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Effects of Local and Global Context on Processing Sentences with Subject and Object Relative Clauses

Fang Yang · Lun Mo · Max M. Louwerse

Abstract An eye tracking study investigated the effects of local and global discourse context on the processing of subject and object relative clauses, whereby the contexts favored either a subject relative clause interpretation or an object relative clause interpretation. The fixation data replicated previous studies showing that object relative clause sentences were more difficult to process than subject relative sentences. Crucially, however, the reading difficulty asymmetry between subject and object relative clause sentences disappeared when the sentences were presented with a local or a global discourse context that favored the objects in the object relative clauses. These findings demonstrate that the evidence for a syntax-based account of sentence processing is found when sentences are presented in isolation. However, if sentences are placed more naturally, in context, discourse factors outweigh the initial structural assignment.

Keywords Syntactic parsing · Sentence processing · Eye tracking · Discourse comprehension · Garden Bath · Linguistic context

Introduction

Much of the research in psycholinguistics has focused on the role of syntactic parsing in the processing of sentences in isolation. To what extent pragmatic and lexical semantic context plays a role on syntactic parsing remains unclear (Altmann 1988; Altmann and Steedman 1988; Rayner et al. 1983; Taraban and McClelland 1998). The present study investigated the extent to which contextual factors exerted effects on sentence processing.

F. Yang
University of Detroit Mercy, Detroit, MI, USA

L. Mo · M. M. Louwerse (✉)
The University of Memphis, 202 Psychology Building, 365 Innovation Drive, Memphis, TN 38152, USA
e-mail: mlouwerse@memphis.edu

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In the psycholinguistic literature two accounts of sentence processing can generally be distinguished depending on the extent to which they emphasize the role of discourse context in syntactic parsing, a syntax-based account and a discourse-based account (Mitchell and Corley 1992).

According to the syntax-based account, parsing commitments are initially made on the basis of purely syntactic considerations, without taking into account the semantic or pragmatic information (e.g., Frazier 1987; Rayner et al. 1983). The most representative model in this account is the garden path model proposed by Frazier and colleagues (Frazier 1978, 1987; Frazier and Rayner 1982; Rayner et al. 1983). According to the garden path model, there exist two largely independent processors that are operative during sentence comprehension: a syntactic processor that initially computes only the structurally preferred analysis of a sentence, and a thematic processor that examines the alternative thematic structures of a word (to compare the relative plausibility of each), selecting the semantically and pragmatically most plausible one. The model postulates that syntactic factors alone are responsible for determining the preliminary interpretation of the sentence structure.

According to the second account, the discourse-based account, parsing is guided from the outset by non-syntactic factors such as semantic and pragmatic information. The most representative model for the discourse based account is the referential support model proposed by Altmann (1988) and Crain and Steedman (1985). According to this model, the structural analysis is resolved by reference to discourse-based features. More specifically, it maintains that sentential structures are always settled in favor of the readings that are most compatible with the discourse features of materials preceding the sentence. The discourse decision is made on the basis of a *principle of parsimony* (Crain and Steedman 1985). This principle states that each reader has only one model of the universe of discourse. The reading that involves fewest alternations to the original one, while being consistent with the presuppositions or entailments, will be adopted as the most plausible one.

In essence, the crucial difference between the syntax-based models and the discourse-based models of parsing lies in whether parsing decisions are initially made on syntactic considerations alone or are guided by the discourse. To discriminate between the two types of accounts, numerous studies have been carried out to address this issue (Ferreria and Henderson 1990; Mitchell 1984; McClelland 1987; Taraban and McClelland 1998).

The present study differs from previous studies by defining contextual factors more broadly than the discourse-based account has done so far. More specifically, the current study focuses on the effect of local and global extra-sentential linguistic context on processing subject relative and object relative clauses. An example of each type of sentence is given in subject relative (SS) clause sentence (2a) and object relative (SO) clause sentence (2b):

2a. *The child that chased the babysitter squealed with delight at the game*. (SS)
2b. *The child that the babysitter chased squealed with delight at the game*. (SO)

In sentences such as (2a), the extracted element (e.g., *the child*) serves as the syntactic subject of the main clause (as in the sentence, *the child squealed with delight*), and also it is the subject of the relative clause (as in the sentence, *the child chased the babysitter*). When the extracted element is the subject in the relative clause, this kind of relative clause is referred to subject relative clause or SS structure (MacWhinney and Pleth 1988; Traxler et al. 2002). In contrast, the extracted element (*the child*) in sentence (2b) serves as the syntactic subject of the main clause, and it is the direct object of the verb in the relative clause (as in the sentence, *the babysitter chased the child*). When the extracted element is the object in the relative clause, this kind of relative clause is referred to object relative clause or SO structure (MacWhinney and Pleth 1988; Traxler et al. 2002).

