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ScienceDirect
Journal of Memory and Language 57 (2007) 299–323
Journal of Memory and Language
www.elsevier.com/locate/jml

The return of the repressed: Abandoned parses facilitate syntactic reanalysis ☆

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Received 20 July 2006; revision received 12 September 2006
Available online 19 October 2006

Abstract

Two eye movement experiments examined effects on syntactic reanalysis when the correct analysis was briefly entertained at an earlier point in the sentence. In Experiment 1, participants read sentences containing a noun phrase coordination/clausal coordination ambiguity, while in Experiment 2 they read sentences containing a subordinate clause object/main clause subject ambiguity. The critical conditions were designed to induce readers to construct the ultimately correct analysis just prior to being garden-pathed by the incorrect analysis. In both experiments, the earliest measures of the garden path effect were not modulated by this manipulation. However, there was significantly less regressive re-reading of the sentence in those conditions in which the correct analysis was likely to have been constructed, then abandoned, at an earlier point. These results suggest that a syntactic analysis that is abandoned in the course of processing a sentence is not lost altogether, and can be re-activated or retrieved from memory. Implications for models of initial syntactic analysis and reanalysis are discussed.

Keywords: Sentence processing; Reanalysis; Eye movements; Syntactic parsing

Introduction

The behavior of the parser when it encounters a temporary phrase structure ambiguity has long been a central topic for psycholinguistic research. It is clear that when faced with such an ambiguity, the parser often adopts an analysis that is later revealed to be incorrect. At this point, the reader or listener must identify the incorrect attachment in the initial parse, undo this attachment, and construct (or, depending on one's theoretical perspective, increase the activation of) an alternate syntactic analysis.

The nature of syntactic reanalysis and the question of what factors influence the difficulty of this process have been addressed in many recent studies (e.g., Bornkessel, McElree, Schlesewski, & Friederici, 2004; Ferreira & Henderson, 1991; Fodor & Inoue, 1998; Frazier & Clifton, 1998; Frazier & Rayner, 1982; Lewis, 1998; Meseguer, Carreiras, & Clifton, 2002; Pickering & Traxler, 1998; Sturt, Pickering, & Crocker, 1999; Sturt, Scheepers, & Pickering, 2002; Tabor & Hutchins, 2004; Van Dyke & Lewis, 2003; Warner & Glass, 1987). This

☆ This research was supported by National Institutes of Health grant HD-18708 to the University of Massachusetts and by a University of Massachusetts Graduate School Fellowship. Thanks to Chuck Clifton, Lyn Frazier, and Keith Rayner for helpful discussion and comments.
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doi:10.1016/j.jml.2006.09.001

research has identified several distinct influences on reanalysis difficulty. A number of studies have examined the influence of the length of the ambiguous region, beginning with Frazier and Rayner (1982), who found that long ambiguous regions resulted in a greater increase in reading time, upon disambiguation, than did short ambiguous regions. Warner and Glass (1987; cf. Ferreira & Henderson, 1991; Van Dyke & Lewis, 2003) later suggested that what matters is not length per se, but the number of linguistic constituents in the disambiguating region. Bailey and Ferreira (2003), on the other hand, found that lengthening the ambiguous region of a spoken sentence by inserting environmental non-speech sounds also increases the difficulty of reanalysis.

The syntactic structure of the ambiguous region has also been an area of focus. Ferreira and Henderson (1991) found that reanalysis is made more difficult when the ambiguous region contains yet another ambiguity, and also when more material intervenes between the head of the ambiguous phrase and the point of disambiguation, even when the overall length of the ambiguous region is held constant. Tabor and Hutchins (2004) also found that reanalysis difficulty is increased when the material in the ambiguous region induces a second incorrect attachment.

A third line of research and theory (Frazier & Clifton, 1998; Lewis, 1998; Sturt et al., 1999, 2002; Pritchett, 1992) has emphasized differences between types of structural revisions. Sturt et al. (1999), for example, performed two self-paced reading experiments demonstrating that it is considerably easier to replace a mistaken direct object attachment with an analysis on which the ambiguous noun phrase is the subject of a complement clause, as in (1a), than with one on which this noun phrase is the subject of the main clause, as in (1b):

(1a) The Australian woman saw the famous doctor had been drinking quite a lot.
(1b) Before the woman visited the famous doctor had been drinking quite a lot.

This difference is interpreted in terms of the need to revise dominance relations between the ambiguous noun phrase and the preceding verb in (1b), but not in (1a). (It is also worth noting that Sturt et al. (1999) did not replicate Ferreira & Henderson's (1991) head position effect.)

The present article describes two eye movement experiments that investigate a potential factor in reanalysis difficulty that has not been studied previously. What was manipulated in these experiments was whether, prior to the ambiguous region, the reader was likely to very briefly entertain the syntactic analysis that ultimately proved to be correct. The primary question these experiments were meant to address was whether reanalysis is facilitated when this process involves returning to an analysis that was entertained at an earlier point in the sentence, compared to when it involves constructing an analysis that is altogether novel. The answer to this question is of theoretical interest because of what it implies about the fate of an abandoned syntactic analysis and about the nature of reanalysis processes. If it is easier to access the correct analysis after a misanalysis when the correct analysis was constructed, then abandoned, at some earlier point, this would have at least two important implications. First, it would suggest that the earlier analysis remains present in the system, in some sense, during the period when an incompatible alternate analysis is dominant. Second, it would suggest that the reanalysis mechanism is able to retrieve and make use of this earlier analysis.

How the continued presence of an abandoned analysis should be interpreted depends to a great extent on whether a parallel (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; McRae, Spivey-Knowlton, & Tanenhaus, 1998; Tabor & Hutchins, 2004; Vosse & Kempen, 2000) or serial (Frazier, 1978, 1987a; Frazier & Clifton, 1996; Frazier & Rayner, 1982) parsing model is assumed. A fully parallel model claims that the parser constructs and maintains multiple syntactic analyses simultaneously, with these analyses receiving varying levels of activation over time. While reading or hearing an ambiguous region of a sentence, the correct and incorrect analyses may both be active. A garden path effect is understood as a case in which the incorrect analysis is temporarily higher in activation than the correct analysis; at the point of disambiguation, this order is reversed. In one sense, a fully parallel parser need not invoke reanalysis as a functionally distinct stage, since updating of the relative activation levels of competing parses is continuously taking place (cf. Lewis, 1998). On this view, reanalysis could be facilitated by a prior activation of the correct parse simply because this parse remains active, albeit at a low level.

On a fully serial model, on the other hand, the adoption of a given analysis at a point of ambiguity entails the rejection of any prior analysis with which this analysis is inconsistent. Consequently, the construction of the correct analysis prior to the adoption of the incorrect analysis could only play a role in later processing if the correct analysis is, in some sense, retained in memory while the incorrect analysis is ascendant. The correct analysis could then be identified relatively quickly at the point of disambiguation because this analysis is stored in an accessible short-term memory store, even though it was not an active candidate structure at the point of disambiguation. Implications of the results of the present experiments for parallel and serial parsing models are taken up in the General Discussion.

Several recent studies, involving a range of constructions and methodologies, have provided evidence that a syntactic analysis that is constructed or activated prior to a revision can indeed exert a continued influence on processing (Christianson, Hollingworth, Halliwell, & Ferreira, 2001; Kaschak & Glenberg, 2004; Lau & Ferreira, 2005; van Gompel, Pickering, Pearson, & Jacob, 2006). These studies have examined the influence of an incorrect initial parse of a sentence on the ultimate interpretation of the sentence (Christianson et al., 2001) and on the acceptability of a spoken sentence containing a disfluency (Lau & Ferreira, 2005), and have explored the role of this incorrect initial parse as a structural prime (Kaschak & Glenberg, 2004; van Gompel et al., 2006). The present study, by contrast, examines the influence of a briefly entertained correct initial parse of a garden path sentence on the later syntactic analysis of the same sentence. Nevertheless, these studies provide important background to the present work.

