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

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ABSTRACT

An eye-tracking study explored Korean-speaking adults' and 4- and 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 in 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; however, 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.

Introduction

When children and adults interpret an utterance, they appear to do so in "real time," rapidly forming a hypothesis about the utterance's meaning as each word is perceived (see Pickering &

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van Gompel, 2006; Tanenhaus, 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 be completed, 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, for example, to inhibit hypotheses proven wrong and to promote hypotheses consistent with newer input. But what about children? In cognitive tasks, even 4- to 6-year-olds have difficulty in exerting control over "prepotent"/automatic responses (e.g., Davidson, Amso, Anderson, & Diamond, 2006). Does this extend to real-time language comprehension? The initial evidence suggests that perhaps it does (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. Here we asked 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 been learned so far 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, & van der Molen, 2006; Miller & Cohen, 2001). EF is crucial in one's ability to control thoughts and actions so as to generate adapting behaviors to changing needs of the environment (Hill, 2004; Müller et al., 2005; Stuss & Knight, 2002). Preschool-age children frequently show deficits in various cognitive control tasks involving these EF components, particularly inhibitory control (i.e., 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). Also, 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, 2002; Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Diamond et al., 2002). This slow development has been linked to the protracted maturation of the associated brain regions, in particular, the prefrontal cortex (Huttenlocher & Dabholkar, 1997; see also Mazuka, Jincho, & Oishi, 2009).

Novick and colleagues (2005) 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, where 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 Example (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 initially pursue 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 NP.

Evidence for these conclusions comes from eye movement studies of spoken language processing in which listeners act on objects in response to spoken instructions (cf. 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 positions tend to be closely time-locked with the speech they hear (e.g., they will typically fixate on an apple 0 to 200 ms after hearing the word *apple*) (see Tanenhaus et al., 1995). Tanenhaus and colleagues (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 an increased fixation tendency was not observed when listeners heard unambiguous sentences such as *Put the apple <u>that's</u> on the towel* . . . Furthermore, on hearing *into the box* after *Put the apple on the towel,* listeners tended to show some general confusion, looking around more as compared with 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 and colleagues (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 prepotent (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 misanalyses (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 prepotent interpretation. In fact, comprehension studies that have used sentences such as Example (1) have found that 4- and 5-year-olds, as compared with adults and older children, have much greater difficulty in revising their initial parsing choice; that is, 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 with the unambiguous condition (*Put the frog that's on the*

[1] The linguistic term for this thematic role is *goal.* However, we have adopted Trueswell and colleagues' (1999) terminology of *destination phrase,* which is a more transparent term for the current purposes.

[2] Numerous studies have replicated these findings (e.g., Chambers, Tanenhaus, & Magnuson, 2004; Spivey, Tanenhaus, Eberhard, & Sedivy, 2002; Trueswell et al., 1999), and a range of methods are now used for recording adult and child eye gaze during listening, including head-mounted eye-tracking 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).

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 more than 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 children 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 reconsider *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 in 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 in the input. Many studies with children (3–5 years of age 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; that is, 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 rely disproportionately on verb information over extrasentential contextual information when resolving structural ambiguities, perhaps due to the higher reliability of verbs to predict structure (Snedeker & Trueswell, 2004; Snedeker & Yuan, 2008; Trueswell & Gleitman, 2004; Trueswell & Gleitman, 2007). Snedeker and 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*. The 5-year-olds' 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, by 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), becomes employed first developmentally and dominates children's early parsing processes (Trueswell & Gleitman, 2004; Trueswell & Gleitman, 2007).