A number of studies have found processing differences between sentences with subject relative clauses and sentences with object relative clauses (Hakes et al. 1976; Holmes and O'Regan 1981; Hsiao and Gibson 2003; MacWhinney and Pleth 1988; Traxler et al. 2002). Traxler et al. (2002), for instance, conducted a study on processing subject and object relative clauses and found that readers have greater difficulty processing sentences with object relative clauses than sentences with subject relative clauses. It seems that readers have an initial bias to treat the sentential subject as the subject of the relative clause (Traxler et al. 2002). From the above example sentences (2a and 2b), it can be seen that the commonality in the two types of the sentences is that both of the two sentences contain temporal structural ambiguity: after the first noun *that* introduces either a subject relative clause or an object relative clause. According to the syntax-based account, syntactic factors cause the subject object relative processing asymmetry. That is, the reader will attach new items within the clause or phrase currently being processed (late-closure principle; Frazier 1978). Thus when processing sentence 2a, after encountering *that*, the reader will assign the upcoming item as the predicate of the currently being processed clause (*that chased the babysitter*), to meet the principle that this item is attached within the same clause. In the same way, when processing sentence 2b, after encountering that, the reader will still assign the next item as the predicate of the main clause, and will not assign the upcoming item as a subject of the relative clause. If the next item is assigned as the subject of the relative clause, this item then becomes a new concept and will not be within the same clause. This assignment obviously violates the principle of late closure, will therefore not be the reader's preliminary choice. However, longer reading time of SO sentence occurs when the initial commitment turns out to be incorrect and the reader has to re-analyze the sentential structure.

But the discourse-based account can explain this phenomenon equally well. Within this account, the referential support theory (Crain and Steedman 1985) can explain the asymmetry of subject and object relative clause. Its principle of parsimony predicts that the reading that carries fewer unsatisfied but consistent presuppositions or entailments would be adopted as the most plausible one (Crain and Steedman 1985). Subsequently, the subject and object relative clause asymmetry is due to the role consistency of the first noun throughout the sentence. In sentences with subject relative clauses (e.g., sentence 2a), the subject of the main clause (the first noun) is consistently presupposed to be the subject of the relative clause. The reader therefore doesn't need to switch attention from the first noun's role as a subject to the first noun's role as an object. However, in object relative clause sentences (e.g., sentence 2b), something different happens when the first noun is presupposed to be the subject in the relative clause but it turns out to be the object in the relative clause, the reanalysis will occur and requires longer reading time.

What is noteworthy in studies on subject and object relative clause asymmetry (including Traxler et al. 2002) is that the relative clause sentences are presented in isolation. Little research has compared subject and object relative clause processing in different discourse contexts as a way to understand comprehension processes of those sentences. This is rather surprising, because it is rarely that we produce or understand sentences in isolation (Holmes and O'Regan 1981). Therefore, for much of the research in sentence processing in general, and the research on subject and object relative clause asymmetry specifically, it is unclear to what extent the asymmetry of subject and object relative clause sentences can be ascribed to a natural language processing effect or a sentence-in-isolation effect. To shed light on this issue, sentences could be placed in different discourse contexts, each one biasing different interpretations. For instance, for the sentences 2a and 2b, suppose that SO sentences (sentences with object relative clauses) are more difficult to read than SS sentences (sentences with subject relative clauses). The syntax-based models predict that the same reading pattern

exists across different discourse contexts. It will make no difference whether the two types of sentences are read in isolation, whether the semantic information of the sentence is manipulated to favor the reading of only one type of sentence or not. On the other hand, according to the discourse-based account, if there is a paragraph preceding sentence 2b that emphasizes the agent *the babysitter*, then *the babysitter* is presupposed to be consistently the thematic role and the reading of a relative clause beginning with *the babysitter* will be favored. In this case, an opposite outcome is predicted because the SO sentence in the paragraph is be more easily to read than the SS sentence in isolation. The referential support model thus predicts that the reading pattern of sentences varies across different contexts. The preceding discourse materials or the semantic information in the sentence itself will directly affect the initial sentence parsing strategy. Depending on the discourse contexts surrounding the sentences, the asymmetry of SS and SO yields similar differences compared to when these sentences are presented in isolation, supporting the syntax-based account, or they disappear (or even reverse) supporting the discourse-based account.