In a now well-known series of experiments, Christianson et al. (2001) had participants read sentences containing a subordinate clause object/main clause subject ambiguity (as in Experiment 2 of the present article), e.g., *While Anna dressed the baby spit up on the bed*. They found a persistent tendency for participants to respond to comprehension questions as if they had maintained the subordinate clause object analysis of the ambiguous noun phrase (*the baby*); e.g., they tended to say "yes" to the question, *Did Anna dress the baby*? Christianson et al., interpreted this result as reflecting a failure on the part of participants to completely abandon the initial, incorrect syntactic analysis, and the corresponding failure to abandon the initial thematic role assignment for the ambiguous noun phrase.

Lau and Ferreira (2005) performed two relevant experiments on processing of disfluencies in spoken language; Experiment 2 will be discussed here. Participants heard sentences containing a reduced relative/main verb ambiguity, resolved in favor of the main verb analysis. In the critical conditions, the potentially ambiguous verb was followed by a disfluency, then by replacement by another verb, e.g., *The little girl chosen-uh selected the right answer, so her teacher gave her a prize*. The disfluent sentence was judged grammatical only 84% of the time when the verb form in the reparandum was unambiguously a passive participle (e.g., *chosen*) but was judged grammatical over 96% of the time when the verb form was ambiguous (e.g., *picked*). Lau and Ferreira interpreted this result as suggesting that the syntactic analysis that is active prior to a repair is not completely abandoned, since a clash between this analysis and the ultimately correct analysis results in reduced acceptability of the sentence.

A potential concern regarding the interpretation of the Christianson et al. (2001) and Lau and Ferreira (2005) experiments arises from the fact that they relied on participants' *post hoc* judgments of sentence meaning or grammatical acceptability. It is possible that the incorrect initial analysis was not actually retained from the initial encounter with the critical sentences, but rather was retrieved during a subsequent reflective process. However, van Gompel et al. (2006) and Kaschak and Glenberg (2004) also reached the conclusion that an initial, incorrect syntactic parse is not fully abandoned or deactivated, using structural priming paradigms in which explicit judgments regarding the critical sentences were not required for, or relevant to, the participants' task. In three experiments, van Gompel et al. (2006) had participants complete sentence fragments that ended with an optionally transitive verb, e.g., *When the doctor was visiting...* Participants were more likely to use a transitive completion if they had just read a garden path sentence with a subordinate clause object/main clause subject ambiguity than if they had read an identical sentence that was disambiguated with a comma (e.g., *While the man was visiting(,) the children played outside*.). Evidently, the initial transitive analysis of the subordinate clause verb in the garden path sentence was capable of priming the production of a sentence with a transitive subordinate clause; crucially, this effect was obtained even when different subordinate clause verbs were used in the prime sentence and the target fragment. Using a different construction, Kaschak and Glenberg (2004) found reduced reading time for a target sentence when the sentence's syntactic structure was likely to have been activated as part of an initial misanalysis of an earlier prime sentence. Clearly, neither the van Gompel et al. (2006) nor the Kaschak and Glenberg (2004) results are likely to have come about through explicit retrieval of, or reflection about, the prime sentence.

A central issue that runs through the studies just discussed is whether the incorrect initial parse has a continuing influence because the reader or listener never actually completes the required reanalysis, or whether this parse has a continuing influence despite the fact that the reader or listener does complete the required reanalysis. van Gompel et al. (2006) discuss this issue at some length, ultimately remaining agnostic. One benefit of the design of the experiments presented here is that it is possible to conclude with some confidence that the initial parse that is posited to affect reanalysis has, in fact, been fully abandoned in favor of an alternate parse prior to the point at which reanalysis is necessary.

Overview of the experiments

In both experiments presented here, readers' eye movements were monitored as they read garden path sentences. In Experiment 1, these sentences involved a noun phrase coordination/clausal coordination ambiguity (e.g., Frazier, 1987b; Hoeks, Vonk, & Schriefers,

2002), while in Experiment 2, they involved a subordinate clause object/main clause subject ambiguity (e.g., Christianson et al., 2001; Ferreira & McClure, 1997; Frazier & Rayner, 1982; Pickering & Traxler, 1998; Pickering, Traxler, & Crocker, 2000). The incorrect analysis was highly plausible at the point of reading the ambiguous material. To measure the strength of the garden path effect, the critical sentences were compared to sentences with a disambiguating comma. In addition, the sentences were varied prior to the main point of ambiguity. In one version of the sentences in Experiment 1, the parser was likely to briefly adopt a clausal coordination analysis, prior to being garden-pathed by the noun phrase coordination analysis. In one version of the sentences in Experiment 2, the parser was likely to briefly adopt an analysis on which the subordinate clause verb before the ambiguous noun phrase was intransitive, prior to being garden-pathed by the direct object analysis of the ambiguous noun phrase. In both experiments, the critical question was whether the transitory adoption of the ultimately correct analysis, prior to the main point of ambiguity, would reduce the difficulty of the reanalysis that was necessary later on.

Clearly, it is critical for the interpretation of the results of these experiments in terms of reanalysis processes that the parser's initial structural preferences with respect to the attachment of the ambiguous material not be affected by the manipulations prior to the point of ambiguity. That is, in order to interpret the effects of these manipulations as effects on reanalysis, it is necessary to show that the parser is indeed garden-pathed. This would be confirmed if the processing difficulty that appears in the earliest eye movement measures on the disambiguating material is not modulated by the pre-ambiguity manipulations. Effects of these manipulations on reanalysis difficulty should appear in later eye-movement measures, such as those that take regressive eye movements into account.

Experiment 1

The critical condition in Experiment 1 included sentences like (2):

(2) Either the boys will use the skis or the sled will make the deliveries.

To motivate the predictions for this experiment, it is necessary to follow the parser through this sentence as it proceeds from left to right. The posited sequence of syntactic analyses is illustrated in Fig. 1. The first important question is how the parser attaches the word *or*; the widely held assumption that syntactic parsing is highly incremental (Frazier & Rayner, 1982; Just & Carpenter, 1980) argues against the possibility that the nature of the coordinate structure is left completely indeterminate at this point. The grammar of English allows *or* to be analyzed as a coordinator between two clauses, two verb phrases, or two noun phrases when *either* is present sentence-initially (e.g., Larson, 1985; Schwarz, 1999). It seems likely, however, that when sentence-initial *either* is present, *or* is initially analyzed as coordinating two clauses, as shown in panel (a) of Fig. 1. (Fig. 1 avoids the question of how the word *either* should itself be attached, as this is a notoriously vexed question (see Larson, 1985; Schwarz, 1999), and does not bear on the present experiment.)

Two lines of evidence support this assumption. The first comes from Staub and Clifton (2006), who monitored participants' eye movements as they read sentences like (3a–d):

(3) (a) Either Linda bought the red car or her husband leased the green one.
(b) Linda bought the red car or her husband leased the green one.
(c) The team took either the train or the subway to get to the game.
(d) The team took the train or the subway to get to the game.