This may explain why preschoolers 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 instead were 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 toward 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 by MacWhinney, Pleh, and Bates (1985). It is possible, then, that children's difficulty in revising the temporarily ambiguous items reflects an information reliability difference in their parsing system. Under this view, as children gain more experience with their language, they become attuned to exceptional parsing circumstances that require reevaluation 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 Example (2) with its Korean equivalent in Example (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 current 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 to *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 (and 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 NPs (e.g., Aoshima, Phillips, & Weinberg, 2004; Kamide et al., 2003). As this evidence suggests, we believe that 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 Example (3) above contains a temporary ambiguity that is illustrated below in Examples (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 PP *naypkhin-ey* appears prior to an NP *kaykwuli-lul,* as in Examples (4a) and (4b), 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

[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.

marker, or a reduced form of a full relative *-ey issnun* (i.e., on/in-). When a verb requires a destination phrase (*put* in Example 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 Example (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 the locative *-ey*). Thus, the phrase *naypkhin-ey kaykwuli-lul* (we use *napkin-on frog-Acc* to refer to these hereafter) in Examples (4a) and (4b) 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 to which the frog will be going). For instance, minimal attachment theory (Frazier, 1987) predicts that listeners have a preference against complex NPs such as the sort required if *napkin-on frog-Acc* were treated as a single NP 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 as a genitive (modifier) in the child-directed linguistic input. In a prior corpus analysis and two sentence-completion experiments, we 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,* with 108 of these marking a destination and only 7 cases where the phrases were modifying the following NP.[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* (Example 4a above) should be an easy sentence for Korean children to understand, whereas the one involving *pick up* (Example 4b) should not; it should cause a garden path.

On the face of it, however, simple sentences such as *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 rely disproportionately on verb information to determine structural interpretations (as the "change in information use" account predicts), Korean children should show little difficulty in 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 that 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 information than with 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 (Example 4b) above requires revision, children, but not adults, should make errors

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[5] The analysis was performed on one set of Korean child-directed speech corpus currently available at the CHILDES database (MacWhinney, 2000), which recorded the interaction between a girl (from 2 years 0 months 13 days to 2 years 1 month 10 days) and her mother during their playtime. The total number of speech tokens was 17,271 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 and 32 fillers). Adults used the *-ey* marker 57% of the time, followed by the genitive *-uy* (20%), comitative *-ko* (7%), directive *-lo* (4%), and others. In the auditory sentence completion study, prerecorded 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 years 4 months) 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%).

when they hear *pick up* and produce nonadult 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. By 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 and 5-year-olds

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

Method

Participants

Participants were 16 adult native speakers of Korean (13 women and 3 men) and 16 children (4 years 0 months to 5 years 4 months of age, mean = 4 years 9 months, 10 girls and 6 boys). Adult participants were recruited via a subject participant pool at Ajou University in Suwon, Korea, and they received course credit for their participation. All participating children were monolingual Korean speakers recruited from preschools in Suwon. The experimenter visited the preschools and tested children individually in unoccupied rooms at their schools. An additional 3 children who participated were excluded from the analysis because they failed to understand the task.

Procedure

An experimental procedure similar to that of Snedeker and Trueswell (2004) was used. Participants 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 Fig. 1). Another digital camera recorded the location of the props and 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 participants with the names for objects ("This is (a) frog, (a) napkin, (a) box," etc.). Then prerecorded instructions were played from a computer, and participants were asked to carry out the action with the objects based on their interpretation of the instructions. All instructions were recorded by a female native Korean speaker. The experimental session began with 2 practice trials followed by 26 test trials (12 target and 14 filler trials), with each trial consisting of three or four 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 on

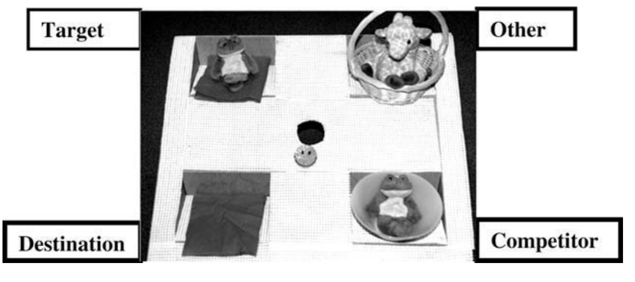

Fig. 1. Example scene for *napkin-ey frog-Acc pick up/put* [*Pick up/Put the frog on the napkin*]. The scene contains, clockwise from upper right, a frog on a napkin (target), a giraffe in a basket (other), a frog in a bowl (competitor), and an empty napkin (destination).

completion of their actions regardless of the accuracy of their responses. If children 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 (a) the first play was interrupted by the children themselves (e.g., started talking to the experimenter) or (b) it was interrupted by others (e.g., teachers, peers). These sorts of interruptions occurred for only a small number of trials. Participants were told to begin their action after the command was over. If participants initiated their action before the instruction was over, they were reminded to wait until the instruction was complete.