Experiment

And eye tracking experiment was conducted in which processing differences between subject relative (SS) clause sentence and object relative (SO) clause sentences were investigated. Importantly, we manipulated the discourse context locally—within the sentence—and globally—extra-sententially (Kintsch and Van Dijk 1978; Louwerse 2004; Van Dijk and Kintsch 1983).

Method

Participants

Sixty undergraduate students from the Department of Psychology at the University of Memphis participated for partial course credit. All of the participants were native speakers of American English and had normal or corrected-to normal vision.

Design

Subject relative and object relative sentences were compared, either with a non-ambiguous or an ambiguous local context, and with either a subject-favored global context or an object favored global context (see Table 1). Thus, the experiment had a 3 ((no global context) vs. (subject emphasized global context) vs. (object-emphasized global context)) $\times$ 2 ((ambiguous local context) vs. (unambiguous local context)) $\times$ 2 ((subject relative clause) vs. (object relative clause)) within-subject design. All experimental items were counterbalanced using a Latin Square design such that the subject saw each item only once.

Materials

The materials consisted of 20 quadruplets of sentences taken from Experiment 1 in Traxler et al.'s study (2002). As described by Traxler et al. (2002), subject relative and object relative clauses were created by changing the order of the words in the relative clause. Thus the items

Table 1 Definitions and examples of discourse contexts

Context	Definition	Example
Null discourse context	The sentence appeared in isolation without prior information being given	*The child that chased the babysitter squealed with delight at the game*
Local discourse context	The lexical information of the verb in the relative clause region was biased towards only one of the two noun phrases, and only the noun phrase in the object relative clause was plausible for the action described by verb	*The child that looked after the babysitter squealed with delight at the game*
Subject-favored discourse context	There is preceding discourse material which emphasized the subject of the subject relative clause in the sentence	*The child with a pony tail was playing on the playground with the babysitter. She looked pretty good in the pink sweater, and her white sport shoes were very cute. When the child laughed, her voice sounded sweet. On this sunny spring day, the breeze gently blew her brown hair. The child was busy picking up wildflowers, chasing the birds, and playing a game of tag. The child that chased the babysitter squealed with delight at the game. Their laughter could be heard a few miles away*
Object-favored discourse context	The same is true as in subject-favored discourse context, except that the focus is biased toward the babysitter	*The babysitter with a pony tail was playing on the playground with the child. She looked pretty good in the pink sweater, and her white sport shoes were very cute. When the babysitter laughed, her voice sounded sweet. On this sunny spring day, the breeze gently blew the brown hair. The babysitter was busy picking up wildflowers, chasing the birds, and playing a game of tag. The child that the babysitter chased squealed with delight at the game. Their laughter could be heard a few miles away*

were matched for length and frequency across conditions, with a total of about 90 words in the paragraph ($M = 94$, SD $= 6.63$). An overview is given in Table 1. All stimuli can be found at http://madresearchlab.org/materials/Yang/YangStimuli.pdf.

Each participant saw four practice text items, 40 different experimental target sentences and 10 filler sentences. Simple yes/no comprehension questions followed each text item to ensure comprehension.

Procedure

Participants were told to read a number of text items with the size of the text item varying from a single sentence to a passage, while their eye gaze was recorded. They were asked to press *yes* or *no* to answer questions following each text. They were told the accuracy of answers was recorded but response times were not. The whole experimental session lasted about 1 h.