One finding from this experiment was that reading time beginning on the word *or* was significantly reduced by the presence of the word *either* before the coordinate structure. This reduction in reading time continued for several words, and did not interact with sentence type; the size of the effect was very similar for sentences in which two clauses were coordinated (3a–b) and in sentences in which two noun phrases were coordinated (3c–d). Staub and Clifton interpreted this result as evidence that the presence of the word *either* enables readers to predict the arrival of a coordinate structure, and that this prediction facilitates processing of the material that satisfies it. In addition, despite the implausibility of the noun phrase coordination analysis in sentences like (3b), there was some evidence of garden-pathing in this condition, in the form of increased regressive eye movements from the final region (*leased the green one*) and more time spent re-reading earlier portions of the sentence, compared to each of the other conditions. In (3a) there was no such evidence of garden-pathing; evidently, the presence of sentence-initial *either* largely eliminated the temptation to adopt the implausible noun phrase coordination analysis. It is this result that suggests that readers may initially attach the word *or* as a clausal coordinator when sentence-initial *either* is present.

The second line of evidence in support of the claim that *or* is analyzed as a clausal coordinator in a sentence

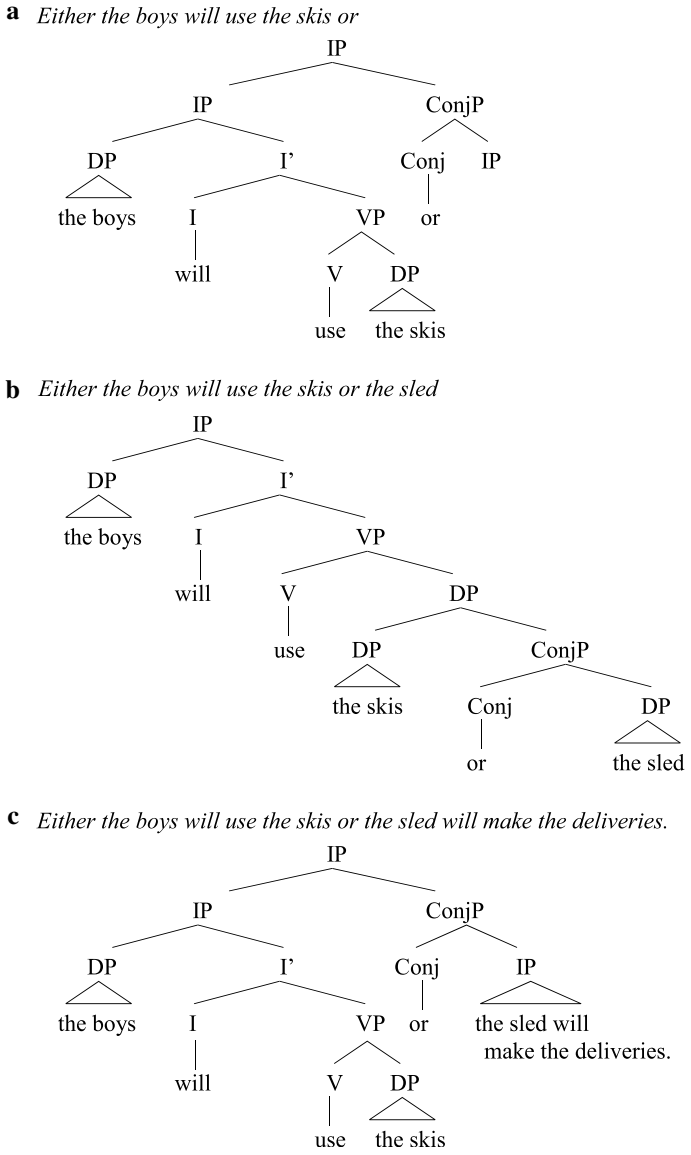

Fig. 1. Postulated stages in the parser's analysis of sentence (2).

like (2) comes from a written sentence completion study, using the materials from the present experiment, in which participants were asked to complete a sentence fragment ending with *or*. The presence of sentence-initial *either* dramatically increased the frequency of clausal coordination continuations, and in fact clausal coordination was the most frequent type of structure when sentence-initial *either* was present. This completion study is described in detail below.

The next question is how the parser attaches *the sled*. Native speakers of English seem to share the intuition that the noun phrase coordination analysis is preferred at the point of reading *Either the boys will use the skis or the sled*. This is the generally preferred initial attachment of a noun phrase in this position (e.g., Engelhardt, Bailey, & Ferreira, 2004; Frazier, 1987b; Hoeks et al., 2002), and in (2) the noun phrase coordination analysis is strongly supported by plausibility. This analysis is shown in panel (b) of Fig. 1.

It is notable that if this posited sequence of analyses is correct, a reanalysis takes place upon reading *the sled*. Clearly, there is little or no intuitive sense of processing difficulty at this point. However, this is not, by itself, evidence against reanalysis. Meseguer et al. (2002; see also Gorrell, 1998; Sturt & Lombardo, 2005) point out that on standard phrase-structural assumptions, parsing any English sentence involving coordination or involving a right adjunct such as a relative clause involves a mild form of reanalysis; no intuitive difficulty is present in these cases, and there is no evidence suggesting that

such very easy reanalyses leave their mark in the eye movement record. In short, it is possible that structural revisions do not always result in intuitive difficulty, and that they do not always have measurable effects on even the most sensitive measures of on-line processing.

Finally, and uncontroversially, the arrival of the verb *will* in (2) requires the reader to abandon the noun phrase coordination analysis, and to (re-) construct the clausal coordination analysis, illustrated in panel (c) of Fig. 1. In this case processing difficulty is intuitively apparent, and has been shown to appear on-line (Engelhardt et al., 2004; Frazier, 1987b; Hoeks et al., 2002).

The question that the present experiment was meant to address was whether the difficulty of moving from the analysis in panel (b) of Fig. 1 to the analysis in panel (c) is reduced by the fact that the analysis in panel (a) was previously constructed. To answer this question, Experiment 1 compared the garden path effect in sentences like (2) and in otherwise identical sentences without the word *either*. When *either* is absent, there is no reason for the parser to adopt the clausal coordination analysis upon reaching the word *or*; in fact, the principle of Late Closure (Frazier, 1978, 1987) would suggest that in the absence of *either* the parser should initially attach the conjunction phrase headed by *or* to the recently processed noun phrase.

Methods

Participants

Thirty-six native speakers of American English, who were students at the University of Massachusetts, Amherst, were given course credit or were paid $7 to participate in the experiment. All had normal or corrected-to-normal vision, and all were naïve to the purpose of the experiment.

Materials

Twenty-four sets of sentences like (4a–d) were constructed.

(4) a. Either the boys will use the skis or the sled will make the deliveries.
b. Either the boys will use the skis, or the sled will make the deliveries.
c. The boys will use the skis or the sled will make the deliveries.
d. The boys will use the skis, or the sled will make the deliveries.

Two variables were manipulated in a 2×2 factorial design. The word *Either* was present (versions a and b) or absent (versions c and d). In addition, a comma was included before the word *or* in versions b and d. Versions a–d will be referred to, respectively, as the *either no comma* condition, the *either comma* condition, the *no either no comma* condition, and the *no either comma* condition. The full set of materials is presented in the Appendix.

In constructing these sentences, a primary criterion was that the noun phrase after *or* should be conceptually similar to the noun phrase that preceded the comma, and that it should also serve as a plausible direct object for the verb of the initial clause. The goal was to induce a relatively strong tendency to misanalyze the "noun phrase or noun phrase" string (e.g., *the skis or the sled*) as noun phrase coordination when the comma was absent. The subsequent material (e.g., *will make*) would then indicate to the reader that this analysis must be incorrect, and that reanalysis is required.