Materials and design

A total of 12 target items were constructed, beginning with an ambiguous PP and ending with either 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*, or unambiguous–*put* (see Examples 5a–d below and Appendix A for the full list of materials). As Fig. 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*** napkin-Loc napkin-on "Pick up the frog on the napkin."	*kaykwuli-lul* frog-Acc frog	*cipu-sey-yo* (ambiguous–*pickup*) pickup-Hon-SE pick up
	(b)	*naypkhin-ey-**iss-nun*** napkin-Loc-**be-Rel** napkin-on-is-that "Pick up the frog **that is** on the napkin."	*kaykwuli-lul* frog-Acc frog	*cipu-sey-yo* (unambiguous–*pickup*) pickup-Hon-SE pick up
	(c)	*naypkhin-**ey*** napkin-Loc napkin-on "Put the frog on the napkin." *Example of a visual scene for (5a–c):* a frog on a napkin (target), a frog in a bowl (competitor), an empty napkin (destination), a giraffe in a basket (other)	*kaykwuli-lul* frog-Acc frog	*nohu-sey-yo* (ambiguous–*put)* put-Hon-SE put
	(d)	Instruction same as (c) above; only the scenes differed (unambiguous–*put*) *Example of a visual scene for (5d):* a frog on a plate (target),[a] a frog in a bowl (target),[a] an empty napkin (destination), a giraffe in a basket (other) [a]Note that no frog on a napkin was present.		

For unambiguous–*pickup* trials, the optional relativizer (*issnun*) was added as in Example (5b). The relativizer appears immediately after *naypkhin-ey*, modifying the upcoming NP *frog;* 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 Example (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 (3 in each condition) were interspersed with 14 filler trials that consisted only of filler instructions (e.g., *Squeeze* *the cow, Cover the apple with the napkin*). The 12 target trials within each list involved different sets of objects; that is, 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 participants to the center fixation point (i.e., *Look at the smiley face*) followed by three or 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 participants. The filler trials were constructed to include two types of instructions that resemble *put* and *pick up* instructions, respectively: (a) to elicit a transfer type of action (e.g., transferring an object to a different location such as a candy from a jar into a bowl) and (b) to elicit direct actions on an object itself (e.g., tickling an animal toy, shaking an object). A total of 32 filler sentences were designed to elicit the transfer type of action, and 33 were designed 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*). A total of 42 different verbs were used with filler instructions. Roughly half of 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 6.0 s long; the target instructions for ambiguous–*pickup,* ambiguous–*put,* and unambiguous–*put* conditions were on average 2.7 s long, whereas the unambiguous–*pickup* instructions were approximately 3.4 s 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 videotapes of participants' faces, viewing them 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 are comparable to data collected from a head-mounted eye-tracker (Snedeker & Trueswell, 2004), and this method has the added benefit of not requiring children 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, or lower right), at the center, or away from the display (e.g., looks to the experimenter or to the camera). If participants' eyes were closed or not visible, the frame was coded as track loss. Trials on which track loss occurred more than 40% of the time were excluded from the analysis (amounting to 3.2% of all trials in the child data but no such trials in the adult data). Reliability over the coding was established by having a second coder fully recode the data of 3 randomly selected participants and by having a third coder resolve disagreements. The direction of eye gaze coded by the two coders was 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 (4 in ambiguous–*pickup,* 2 in ambiguous–*put,* and 8 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: (a) *VP actions,* or actions that clearly showed the 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); (b) *NP actions,* or 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 NP); and (c) *other actions,* or 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 in revising their initial parsing as compared with adults. To assess this, we examined looks to the destination object (the empty napkin) on hearing the sentence-final verb—*pick up* 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 *pick up* to block consideration of the destination parse, showing far fewer looks to the destination object in ambiguous–*pickup* sentences as compared with ambiguous–*put* sentences, with the size of this effect being nearly identical to unambiguous versions of these sentences (unambiguous–*pickup* and unambiguous–*put*). By comparison, if immature cognitive control was the underlying factor of children's parsing errors, Korean-speaking children are expected to show difficulty in using their knowledge of *pick up* to prohibit consideration of the destination interpretation. Both ambiguous–*put* and ambiguous–*pickup* sentences should 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 with 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, Korean children are expected to show little to no difficulty in parsing these ambiguous sentences; their looks to the destination object should be blocked on hearing *pick up*, similar to adults.

