Relative-clause processing in Korean adults: Effects of constituent order and prosody

Choonkyu Lee and Karin Stromwold
Department of Psychology & Center for Cognitive Science
Rutgers University – New Brunswick

Abstract

In this paper, we investigate mechanisms of sentence comprehension based on our study of adults' processing of sentences containing relative clauses (RCs) in Korean. The major issues of concern in the paper are similarities and differences between (1) parsing in Korean and parsing in English, and between (2) Korean adults' parsing and Korean children's parsing. For the first issue, we consider our experimental results and previous findings in psycholinguistic literature based on Korean and English studies in light of the relevant linguistic differences between the two languages, such as those in basic constituent order and Case-marking morphology. For the second, we compare our results to previous data from studies with Korean children – particularly Clancy, Lee, and Zoh (1986), in which the authors' hypothesis of a garden-path effect was consistent with their results.

In our query-based comprehension study with auditory presentation of pre-recorded sentences and queries, different types of RCs and distinct levels of prosody were introduced. We measured participants' accuracy levels and reaction times to infer the relative levels of difficulty of the different conditions. The independent and interacting effects of morphosyntax and prosody on rapid processing were a main focus of our study.

Abbreviations

ACC: accusative
COMP: complementizer
COP: copula
DECL: declarative
DEM: demonstrative
NOM: nominative
Q: question
REL: relativizer
TOP: topic

Introduction

A relative clause (RC) is a clause that modifies a noun, called its *head noun*, to restrict the set of potential referents, or to provide an additional description about the chosen referent(s). See (1) for an example in English and (2) for its counterpart in Korean:

(1) English

[The paper [(that) I am writing ___]] is for my master's degree.

(2) Korean

[[nay-ga ___ ssugoiss-nun] nonmwun]-un seksahakwui-rul wuihan ges-i-da

I-NOM ___ writing-COMP.present paper-TOP master's-ACC for thing-COP-DECL

As one can see from these examples, depending on the language, an RC – *I am writing* ___ – either immediately precedes (as in Korean) or follows (as in English) the head noun – *the paper*. The linguistic analyses diverge as to the position within the RC where the head noun would normally be if the clause were a simple non-RC. Some posit a gap in the '___' position as a trace of movement from that original base position to the surface position where the head noun is pronounced, while others postulate a null or silent pronoun in the '___' position as a case of anaphora.

RCs have been a topic of great interest to psycholinguists for a number of reasons. First, a sentence containing an RC involves embedding, in which the RC "interrupts" the main clause. There is the main clause in which the head noun has a grammatical role independent of the gap, which has its own role within the embedded RC. A sentence containing an RC thus presents more challenges to our language-processing mechanism than simpler constructions such as a short single-clause declarative. Observing how our parser works under pressure can provide us with valuable insight into how it achieves rapid parsing effortlessly most of the time. Various models have been proposed for our parsing mechanism, with a general distinction between the serial and the parallel models among them. In the serial model, for which the main underlying motivation is our limitations in processing resources such as working memory and attention, our parser takes one parse at a time, and the initial parse, in most versions of the model, is selected based on syntactically motivated principles – e.g. minimal attachment (Frazier & Rayner, 1982) – that prefer the structurally "simplest" alternative in case of an ambiguity. The parallel model represents the view that multiple constraints based on syntax, semantics, and pragmatics are simultaneously at work for us to consider multiple parses *in parallel* even in the extremely narrow time windows of rapid parsing. Although only a truly on-line study, involving for instance eye-tracking or brain-imaging with high temporal resolution, can address the issues regarding the time course of rapid sentence processing on a fine-grained level, testing participants' comprehension off-line can also help us understand the interactive effects of various factors of rapid language processing and the consequences of “on-line” effects (e.g. see Frazier, 1987, for “garden-path” effects) if we manage to collect data within a narrow window of time.

Second, crosslinguistic differences relevant to RC processing offer an excellent basis for comparing the different contributions of various factors. Successful comprehension of a sentence containing an RC involves, among others, identifying the RC as a syntactically separate unit from the main clause and assigning the correct cases and thematic roles to the nominals. Languages differ in (a) whether they have explicit cues for certain parts of this task, and in (b) the types of explicit cues they have. For example, explicit post-nominal case markers in Korean and Japanese indicate the role of a noun as a subject, object, etc., and facilitate case assignment, whereas English does not have the same degree of explicit case-marking morphology and relies on more rigid adherence to its basic constituent order. While the English RC has an optional relative pronoun – such as *who* and *that* – the Korean RC has an obligatory complementizer, -(*nu*)*n*, indicating the presence of a preceding RC (see (1) and (2) above), and the Japanese RC has neither. In the Hindi correlative construction, a demonstrative pronoun that corresponds to the semantic head appears separately from the RC, and in some Cantonese RCs in which the role – thematic or grammatical – of the gap is more complex than the more common subject and object, we see resumptive pronouns, which are in a sense redundant with the head noun. The different kinds of RCs are presented within sentences below ((4) from Srivastav, 1991, (5) from Hawkins, 2005)

(3) Japanese

kodomo-ga [kirin -o taoshi-ta] shika-o nade-ta
child-NOM [giraffe-ACC knock.down-PAST] deer-ACC pat-PAST
‘The child patted the deer that knocked down the giraffe.’

(4) Hindi

[jo laRkii khaRii hai,] vo lambii hai.
REL girl standing is DEM tall is
lit. ‘Which girl is standing, she is tall.’
‘The girl who is standing is tall.’

(5) Cantonese

[ngo ceng keoi-dei sik-faan] go di pang-jau
I invite them eat-rice those COMP friend
‘friends that I invite to have dinner’

The variety we can see across languages in such linguistic properties as case-marking morphology and the presence/absence of resumptive pronoun, relative pronoun, or complementizer represents the treasure chest that RC processing holds for language processing in general. (Although there is a range of additional types of RCs – from free relatives without an explicit head to internally-headed RCs with a head noun *inside* the RC – we will restrict our discussion to head-external RCs, mostly in Korean and English.)

The important characteristics of Korean that deserve mention are (a) its head-finality and its basic constituent order, SOV (subject-object-verb), which is different from SVO in English; (b) relatively free scrambling – aside from rigid verb-finality – with an explicit case-marking morphology; and (c) the fact that it is a highly pro-drop language, with pronoun omissions commonly allowed when the arguments are pragmatically recoverable. The constituent-order differences between Korean and English presumably influence the sources of information our parsing mechanism makes use of in rapid processing, e.g. the relative roles of verb-based information vs. case-based information, even if we assume a delay model, in which premature commitments to a particular parse are avoided.

In our discussion below, we will also address a major issue of interest to linguists and psycholinguists alike, based on a comparison to other studies in Korean sentence processing: the question of the continuity/discontinuity of the parsing mechanism, i.e., whether there are qualitative or only quantitative changes in the kinds of information incorporated in making decisions as to the correct parse of input structures. Qualitative changes would imply that children and adults have fundamentally different mechanisms for language processing, whereas quantitative changes would imply that, despite differences in how fully developed the mechanism is, the underlying principles are the same for both age groups.

In order to investigate the above issues, we conducted an auditory comprehension study with adult native speakers of Korean. We manipulated (a) the grammatical roles of the head noun and the gap, and (b) prosody levels, to investigate the contributions from various factors such as syntax, morphology, and phonology. Although – or because – a large part of the sentence processing literature is based on reading studies, in which the experimenter can expect better experimental control and generally cleaner stimuli, we decided to improve the naturalness of the linguistic task with our auditory stimuli. Reading is evolutionarily a much more recent development in human behavior in comparison to spoken language based on the oral-auditory modality, and also requires years of explicit formal instruction for successful learning, unlike spoken language, which is present even in cultures with no formal schooling at all. In addition, written language deprives us of natural phonological input, such as prosody, which the reader has to recover from the silent characters if (s)he is to use the information at all. In other words, in the case of reading, the layers of performance through which our fundamental linguistic competence is reflected are not the most natural ones.

In sum, our study can shed light on (a) how different aspects of language contribute to processing; and, in conjunction with previous literature on sentence processing in Korean and English by children and adults, (b) the universals and particularities of parsing mechanisms across speakers of different languages, and (c) the similarities and differences between children and adults in their parsing abilities. Sentence processing is a particularly useful area of research, as it is the meeting point of linguistic *competence* and psychological *performance*, developing possibly with sensitivity to the interaction between processing resource limitations and language-particular properties, but also in accordance with the structure of the innate basis for language. With our auditory task, we have reduced the limitations of reading tasks whose results might generalize to spoken language only with qualification.