Apparatus

Eye movements were recorded using SMI iView X High-Speed eye tracker. The participant's head was comfortably stabilized by an ergonomic chinrest. Participants were calibrated both before they began the experimental session and throughout the session to ensure reliable fixation data. During calibration, participants viewed nine points on a $1{,}024 \times 768$ computer monitor and the tracker recorded corresponding x-y coordinates. The eye tracker had a temporal resolution of 240 Hz. The horizontal viewing angle was $\pm 30°$ and vertical view angle was 30° up and 45° down. The initial calibration process took approximately 5 min. All experimental stimuli were presented through E-Prime software, so the subjects could proceed to the next stimulus without experimenter interference.

Results

Three measures commonly used in eye tracking experiments were used: gaze duration, total fixation time, and regressive eye movements. Gaze duration is the sum of all the fixations made in that one region (e.g., a word) until the eyes leaves that region; total time sums all fixation times made within a region of text, including those fixations made when re-reading the region; regressive eye movements included the times of leaving a region and returning back to it (Liversedge et al. 1998). Gaze duration tells us that the difficulty is experienced immediately on processing that region of text. The total fixation time indicates a later effect on processing, for instance, one that extends beyond the word level. Presumably, the effects of both total time and gaze duration will strengthen the observed difficulty on a region. Finally, the effect of regressive eye movements indicates that the reader is experiencing difficulty when processing a critical region (Liversedge et al. 1998).

Following Traxler et al. (2002), two areas of interest were examined: the relative clause region and the matrix verb. The relative clause region included all of the words in the relative clause except for the relativizer *that* (for example, *chased the babysitter* vs. *the babysitter chased*). The matrix verb region included the verb of the main clause (for example, *squealed*). The reading on matrix verb region was considered because it could reveal if the reading difficulty or the reading ease between the subject and object relative clauses would extend further into the upcoming reading area.

Six participants were eliminated from the analysis because of calibration problems. These subjects either had poor vision that could not get focused on the recording screen or the recording of eye movement was disrupted and the participant had to be re-calibrated. The remaining 54 participants scored at least 90% accuracy on the comprehension questions, and had reliable eye gaze calibration throughout the experiment.

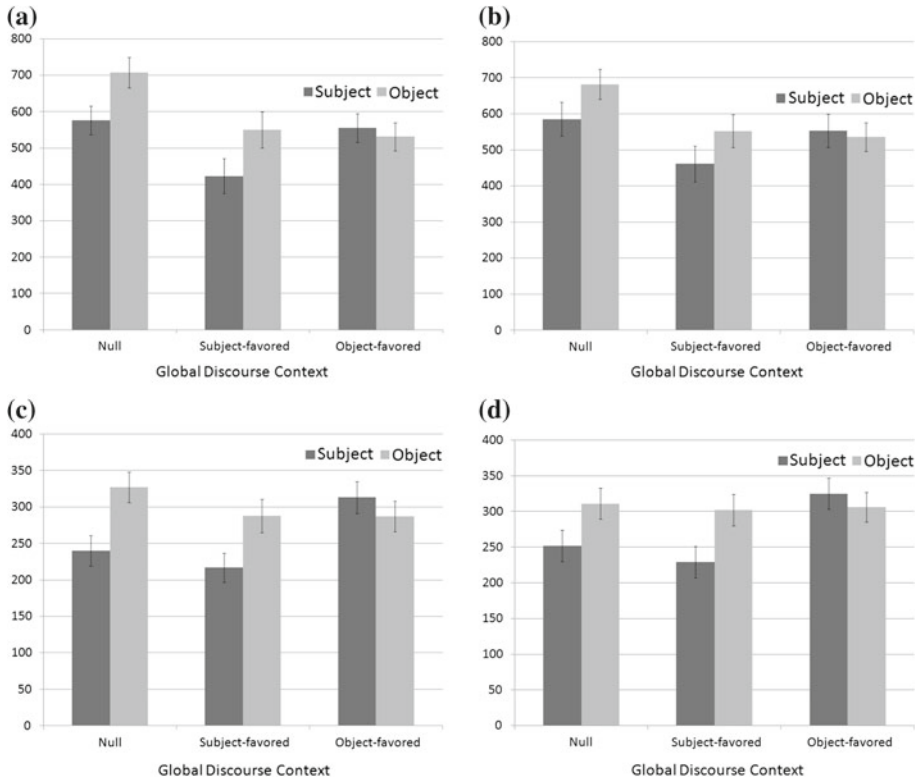

Fig. 1 Analyses of gaze duration. **a** Average mean gaze duration for ambiguous local discourse context. **b** Average mean gaze duration for non-ambiguous local discourse discourse context. **c** Average mean gaze duration on matrix verb for ambiguous local discourse context. **d** Average mean gaze duration on matrix verb for non-ambiguous local discourse discourse context

