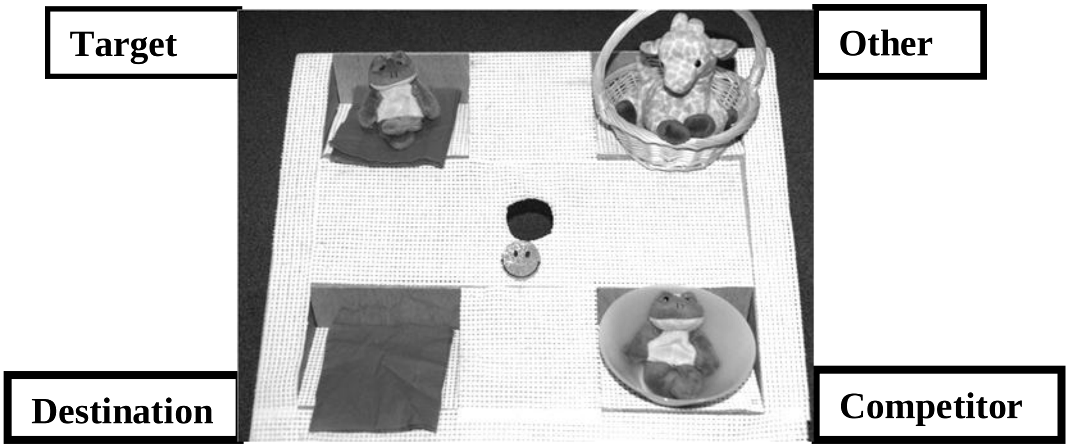
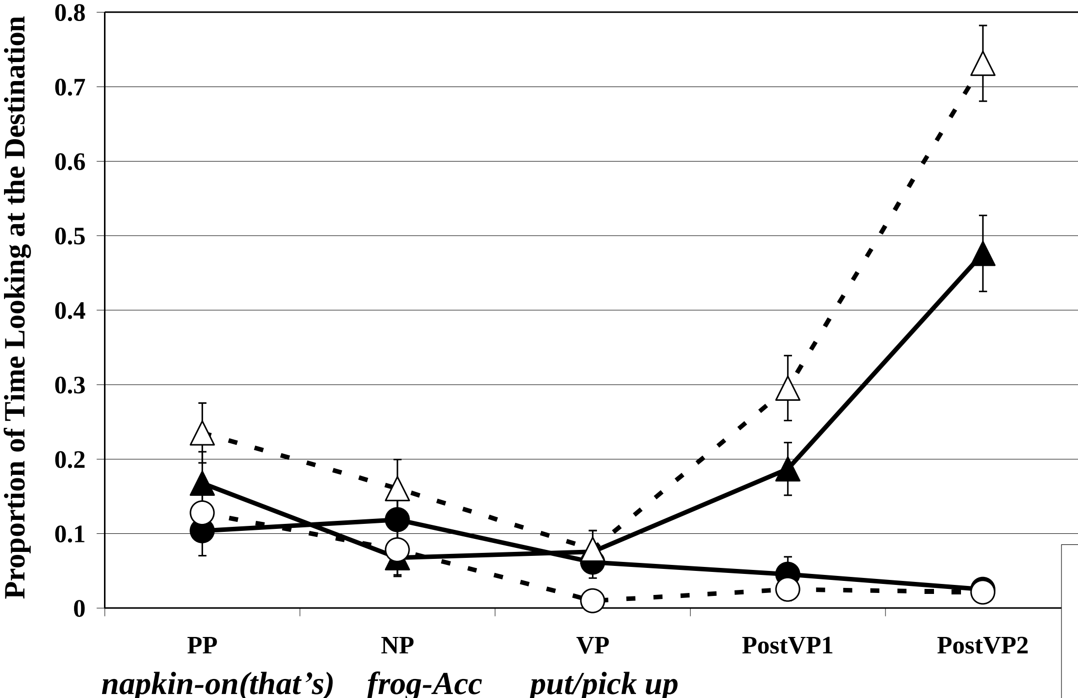


Figure 1. Example scene for *napkin-ey frog-Acc pickup / put.* (*Pick up / Put the frog on the napkin.*) The scene contains, clockwise from upper right, a frog on a napkin (Target), a giraffe in a basket (Other), a frog in a bowl (Competitor) and an empty napkin (Destination).