Background literature

The acquisition-of-processing study with Korean 6-year-olds by Clancy, Lee, and Zoh (1986) is the main study for comparison to our study. The authors use a distinction of prosodic level similar to ours in their experimental design, between "clear" intonation with cues to constituent boundaries and "list" intonation on a word-by-word basis – probably a more extreme, unnatural version of our "LOW Prosody" level. Their structural conditions were the same as ours, except for the fact that they also looked at scrambled, OSV sentences, whereas we only looked at the canonical SOV order for main clauses. The 4 structural conditions (henceforth RC-Types) based on grammatical roles of head noun and gap are as follows (from Clancy et al.):

(6) SS (head noun: subject, gap: subject)

[oli-lul nemettuli-n] thokki-ka talamcwi-lul ccochaka-ss-ta
[duck-ACC knock.down-COMP.past] rabbit-NOM squirrel-ACC chased
'The rabbit that knocked down the duck chased the squirrel'

(7) SO (head noun: subject, gap: object)

[thokki-ka nemettuli-n] oli-ka talamcwi-lul ccochaka-ss-ta
[rabbit-NOM knock.down-COMP.past] duck-NOM squirrel-ACC chased
'The duck that the rabbit knocked down chased the squirrel'

(8) OS (head noun: object, gap: subject)

talamcwi-ka [thokki-lul nemettuli-n] oli-lul ccochaka-ss-ta
squirrel-NOM [rabbit-ACC knock.down-COMP.past] duck-ACC chased
'The squirrel chased the duck that knocked down the rabbit'

(9) OO (head noun: object, gap: object)

talamcwi-ka [oli-ka nemettuli-n] thokki-lul ccochaka-ss-ta
squirrel-NOM [duck-NOM knock.down-COMP.past] rabbit-ACC chased
'The squirrel chased the rabbit that the duck knocked down'

Perhaps for lack of a solid alternative at the time, Clancy et al. assumed that the linear nature of the surface input implies a serial mechanism of processing on the listener's part. Various "garden-path" effects (Frazier, 1987) have been cited as evidence for the commitment to a single initial parse in serial models, and much of the early literature on sentence processing concerned the issue of various factors that might contribute to the initial choice. One suggestion for children's processing was that they make use of the typical features of clauses in their language to develop *canonical sentence schemas* (Slobin & Bever, 1982), and the children in Clancy et al.'s study produced high rates of errors that seemed to indicate a tendency to fit the input string into the basic word order in the OS condition, in which the first NP is nominative-marked, the second NP accusative-marked just as in sentences following the basic word order. The authors thus concluded that the case markers in the OS condition provided misleading cues to the incorrect, canonical frame, and that these results based on RC processing supported the presence of a canonical-order strategy in children's sentence processing.

Other processing heuristics have been suggested based on data from English-speaking children. Sheldon (1974) proposed that children process RCs more easily when the grammatical roles of the gap and the head match, and this *parallel function* hypothesis predicts better performance on SS and OO over SO or OS across languages. Tavakolian (1981) proposed the conjoined-clause analysis, claiming that children tend to fit RCs into a schema they have developed for conjoined clauses, often misinterpreting the relative pronoun *that* as the conjunction *and*. Overall, the most consistent patterns in these data from English-speaking children are SS being one of the easiest conditions and SO being one of the most difficult conditions, with OO and OS producing varying results from one study to another. Data from adult English speakers also point to a general performance advantage for subject-gap RCs over object-gap RCs (e.g. Wanner & Maratsos, 1978; Frazier, Clifton, & Randall, 1983; see below for more discussion).

In a more recent study on Korean, Kwon, Polinsky, and Kluender's (2004) conducted a self-paced, word-by-word reading task with Korean adults. Kwon et al. started out with the assumption that the OS and OO sentences would result in a garden-path effect, and used a scrambled OSV order for main clauses in these conditions to avoid the assumed effect.[1] The garden-path assumption made by Kwon et al. seems to predict some difficulty with unscrambled OS and OO sentences for Korean-speaking adults. Based on their results with stimuli involving scrambling in the above conditions, Kwon et al. conclude that subject-gap RCs are easier to process than object-gap RCs, favoring O'Grady's (1997) structural distance hypothesis and Keenan and Comrie's (1977) NP accessibility hierarchy over contrasting accounts.

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[1] An unscrambled OO sentence in Korean begins with two nominative-marked NPs, which *is* a construction that is often seen but restricted to certain predicates. Kwon et al.'s assumption of a garden-path effect for the OO condition is gratuitous at least for two reasons. First, though an acceptable construction in Korean, double nominatives are *not* the typical SOV with a nominative NP first and an accusative NP next, and claiming the second nominative NP in double nominatives is in fact an object makes a theoretical commitment that is not without controversy. Second, the verbs Kwon et al. use in their study do *not* seem to be included in the restricted set of typical predicates that allow double nominatives in the first place.

Keenan and Comrie’s (1977) accessibility hierarchy for relativization based on a crosslinguistic survey links the implicational universal of appearance of different types of RCs across languages (subject > object > indirect object > object of a preposition > possessive > object of a comparative) directly to the “psychological ease of comprehension” without a specific account of the exact cognitive basis for the varying degrees of difficulty. O’Grady’s (1997) notion of *structural distance* between the gap and the head noun is a possible account of the psychological basis for the accessibility hierarchy, which predicts greater ease of processing for subject-gap RCs over object-gap RCs. The *depth of embedding* for objects is greater than that for subjects – an extra VP node between the object gap and the head, or an extra V’ level even under the VP-internal subject hypothesis in X-bar syntax (Koopman & Sportiche, 1991) – and the deeper embedding, according to O’Grady, makes it more difficult to connect the object-gap position and its head noun in RC processing. The pre-nominal RC (clause *before* head noun) in Korean is the ideal test case for O’Grady’s account: unlike the English post-nominal RC (clause *after* head noun) in which the subject gap position is closer to the head noun position in terms of both structural and linear distance, the Korean pre-nominal RC pits structural distance directly against linear distance, because the subject gap is *structurally closer* to its head than the object gap, but is *linearly farther away* from the post-clausal head than the object gap.

Methods

Participants

The participants in the study were 15 adult native speakers of Korean living in central Jersey, with ages ranging from 20 to 34, with a mean age of 29 years. All of them except one had less than 5 years of experience in America, and all had a substantially greater command of Korean according to self-report. All the participants were right-handed, and none had a history of language disorders themselves or in their families. One participant reported fluency in Japanese as well. The participants received $10 in cash as reward for their participant in the experiment, which lasted approximately 40 minutes.

Equipment

In recording the auditory stimuli for the study, we used a head-mounted microphone and ***WaveEdit(?).*** The answer choices containing words in Korean text were prepared on Photoshop. We used PowerPoint to prepare and present our background images before the main experiment (see below). Matlab 7.1 was used for the main experiment, in presenting the stimuli and recording participants’ responses. Participants used a headset with a volume control to listen to the stimuli. All phases of the experiment, from preparation to the actual run, were conducted on a laptop running on Windows.

Stimuli

Our independent variables were RC-Type and Prosody. There were 4 kinds of RC-Types, as we looked only at the grammatical roles of subject and object for the head noun and the gap (2 head roles x 2 gap roles): SS, SO, OS, and OO. Because we limited our focus to the roles of morphosyntax and prosody, we took pains to balance our stimuli in terms of their semantic and pragmatic properties within each trial so that our sentences were reversible (see below). RC-Type examples from our experiment are below:

(10) SS (subject head noun, subject gap)
[yang-ul cidoha-n] yemso-ga tweyci-rul kyekryehaytta
[sheep-ACC teach-COMP.past] goat-NOM pig-ACC encouraged
'The goat that taught the sheep encouraged the pig'

(11) SO (subject head noun, object gap)
[mogi-ga annayha-n] phari-ga nabang-ul chiryohaytta
[mosquito-NOM usher-COMP.past] fly-NOM moth-ACC treated
'The fly that the mosquito ushered (medically) treated the moth'

(12) OS (object head noun, subject gap)
may-ga [toksuri-rul haychi-n] solgay-rul pwucabatta
hawk-NOM [eagle-ACC hurt-COMP.past] kite-ACC caught
'The hawk caught the kite that hurt the eagle'

(13) OO (object head noun, object gap)
kalmaygi-ga [payco-ga chodayha-n] kiregi-rul tolboatta
sea.gull-NOM [swan-NOM invite-COMP.past] wild.goose-ACC looked.after
'The sea gull looked after the wild goose that the swan invited'

There were 2 levels of Prosody: HIGH and LOW. The Prosody levels were manipulated during the recording of our auditory stimuli, in which the experimenter read the test sentences in blocks based RC-Type (all the SS sentences first, all the SO sentences next, and so on) and a naïve volunteer read the queries. For the HIGH Prosody condition, the experimenter prepared the stimuli with longer pauses and stronger stress and intonations than for the LOW Prosody condition, in which the experimenter intended to sound as if he was reading a book out loud rather than engaging in a spontaneous conversation. The HIGH Prosody condition is thus much closer to natural conversational speech in its prosodic character. Because the stimuli were produced by a human speaker and not artificially controlled, there was presumably some prosodic information that remained in the LOW Prosody condition. It was not our intention, however, to remove all prosodic information necessarily, and it was sufficient that in one condition, the prosodic information was consistently richer than in the other condition.

The auditory stimuli consisted of 5 test sentences and queries respectively for training, and 160 test sentences and queries respectively for the main experiment – composed of 2 separate lists, each with 80 test sentences and queries. Each test sentence described two different actions, and contained a triplet of animals and a pair of transitive verbs. We chose animals over other possibilities for our nouns, because it was easier to find highly familiar triplets of perceptually and conceptually similar kinds among animals than it was for human professions with a stronger inherent hierarchy.

For the main experiment, we created 20 triplets of animals, so each triplet was used 4 times in each list (or, 8 times in each run). Each animal triplet was chosen to be as homogeneous and thematically related as possible along such critical dimensions as size, appearance, ferocity, and natural habitat so that participants would not respond simply based on common-sense considerations of dominance hierarchy, imageability, etc. All of our animal words were morphologically simple, containing two morphemes at most.[2] Our animal words also consisted of 4 or fewer syllables.