An additional sentence followed the critical sentence in each item, on a separate line. In the case of (4a–d) above, this sentence was *The snow has been hard to deal with*. This sentence was included primarily for uniformity with a set of unrelated experimental materials that were intermixed with the materials in this experiment, which consisted of two sentences on each trial. However, the presence of the additional sentence allowed for the assessment of any effects of the experimental manipulations that may have lingered beyond the end of the critical sentence.

To assess whether it is in fact the case that the word *or* is preferentially analyzed as a clausal coordinator when *either* is present, but not when *either* is absent, a written sentence completion study with sixteen participants was carried out using the materials designed for the eye movement study. No participant who participated in this off-line study took part in the eye movement experiment. Participants were provided with each of the experimental items through the word *or*, without a comma. Half of the sentences began with the word *either*, and half did not, with the materials counterbalanced so that each item was completed by eight participants in each of its two versions. Participants were instructed to write in a completion for each fragment with the first response that came to mind. The 24 items from the present experiment were intermixed in a random order with 24 items from Experiment 2, described below, and 10 unrelated fillers.

Each completion was scored with respect to whether or not *or* was treated as a clausal coordinator. When *either* was present, a clausal coordination structure was used 53% of the time, compared to 21% of the time when *either* was absent. This difference was highly significant by both participants and items ($t_1(15) = 4.25$, $p = .001$; $t_2(23) = 6.59$, $p < .001$). Clearly, the presence of *either* dramatically increases the likelihood that the word *or* will be interpreted as a clausal coordinator, at least in a written production task.

It is important to note that in principle, a clausal coordination structure could be used while the initial *or* is treated as a coordinator between two noun phrases,

e.g., *Either the boys will use the skis or the sled, or they'll have to stay home*. A completion of this kind was produced exactly once, and was not counted as a clausal coordination completion for present purposes.

For the purpose of analysis of the eye movement data, the critical sentence was divided into five regions. This division is shown below, with a slash between regions and optional material in parentheses:

(6) (Either) the boys will use/the skis(,)/or the sled/ will make/the deliveries.

The second sentence was analyzed as a single region.

No differences were expected on the initial region of the critical sentence, with the exception of longer reading times when *either* was present due to the increase in length. On the second region (*the skis*(,)), which will be referred to as the *direct object region*, the only expected effect was a possible increase in reading times and/or regressive eye movements when the comma was present, due to clause wrap-up effects (Hirotani, Frazier, & Rayner, 2006; Rayner, Kambe, & Duffy, 2000).

The third region will be referred to as the *ambiguous region*. This region consisted of the word *or* and the following determiner and noun. The word *or* was included in a single region with the subsequent noun phrase so that effects of the comma on reading times on the preceding and subsequent regions could be easily identified, as discussed below. It is important to note that any reading time effects on the region consisting of *or* and the subsequent noun phrase are very unlikely to be driven by the word *or* itself. Due to its length, this word is likely to be fixated directly on only a minority of trials (e.g., Drieghe, Rayner, & Pollatsek, 2005). As discussed above, a central claim of this article is that a minor reanalysis takes place on this region in the *either no comma* condition, but it was not assumed that this reanalysis would have a measurable effect on eye movements.

The fourth region (*will make*) will be referred to as the *disambiguating region*, and the fifth region (*the deliveries*) as the *final region*. The disambiguating region consisted of the two words immediately following the ambiguous region, except for a few items in which the entire verb phrase in the second clause was two words in length, in which case the disambiguating and final regions consisted of one word each. A garden path effect was expected on the disambiguating region in both of the no comma conditions. The size of this garden path effect was expected to be similar in the *either no comma* and *no either no comma* conditions, on early eye movement measures; the critical question was whether this effect would be smaller in the *either no comma* condition on later eye movement measures.

Four lists were created from the 24 sets of experimental sentences, so that each list contained six sentences of each type, and one version of each item. The experimental sentences were intermixed with 92 filler items, for a total of 116 items. The sentences were presented in an individually randomized order to each participant.

Procedure

Participants were tested individually. Eye movements were recorded using a Fourward Technologies Dual Purkinje Image eyetracker, which has an angular resolution of less than 10 min of arc. The eyetracker was interfaced with an IBM compatible computer. Each item in this experiment was displayed on two lines, with the critical sentence on the first line, and the second, noncritical sentence on the second line. While viewing was binocular, only the right eye was monitored. Stimuli were displayed on a 15-inch NEC MultiSync 4FG monitor. Participants were seated 61cm from the computer screen; at this distance, 3.8 characters subtended 1° of visual angle.

On arrival at the laboratory, participants were given instructions and had a bite bar prepared for them that served to stabilize the head. A calibration routine was performed, and its accuracy was checked after each sentence. Participants were instructed to read for understanding, and to read at a normal rate. After reading each pair of sentences, the participants pressed a button to remove the stimulus. The first eight trials of the experimental session were practice trials. Comprehension was checked on approximately one-third of all trials during the experiment by presenting the participant with a yes/no question. Average accuracy for these questions was 88%, with no participant scoring below 74%. The entire experiment lasted approximately 30 min.

Results

Four reading time measures were computed for each region: *first fixation duration*, *first pass time* (which is referred to as *gaze duration* when discussing single-word regions), *go-past time*, and *percent regressions* (Rayner, 1998). First fixation duration is simply the duration of the first fixation in a region, whether it is the only fixation in the region or the first of multiple fixations. This measure is often used with single-word regions as an index of lexical processing difficulty (e.g., Reichle, Rayner, & Pollatsek, 2003). However, it has also been shown to be sensitive to difficulty associated with syntactic disambiguation (e.g., Frazier & Rayner, 1982). In the present experiment, this measure is of interest primarily on the disambiguating region, but for completeness, it is reported for all regions. First pass time is the sum of all fixations in a region prior to leaving the region for the first time, either to the left or the right. Go-past time, which is also known as *regression path duration* (e.g., Rayner & Duffy, 1986) is the sum of all fixation durations from when

the reader first fixates the region until the reader's eyes leave the region to the right, including any time spent to the left of the region after a regressive eye movement and any time spent re-reading material in the region before moving on. The percent regressions measure gives the probability that a reader makes a regressive eye movement after fixating the region. This measure includes only regressions made during the reader's first pass through the region; it does not include regressions made after re-fixating the region. Effects of syntactic reanalysis are often apparent in the go-past and regression measures. (See Staub & Rayner, in press, for more detailed discussion of the interpretation of these and other eye movement measures.) Planned supplementary analyses were also carried out to isolate effects of the experimental manipulations on reanalysis. These supplementary analyses are discussed in detail below.

Prior to all analyses, sentences with track losses were excluded (4.2% of trials). In addition, fixations less than 80 ms in duration, and within one character of the previous or subsequent fixation, were incorporated into this neighboring fixation. Remaining fixations of less than 80 ms were deleted, as were fixations of longer than 800 ms. It is thought that readers do not extract useful information from fixations shorter than 80 ms (see Rayner & Pollatsek, 1989), and that fixations longer than about 800 ms are likely to reflect track losses. Less than 1.5% of all fixations were eliminated based on these criteria.