Figure 2A-B. Mean proportion of time spent looking at the Destination object among adults (2A) and children (2B) across the four experimental conditions.

(2A) Adults



(2B) Children

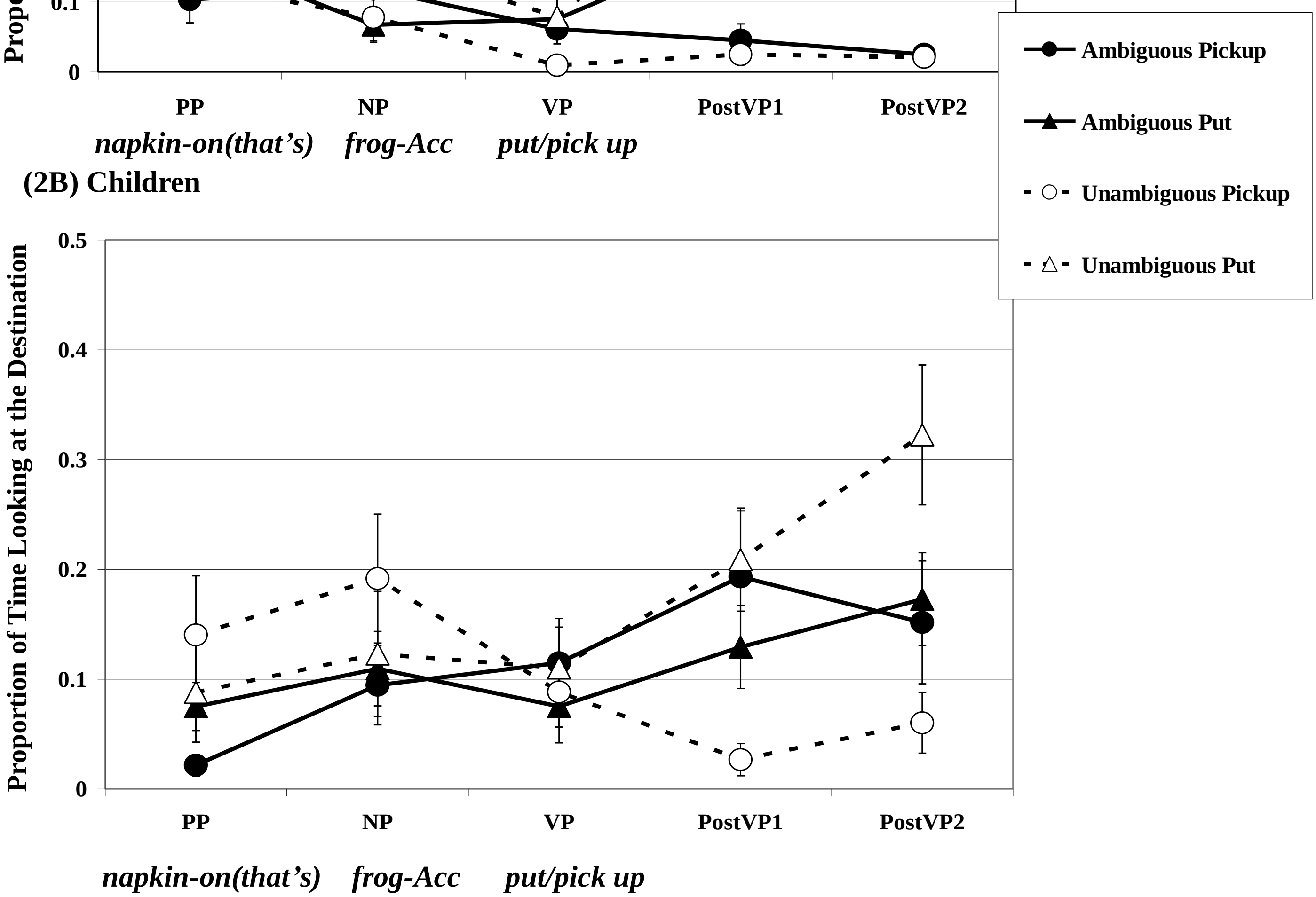
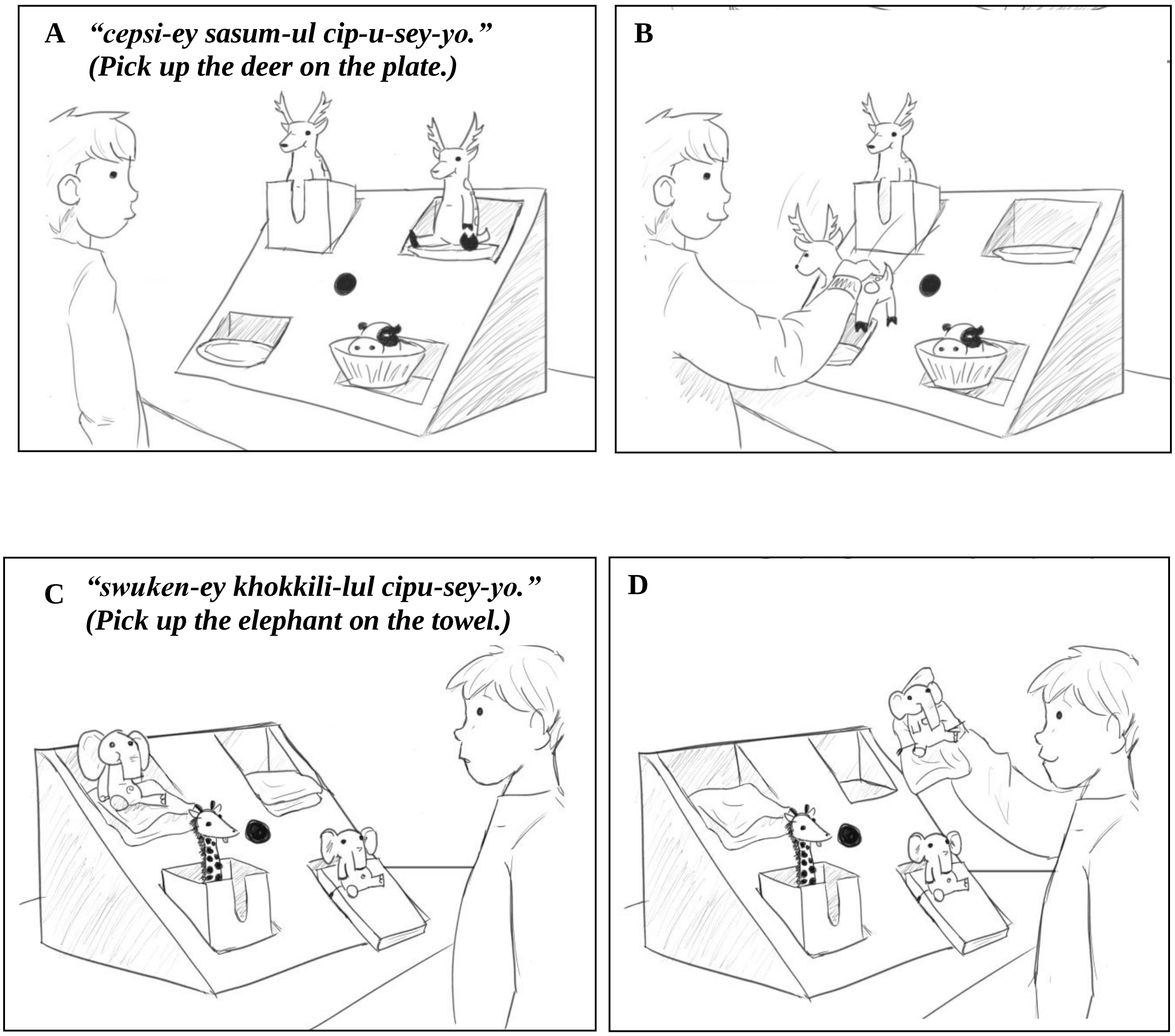