Eighty transitive verbs were chosen and paired for the main experiment, and the verb pairings were kept constant across the two lists. Each verb pair was thus used 2 times in each list (or, 4 times for each participant). We included not only concrete action verbs but also experiential or other abstract verbs (e.g. *love*, *protect*) to come up with a large number of transitive verbs, but there was no bias across different conditions. We assigned the verb pairs to different animal triplets in the two lists in such a way that there were no awkward groupings of nouns and verbs (e.g. an ostrich flying or a camel swimming) beyond some anthropomorphic license.

There were 4 noun positions that could be the answer to a query: subject of the first verb, object of the first verb, subject of the second verb, and object of the second verb. These 4 query types were evenly distributed within each condition – 5 instances of each query type within each RC-Type in a list. The position of the image file containing the correct answer was randomized between left and right.

The order of presentation of the test sentences was determined based on pseudo-randomization: The test sentences were numbered 1-80 in each list, and the numbers were ordered in a pseudo-random manner so that we prevented a series of 4 or more consecutive test sentences of the same RC-Type. The linear order of the animals within each sentence was also as evenly distributed as possible among the possible positions, given the fact that a perfectly even distribution was impossible (6 possible orderings of the animal kinds, but 20 sentences of each RC-Type within a list). The linear order of the verbs to appear, however, was kept constant throughout the experiment, because some monosyllabic verb stems are more transparently

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[2] The only exception is *k^{h}oppwulso* ‘rhinoceros’ with 3 free morphemes (lit. ‘nose-horn-bull’); however, even this word is considered simply one word, rather than a complex compound word, by native speakers. All the two-morpheme words in our study contain a bound morpheme, so the generality of morphological simplicity holds.

represented before a past-tense declarative ending (at the end of our test sentences) than before a past-tense complementizer (at the end of our RCs), which replaces the preceding coda consonant, thus making the sentence-final position more desirable for these verbs.

The test sentences in the training phase included a triplet of animals but just one transitive verb, as the subject noun phrase was just a compound of two animal kinds, and there were no RCs in the training stimuli.

The visual stimuli in the study included background images that participants saw before the main experiment. For these images, we picked drawings from children's storybooks in which animals were depicted in an anthropomorphic manner and often engaged in physical interaction with one another. We took pictures of these drawings using a digital camera to reduce any surprise effect that might result from sudden exposure to anthropomorphic descriptions of animals' actions with the use of transitive verbs normally attributed to humans. In addition, most of these drawings included animals of the same or similar kinds, which, if anything, presumably prepared the participants for the typical discourse implications of use of an RC, rather than contributing to a possible shock effect.[3] During the main experiment, the visual stimuli were presented on a black background. The participants looked at a white cross at the center of the screen during the presentation of a test sentence, and as the computer began playing the following query, the white cross was replaced with two images of written Korean words that were the possible answer choices, one to the left and the other to the right of the center. We used Adobe Photoshop to create the image files, which had black 48-point sharp-font text at the center of a white rectangle.

Procedure

All the necessary documents for the participants to fill out were written in Korean, and instructions were also given in Korean. Participants then saw a PowerPoint presentation of the background images for the experiment. There were 16 slides, each lasting for 4 seconds.

In the main experiment on Matlab, the experimenter first typed in the participant information before each of the three sessions (Training, List 1, and List 2) for each participant. With the headset on, participants first carried out the 5 practice trials and were allowed to adjust the volume. After List 1 of the main experiment was over, participants had the option to take a short break. All the sound stimuli in the study were pre-recorded. Participants listened to the test sentence while looking at a white cross on a black background at the center of the screen; as soon

[3] We were reminded of the Kaiser and Trueswell (2004) study with the suggestion that building in the particular discourse demands that RCs impose on the processing task would be crucial to our study. While we accept the importance of the particular discourse roles of the typical relative clause – which is why we built in the background, though quite minimal – it should be noted that we did *not* make use of any uncanonically-ordered ("scrambled") sentences in our study. This fact about our study is a crucial divergence from studies such as Kwon, Polinsky, and Kluender (2004) (see Introduction).

as the sound file for the query began playing with a 0.5-second interval after the test sentence, the images containing words that were the possible answer choices appeared to the left and right of the center, replacing the white cross. Participants pressed the left arrow for the word on the left and the right arrow for the word on the right as their response. To move onto the next trial, they pressed the space bar, so between trials, there was self-pacing. Because our participants were *adult* native speakers of Korean, a near-ceiling level of accuracy is possible, so reaction times (RTs) were automatically measured between the moment the word images appeared on the screen – or, the beginning of the query sound – and the participant's key press. When the participant made the key press before the end of the query, the query sound file stopped being played. We gave our participants a questionnaire for post-experiment debriefing.

Results

We analyzed our 15 participants' accuracy and RT (reaction time) data, using 2 kinds of 2-way ANOVAs (analyses of variance): The first one was a 4 x 2 ANOVA, with 4 levels of RC-Type and 2 levels of Prosody; and the second one was a 4 x 4 ANOVA, with 4 levels of RC-Type and 4 levels of Query-Type – both with subject as a random variable to compensate for differences in individual subjects' accuracy and RTs. We carried out a few separate analyses limited to the queries about the linearly first verb ("V1," the embedded RC verb followed by a complementizer) to investigate RC comprehension per se. Various pairwise and grouped comparisons followed as necessary.

<u>Accuracy</u>

RC-Type (Fig. 1)

In terms of accuracy, there was a significant main effect of RC-Type [$F(3,42) = 2.97$, $p = 0.04$] (see Table 1). Pairwise comparisons indicated that participants were significantly more accurate on OS than on OO RCs [$F(1,14) = 7.05$, $p < 0.02$] and on OS than on SO RCs [$F(1,14) = 6.66$, $p < 0.03$], but there were no significant differences between OS and SS [$F(1,14) = 1.67$, $p > 0.21$], SS and OO [$F(1,14) = 1.11$, $p > 0.31$], SS and SO [$F(1,14) = 3.69$, $p > 0.07$], and OO and SO [$F(1,14) = 0.01$, $p > 0.93$]. A noticeable pattern from the chart in Table 1 is the general advantage for _S (SS and OS, "subject-gap") RC-Types over _O (SO and OO, "object-gap") RC-Types. We thus combined SS and OS into one group and OS and OO into another, for a comparison between the subject-gap and the object-gap conditions. The comparison analysis revealed a significant main effect of RC-Type (grouped by gap role) on accuracy in favor of the subject-gap conditions (with a mean accuracy of 0.83, SE = 0.021) over the object-gap conditions (with a mean accuracy of 0.78, SE = 0.027) [$F(1,14) = 7.33$, $p < 0.02$]. Although successful comprehension of the RC would help the participant, as the combination of the query NP and the answer-choice NPs always exhaust the NP triplet for each trial, queries strictly relevant to the comprehension of the RCs per se are the ones that ask about the arguments of the first verb, V1, which is the one embedded within the RC, and the V2 queries *might* only indicate the indirect impact of the various RC-Types on the general comprehension of the main-clause content. We thus analyzed the RC-Type effect on accuracy levels only in the V1 Query-Types, which revealed an increased difference between the highest and lower accuracy averages [$F(3,42) = 4.90$, $p = 0.0052$] (Table 2).

Table 1. Accuracy by RC-Type (with SEs)

	SS	SO	OS	OO
Proportion of correct responses	0.82 (0.016)	0.78 (0.023)	0.84 (0.022)	0.78 (0.026)

Table 2. Accuracy by RC-Type only in "V1" Query-Types, 1 and 2 (with SEs)

	SS	SO	OS	OO
Proportion of correct responses	0.77 (0.025)	0.70 (0.034)	0.86 (0.030)	0.75 (0.036)

Prosody (Fig. 2) and Prosody x RC-Type

We found a significant main effect of Prosody on accuracy, with the mean accuracy of 0.83 (SE = 0.015) for HIGH Prosody significantly better than 0.78 (SE = 0.016) for LOW Prosody [$F(1,14) = 10.51$, $p < 0.01$]. There was no significant overall interaction effect of RC-Type by Prosody on accuracy [$F(3,42)$, = 1.28, $p > 0.29$].

Query-Type

Though not a main variable of the study, Query-Type was also analyzed in terms of its effects on accuracy. Balancing the relative frequencies of the possible positions to be asked about was the most reasonable choice we could think of in designing our experiment, and we were curious as to whether the experimental design, with 4 Query-Types, affected the 4 RC-Types differentially. As mentioned in Methods, the 4 Query-Type categories were based on the linear order and the grammatical role of the correct answer to the query: 1 (when the answer was the subject of the first verb; wh-NOM), 2 (the object of the first verb; wh-ACC), 3 (the subject of the second verb; wh-NOM), and 4 (the object of the second verb; wh-ACC). The main effect of Query-Type was significant [$F(3,42) = 8.27$, $p < 0.01$] (see Table 6). A general pattern that emerges in Table 6 is the overall advantage for the "V2" conditions with queries on the linearly second – or, more recent – verb of the test sentence. A grouped analysis with V1 (Query-Types 1 and 2, with a mean accuracy of 0.77) and V2 (Query-Types 3 and 4, with a mean accuracy of

0.84) Query-Type categories revealed a significant main effect of Query-Type in favor of the V2 group [$F(1,14) = 17.92$, $p < 0.01$].