The results are consistent with the cognitive control account. Fig. 2A summarizes the proportion of time[7] adults spent looking at the destination object in five time windows: (a) *PP*, from the onset of the PP until the onset of the NP; (b) *NP*, from the onset of NP until the onset of the verb; (c) *VP*, from the onset of the verb until the offset of the verb; (d) *post-VP1*, a 1-s time window immediately after the offset of the verb; and (e) *post-VP2*, a second 1-s time window following the previous time window.[8] We focus particularly on three windows (VP, post-VP1, and post-VP2) that are 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 Fig. 2A). No such looks were observed when adults heard *pick up* (ambiguous–*pickup* and unambiguous–*pickup*). By contrast, the child eye movement patterns (see Fig. 2B) showed increased looks to the destination object in both the ambiguous–*put* and ambiguous–*pickup* conditions. Unambiguous items showed effects similar to those for adults such that unambiguous–*put* showed increased looks to the destination, but unambiguous–*pickup* did not.

To assess these patterns statistically, we fit the data for children and adults separately within each of the three time windows using a multilevel mixed linear model that treated the experimental factors of ambiguity (ambiguous vs. unambiguous) and verb (*pick up* vs. *put*) as fixed effects, with crossed random intercepts for participants 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]

[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 allow 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 (see, e.g., Allopoenna, Magnuson, & Tanenhaus, 1998; Matin, Shao, & Boff, 1993; but see Altmann & Kamide, 2004, for a 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 participant and item means, using arcsin transformations of the proportional data. The patterns of results were nearly identical to those reported here, and we would have drawn the same conclusions. We report only cross-random intercept, multilevel modeling because we believe that the assumptions of such models are better met by the current data set (see, e.g., Barr, 2008; Jaeger, 2008).