For each measure on each region two ANOVAs were performed, treating participants (F_1) and items (F_2) as random effects variables. The presence or absence of *either* and the presence or absence of a comma were treated as within-participants or within-items factors. In all ANOVAs, counterbalancing group was treated as a between-participants or between-items factor (Pollatsek & Well, 1995). Table 1 presents the participant means, on each measure, for each of the analysis regions in the first sentence, together with the standard errors of these means. Table 2 presents the results of the F tests, along with MinF'. The results for each region are discussed separately in the following sections. Results are reported as significant if both the participants and items analyses rejected the null hypothesis at the .05 level; for these results the 95% confidence interval for the difference between participant means is also reported, using the method for within-participant designs recommended by Masson and Loftus (2003; Loftus & Masson, 1994). Fig. 2 displays the go-past times for regions 2–5 of the critical sentence, together with within-participant standard errors of these means (Masson & Loftus, 2003).

Table 1
Experiment 1 participant mean reading times, in milliseconds, and percent regressions

Measure	Initial region ((either) John borrowed)	Direct object region (the rake(,))	Ambiguous region (or the shovel)	Disambiguating region (turned out)	Final region (to be sufficient)
First fixation duration					
Either no comma	208 (6.7)	246 (6.0)	252 (8.5)	263 (7.3)	251 (7.3)
Either comma	210 (7.5)	244 (6.5)	241 (7.4)	258 (6.2)	246 (8.0)
No either no comma	198 (5.3)	241 (7.2)	249 (6.9)	278 (7.9)	262 (8.6)
No either comma	200 (7.2)	242 (6.5)	253 (8.6)	265 (8.0)	247 (7.3)
First pass time					
Either no comma	936 (33.6)	348 (12.5)	514 (20.7)	368 (15.2)	411 (15.6)/*441 (19.9)
Either comma	938 (32.5)	353 (18.4)	456 (19.8)	336 (10.6)	385 (18.4)/*398 (22.4)
No either no comma	718 (21.4)	341 (11.9)	527 (24.9)	380 (15.5)	410 (21.8)/*443 (28.5)
No either comma	726 (29.2)	335 (13.8)	522 (24.3)	366 (12.9)	410 (17.8)/*415 (21.7)
Go-past time					
Either no comma	936 (33.6)	390 (16.5)	530 (21.0)	386 (16.3)	517 (25.5)/**55 (12.6)
Either comma	938 (32.5)	393 (19.4)	482 (20.5)	363 (14.0)	473 (29.7)/**56 (16.2)
No either no comma	718 (21.4)	369 (13.6)	539 (24.9)	427 (24.1)	663 (55.5)/**181 (43.2)
No either comma	726 (29.2)	406 (19.6)	557 (27.8)	392 (17.0)	522 (27.8)/**75 (20.3)
Percent regressions					
Either no comma	0	8.2 (1.92)	2.3 (.99)	4.9 (1.34)	18.5 (3.28)
Either comma	0	10.8 (2.87)	2.8 (1.06)	5.1 (1.59)	18.3 (3.44)
No either no comma	0	6.3 (2.06)	1.6 (.91)	6.6 (1.71)	29.8 (4.12)
No either comma	0	13.5 (2.93)	3.4 (1.34)	5.3 (1.79)	20.7 (4.30)

Note: Standard error of the mean is in parentheses. A single asterisk (*) is used to denote first pass time on the final region based on trials on which first-pass reading of this region was not terminated by a regressive eye movement. Two asterisks (**) denote time spent to the left of the final region after entering this region, but before leaving it to the right. See the text for discussion of these analyses.

Table 2
Experiment 1 F values for tests of main effects and interaction effect

Measure	Initial region ((either) John borrowed)	Direct object region (the rake(,))	Ambiguous region (or the shovel)	Disambiguating region (turned out)	Final region (to be sufficient)
First fixation duration					
Either	$F_1 = 8.05$, $p < .01$ $F_2 = 6.16$, $p < .05$ Min$F'(1,45) = 3.49$, $p = .07$	Fs < 1.5	Fs < 1.5	$F_1 = 3.27$, $p = .08$ $F_2 = 3.17$, $p = .09$ Min$F'(1,48) = 1.61$, $p = .21$	Fs < 1.5
Comma	Fs < 1.5	Fs < 1.5	Fs < 1.5	$F_1 = 3.24$, $p = .08$ $F_2 = 8.59$, $p < .01$ Min$F'(1,49) = 2.35$, $p = .13$	$F_1 = 2.56$, $p = .12$ $F_2 = 1.93$, $p = .18$ Min$F'(1,45) = 1.10$, $p = .30$
Either × comma	Fs < 1.5	Fs < 1.5	$F_1 = 3.26$, $p = .08$ $F_2 = 3.80$, $p = .07$ Min$F'(1,50) = 1.75$, $p = .19$	Fs < 1.5	Fs < 1.5
First pass time					
Either	$F_1 = 150.53$, $p < .01$ $F_2 = 251.16$, $p < .01$ Min$F'(1,51) = 94.12$, $p < .01$	$F_1 = 1.80$, $p = .19$ $F_2 = 1.47$, $p = .24$ Min$F'(1,46) = .81$, $p = .37$	$F_1 = 11.73$, $p < .01$ $F_2 = 15.41$, $p < .01$ Min$F'(1,51) = 6.66$, $p < .02$	$F_1 = 3.77$, $p = .06$ $F_2 = 3.06$, $p = .10$ Min$F'(1,46) = 1.69$, $p = .20$	$F_1 = 1.02$, $p = .32$ $F_2 = 2.36$, $p = .14$ Min$F'(1,50) = .71$, $p = .40$
Comma	Fs < 1.5	Fs < 1.5	$F_1 = 6.12$, $p < .02$ $F_2 = 4.86$, $p < .05$ Min$F'(1,46) = 2.71$, $p = .11$	$F_1 = 6.96$, $p < .02$ $F_2 = 6.68$, $p < .02$ Min$F'(1,48) = 3.41$, $p = .07$	Fs < 1.5
Either × comma	Fs < 1.5	Fs < 1.5	$F_1 = 3.67$, $p = .06$ $F_2 = 4.95$, $p < .05$ Min$F'(1,51) = 2.11$, $p = .15$	Fs < 1.5	Fs < 1.5
Go-past time					
Either	$F_1 = 150.53$, $p < .01$ $F_2 = 251.16$, $p < .01$ Min$F'(1,51) = 94.12$, $p < .01$	Fs < 1.5	$F_1 = 9.83$, $p < .01$ $F_2 = 10.44$, $p < .01$ Min$F'(1,49) = 5.06$, $p < .05$	$F_1 = 6.88$, $p < .02$ $F_2 = 4.34$, $p = .05$ Min$F'(1,42) = 2.66$, $p = .11$	$F_1 = 10.49$, $p < .01$ $F_2 = 8.91$, $p < .01$ Min$F'(1,47) = 4.82$, $p < .05$
Comma	Fs < 1.5	$F_1 = 4.55$, $p < .05$ $F_2 = 1.35$, $p = .26$ Min$F'(1,31) = 1.04$, $p = .32$	$F_1 = 2.14$, $p = .15$ $F_2 = 1.43$, $p = .25$ Min$F'(1,43) = .86$, $p = .36$	$F_1 = 4.40$, $p < .05$ $F_2 = 4.92$, $p < .05$ Min$F'(1,50) = 2.32$, $p = .13$	$F_1 = 6.32$, $p < .02$ $F_2 = 14.05$, $p < .01$ Min$F'(1,50) = 4.36$, $p < .05$
Either × comma	Fs < 1.5	$F_1 = 2.25$, $p = .14$ $F_2 = 3.28$, $p = .09$ Min$F'(1,51) = 1.33$, $p = .25$	$F_1 = 6.37$, $p < .02$ $F_2 = 9.06$, $p < .01$ Min$F'(1,51) = 3.74$, $p = .06$	Fs < 1.5	$F_1 = 3.83$, $p = .059$ $F_2 = 4.43$, $p < .05$ Min$F'(1,50) = 2.05$, $p = .16$
Percent regressions					
Either	N/A	Fs < 1.5	Fs < 1.5	Fs < 1.5	$F_1 = 4.20$, $p < .05$ $F_2 = 3.74$, $p = .07$ Min$F'(1,47) = 1.98$, $p = .17$
Comma	N/A	$F_1 = 6.99$, $p < .02$ $F_2 = 5.27$, $p < .05$ Min$F'(1,45) = 3.00$, $p = .09$	$F_1 = 1.56$, $p = .22$ $F_2 = 1.27$, $p = .27$ Min$F'(,) =$	Fs < 1.5	$F_1 = 2.54$, $p = .12$ $F_2 = 2.44$, $p = .13$ Min$F'(1,48) = 1.24$, $p = .27$
Either × comma	N/A	$F_1 = 1.62$, $p = .21$ $F_2 = 3.15$, $p = .09$ Min$F'(1,51) = 1.07$, $p = .31$	Fs < 1.5	Fs < 1.5	$F_1 = 2.20$, $p = .15$ $F_2 = 2.66$, $p = .12$ Min$F'(1,51) = 1.20$, $p = .28$