Gaze Duration

The patterns for gaze duration are presented in Fig. 1a–d. An ANOVA on gaze duration showed a strong effect of relative clause type, $F_1(1, 53) = 9.42, p = .003, \text{MSE} = 2{,}285$; $F_2(1, 39) = 10.19, p = .003, \text{MSE} = 2{,}208$. The subject-relative clause yielded shorter gaze durations than the object-relative clause ($M = 596$, SD $= 318$; $M = 525$, SD $= 311$, respectively). There was also main effect of factor on the global discourse context, $F_1(1, 53) = 13.11, p = .001, \text{MSE} = 2{,}683$; $F_2(1, 39) = 11.96, p = .001, \text{MSE} = 2{,}653$. The reading time on all the relative clauses in null global discourse context was longer ($M = 637$, SD $= 324$) than the reading time on relative clauses in subject-favored ($M = 449$, SD $= 339$) and object-favored global discourse context ($M = 536$, SD $= 308$). There was no main effect on the factor of local discourse context (both $F < 1$). No three-way interaction was found, but there was a significant interaction between the global discourse context and the relative clause type, $F_1(1, 53) = 3.22, p = .044, , \text{MSE} = 3{,}030$, though with a marginally significant effect in the by-items analysis, $F_2(1, 39) = 2.82, p = .066, \text{MSE} = 3{,}056$. The interaction occurred because in the null global discourse context, the subject relative clause type produced shorter gaze duration ($M = 580$, SD $= 370$) than the object relative clause ($M = 695$, SD $= 327$), $F_1(1, 53) = 6.83, p = .038, \text{MSE} = 4{,}400$; $F_2(1, 39) = 7.31, p = .036, \text{MSE} = 4{,}207$. When being presented in the subject favored global

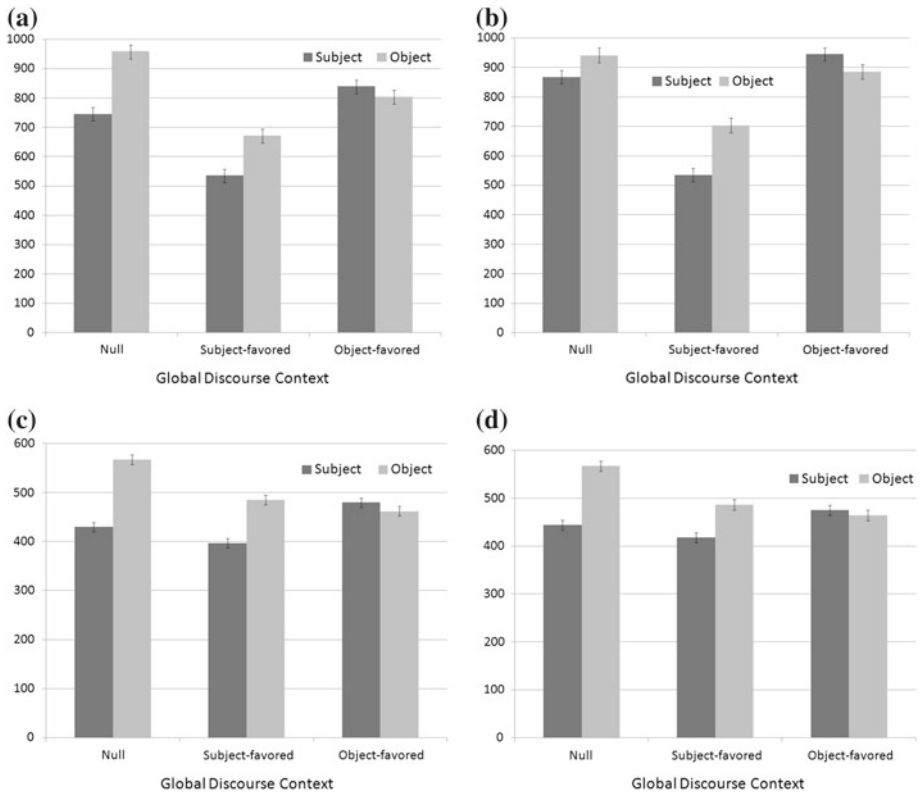

Fig. 2 Analyses of total fixation time. **a** Average mean durations for ambiguous local discourse context. **b** Average mean durations for non-ambiguous local discourse discourse context. **c** Average mean durations on matrix verb for ambiguous local discourse context. **d** Average mean durations on matrix verb for non-ambiguous local discourse discourse context