Table 3. Accuracy by Query-Type (with SEs)

	1 (NOM-V1)	2 (ACC-V1)	3 (NOM-V2)	4 (ACC-V2)
Proportion of correct responses	0.75 (0.023)	0.79 (0.018)	0.84 (0.019)	0.84 (0.018)

Query-Type x RC-Type

The interaction effect between Query-Type and RC-Type was also significant both with the 4 Query-Type conditions [$F(9,126) = 2.01$, $p = 0.04$] and in a grouped analysis with the 2 Query-Type categories, V1 and V2 [$F(3,42) = 4.44$, $p < 0.01$]. Query-Type effect analysis within each RC-Type condition revealed a significant Query-Type effect in SS [$F(3,42) = 3.82$, $p < 0.02$] and SO [$F(3,42) = 8.56$, $p < 0.01$], but *not* in OS [$F(3,42) = 0.81$, $p > 0.49$] or OO [$F(3,42) = 1.46$, $p = 0.24$], leading to the significant overall interaction effect between Query-Type and RC-Type on accuracy. Table 6 shows the interactive patterns.

Table 4. Accuracy by Query-Type x RC-Type (with SEs)

	1 (NOM-V1)	2 (ACC-V1)	3 (NOM-V2)	4 (ACC-V2)
SS	0.75 (0.038)	0.79 (0.032)	0.82 (0.038)	0.90 (0.028)
SO	0.70 (0.041)	0.72 (0.028)	0.87 (0.040)	0.83 (0.029)
OS	0.83 (0.048)	0.88 (0.030)	0.85 (0.041)	0.81 (0.038)
OO	0.73 (0.056)	0.78 (0.045)	0.81 (0.030)	0.81 (0.046)

Reaction time (RT)

RTs were measured to the tenth of a millisecond by a timer that started at the onset of the query presentation and stopped at the key press by the participant. RTs ranged from a minimum of 0.69 seconds to a maximum of 18.22 seconds. RTs at over 10 seconds made up about 2 percent of the entire data (48 out of 2384 trials). For statistical analysis, we used adjusted RTs (henceforth RT-adjusted) that took into account the durations of the query sound files for our analyses and subtracted them from the raw RTs. RT-adjusted values ranged from -1.02 seconds to 16.32 seconds. RT-adjusted values below 0, in which the participants made the key-press response before the end of the query sound file, were not anomalous, as they composed about 10 percent of the data (242 out of 2384 trials).

RC-Type

Longer RTs are generally expected for more difficult tasks, and we wanted to see whether there was a pattern in RT data from our adult participants that reflected the same pattern of relative difficulty depending on RC-Type as Clancy, Lee, and Zoh (1986) found in their behavioral-response data from 6-year-olds. Our accuracy data from adults are clearly *not* in agreement with Clancy et al.'s child data, but if there were an agreement in pattern between adult RT data and children's errors in act-out responses, we could hypothesize the RT patterns in adults as a residual effect of the varying levels of difficulty they had with different types of RCs at a younger age and put the idea to further test. Our RT analysis, however, did *not* reveal any significant main effects of RC-Type, either in RT-adjusted [$F(3,42) = 1.89$, $p > 0.14$] or in RT-adjusted only on correct trials (henceforth RT-adjusted-correct) [$F(3,42) = 1.72$, $p > 0.17$].

Interestingly, however, RT analysis limited to the V1 Query-Types for an investigation strictly relevant to *RC* comprehension per se revealed a significant main effect of RC-Type [$F(3,42) = 3.17$, $p = 0.034$], with a general advantage – i.e., shorter RT-adjusted averages – for S_, or "subject-head," conditions over the O_, or "object-head," conditions (see Table 5).

Table 5. RT-adjusted by RC-Type when in V1 Query-Types (with SEs)

	SS	SO	OS	OO
RT-adjusted (seconds)	2.06 (0.20)	2.02 (0.17)	2.48 (0.22)	2.54 (0.21)

Prosody and RC-Type x Prosody

We did not find a significant main effect of Prosody on RT-adjusted [$F(1,14) = 1.27$, $p > 0.27$]. There was, however, a significant interaction between RC-Type and Prosody on RT-adjusted [$F(3,42) = 3.76$, $p < 0.02$] and on RT-adjusted-correct [$F(3,42) = 4.04$, $p = 0.01$]. Post-hoc analyses indicated that the interaction effect is due to the effect of Prosody on RT-adjusted and RT-adjusted-correct in the SS RC-Type condition, which was found to be significant [$F(1,14) = 9.62$, $p < 0.01$, and $F(1,14) = 7.56$, $p < 0.02$, respectively]. With the SS condition removed, the interaction effect became non-significant [$F(2,28) = 1.75$, $p > 0.19$ for RT-adjusted; $F(2,28) = 2.34$, $p > 0.11$ for RT-adjusted-correct]. In the SO condition – the RC-Type condition with the second greatest difference in RT-adjusted-correct between the HIGH and LOW Prosody levels, after SS – there was no significant main effect of Prosody [$F(1,14) = 3.52$, $p > 0.08$].

Interestingly, RT analysis limited to the V1 Query-Types directly relevant to RC comprehension revealed a significant main effect of Prosody [$F(1,14) = 5.92$, $p = 0.029$]. Along with the RC-Type effect data, the Prosody main-effect data present patterns that differ between V1 – "strictly RC" – Query-Types and all Query-Types combined.

Query-Type

Another indication that our measure of RTs did in fact depend on the nature of our test-sentence stimuli at least in certain aspects comes from our Query-Type analysis. We found a significant main effect of Query-Type on RT-adjusted [$F(3,42) = 7.83$, $p < 0.01$] (see Table 6). As can be seen in the chart in Table 6, the RT-adjusted values for Query-Types 3 and 4, asking about the arguments of the linearly second, or more recent, verb, are shorter on average than the Query-Types asking about the first verb of the test sentence. A V1 (Query-Types 1 and 2, with a mean RT-adjusted of 2.26 seconds, SE = 0.12) vs. V2 (Query-Types 3 and 4, with a mean RT-adjusted of 1.80 seconds, SE = 0.11) grouped comparison for Query-Type effects on RT-adjusted revealed a significant main effect of Query-Type [$F(1,14) = 15.32$, $p < 0.01$].

Table 6. RT-adjusted by Query-Type (with SEs)

	1 (NOM-V1)	2 (ACC-V1)	3 (NOM-V2)	4 (ACC-V2)
RT-adjusted (seconds)	2.06 (0.12)	2.46 (0.17)	1.77 (0.14)	1.81 (0.14)

Query-Type x RC-Type

The interaction between Query-Type and RC-Type was also significant [$F(3,42) = 5.33$, $p < 0.01$]. The interaction was due to the lack of a significant Query-Type effect *only* in the SO condition [$F(1,14) = 0.02$, $p > 0.89$]; all other RC-Type conditions showed a significant Query-Type effect on RT-adjusted, with RT-adjusted being significantly shorter in the V2 group. Another pattern that stands out in the RT data is the shorter RT-adjusted averages for Query-Types 1 and 3, compared to those for Query-Types 2 and 4. Query-Types 1 and 3 are the “nominative” conditions, and 2 and 4 the “accusative” ones; thus, we carried out a grouped comparison between the nominative (mean RT = 1.91 s, SE = 0.20) and accusative (mean RT = 2.15 s, SE = 0.21) categories, which indicated a significantly lower RT-adjusted average for the nominative group [$F(1,14) = 8.10$, $p = 0.013$].

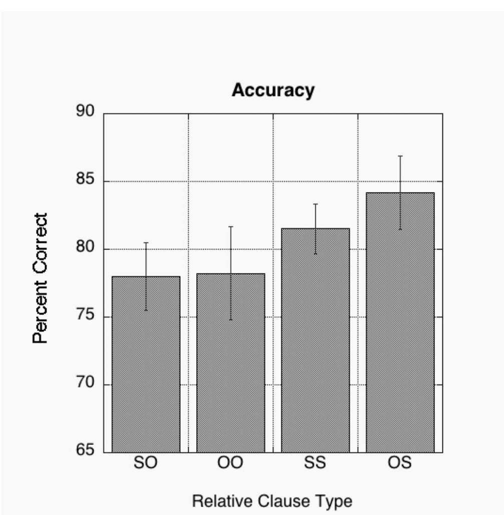


Figure 1. Accuracy by RC-Type

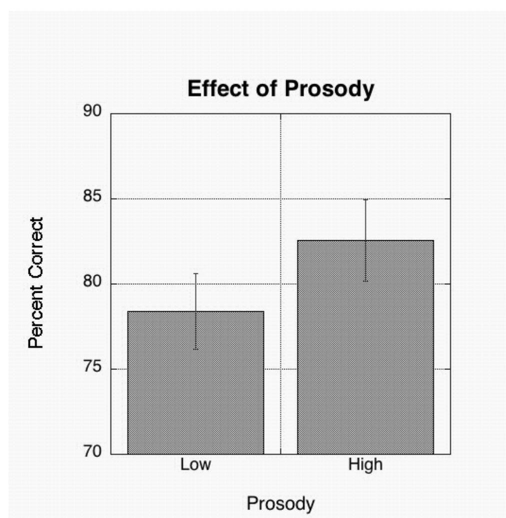


Figure 2. Accuracy by Prosody

Discussion

We discuss our main findings below, variable by variable.