Note: For participants analyses, $df = (1, 32)$; for items analyses, $df = (1, 20)$. Results of supplementary analyses of reading times for the final region are included in the text.

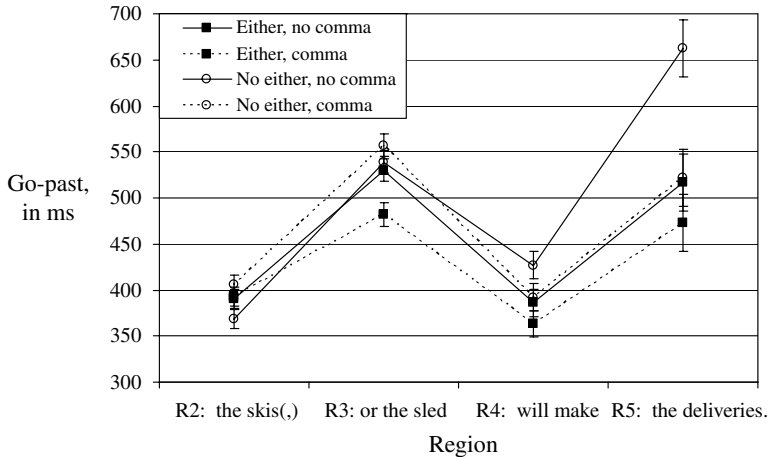

Fig. 2. Experiment 1 Go-past reading times for regions 2–5, in milliseconds. *Note:* Error bars reflect the standard error of the within-participant mean, computed according to the Masson and Loftus (2003) method.

Initial region

First pass reading times were significantly longer when *Either* was present (937 vs. 722 ms; 95% confidence interval of the difference from 179 to 251 ms), due to the increased length of the region. Because this was the first region of the sentence, no regressions were possible, and go-past time is equal to first pass time. First fixation duration was also significantly longer when *Either* was present (209 vs. 199 ms; 95% confidence interval of the difference from 3 to 17 ms). Low-level factors such as word length may be responsible for this effect; this issue is not explored further in the present paper. No other effects approached significance.

Direct object region

On the direct object region, the experimental manipulations did not significantly influence first fixation or first pass times. However, readers made regressive eye movements from this region more frequently when it ended with a comma (12.2 vs. 7.3%; 95% confidence interval of the difference from 1.1 to 8.7%). As noted above, this is consistent with previous findings of increased regressions before a clause-final comma (Hirotani et al., 2006; Rayner et al., 2000). There was no effect of *either* on regressions, and the interaction of the two factors was marginal by items but did not approach significance in the participants analysis. The effect of the comma on go-past times was significant by participants, but did not approach significance by items. Again, there was no hint of an effect of *either*. The interaction of the two factors was marginal by items, but not significant by participants.

Ambiguous region

On the first fixation measure, neither main effect approached significance, while the interaction was marginal by both participants and items. This marginal interaction effect was due to the fact that when the comma was present, the mean first fixation duration on this region was 12 ms shorter when *either* was also present, but when the comma was absent, the mean first fixation on this region was 3 ms longer when *either* was present. First pass reading time was significantly shorter in the presence of *either* (485 vs. 525 ms; 95% confidence interval of the difference from 16 ms to 64 ms) and in the presence of a comma (489 vs. 521 ms; 95% confidence interval of the difference from 6 to 58 ms), while the interaction of these two factors was significant by items and very close to significance ($p = .06$) by participants (interaction effect of 53 ms; 95% confidence interval from −3 to 109 ms). The frequency of regressive eye movements was not influenced by the experimental manipulations. On the go-past measure, reading time was again significantly shorter in the presence of *either* (506 vs. 548 ms; 95% confidence interval of the difference from 15 to 69 ms) but the effect of the comma was not significant. However, the interaction effect was significant by both participants and items (interaction effect of 66 ms; 95% confidence interval from 12 to 110 ms). Inspection of the pattern of means suggests that on both the first-pass and go-past measures, the interaction effect resulted from a one-versus-three pattern, with shorter reading times in the *either comma* condition than in the other three conditions.

The same studies that have found increased regressive eye movements before a clause-final comma (Hirotani et al., 2006; Rayner et al., 2000) have also found that the saccade that crosses a clause boundary tends to be longer when a comma is present at the boundary than when a comma is absent. As a result, the eyes tend to land further into the next region in the presence of a comma. To determine whether such landing position effects might have been responsible, in whole or in part, for the pattern of reading times on the ambiguous region, the mean position of the first fixation in the ambiguous region was computed, measured in

characters from the start of the region. These means were 4.18, 4.48, 4.39, and 4.69 in conditions (a) through (d), respectively. While the position of the first fixation was earlier when *either* was present, this effect did not approach significance ($ps > .10$). Consistent with the previous literature, the position of the first fixation was further to the right when a comma appeared at the end of the previous region, and this effect was marginal by participants and significant by items (4.59 vs. 4.29; $F_1(1, 32) = 2.89$, $p = .10$; $F_2(1, 20) = 4.85$, $p < .05$; Min$F'(1, 51) = 1.81$, $p = .18$). There was no hint of an interaction effect ($ps > .9$). In sum, it is possible that at least part of the effect of the comma on reading times on the ambiguous region is due to differences in the position of the first fixation in the region, with shorter reading times resulting when the eyes start out further into the region. However, it is clear that the interaction effects on this region could not be due to landing position differences. A speculative account of these interaction effects is offered in the Discussion, below.

Disambiguating region

The presence of *Either* and the presence of a comma each had a marginal facilitating influence on the duration of the first fixation on this region, while there was no hint of an interaction between these two factors. The effect of *either* remained marginal on the first pass measure, while the effect of a comma reached full significance, with a 23 ms advantage when the comma was present (351 vs. 374 ms; 95% confidence interval of the difference from 5 to 41 ms). Again, the interaction of the two factors did not approach significance. The frequency of regressive eye movements was not influenced by the experimental manipulations, and there were few regressive eye movements overall. Finally, on the go-past measure both main effects were significant, with shorter reading times when *Either* was present (375 vs. 410 ms; 95% confidence interval of the difference from 7 to 63 ms), and when a comma was present (378 vs. 407 ms; 95% confidence interval from 1 to 57 ms). Again, there was no hint of an interaction effect.