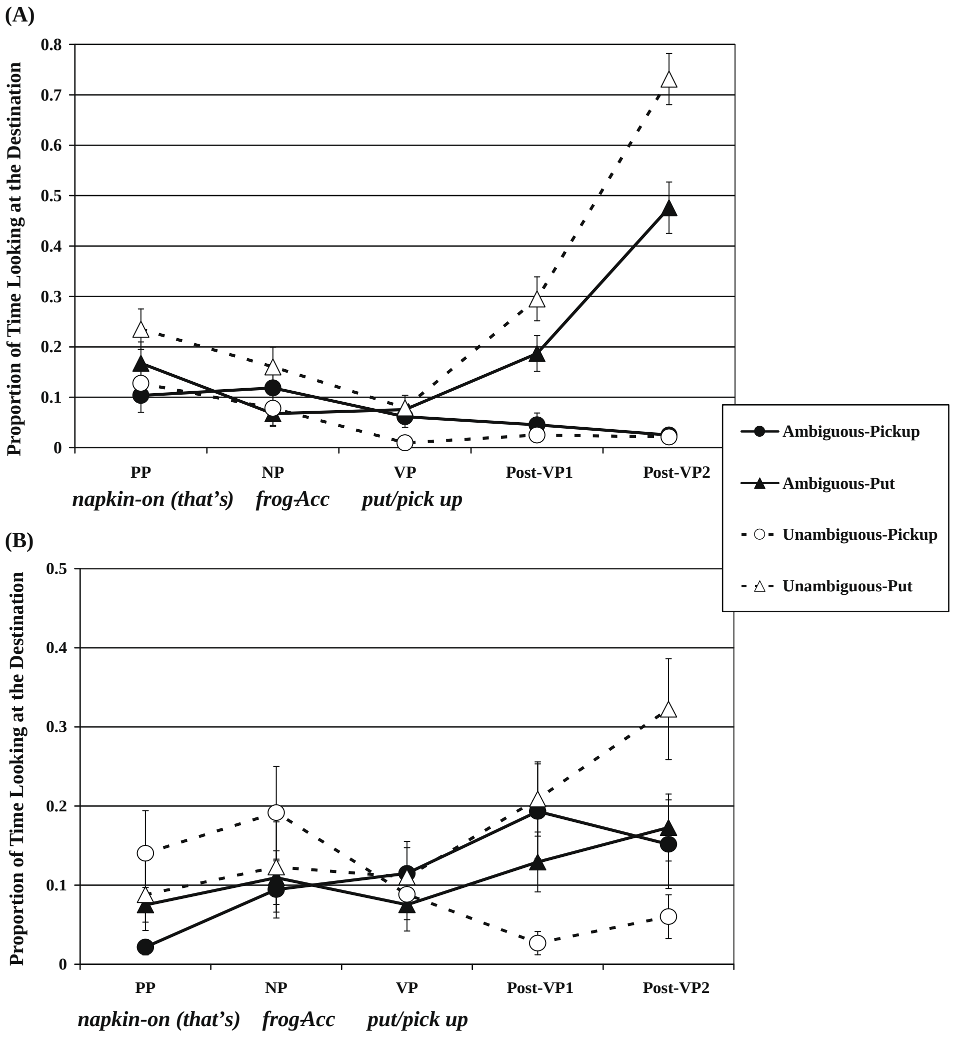

Fig. 2. Mean proportions of time spent looking at the destination object among adults (A) and children (B) across the four experimental conditions.

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 with 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 Fig. 2A). In the next two time windows (post-VP1 and 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 *pick up* does not (see Fig. 2A). This effect interacts with ambiguity such that unambiguous items produce reliably larger effects of verb than ambiguous items, although 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

Table 1
Fixed effects from best-fitting multilevel linear model of proportion of time spent looking at destination object (empirical logit transformed): Adult data only.

Window	Effect	Estimate	SE	*t* Value
VP	Intercept	−3.24	0.17	−18.54*
	Verb (put vs. pickup)	−0.01	0.25	−0.03
	Ambiguity (unambiguous vs. ambiguous)	−0.54	0.25	−2.19*
	Verb × Ambiguity	0.72	0.35	2.05*
Post-VP1	Intercept	−3.65	0.31	−11.91
	Verb (put vs. pickup)	1.32	0.31	4.18*
	Ambiguity (unambiguous vs. ambiguous)	−0.23	0.31	−0.72
	Verb × Ambiguity	1.05	0.45	2.37*
Post-VP2	Intercept	−3.80	0.32	−11.77*
	Verb (put vs. pickup)	3.40	0.38	8.84*
	Ambiguity (unambiguous vs. ambiguous)	0.01	0.39	0.02
	Verb × Ambiguity	1.91	0.54	3.51*

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.
* $p < .05$ (on normal distribution).

Table 2
Fixed effects from best-fitting multilevel linear model of proportion of time spent looking at destination object (empirical logit transformed): Child data only.