RC-Type

The RC-Type effect on the accuracy of participants' responses to our queries revealed itself in the significant advantage for the OS condition over OO and SO. This OS advantage would be surprising if we considered its unique "garden-path" candidacy based on its misleading surface similarity to the canonical sentence order, SOV. Based on accounts of sentence processing as governed primarily by syntactic simplicity initially or by heuristics based on familiar, canonical frames, one would expect one of the following alternatives: (a) the garden-path misanalysis is not repaired at the time of the presentation of the query, and affects performance in the OS condition; (b) the misanalysis is repaired, but there is a residual effect of the garden-path mistake on subsequent responding to comprehension queries; or at least (c) there is no difference between OS and non-OS conditions if one expected garden-path mistakes to be so rapidly revised that they leave no visible effects even on subsequent querying within just a second. The absence of an RC-Type effect in our RT data suggests either that our RT measurements are not sensitive to the possibly ephemeral garden-path effects (the (c) alterative above), or that there is *no* garden-path effect unique to the OS condition in the first place. In any case, the OS advantage is an unexpected result under the basic assumptions of structural simplicity, unless one makes the unappealing conclusion that an initial garden-path effect in the OS condition results in greater assembling of attentional resources in a way that somehow leads not only to the revision of the initial misanalysis but also eventually to higher accuracy of subsequent responses to comprehension questions.

The OS advantage makes more sense when we look at the "big picture" and account for the other structural conditions as well. Not only the OS condition, but also the next highest condition in terms of accuracy, SS, contains a so-called subject-gap relative clause: The grammatical role of the gap within a relative clause in each of these conditions is a subject. That is, viewed in another light, the general pattern is a *subject-gap* advantage over object-gap conditions, which was also found to be significant. Some previous literature has pointed to the subject-gap advantage in relative clauses: Keenan and Comrie's (1977) NP accessibility hierarchy and O'Grady's (1997) structural distance hypothesis. While Keenan and Comrie only expressed their intuition that their hierarchy "directly reflects the psychological ease of comprehension" (quoted in Clancy et al., 1986, p. 229), O'Grady formalized the intuition about varying degrees of accessibility in terms of the *depth of embedding* of the gap, measured in terms of the number of structural nodes intervening between the gap and the filler modified by the RC (see below).

It is worth noting that the impact of RC-Type on accuracy is more dramatic when the analysis is limited to trials with queries *directly* about the RCs – containing the embedded verb, V1 – and the RC-Type effect is visible even in our RT results in this "strictly RC" analysis, whereas the overall RT results do not reveal such an effect. It points to the possibility that some of the effects we found would be magnified if we looked *not* at constructions with rich RC-external factors, but at constructions with *minimal* RC-external factors – e.g. with the use of a copula, as suggested by Jun and Lee (2004). (Researchers particularly interested in RC processing per se could use a design closer to Jun and Lee's than to ours.)

Prosody and Prosody x RC-Type

We found a significant advantage in accuracy for our HIGH Prosody level over our LOW Prosody level, indicating that richer prosody facilitates answering questions about RC-containing sentences in terms of accuracy. The advantage associated with richer prosody is expected in light of other studies in Korean pointing to a prosodic effect in sentence processing, e.g. Schafer and Jun (2002), Kim (2004), and Kim and Lee (2004), but it is nevertheless remarkable that the role of prosody in sentence processing is found not only in ambiguity resolution as in previous studies, but also in accuracy levels of responses to queries about RC-containing sentences in our study. In children's data, Clancy et al. (1986) found their 6-year-old participants to have a significant advantage in the "clear" – syntactically motivated – intonation condition over the "list" or monotonous intonation *only* with the center-embedded RC sentences, and *not* in the left-branching RC sentences. The center-embedded constructions were the ones with the embedded RC "interrupting" the main clause – in their case, OS and OO conditions for their canonical SOV sentences, and SS and SO for their scrambled, OSV sentences, which are also allowed in Korean. Clancy et al.'s conclusion was that intonation seemed important only for sentences that could not be processed "in a simple left-to-right fashion" (p. 235) in their experiment. The absence of an overall interaction effect of Prosody by RC-Type suggests that the prosodic effect is not considerably different from one RC-Type condition to the next.

RT data present a more complex picture, however, as we found *no* significant main effect of Prosody, but *did* find an interaction effect between Prosody and RC-Type. The interaction effect implies the varying impact of Prosody on processing speed across RC-Type conditions. Specifically, SS was the RC-Type condition in which we found the largest HIGH Prosody advantage, and SO was the condition with the next largest HIGH Prosody advantage – a non-significant, but marginal effect. (In fact, OS and OO conditions present the *reverse* pattern, with shorter RT-adjusted intervals for LOW Prosody, though with non-significant differences.) SS and SO are the RC-Types in which the head noun is the subject of the main clause – in short, the "left-branching" conditions in Clancy et al.'s experiment; therefore, based on *our* RT data, if shorter RTs are taken to imply easier processing, richer prosody seems to have a greater facilitative effect for *speed* of processing in left-branching conditions, rather than center-embedding conditions, for our adult participants engaged in our listening comprehension task.

When we limited our analysis to trials with queries directly about the RCs – a "strictly RC" analysis – we *did* find a significant overall main effect of Prosody on RT, not just limited to left-branching conditions and with no interaction with RC-Type. It is possible that the Prosody effect on RT in "V1" trials is, though present, weaker in center-embedding than in left-branching conditions, and when analyzed together with "V2" trials, the Prosody effect disappears for center-embedding conditions.

Query-Type

Because of our methods based on queries and the 4 possible positions to ask about, it was only natural to do justice to the 4 positions by balancing their relative frequencies. It would have been naïve, perhaps, to assume the RC-Type effects to be identical across all Query-Type possibilities and ignore Query-Type considerations.

A general advantage for the linearly second verb, or V2, was visible in the significantly higher accuracy levels and significantly shorter RT-adjusted intervals. For the V2 advantage, with converging evidence from accuracy and RT data, we can think of 2 most plausible lines of reasoning: (a) The advantage is a kind of *recency* effect, in which recovering the arguments of the more recent verb is easier than the same task for the linearly earlier verb (V2's arguments appear later on average than those for V1, as well); (b) V2 is the *main* verb in all our test-sentences – as a corollary of head-finality in Korean – and Query-Types 3 and 4 thus concern the arguments of the verb that is both non-embedded and with the more frequent, familiar declarative ending, compared to the embedded V1 with a much less frequent postverbal complementizer. The (a) alternative has the most "psychological" flavor, while (b) offers both a linguistic account based on embedding and a more psychological account based on frequency of postverbal particles.

Another noteworthy pattern is the "nominative" advantage in RT: participants responded significantly more quickly in Query-Types 1 and 3, which ask about the subjects of the verbs, than in Query-Types 2 and 4, which ask about the objects. We should note that if we accept the 'depth-of-embedding' account of the subject-gap advantage above for the RC-Type effect on accuracy, the nominative Query-Type conditions will benefit from the subject-gap advantage in half of the "nominative" trials – when they are about V1, the embedded verb within the RC.

Query-Type x RC-Type

Query-Type had varying impact from one RC-Type condition to the next, which we found in the significant interaction effects between the two variables on both accuracy and RT-adjusted. Patterns in Table 4 suggest that the OS condition, with its conspicuously higher accuracy rates in V1 Query-Types compared to the other RC-Type conditions, was the most deviant one from the general V2 advantage in accuracy, and based on our data, it seems that the accuracy rates for OS in V1 Query-Types might in fact be near the ceiling for the task we presented and possibly the main cause of the overall interaction effect on accuracy.

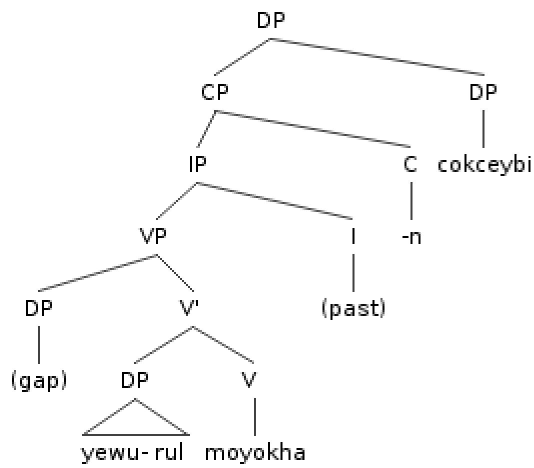
In our RT data, the most distinctive pattern that could provide a clue to the overall interaction effect on RT-adjusted was a particularly large V1 disadvantage – significantly longer RT-adjusted intervals – for the OS and OO conditions, which was not as large in SS and altogether absent in SO. The most intuitive explanation for the V1 disadvantage in OS and OO seems to be the fact that these RC-Types involve center-embedding: The V1 queries in these RC-Types require recovery of arguments in the center-embedded structure, which might make higher demands on processing resources while not resulting ultimately in lower accuracy rates.

General discussion

Inspired by Clancy et al.'s (1986) pioneering study on children's processing of Korean sentences, which pointed out a potential textbook candidate for a garden-path effect, we conducted an RC-processing study with Korean adults to see how general the garden-path effect is. We studied the respective contributions of morphosyntactic structure and prosodic information in RC processing, using the variables RC-Type and Prosody, in order to see also whether prosodic cues have a detectable role in determining the relative difficulty of processing across different structural types of RC sentences. Because our participants were adult native speakers of Korean, we had a wide variety of methodological options, from which we chose an auditory query-based paradigm with pre-recorded stimuli, to approximate the everyday conversation in important ways while having the necessary experimental control. RT measures were included in our design to ensure a meaningful analysis in case accuracy levels were mostly near-ceiling, but with accuracy averages around 80 percent, our results eliminated worries about a ceiling effect or chance-level performance in accuracy.