discourse context, the subject relative clause type produced numerically shorter gaze duration ($M = 442$, SD $= 371$) than the object relative clause ($M = 553$, SD $= 380$), $F_1(1, 53) = 6.11$, $p = .035$, MSE $= 4{,}623$; $F_2(1, 39) = 6.02$, $p = .045$, MSE $= 4{,}700$. However, the difference disappeared in the object-favored global discourse context, both $F < 1$, $p > .05$. The subject relative clauses no longer showed any reading ease over the object relative clauses.

The processing pattern on the matrix verb region (the verb of the main clause, e.g. *squealed* in sentence 2a and 2b) produced a nearly identical pattern as in the relative region. The main effect of relative clause type was significant, $F_1(1, 53) = 5.94$, $p = .018$, MSE $= 2{,}636$; $F_2(1, 39) = 5.01$, $p = .029$, MSE $= 2{,}917$. The result showed that subject relative clauses had shorter gaze duration that the object relative clauses. There was a significant interaction between the global context and the relative clause type in the by participants analysis, $F_1(1, 53) = 3.19$, $p = .05$, MSE $= 3{,}302$. The interaction was marginally significant in the by items analysis, $F_2(1, 39) = 2.64$, $p = .09$, MSE $= 3{,}772$.

Total Fixation Time

The patterns for total fixation time are presented in Fig. 2a–d. In the by-participant analysis, statistical analyses on the total fixation data from the relative clause region showed a strong

effect of sentence type, $F_1(2, 53) = 6.90$, $p = .011$, MSE = 10,531; $F_2(2, 39) = 5.97$, $p = . < .019$, MSE = 10,726. There was no main effect on the factor of global discourse context, $F_1(2, 53) = 1.98$, $p = .14$, MSE = 14,070, $F_2(2, 39) = 1.94$, $p = .15$, MSE = 14,096, and there was no main effect on the factor of the local discourse context, $F_1(2, 53) = 2.49$, $p = .12$, MSE = 11,613, $F_2(2, 39) = 2.15$, $p => .12$, MSE = 9,339. The three factors did not interact in the total time (both $F < 1$, $p > .05$). There was a significant interaction between the global discourse context and the sentence type in the by-participants analysis, $F_1(2, 53) = 3.06$, $p = .05$, MSE = 16,001. Furthermore, the interaction was still marginally significant in the by-items analysis, $F_2(1, 39) = 2.97$, $p = .57$, MSE = 16,197. The interaction occurred because in the null global discourse context, the subject relative clause ($M = 805$, SD = 141) produced significantly shorter total reading time than the object relative clause ($M = 949$, SD = 151), $F_1(1, 53) = 4.81$, $p = .03$, MSE = 18,823; $F_2(1, 39) = 4.53$, $p = .025$, MSE = 20,129. Meanwhile, in subject-favored global discourse context, the subject relative clause ($M = 690$, SD = 143) still produced numerically shorter total reading time than the object relative clause ($M = 859$, SD = 155), $F_1(1, 53) = 9.57$, $p = .015$, MSE = 15,520; $F_2(1, 39) = 8.05$, $p = .026$, MSE = 17,240. However, the difference disappeared in the object-favored global discourse context.

The total time data from the matrix verb region conformed to the same pattern as in the relative clause region. There was a main effect of relative clause type, $F_1(1, 53) = 7.40$, $p = .008$, MSE = 9,992; $F_2(1, 39) = 8.83$, $p = .003$, MSE = 8,768, with the subject relative clause produced shorter total reading time than the object relative clause. The interaction between the global discourse context and the relative clause type was significant, $F_1(1, 53) = 3.67$, $p = .029$, MSE = 16,529; $F_2(1, 39) = 3.02$, $p = .05$, MSE = 17,422.