Window	Effect	Estimate	SE	*t* Value
VP	Intercept	−2.96	0.18	−16.80*
Post-VP1	Intercept	−2.70	0.33	−8.31*
	Verb (put vs. pickup)	−0.03	0.40	−0.08
	Ambiguity (unambiguous vs. ambiguous)	−1.11	0.41	−2.70*
	Verb × Ambiguity	1.70	0.60	2.86*
Post-VP2	Intercept	−2.81	0.40	−6.97*
	Verb (put vs. pickup)	0.28	0.46	0.61
	Ambiguity (unambiguous vs. ambiguous)	−0.65	0.47	−1.39
	Verb × Ambiguity	2.23	0.68	3.26*

* $p < .05$ (on normal distribution).

exception of unambiguous–*pickup* are showing elevated looks to the destination object (see Fig. 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 in 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 offers perhaps the most striking demonstration that they had difficulty in using verb information to revise initial parsing choices. As predicted, children produced nonadult (erroneous) actions on the majority (54%) of the trials in the ambiguous–*pickup* condition but not in the other three conditions (see Table 4).

Table 3
Fixed effects from best-fitting multilevel linear model of proportion of time spent looking at destination object (empirical logit transformed): Adult and child data combined.

Window	Effect	Estimate	SE	*t* Value
VP	Intercept	−3.33	0.13	−26.37
	Group (child vs. adult)	0.37	0.18	2.05*
Post-VP1	Intercept	−3.59	0.28	−12.79*
	Verb (put vs. pickup)	1.19	0.31	3.84*
	Ambiguity (unambiguous vs. ambiguous)	−0.36	0.31	−1.15
	Group (child vs. adult)	0.79	0.33	2.44*
	Verb × Ambiguity	1.32	0.37	3.56*
	Verb × Group	−1.07	0.37	−2.87*
	Ambiguity × Group	−0.58	0.37	−1.57
Post-VP2	Intercept	−3.66	0.30	−12.10*
	Verb (put vs. pickup)	3.34	0.36	9.20*
	Ambiguity (unambiguous vs. ambiguous)	−0.26	0.31	−0.86
	Group (child vs. adult)	0.69	0.31	2.25*
	Verb × Ambiguity	2.02	0.44	4.65*
	Verb × Group	−2.98	0.44	−6.80*

* $p < .05$ (on normal distribution).

Table 4
Percentages of action types for adults and children.

Verb	Ambiguity	Group	Type of action		
			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

Most of these errors involved the use of the destination object (VP actions), with the two most typical VP actions being illustrated in Fig. 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).

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 Fig. 4). These action data were fit to multilevel mixed linear models using the same methods as those used for eye gaze data. Table 5 presents the three models: (a) for adults, (b) for children, and (c) 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, whereas *pick up* does not. Ambiguity is not a predictor because adults responded to the ambiguous sentences as if they were unambiguous. By 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 among 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