Contrary to our expectations, we found the OS RC-Type – the locus of Clancy et al.'s garden-path phenomenon – to be the condition in which our participants responded most accurately, and a careful analysis suggests a subject-gap advantage in RC processing: RC-containing sentences in which the gap is the subject of the RC are easier to process than those in which it is the object. An account consistent with this finding is O'Grady's (1997) structural distance hypothesis: The processing advantage for subject-gap RCs often found in English is due to the greater structural proximity between the gap and the head noun, with fewer intervening structural nodes, and the structure-based advantage should apply also to other languages. Korean has *pre*-nominal RCs, and consequently, the *linear* distance between a subject gap and the head noun is *greater* than that between an object gap and the head noun unlike in English – because subjects come before objects in both languages, but English has *post*-nominal RCs – while the *structural*-distance patterns remain the same as in English.

(14) Subject-gap RC

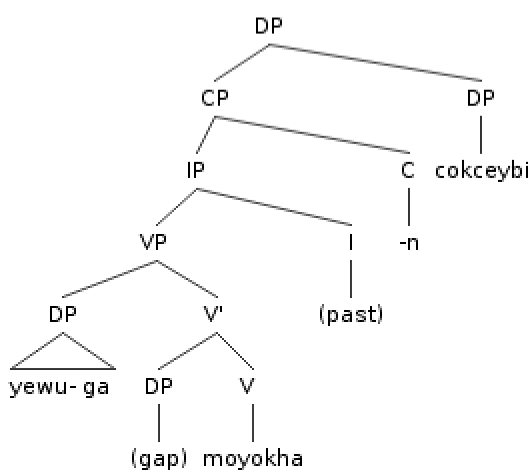


[___ yewu-rul moyokha-n] cokceybi

[___ fox-ACC insult-COMP.past] weasel

'the weasel that insulted the fox'

(15) Object-gap RC



[yewu-ga ___ moyokha-n] cokceybi

[fox-NOM ___ insult-COMP.past] weasel

'the weasel that the fox insulted'

Comparing the trees in (14) and (15) should make it clear that there is an additional V' node to cross in order to link the filler *cokceybi* to the object gap in (15). In O'Grady's account, the extra V' node represents 'deeper embedding' of the object gap compared to the subject gap, and the greater depth of embedding leads to an object-gap disadvantage in processing and development. (Whether we adopt a gap-movement account or a null-pronoun account of RCs has little bearing on the issue of structural distance, as both accounts require recovery of the connection between the gap and the head noun – a filler-trace link in the former; an anaphoric link in the latter.

Although the latter view allows a local resolution of such lexical decisions as predicate-argument relation and thematic role assignment between the subcategorizing verb and the NP that is relativized on, the issue of depth of embedding arises in recovering anaphoric relations with implications for processing – cf. Hawkins, 2005, however, for a discussion of an alternative account, namely, trace-free or “direct association” models.)

Despite great differences in methodology and stimuli from our study, Kwon et al.’s (2004) RC-processing study with Korean adults also found a similar overall advantage for subject-gap RCs. Kwon et al. thus favor O’Grady’s structural distance account and Keenan and Comrie’s (1977) NP accessibility hierarchy over other processing accounts as well (cf. Kwon, Polinsky, and Kluender (2006) for a discussion slightly complicating the issue, but in the same general direction in regard to the relevant data).

We attribute the difference in performance in the OS RC-Type between the children in Clancy et al.’s study and the adults in Kwon et al.’s and our studies to developmental changes in sentence processing. Specifically, we conclude that adults rely primarily on processing principles that are based on a deep understanding of syntactic structure, whereas children – who are either different from adults in their underlying syntactic knowledge, or have not completed their task of unveiling the full potential of their language faculty, with limited experience and processing resources – rely more heavily on processing heuristics that allow *some* success without an equally heavy use of syntactic structure, but are *not* mistake-proof. Kwon et al. (2004) see a challenge to the credibility of O’Grady’s account in the notion of counting structural nodes, but such a notion is not unfamiliar in light of psycholinguistic theories driven by computational complexity and processing resources (e.g., Hawkins, 2005, as well as O’Grady, 1997; although Hawkins dissents on the particular issue of RC processing, motivating a filler-*subcategorizer* relation over a strict filler-*gap* relation for the task of filler-gap identification). Although O’Grady’s account is motivated in his review of developmental literature on English RC processing, his structure-based account is more applicable to adults than to young children for theoretical and empirical reasons: (a) the account minimally requires complex syntactic knowledge and processing principles; and (b) the data in disagreement with his account that are often found in studies with English- as well as Korean-speaking children (see below for further discussion) and Korean-English bilingual children (O’Grady, Cho, Song, & Lee, 1996; Jun, 2001) are likely due to their reliance primarily on structurally simpler heuristics, such as the canonical sentence schema suggested by Slobin and Bever (1982). Our failure to find any detectible consequences of a possible garden-path effect in the OS condition, along with Kim’s (2004) observation of a garden-path phenomenon limited to prosodic and semantic neutrality conditions in her crossmodal naming experiment in ambiguity resolution with Korean-speaking adults, casts doubt on the general applicability of the garden-path effect in the serial-model tradition to linguistically competent adults' everyday language, which is rarely completely neutral along prosodic and semantic dimensions.

An unresolved mystery remains in the contrast between Cho's (1999) and Jun and Lee's (2004) findings. Despite great similarities in the linguistic stimuli and the experimental task – with reduced RC-external factors with the use of the copula *to be* instead of a transitive verb in the main clause, and a picture-selection task in which test sentences are uttered by the experimenter – between the two studies, Cho finds a subject-gap advantage in the former study with Korean children of age 4 to 7, while Jun and Lee find an object-gap advantage in the latter with Korean children of age 3 to 6. A resolution of the disagreement requires a careful look at the differences in the practice trials – with irrelevant stimuli in Cho's study, but unclear in Jun and Lee's – and at the method of presentation of the 2 picture choices – vertically in Jun and Lee's, and probably horizontally in Cho's – among other differences.

As for prosody, the usual question is whether stronger stress in intonation and natural pauses at constituent boundaries – i.e. syntactically motivated and generally "cooperative" prosody – has a *noticeable* facilitative effect or not. Our study indicates an important role of prosody in processing of spoken RC-containing sentences. It is noteworthy that we found a detectable role of prosody in the *accuracy* of adults' responses to queries. Our finding generalizes the role of prosody that had been found primarily in ambiguity resolution in previous Korean processing literature. A comparison of our results to Clancy et al.'s findings – a non-significant main effect of intonation and only a significant 3-way interaction between intonation, main-clause word order, and role of the head noun due to prosody effects in center-embedding trials – also points to developmental changes in our sentence-processing mechanism: adults' greater ability to make use of prosodic cues in sentence processing and the disagreement in the condition in which prosody has greatest impact – center-embedding conditions suggested by Clancy et al.'s accuracy data, and left-branching conditions suggested by our RT data.

Various aspects of our study require further discussion and improvement. The Query-Type variable would be of greater interest when studied based on methods with a finer temporal resolution, as it can address the issues of processing resources – particularly, working memory – as well as the impact of grammatical factors on the ease of processing, e.g. specifier vs. complement (see the "nominative" Query-Type advantage in RT above). Better temporal resolution would also allow a rigorous investigation of the moment-by-moment contribution or disruption from various case markers. For future research focusing on the processing of RCs *proper*, it might be desirable to reduce RC-external factors and use the most content-neutral, intransitive verb for the main clause.

Appendix A: Stimuli sentences and queries

160 sentences and 160 queries

Sentences: List 1

75 족제비가 늑대가 때린 여우를 방문했다.

36 까치가 의심한 참새가 제비를 탓했다.

74 생쥐가 햄스터가 위협한 다람쥐를 보호했다.

47 매가 독수리를 해친 솔개를 붙잡았다.

33 모기가 안내한 파리가 나방을 치료했다.

62 갈매기가 백조가 초대한 기러기를 돌보았다.

10 양을 지도한 염소가 돼지를 격려했다.

54 생쥐가 다람쥐를 억압한 햄스터를 추방했다.

13 파리를 간지럽힌 모기가 나방을 웃겼다.

38 침팬지가 꼬집은 오랑우탄이 고릴라를 쳤다.

27 독수리가 속인 솔개가 매를 밀었다.

50 양이 돼지를 잊은 염소를 냉대했다.

4 부엉이를 오해한 올빼미가 소쩍새를 저주했다.

30 돼지가 쓰다듬은 양이 염소를 숨겼다.

64 부엉이가 올빼미가 위협한 소쩍새를 보호했다.

3 낙지를 간지럽힌 오징어가 문어를 웃겼다.

57 다랑어가 상어를 해친 고래를 붙잡았다.

26 거북이가 의심한 자라가 남생이를 탓했다.

55 늑대가 여우를 모욕한 족제비를 추격했다.

19 들소를 앉힌 얼룩말이 기린을 일으켰다.

41 표범이 사자를 할퀸 호랑이를 혼냈다.

67 솔개가 매가 지지한 독수리를 헐뜯었다.

52 두더지가 스컹크를 제압한 고슴도치를 칭찬했다.

1 사자를 엿들은 호랑이가 표범을 방해했다.

16 제비를 알아본 참새가 까치를 불렀다.

21 호랑이가 길들인 사자가 표범을 사랑했다.

11 코뿔소를 엿들은 코끼리가 하마를 방해했다.

80 말이 소가 핥은 당나귀를 씻겼다.

71 코뿔소가 코끼리가 넘어뜨린 하마를 껴안았다.

15 족제비를 배반한 늑대가 여우를 유혹했다.

40 당나귀가 쓰다듬은 소가 말을 숨겼다.

32 스컹크가 가르친 고슴도치가 두더지를 도왔다.

69 오리가 거위가 무시한 칠면조를 놀렸다.