Figure 3. Illustrations of typical non-adult actions from children. Panels A and B illustrate an incorrect destination action. In response to hearing *Pick up the deer on the plate,* the child moves the Target (the deer that was on a plate) over to the Destination (a plate that was originally empty). Panels C and D illustrate an incorrect instrument action. In response to hearing *Pick up the elephant on the towel,* the child first picks up the Destination (the towel that had nothing on it, in the upper right shelf) and uses it to grasp the Target (the elephant that was originally on another towel). The child then holds the Target in the air. Both destination and instrument actions were coded as VP actions.



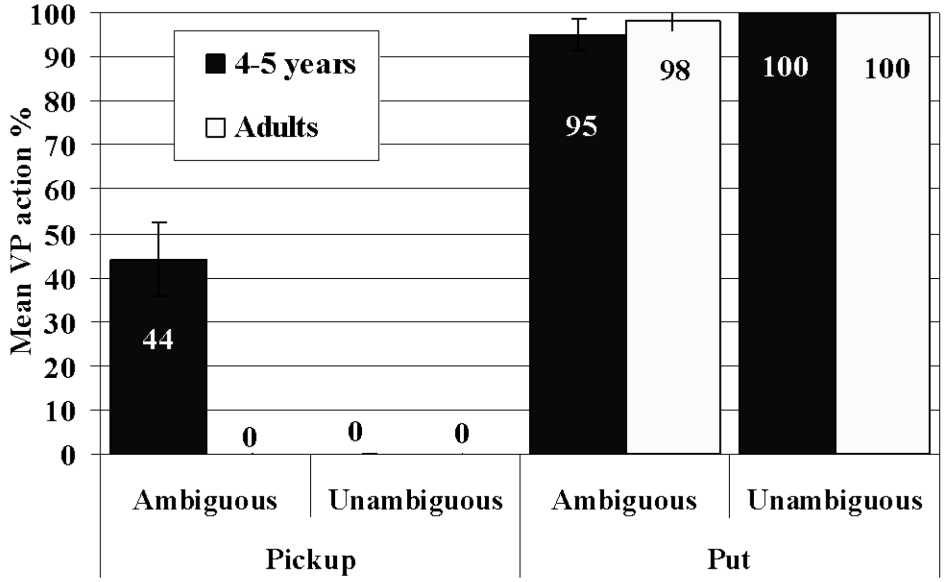


Figure 4. Mean % VP-attachment action proportion split by verb type, ambiguity, and age groups. Percentages out of the sum of all VP action and NP actions {(VP action) divided by (VP action + NP action)}, after excluding 'Other' types of action

Table 1. Fixed effects from best fitting multi-level linear model of proportion of time spent looking at Destination Object (E-Logit transformed): Adult data only.

Window	Effect	Estimate	S.E.	t-value
VP	Intercept	-3.24	0.17	-18.54*
	Verb (put vs. pickup)	-0.01	0.25	-0.03
	Ambiguity (unamb. vs. amb.)	-0.54	0.25	-2.19*
	Verb x Ambiguity	0.72	0.35	2.05*
PostVP1	Intercept	-3.65	0.31	-11.91
	Verb (put vs. pickup)	1.32	0.31	4.18*
	Ambiguity (unamb. vs. amb.)	-0.23	0.31	-0.72
	Verb x Ambiguity	1.05	0.45	2.37*
PostVP2	Intercept	-3.80	0.32	-11.77*
	Verb (put vs. pickup)	3.40	0.38	8.84*
	Ambiguity (unamb. vs. amb.)	0.01	0.39	0.02
	Verb x Ambiguity	1.91	0.54	3.51*