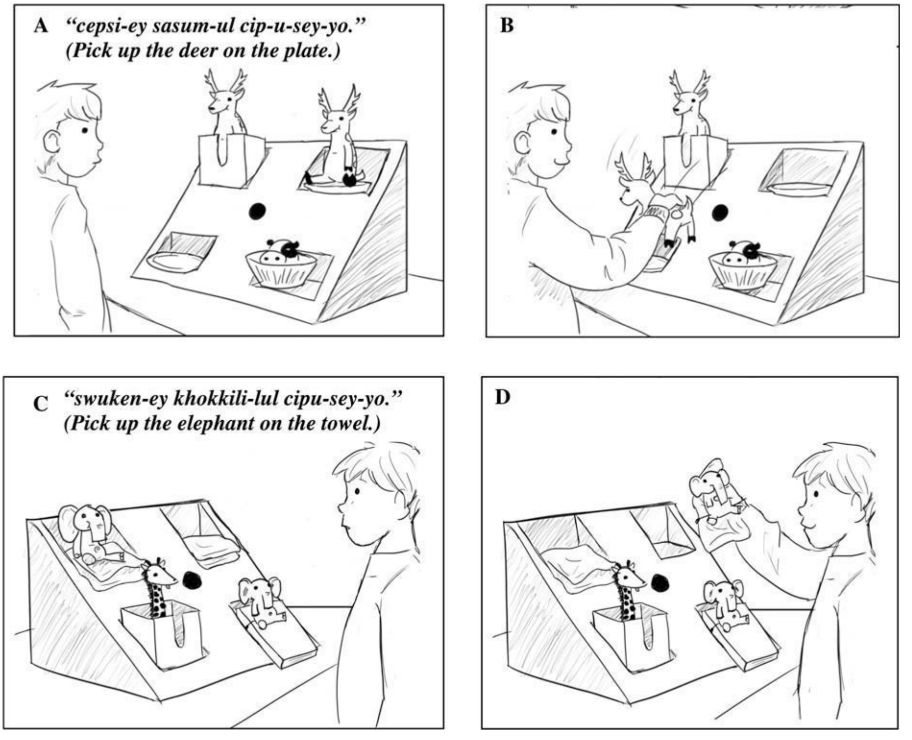

Fig. 3. Illustrations of typical non-adult actions from children. Panels A and B illustrate an incorrect destination action. In response to hearing *Pick up the deer on the plate,* the child moves the target (the deer that was on a plate) over to the destination (a plate that was originally empty). Panels 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.

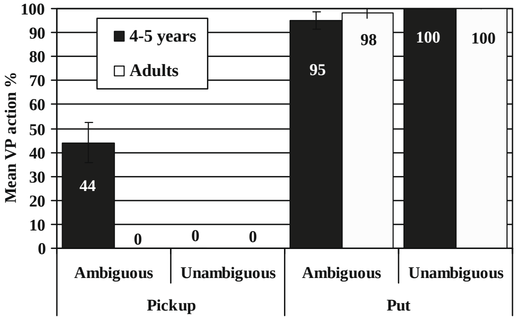

Fig. 4. Mean percentage VP attachment action proportions split by verb type, ambiguity, and age groups: Percentages of the sum of all VP actions and NP actions [(VP action)/(VP action + NP action)] after excluding “other” types of action.

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; in total, 5 children committed errors more than 75% of the time (age range: 4 years 0 months to 5 years 1 month), and 5 children committed errors between 25 and 75% of the time (age range: 4 years 2 months to 5 years 3 months).

Table 5
Fixed effects from best-fitting multilevel linear models of the proportion of VP actions of VP and NP actions (empirical logit transformed).

Group	Effect	Estimate	SE	*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 (unambiguous vs. ambiguous)	−0.95	0.13	−7.22*
	Verb × 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 (unambiguous vs. ambiguous)	0.00	0.08	0.01
	Group (child vs. adult)	0.98	0.10	9.86*
	Verb × Ambiguity	0.05	0.11	0.40
	Verb × Group	−1.05	0.12	−8.54*
	Ambiguity × Group	−0.95	0.12	−7.81*
	Verb × Ambiguity × Group	1.01	0.17	5.83*

* $p < .05$ (on normal distribution).

However, there were 6 children who did not make any errors in the ambiguous–*pickup* condition; this also shows 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 children act on? Recall that English-speaking children in Trueswell and colleagues' (1999) study were at chance when selecting the target or competitor object to act on, suggesting that they did not realize that *on the napkin* could be a modifier (English-speaking adults almost always pick the target). A similar pattern was observed here for *pick up* instructions. Adults always acted on the target (100% of the time) regardless of whether the phrase was temporarily ambiguous or not. Children, by contrast, showed some confusion about which object to act on for temporarily ambiguous instructions. Of the NP and VP actions, they used the target 64% of the time and used the competitor 32% of the time. For unambiguous instructions, they acted on the target 81% of the time and acted on the competitor only 6% of the time. This pattern suggests that children sometimes failed to realize that the temporarily ambiguous PP could be a modifier telling them which object to act on (see Appendixes B and C).