51 코끼리가 하마를 할퀸 코뿔소를 혼냈다.

60 말이 당나귀를 잊은 소를 냉대했다.

61 사자가 호랑이가 넘어뜨린 표범을 껴안았다.

23 문어가 안내한 낙지가 오징어를 치료했다.

20 말을 지도한 소가 당나귀를 격려했다.

49 칠면조가 오리를 얕본 거위를 비판했다.

78 오랑우탄이 고릴라가 좋아한 침팬지를 멀리했다.

28 맹꽁이가 꼬집은 개구리가 두꺼비를 찼다.

2 갈매기를 깔본 백조가 기러기를 증오했다.

7 솔개를 배웅한 매가 독수리를 만났다.

79 들소가 얼룩말이 무시한 기린을 놀렸다.

22 기러기가 가르친 갈매기가 백조를 도왔다.

43 오징어가 문어를 괴롭힌 낙지를 피했다.

73 파리가 모기가 울린 나방을 위로했다.

6 자라를 알아본 남생이가 거북이를 불렀다.

18 오랑우탄을 물리친 고릴라가 침팬지를 경멸했다.

44 부엉이가 소쩍새를 억압한 올빼미를 추방했다.

29 거위가 보살핀 오리가 칠면조를 환영했다.

66 자라가 남생이가 흉내낸 거북이를 시기했다.

37 고래가 속인 상어가 다랑어를 밀었다.

12 두더지를 깔본 고슴도치가 스컹크를 증오했다.

48 두꺼비가 맹꽁이를 미행한 개구리를 가두었다.

34 다람쥐가 존경한 생쥐가 햄스터를 앞질렀다.

46 자라가 거북이를 흉본 남생이를 깨물었다.

24 소쩍새가 존경한 올빼미가 부엉이를 앞질렀다.

5 메뚜기를 배반한 베짱이가 귀뚜라미를 유혹했다.

76 제비가 참새가 흉내낸 까치를 시기했다.

42 갈매기가 기러기를 제압한 백조를 칭찬했다.

9 오리를 앉힌 거위가 칠면조를 일으켰다.

56 제비가 까치를 흉본 참새를 깨물었다.

35 여우가 깨운 족제비가 늑대를 기다렸다.

58 오랑우탄이 침팬지를 미행한 고릴라를 가두었다.

31 하마가 길들인 코뿔소가 코끼리를 사랑했다.

39 기린이 보살핀 들소가 얼룩말을 환영했다.

17 상어를 배웅한 고래가 다랑어를 만났다.

14 생쥐를 오해한 햄스터가 다람쥐를 저주했다.

77 상어가 고래가 지지한 다랑어를 헐뜯었다.

72 두더지가 고슴도치가 초대한 스컹크를 돌보았다.

8 두꺼비를 물리친 개구리가 맹꽁이를 경멸했다.

53 나방이 파리를 괴롭힌 모기를 피했다.

59 얼룩말이 기린을 얕본 들소를 비판했다.

70 양이 염소가 핥은 돼지를 씻겼다.

65 메뚜기가 베짱이가 때린 귀뚜라미를 방문했다.

45 귀뚜라미가 메뚜기를 모욕한 베짱이를 추격했다.

25 베짱이가 깨운 메뚜기가 귀뚜라미를 기다렸다.

63 낙지가 오징어가 울린 문어를 위로했다.

Sentences: List 2

80 호랑이가 사자가 무시한 표범을 놀렸다.

31 양이 길들인 염소가 돼지를 사랑했다.

54 독수리가 매를 모욕한 솔개를 추격했다.

9 고슴도치를 앉힌 두더지가 스컹크를 일으켰다.

34 매가 존경한 독수리가 솔개를 앞질렀다.

53 맹꽁이가 개구리를 괴롭힌 두꺼비를 피했다.

10 하마를 지도한 코뿔소가 코끼리를 격려했다.

79 당나귀가 소가 핥은 말을 씻겼다.

58 문어가 오징어를 미행한 낙지를 가두었다.

22 얼룩말이 가르친 기린이 들소를 도왔다.

3 고릴라를 간지럽힌 침팬지가 오랑우탄을 웃겼다.

59 소가 말을 얕본 당나귀를 비판했다.

35 자라가 깨운 남생이가 거북이를 기다렸다.

50 하마가 코끼리를 잊은 코뿔소를 냉대했다.

48 모기가 나방을 미행한 파리를 가두었다.

69 고슴도치가 두더지가 핥은 스컹크를 씻겼다.

23 오랑우탄이 꼬집은 고릴라가 침팬지를 찼다.

27 생쥐가 속인 햄스터가 다람쥐를 밀었다.

57 소쩍새가 올빼미를 해친 부엉이를 붙잡았다.

70 하마가 코뿔소가 무시한 코끼리를 놀렸다.

25 제비가 깨운 참새가 까치를 기다렸다.

6 여우를 알아본 족제비가 늑대를 불렀다.

12 거위를 깔본 오리가 칠면조를 증오했다.

41 백조가 기러기를 할퀸 갈매기를 혼냈다.

17 올빼미를 배웅한 부엉이가 소쩍새를 만났다.

7 햄스터를 배웅한 다람쥐가 생쥐를 만났다.

18 문어를 물리친 낙지가 오징어를 경멸했다.

46 여우가 늑대를 흉본 족제비를 깨물었다.

14 독수리를 오해한 솔개가 매를 저주했다.

64 고래가 상어가 위협한 다랑어를 보호했다.

71 염소가 돼지가 넘어뜨린 양을 껴안았다.

74 독수리가 솔개가 위협한 매를 보호했다.

26 늑대가 의심한 여우가 족제비를 탓했다.

24 다랑어가 존경한 상어가 고래를 앞질렀다.

19 당나귀를 앉힌 소가 말을 일으켰다.

2 기린을 깔본 들소가 얼룩말을 증오했다.

78 문어가 낙지가 좋아한 오징어를 멀리했다.

40 표범이 쓰다듬은 사자가 호랑이를 숨겼다.

75 남생이가 거북이가 흉내낸 자라를 시기했다.

39 말이 보살핀 당나귀가 소를 환영했다.

11 염소를 엿들은 양이 돼지를 방해했다.

45 까치가 참새를 억압한 제비를 추방했다.

65 참새가 제비가 흉내낸 까치를 시기했다.

42 기린이 얼룩말을 제압한 들소를 칭찬했다.

1 기러기를 엿들은 갈매기가 백조를 방해했다.

28 나방이 안내한 파리가 모기를 치료했다.

76 베짱이가 메뚜기가 지지한 귀뚜라미를 헐뜯었다.

43 침팬지가 오랑우탄을 괴롭힌 고릴라를 피했다.

16 베짱이를 알아본 메뚜기가 귀뚜라미를 불렀다.

77 올빼미가 부엉이가 때린 소쩍새를 방문했다.

44 고래가 다랑어를 모욕한 상어를 추격했다.

51 돼지가 양을 할퀸 염소를 혼냈다.

47 다람쥐가 생쥐를 해친 햄스터를 붙잡았다.

38 오징어가 안내한 문어가 낙지를 치료했다.

15 남생이를 배반한 거북이가 자라를 유혹했다.

20 호랑이를 지도한 사자가 표범을 격려했다.

72 거위가 오리가 초대한 칠면조를 돌보았다.

60 호랑이가 표범을 잊은 사자를 냉대했다.

62 기린이 들소가 초대한 얼룩말을 돌보았다.

30 코끼리가 쓰다듬은 하마가 코뿔소를 숨겼다.

21 갈매기가 길들인 기러기가 백조를 사랑했다.

56 배짱이가 귀뚜라미를 흉본 메뚜기를 깨물었다.

33 두꺼비가 꼬집은 개구리가 맹꽁이를 찼다.

67 햄스터가 다람쥐가 때린 생쥐를 방문했다.

32 칠면조가 가르친 오리가 거위를 도왔다.

55 거북이가 자라를 억압한 남생이를 추방했다.

61 기러기가 갈매기가 넘어뜨린 백조를 껴안았다.

63 고릴라가 침팬지가 울린 오랑우탄을 위로했다.

37 부엉이가 속인 올빼미가 소쩍새를 밀었다.

13 개구리를 간지럽힌 두꺼비가 맹꽁이를 웃겼다.

73 개구리가 두꺼비가 울린 맹꽁이를 위로했다.

4 고래를 오해한 상어가 다랑어를 저주했다.

29 두더지가 보살핀 고슴도치가 스컹크를 환영했다.

66 여우가 족제비가 지지한 늑대를 헐뜯었다.

36 귀뚜라미가 의심한 메뚜기가 베짱이를 탓했다.

8 모기를 물리친 파리가 나방을 경멸했다.

49 스컹크가 고슴도치를 얕본 두더지를 비판했다.

52 거위가 칠면조를 제압한 오리를 칭찬했다.

5 참새를 배반한 제비가 까치를 유혹했다.

68 모기가 파리가 좋아한 나방을 멀리했다.