* $p < 0.05$ (on normal distribution)

Note: Models presented here and in Tables 2, 3 and 5 all have significantly better fits than empty models with no fixed effects, based on a chi-square test of the change in -2 restricted log likelihood (Baayen, Davidson, & Bates, 2008). Models reporting interactions were significantly better fits than the corresponding models that did not have these interaction terms. When main effects or interactions do not appear above, it is because adding them to the models did not reliably improve the fit. All *t*-values provide the results of significance tests of the beta estimates (Estimate) tested against zero.

Table 2. Fixed effects from best fitting multi-level linear model of proportion of time spent looking at Destination Object (E-Logit transformed): Child data only.

Window	Effect	Estimate	S.E.	t-value
VP	Intercept	-2.96	0.18	-16.80*
PostVP1	Intercept	-2.70	0.33	-8.31*
	Verb (put vs. pickup)	-0.03	0.40	-0.08
	Ambiguity (unamb. vs. amb.)	-1.11	0.41	-2.70*
	Verb x Ambiguity	1.70	0.60	2.86*
PostVP2	Intercept	-2.81	0.40	-6.97*
	Verb (put vs. pickup)	0.28	0.46	0.61
	Ambiguity (unamb. vs. amb.)	-0.65	0.47	-1.39
	Verb x Ambiguity	2.23	0.68	3.26*

* $p < 0.05$ (on normal distribution)

Table 3. Fixed effects from best fitting multi-level linear model of proportion of time spent looking at Destination Object (E-Logit transformed). Adult and child data combined.

Window	Effect	Estimate	S.E.	t-value
VP	Intercept	-3.33	0.13	-26.37
	Group (child vs. adult)	0.37	0.18	2.05*
PostVP1	Intercept	-3.59	0.28	-12.79*
	Verb (put vs. pickup)	1.19	0.31	3.84*
	Ambiguity (unamb. vs. amb.)	-0.36	0.31	-1.15
	Group (child vs. adult)	0.79	0.33	2.44*
	Verb x Ambiguity	1.32	0.37	3.56*
	Verb x Group	-1.07	0.37	-2.87*
	Ambiguity x Group	-0.58	0.37	-1.57
PostVP2	(Intercept)	-3.66	0.30	-12.10*
	Verb (put vs. pickup)	3.34	0.36	9.20*
	Ambiguity (unamb vs. amb.)	-0.26	0.31	-0.86
	Group (child vs. adult)	0.69	0.31	2.25*
	Verb x Ambiguity	2.02	0.44	4.65*
	Verb x Group	-2.98	0.44	-6.80*

* $p < 0.05$ (on normal distribution)

Table 4. Percentage of Action Types for Adults and Children

			Type of Action		
Verb	**Ambiguity**	**Group**	VP-Action	NP-Action	Other
Pickup	**Ambiguous**	**Adults**	0%	100%	0%
		Children	37%	46%	17%
	Unambiguous	**Adults**	0%	100%	0%
		Children	0%	81%	19%
Put	**Ambiguous**	**Adults**	100%	0%	0%
		Children	78%	4%	18%
	Unambiguous	**Adults**	100%	0%	0%
		Children	91%	0%	9%

Table 5. Fixed effects from best fitting multi-level linear models of the proportion of VP actions out of VP and NP actions (E-Logit transformed).