Put trials, if parsed correctly as destinations, are referentially ambiguous (e.g., either frog could be acted on). 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 with the target (39%), with 1 clever child using both the target and competitor in the action (a type of action observed with some English-speaking children). We refer the reader to Appendix C 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 in 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 in using their knowledge of *pick up* to block consideration of the initial destination interpretation of *napkin-on;* both sentences ending with *pick up* and sentences ending with *put* 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 sizable proportion of the trials; children frequently performed nonadult actions that 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 parsing (e.g., Hurewitz et al., 2000; Trueswell et al., 1999; Weighall, 2008). The current data from Koreans 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 show 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 was 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. By 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 (8-year-olds) 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/EF abilities play a central role in garden path recovery. Consistent with this account, Novick and colleagues recently demonstrated that a patient with a focal lesion to the left inferior frontal gyrus (LIFG) in the prefrontal cortex showed deficits in cognitive control tasks and garden path recovery (Novick, Kan, Trueswell, & Thompson-Schill, in press). Strikingly, this patient's language deficits appeared to be 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 current 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 do 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 with the type of morphosyntactic information in head-initial languages such as English and thus affects children's parsing processes differently. Hence, Korean children perhaps were more willing to rely on case-marking morphosyntax contingencies than the verb as compared with 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 the morphosyntactic information in Korean (e.g., *Pick up! ... napkin-on frog-Acc*). If the revision difficulty observed in both Korean and English children was due mainly to their difficulty in inhibiting an initial representation, it is expected that children will not be as prone to committing erroneous interpretations when the presentation of biasing information such as verb or case-marking 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 interpretation errors when the verb in English and the case-marking information in Korean are presented later in the sentence (Choi & Trueswell, 2010).

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 EFs 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, although 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 children's parsing abilities involving a broader set of linguistic materials beyond the limited set of items that we used in our study (one pair of verbs: *put* vs. *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 EF and cognitive control abilities should be integrated into current theories of sentence processing. Although we expect that it would be possible to integrate such mechanisms into most theories, we argued elsewhere that control mechanisms of this sort fit more naturally into constraint-based parsing accounts and that the evidence to date supports such a view (Novick et al., 2005). Indeed, the work conducted so far on ambiguity resolution abilities in children and adults is mostly consistent with a system that is highly sensitive to morphosyntactic/lexical–syntactic regularities. Children appear to be greedily collecting statistical regularities regarding the syntactic environments within which lexical items can appear. The current findings are consistent with this general view and point out that morphemes are the contingency that children are relying on quite heavily, whether they be derived from verbs, prepositions, case markers, tense/aspect markers, or the like.

However, as suggested here, late-developing EF/cognitive control abilities interact with structural processing in significant ways. In situations where cues to structure conflict, the serial nature of the input causes learners with natural deficits in cognitive control to rely disproportionately on early-arising cues to structure rather than late-arising ones.

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) rely disproportionately on early-arriving constraints on structure to resolve ambiguity, whereas postambiguity 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 EF and/or cognitive control.

Acknowledgments

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Appendix A

Materials used in the experiment.

Auditory stimuli (PP–NP)	Visual stimuli	
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

(*continued on next page*)

Appendix A (*continued*)

Auditory stimuli (PP–NP)	Visual stimuli	
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)

Note. Scenes for unambiguous–*put* condition are in parentheses.

Appendix B

Summary of detailed breakdown of adult action responses.

Verb	Ambiguity	Object grabbed	Empty	Type of platform (e.g., a napkin) used in action			
				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)		0 (2)		48 (100)
		Both					
		Other					
		Total	48 (98)	0 (0)	0 (2)	0 (0)	48 (100)

Note. Percentages are in parentheses. “Empty” refers to the empty platform, that is, the possible destination (the empty napkin). “Under target” refers to the platform under the target object (e.g., the napkin under the frog). “None” means that no platform was used in the action, indicating a picking-up action, that is, picking up an object and holding it in one’s hand.

Appendix C

Summary of detailed breakdown of child action responses.

Verb	Ambiguity	Object grabbed	Empty	Type of platform (e.g., napkin) used in action			
				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)

Note. Percentages are in parentheses. ‘‘Empty” refers to the empty platform, that is, the possible destination (the empty napkin). ‘‘Under target” refers to the platform under the target object (e.g., the napkin under the frog). ‘‘None” means that no platform was used in the action, indicating a picking-up action, that is, picking up an object and holding it in one’s hand.

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