Queries: List 1

75 누가 여우를 방문했죠? (족제비)

36 누가 제비를 탓했죠? (참새)

74 누가 다람쥐를 위협했죠? (햄스터)

47 누가 독수리를 해쳤죠? (솔개)

33 누가 파리를 안내했죠? (모기)

62 누가 기러기를 돌보았죠? (갈매기)

10 염소가 누굴 지도했죠? (양)

54 누가 다람쥐를 억압했죠? (햄스터)

13 누가 나방을 웃겼죠? (모기)

38 침팬지가 누굴 꼬집었죠? (오랑우탄)

27 누가 매를 밀었죠? (솔개)

50 염소가 누굴 잊었죠? (돼지)

4 누가 소쩍새를 저주했죠? (올빼미)

68 두꺼비가 누굴 멀리했죠? (맹꽁이)

30 양이 누굴 숨겼죠? (염소)

64 올빼미가 누굴 위협했죠? (소쩍새)

3 누가 낙지를 간지럽혔죠? (오징어)

57 다랑어가 누굴 붙잡았죠? (고래)

26 누가 남생이를 탓했죠? (자라)

55 늑대가 누굴 추격했죠? (족제비)

19 누가 들소를 앉혔죠? (얼룩말)

41 호랑이가 누굴 할퀴었죠? (사자)

67 매가 누굴 지지했죠? (독수리)

52 누가 고슴도치를 칭찬했죠? (두더지)

1 누가 표범을 방해했죠? (호랑이)

16 누가 제비를 알아봤죠? (참새)

21 누가 사자를 길들였죠? (호랑이)

11 누가 코뿔소를 엿들었죠? (코끼리)

80 말이 누굴 씻겼죠? (당나귀)

71 코끼리가 누굴 넘어뜨렸죠? (하마)

15 늑대가 누굴 유혹했죠? (여우)

40 누가 소를 쓰다듬었죠? (당나귀)

32 고슴도치가 누굴 도왔죠? (두더지)

69 누가 칠면조를 무시했죠? (거위)

51 누가 하마를 할퀴었죠? (코뿔소)

60 말이 누굴 냉대했죠? (소)

61 호랑이가 누굴 넘어뜨렸죠? (표범)

23 낙지가 누굴 치료했죠? (오징어)

20 소가 누굴 격려했죠? (당나귀)

49 누가 오리를 얕봤죠? (거위)

78 오랑우탄이 누굴 멀리했죠? (침팬지)

28 누가 두꺼비를 찼죠? (개구리)

2 백조가 누굴 깔봤죠? (갈매기)

7 매가 누굴 만났죠? (독수리)

79 누가 기린을 놀렸죠? (들소)

22 누가 갈매기를 가르쳤죠? (기러기)

43 누가 낙지를 피했죠? (오징어)

73 누가 나방을 울렸죠? (모기)

6 남생이가 누굴 불렀죠? (거북이)

18 고릴라가 누굴 경멸했죠? (침팬지)

44 올빼미가 누굴 억압했죠? (소쩍새)

29 오리가 누굴 환영했죠? (칠면조)

66 남생이가 누굴 흉내냈죠? (거북이)

37 고래가 누굴 속였죠? (상어)

12 누가 스컹크를 증오했죠? (고슴도치)

48 누가 개구리를 가두었죠? (두꺼비)

34 누가 생쥐를 존경했죠? (다람쥐)

46 자라가 누굴 깨물었죠? (남생이)

24 소쩍새가 누굴 존경했죠? (올빼미)

5 누가 귀뚜라미를 유혹했죠? (베짱이)

76 제비가 누굴 시기했죠? (까치)

42 누가 백조를 칭찬했죠? (갈매기)

9 누가 오리를 앉혔죠? (거위)

56 제비가 누굴 깨물었죠? (참새)

35 여우가 누굴 깨웠죠? (족제비)

58 고릴라가 누굴 미행했죠? (침팬지)

31 코뿔소가 누굴 사랑했죠? (코끼리)

39 누가 얼룩말을 환영했죠? (들소)

17 고래가 누굴 배웅했죠? (상어)

14 햄스터가 누굴 오해했죠? (생쥐)

77 누가 다랑어를 헐뜯었죠? (상어)

72 두더지가 누굴 돌보았죠? (스컹크)

8 개구리가 누굴 물리쳤죠? (두꺼비)

53 모기가 누굴 괴롭혔죠? (파리)

59 누가 기린을 얕봤죠? (들소)

70 누가 돼지를 핥았죠? (염소)

65 누가 귀뚜라미를 때렸죠? (베짱이)

45 누가 베짱이를 추격했죠? (귀뚜라미)

25 베짱이가 누굴 깨웠죠? (메뚜기)

63 누가 문어를 위로했죠? (낙지)

Queries: List 2

80 누가 표범을 놀렸죠? (호랑이)

31 누가 염소를 길들였죠? (양)

54 누가 매를 모욕했죠? (솔개)

9 누가 스컹크를 일으켰죠? (두더지)

34 누가 독수리를 존경했죠? (매)

53 누가 개구리를 괴롭혔죠? (두꺼비)

10 코뿔소가 누굴 격려했죠? (코끼리)

79 소가 누굴 핥았죠? (말)

58 문어가 누굴 가두었죠? (낙지)

22 기린이 누굴 도왔죠? (들소)

3 침팬지가 누굴 웃겼죠? (오랑우탄)

59 당나귀가 누굴 얕봤죠? (말)

35 누가 거북이를 기다렸죠? (남생이)

50 누가 코끼리를 잊었죠? (코뿔소)

48 모기가 누굴 가두었죠? (파리)

69 누가 스컹크를 씻겼죠? (고슴도치)

23 누가 침팬지를 찼죠? (고릴라)

27 생쥐가 누굴 속였죠? (햄스터)

57 누가 부엉이를 붙잡았죠? (소쩍새)

70 누가 코끼리를 놀렸죠? (하마)

25 참새가 누굴 기다렸죠? (까치)

6 족제비가 누굴 알아봤죠? (여우)

12 오리가 누굴 깔봤죠? (거위)

41 백조가 누굴 혼냈죠? (갈매기)

17 누가 소쩍새를 만났죠? (부엉이)

7 다람쥐가 누굴 배웅했죠? (햄스터)

18 누가 문어를 물리쳤죠? (낙지)

46 누가 족제비를 깨물었죠? (여우)

14 누가 독수리를 오해했죠? (솔개)

64 누가 다랑어를 위협했죠? (상어)

71 누가 양을 넘어뜨렸죠? (돼지)

74 누가 매를 위협했죠? (솔개)

26 누가 여우를 의심했죠? (늑대)

24 상어가 누굴 앞질렀죠? (고래)

19 누가 말을 일으켰죠? (소)

2 누가 기린을 깔봤죠? (들소)

78 문어가 누굴 멀리했죠? (오징어)

40 누가 사자를 쓰다듬었죠? (표범)

75 거북이가 누굴 흉내냈죠? (자라)

39 누가 소를 환영했죠? (당나귀)

11 누가 염소를 엿들었죠? (양)

45 까치가 누굴 추방했죠? (제비)

65 참새가 누굴 시기했죠? (까치)

42 들소가 누굴 제압했죠? (얼룩말)

1 갈매기가 누굴 엿들었죠? (기러기)

28 누가 파리를 안내했죠? (나방)

76 누가 귀뚜라미를 헐뜯었죠? (베짱이)

43 누가 오랑우탄을 괴롭혔죠? (고릴라)

16 메뚜기가 누굴 알아봤죠? (베짱이)

77 부엉이가 누굴 때렸죠? (소쩍새)

44 누가 다랑어를 모욕했죠? (상어)

51 누가 염소를 혼냈죠? (돼지)

47 햄스터가 누굴 해쳤죠? (생쥐)

38 누가 낙지를 치료했죠? (문어)

15 거북이가 누굴 유혹했죠? (자라)

20 누가 호랑이를 지도했죠? (사자)

72 누가 칠면조를 초대했죠? (오리)

60 누가 사자를 냉대했죠? (호랑이)

62 들소가 누굴 초대했죠? (얼룩말)

30 코끼리가 누굴 쓰다듬었죠? (하마)

21 갈매기가 누굴 길들였죠? (기러기)

56 누가 메뚜기를 깨물었죠? (베짱이)

33 두꺼비가 누굴 꼬집었죠? (개구리)

67 햄스터가 누굴 방문했죠? (생쥐)

32 칠면조가 누굴 가르쳤죠? (오리)

55 남생이가 누굴 억압했죠? (자라)

61 누가 백조를 껴안았죠? (기러기)

63 고릴라가 누굴 위로했죠? (오랑우탄)

37 올빼미가 누굴 밀었죠? (소쩍새)

13 누가 맹꽁이를 웃겼죠? (두꺼비)

73 두꺼비가 누굴 울렸죠? (맹꽁이)

4 누가 다랑어를 저주했죠? (상어)

29 고슴도치가 누굴 환영했죠? (스컹크)

66 누가 늑대를 지지했죠? (족제비)

36 누가 베짱이를 탓했죠? (메뚜기)

8 파리가 누굴 경멸했죠? (나방)

49 스컹크가 누굴 비판했죠? (두더지)

52 오리가 누굴 제압했죠? (칠면조)

5 제비가 누굴 유혹했죠? (까치)

68 모기가 누굴 멀리했죠? (나방)

Appendix B: Instructions (translated into English)

Animal Farm Experiment

This experiment is intended to investigate how Korean speakers understand spoken language. You will hear Korean sentences and then be asked a question about the sentence through the headphones. Answer the question by choosing from the two options displayed on the screen. If you like the option on the left side of the screen, hit the left arrow. If you like the option on the right, hit the right arrow. The sentences all involve animals, so I'll begin by showing you some pictures of animals. You won't be quizzed on the pictures. Then I will give you some sentences to practice on. After the practice, there will be a pause, and then the main part will begin. Listen to the sentences and questions carefully.

Some of the sentences will be difficult, but go as quickly as you can without making too many mistakes. If you are not sure what the correct answer is, take your best guess.

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