It is important to note that the significant reading time effects on the disambiguating region are not due to landing position effects. An analysis of the position of the first fixation in this region revealed no hints of effects of the experimental manipulations (all $ps > .5$).

Final region

There were no significant effects of the experimental manipulations on the duration of the first fixation in this region or on first pass time. However, there were significant differences in the probability of regressing from this region in different conditions, as discussed below, and as a result first pass time may have been differentially influenced by trials in which the reader regressed after making only one or two fixations (see Altmann, Garnham, & Dennis, 1992; Rayner & Sereno, 1994; Staub & Clifton, 2006). Therefore, first pass time for those trials on which readers did not make a regressive eye movement was also computed. On this measure, reading times were shorter when there was a comma (407 vs. 442 ms), though this difference was significant only in the participants analysis ($F_1(1, 32) = 4.97$, $p = .03$, $F_2(1, 20) = 3.06$, $p = .10$, Min$F'(1, 42) = 1.89$, $p = .18$). There was no hint of an effect of *either* or an interaction effect (all $ps > .5$).

The effect of *either* on regressive eye movements was significant by subjects and marginal by items, with fewer regressions when *either* was present. Neither the effect of a comma nor the interaction effect reached significance. However, planned comparisons revealed that while the presence of a comma significantly reduced the frequency of regressive eye movements when *either* was absent (29.8% vs. 20.7%; $t_1(35) = 2.06$, $p < .05$; $t_2(23) = 2.29$, $p < .05$), there was no hint of such an effect when *either* was present (18.3 vs. 18.5%; $ps > .5$). On the go-past measure, the presence of *either* significantly reduced reading times (495 vs. 593 ms; 95% confidence interval of the difference from 36 to 160 ms), and the comma did as well (498 vs. 590 ms; 95% confidence interval of the difference from 17 to 167 ms) while the interaction effect was significant by items and almost significant ($p = .059$) by participants (interaction effect of 97 ms; 95% confidence interval from −4 to 198 ms). Again, planned comparisons revealed that while the presence of a comma significantly reduced go-past time when *either* was absent (663 vs. 522 ms; $t_1(35) = 2.59$, $p < .02$; $t_2(23) = 3.22$, $p < .01$), the difference between the *comma* and *no comma* conditions was not significant when *either* was present (517 vs. 473 ms; $ps > .15$).

As noted above, the go-past measure is informative about reanalysis difficulty because it includes re-reading that is due to regressions initiated from the region of interest. However, because go-past time includes first pass time on the region of interest, it is far from a pure measure of reanalysis difficulty. In fact, because much of the variability in go-past time is due to first pass variability, effects of experimental manipulations on reanalysis difficulty may be missed even in the go-past measure. In order to focus more closely on the process of reanalysis itself, the mean time spent to the left of the final region after first fixating it, and before leaving it to the right, was computed (see Staub & Clifton, 2006). For ease of discussion, this measure will be referred to as *regression path left*. On this measure there were shorter reading times in the presence of *either* (56 vs. 128 ms; $F_1(1,32) = 10.47$, $p < .01$, $F_2(1,20) = 7.00$, $p < .02$, Min$F'(1, 43) = 4.20$, $p < .05$; 95% confidence interval of the difference from 27 to 117 ms), shorter reading times in the presence of the comma (66 vs. 118 ms; $F_1(1,32) = 4.18$, $p < .05$, $F_2(1,20) = 6.21$, $p < .05$, Min$F'(1, 51) = 2.50$, $p = .12$; 95% confidence interval

of the difference from 0 ms to 104 ms), and a significant interaction between these two factors ($F_1(1,32) = 7.59$, $p < .02$, $F_2(1,20) = 6.54$, $p < .02$, $\mathrm{Min}F'(1, 47) = 3.51$, $p = .07$; 107 ms interaction effect; 95% confidence interval from 28 to 186 ms). The time spent to the left of the region was almost two-and-a-half times as long in the *no either no comma* condition as in the *no either comma* condition (181 vs. 75 ms); when *either* was present, there was essentially no difference between conditions (55 vs. 56 ms).

Second sentence

There were no significant effects of the experimental manipulations on any of the reading time measures on this region, though the pattern of first pass and go-past means mirrored that found for go-past time on the final region: when *either* was absent, reading times were longer when the comma was absent, but when *either* was present there was no corresponding difference. The go-past means are illustrative: 1443 in the *either no comma* condition, 1435 ms in the *either comma* condition, 1502 ms in the *no either no comma* condition, and 1418 ms in the *no either comma* condition. There were significantly fewer regressions from this second sentence when *either* was present (4.2 vs. 7.3%; $F_1(1,32) = 4.93$, $p < .05$, $F_2(1,20) = 4.96$, $p < .05$, $\mathrm{Min}F'(1, 49) = 2.47$, $p = .12$; 95% confidence interval of the difference from 0.3 to 5.9%). The comma and the interaction of the two factors did not significantly affect the regression rate.

Discussion

The findings that emerged from this experiment will be discussed in the order in which they appeared in the critical sentences. On the ambiguous region, there was an almost significant interaction of the comma and *either* in first pass time, and a fully significant interaction in go-past time. This resulted from a one-versus-three pattern, with faster reading in the *either comma* condition than in the other three conditions. This finding could be interpreted as reflecting the mild reanalysis that is predicted to take place on the ambiguous noun phrase in the *either no comma* condition. As noted above, Staub and Clifton (2006) found that in general an *or noun phrase* string is read more quickly when *either* is present than when *either* is absent. In the present experiment, then, it is possible that the one-versus-three pattern resulted from a combination of this facilitation from *either* and a reanalysis effect, working in the opposite direction, in the *either no comma* condition. Obviously this is a somewhat speculative account (especially because the effect of the comma itself also must be taken into consideration), though it has some degree of plausibility.

The first critical prediction for the present experiment was of a garden path effect on the disambiguating region in the *no comma* conditions. This effect was present in both first pass time and go-past time, and there was no hint of a reduction in the garden path effect in the presence of *either*. In fact, on the first pass measure there was a numerically larger garden path effect when *either* was present than when *either* was absent. These results suggest that whether or not the word *either* was present, readers did indeed adopt the noun phrase coordination analysis at the point of reading *the sled*, and were forced to abandon this analysis upon encountering the subsequent material. It appears that the probability of adopting the noun phrase coordination analysis was not reduced by the presence of *either*.

The pattern of data once the eyes reached the final region makes clear that reanalysis was easier when *either* was present. It is notable that there were no fully significant differences between the *either no comma* condition and the *either comma* condition on this region, on any measure; evidently, processing difficulty associated with the forced reanalysis in the *either no comma* condition was largely resolved by the time the eyes left the disambiguating region. By contrast, in the comparison of the *no either no comma* condition and *no either comma* condition it is clear that processing difficulty continued onto the final region. Furthermore, a significant interaction effect appeared on the regression path left measure, which focuses most specifically on reanalysis processes.

In sum, it is clear that at the point of reading *the sled*, the parser does indeed adopt a noun phrase coordination analysis, as shown in panel (b) of Fig. 1. The modulation of the garden path effect on the final region is fully consistent with the hypothesis that the ultimate adoption of the clausal coordination analysis in panel (c) is made easier by the fact that this analysis was adopted (then abandoned) at an earlier point, as shown in panel (a).