Regressive Eye Movements

The number of regressive eye movements produced the same pattern as gaze duration and total time. In the by participants analysis, the statistical analysis produced reliable main effect of relative clause type, $F_1(1, 53) = 6.49$, $p = .014$, MSE = 1.92; $F_2(1, 39) = 7.86$, $p = .017$, MSE = 1.89. There was no main effect on the factor of the global discourse context and the local discourse context (both $F < 1$, $p > .05$). No interactions were found rather than a significant interaction between the global discourse context and the relative clause type, $F_1(1, 53) = 4.55$, $p = .016$, MSE = 3.01; $F_2(1, 39) = 3.2$, $p = . < .017$, MSE = 3.1 (Fig. 2). The interaction occurred because in the null global discourse context, the subject relative clause produced significantly less number of regressive eye movements ($M = 9$, SD = 6) than the object relative clause ($M = 11$, SD = 7), $F_1(1, 53) = 6.52$, $p = .015$, MSE = 3.003; $F_2(1, 39) = 4.32$, $p <= .044$, MSE = 3.3. Meanwhile in the subject-favored global discourse context, the subject relative clause also produced significantly less number of regressive eye movements ($M = 9$, SD = 8) than the object relative clause ($M = 11$, SD = 7), $F_1(1, 53) = 11.03$, $p < .001$, MSE = 2.9; $F_2(1, 39) = 12.15$, $p = .001$, MSE = 3.2. However, in the object-favored global discourse context, the difference of regressive numbers between the two relative clauses disappeared. The subject relative clauses no longer showed any reading ease over the object relative clauses.

The data on the number of regressive eye movements from the matrix verb was similar to the processing patterns observed so far. The main effect of relative clause type was significant, $F_1(1, 53) = 11$, $p < .05$, MSE = .7; $F_2(1, 39) = 10$, $p < .05$, MSE = .6, with the subject relative clause produced less number of regressive eye movements than the object relative clause. The interaction between the global discourse context and the relative clause

type was significant in the by participants analysis, $F_1(1, 53) = 3.14$, $p < .05$, MSE $= .9$. The interaction was marginally significant in the by items analysis, $F_2(1, 39) = 2.4$, $p < .1$, MSE $= .9$.

General Discussion

The results of the eye tracking experiment indicate that sentences with object-relative clauses were more difficult to process than sentences with subject relative clauses and the difficulty even extended into the matrix verb. These results are consistent with the pattern found in Traxler et al. (2002). However, the interaction between the global discourse context and the relative clause type reveals that the difference in processing difficulty between the subject and object relative clauses varies as a function of discourse context. When the sentence is presented in isolation (null global discourse context), the object relative clause is more difficult to read than the subject relative clause. Similarly, when the sentence is preceded by a text segment that emphasizes the subject of the relative clause (the subject-favored global discourse context), the object-relative clause is still more difficult to read than the subject relative clause as well. So far, the findings support a syntax-based account of sentence processing. However, when the sentence emphasizes the object-favored global discourse context, the object relative clause now becomes easier to read than the subject relative clause. These results thus demonstrate that placing global discourse contexts for the sentences greatly reduces the difficulty normally associated with subject and object relative clauses, providing further support for a discourse-based account.

These findings are important for experimental research, as they suggest that the scope of the linguistic stimuli impacts conclusions drawn on cognitive processes. But the results are not strictly theoretical. They also have an applied component, for instance, when considering language acquisition and language pedagogy. Children having difficulty with the parsing of a sentence might in fact not necessarily have so much of a language processing difficulty as a language-out-of-context difficulty. That is, by providing the relevant discourse context, the results from the current study suggests that sentence processing difficulties are in fact resolved. Even though we cannot make strong applied claims based on the experimental findings, the results do support work in such applied questions.

The concern about the presentation of sentences in isolation has lead to a large research community emphasizing the role of text and discourse in comprehension (Graesser et al. 2003; Kintsch 1998; Louwerse and Van Peer 2002; Van Dijk and Kintsch 1983). Typically, these studies focus on text and discourse, but do not compare their findings with sentences in isolation. The results from the eye tracking experiment presented here have shown that context indeed plays an important role on sentence processing, so much so that conclusions previously drawn for sentence processing need being modified when local and global discourse contexts are considered.

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