Group	Effect	Estimate	S.E.	t-value
Adults	Intercept	-1.10	0.02	-67.71*
	Verb (put vs. pickup)	2.17	0.02	94.50*
Children	Intercept	-0.12	0.11	-1.13
	Verb (put vs. pickup)	1.11	0.13	8.30*
	Ambiguity (unamb. vs. amb.)	-0.95	0.13	-7.22*
	Verb x Ambiguity	1.05	0.19	5.62*
Combined	Intercept	-1.10	0.07	-16.65*
	Verb (put vs. pickup)	2.15	0.08	26.79*
	Ambiguity (unamb. vs. amb)	0.00	0.08	0.01
	Group (child vs. adult)	0.98	0.10	9.86*
	Verb x Ambiguity	0.05	0.11	0.40
	Verb x Group	-1.05	0.12	-8.54*
	Ambiguity x Group	-0.95	0.12	-7.81*
	Verb x Ambiguity x Group	1.01	0.17	5.83*

* $p < 0.05$ (on normal distribution)

[1] The linguistic term for this thematic role is Goal. However, we have adopted the Trueswell et al. (1999) terminology of Destination phrase, which is a more transparent term for the present purposes.

[2] Numerous studies have replicated these findings (e.g, Chambers, Tanenhaus, & Magnuson, 2004; Spivey, Tanenhaus, Eberhard & Sedivy, 2002; Trueswell, Sekerina, Hill, & Logrip, 1999) and a range of methods are now used for recording adult and child eye gaze during listening, including head-mounted eyetracking and video-based coding of the eyes and face (see Tanenhaus, 2007; Trueswell, 2008).

[3] Children around this age range show a similar eye movement pattern to that of adults in response to speech; their eyes are launched to the corresponding visual item immediately after hearing the word (Snedeker & Trueswell, 2004; Trueswell et al., 1999).

[4] Note that if the PP appears after the NP as in "*kaykwuli-lul naypkhin-ey*…", the PP can only fill a Destination role and cannot be taken as a Modifier. The ambiguity disappears with this ordering.

[5] The analysis was performed on one set of Korean CDS corpus currently available at CHILDES database (MacWhinney, 2000), which recorded the interaction between a girl (from 2;0.13 to 2;1.10) and her mother during their play time. The total number of speech tokens was 17271 words with the 5622 word types.

[6] In the written sentence completion study, 42 adults showed strong preference for a locative when they were asked to generate case markers and predicates of sentence fragments such as "“Bowl __ cookie-ACC ____" (16 targets & 32 fillers). Adults used –*ey* marker 57% of the time, followed by the genitive –*uy* (20%), concomtative –*ko* (7%), directive –*lo* (4%), and others. In the auditory sentence completion study, pre-recorded PP-NP sentence fragments (e.g., "cup-ey toothbrush-ACC…") were presented for both adults (*n*=20) and 5-year-olds (*n*=20, F=11; mean age=5;4) to complete, together with a visual scene containing two referents (favorable for a Modifier interpretation). Children showed a preference for the Destination interpretation (66%) even in the presence of two-referent contexts. Adults' preferences appeared to reflect an ability to revise "cup-ey" from a Destination to a Modifier interpretation based on the context, showing a reduced preference for the Destination interpretation (33%).

[7] The proportion of time was calculated by dividing the total number of frames fixating the item of interest by the total frame numbers given each fixation window. This was done to equate for the fact that the first three time windows differed in their duration. Duration was determined by the onsets of each phrase, which differed from item to item.

[8] All time windows were delayed by 200 ms to take into account the time it takes to observe effects of linguistic input on eye movements (e.g., see Allopoenna, Magnuson, & Tanenhaus, 1998; Matin, Shao, & Boff, 1993 but see Altmann & Kamide, 2004 for discussion of variability of the time taken for linguistic input to affect eye movements).

[9] According to Jaeger (2008), Empirical-logit transformation corrects the problem of heterogeneity of variance distribution in using proportion data better than arcsin transformations to suit the current type of statistical analyses. For all modeling results, we also performed repeated measures Analysis of Variance (ANOVA) tests on subject and item means, using arcsin transformations of the proportional data. The patterns of results were almost identical to those reported here and we would have drawn the same conclusions. We report only cross-random intercept, multi-level modeling because we believe the assumptions of such models are better met by the current data set (see, e.g., Barr, 2008; Jaeger, 2008).