Though there are several independent reasons to accept that when *either* is present, the clausal coordination analysis is indeed constructed upon reading *or*, it remains possible that this is not what is responsible for the pattern of results in Experiment 1. Specifically, it is possible that what facilitates reanalysis in the *either no comma* condition is not retrieval, or re-activation, of the clausal coordination analysis, but simply the presence of the word *either*. Perhaps the presence of this specific lexical item in memory in some way highlights the possibility of a different coordination structure than the noun phrase coordination structure that the parser has built. One of the purposes of Experiment 2 was to determine whether a similar pattern of results would appear when there was no specific lexical cue that could guide the parser toward the correct analysis.

Experiment 2

Experiment 2 examined the processing of sentences like (7):

(7) Though the maid arrived and mopped the floor would not get clean.

Again, it was assumed that the parser passes through three critical stages, illustrated in Fig. 3. At the point of processing *Though the maid arrived and mopped*, the parser was assumed to analyze the subordinate clause verb phrase as involving an intransitive verb-and-verb structure, as shown in panel (a) of Fig. 1, due to the parallelism preference in coordinate structures (e.g., Frazier, Munn, & Clifton, 2000; Frazier, Taft, Roeper, Clifton, & Ehrlich, 1984; Schepman & Rodway, 2000). This parallelism preference has been demonstrated in both comprehension and production tasks. In an eye movement experiment, Frazier et al. (2000) demonstrated a

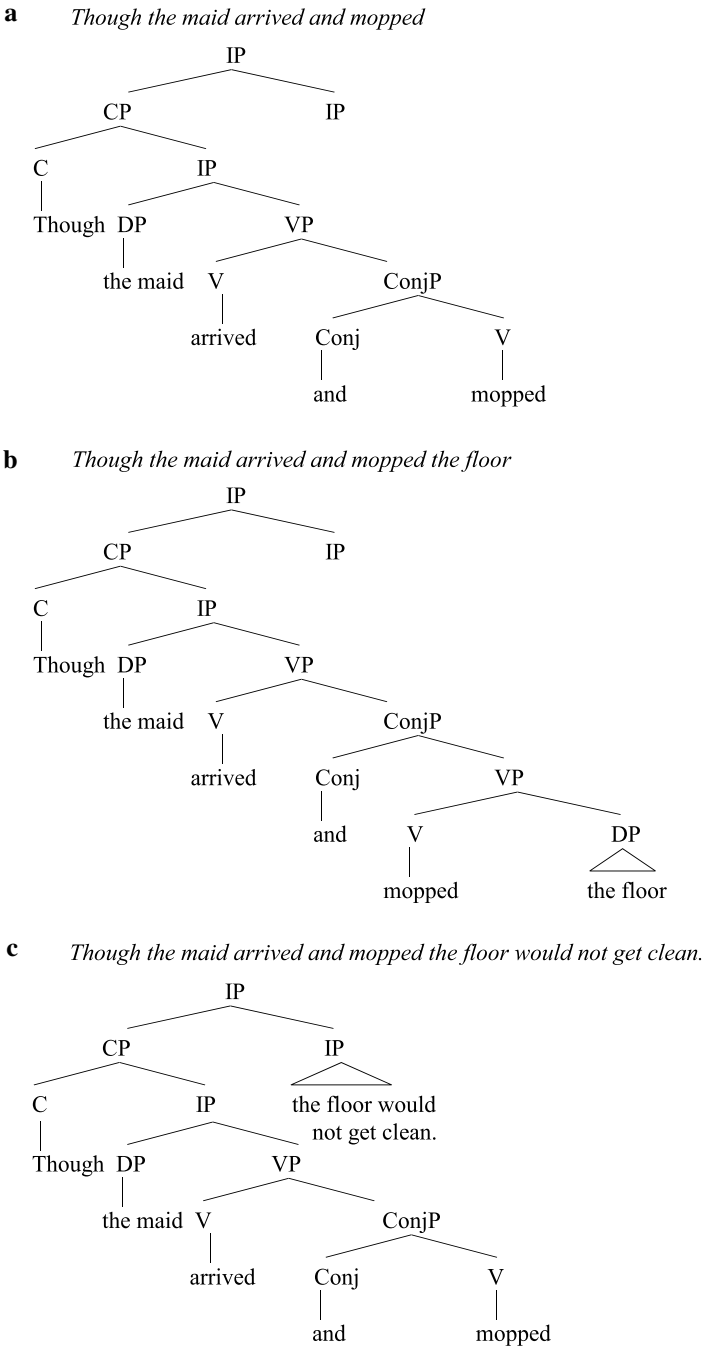

Fig. 3. Postulated stages in the parser's analysis of sentence (7).

processing advantage for coordinate structures in which the internal structure of the two conjuncts was identical. Schepman and Rodway (2000) had participants perform a cloze task in which they were to fill in the missing auxiliary verb (*was* or *were*) in sentences like (8):

(8) The lawyer greeted the powerful barrister and the wise judge who _____ walking to the courtroom.

A plural auxiliary was used 87% of the time, indicating a very strong preference to interpret the relative clause beginning with *who* as modifying the coordinate structure *the powerful barrister and the wise judge*, rather than just the second conjunct (see also Altmann, Henstra, & Garnham, 1993). This result is plausibly interpreted as reflecting the parallelism preference; only if the relative clause modifies the conjoined structure as a whole is parallelism of the internal structure of the conjuncts maintained. Notably, the preference for "high" attachment of the relative clause to the conjoined structure as a whole, rather than "low" attachment to the second noun phrase, is not predicted by the principle of Late Closure (Frazier, 1978, 1987a), or by other structural heuristics such as recency (e.g., Phillips & Gibson, 1997). Furthermore, readers have been shown in at least some studies to prefer to attach relative clauses to the most recent noun phrase in a construction like *the servant of the actress who was on the balcony* (see, e.g., Traxler, Pickering, & Clifton, 1998, for Discussion).

As in Experiment 1, a completion norming study was used to confirm the hypothesis that the analysis in panel (a) of Fig. 3 is indeed the preferred analysis at the point of reading *mopped* in (7). The frequency of intransitive completions was increased significantly by the presence of a coordinated verb phrase in the subordinate clause. The details are discussed below.

At the point of reading *the floor* in (7), it was again hypothesized that a very minor reanalysis takes place, with the parser making a direct object attachment. The preference to attach a post-verbal noun phrase as the direct object has been shown to be extremely strong, appearing even with preferentially intransitive verbs (Pickering et al., 2000) and even when the resulting interpretation is implausible (Pickering & Traxler, 1998). In the present experiment, by contrast, the critical verb had a frequent transitive frame, and the resulting interpretation was highly plausible. This analysis is shown in panel (b) of Fig. 3.

Finally, the subordinate clause object analysis is shown to be untenable upon reaching the verb *would* in (7). At this point, the parser must (re-)construct an analysis on which the verb *mopped* is intransitive, and must make *the floor* the subject of a new clause. This analysis is shown in panel (c) of Fig. 3. The critical question, as in Experiment 1, is whether the move from the analysis in panel (b) to the analysis in panel (c) is easier when the intransitive analysis in (a) was previously constructed than in a comparable sentence in which this intransitive analysis was not previously constructed. In Experiment 2, the comparison was to a sentence in which the subordinate clause verb phrase did not contain a verb-and-verb structure (e.g., *Though the maid mopped the floor would not get clean.*), so that the preference for parallelism in coordinate structures would not have been initially operative in supporting an intransitive analysis of the critical verb.

Methods

Participants

Thirty-six native speakers of American English, who were students at the University of Massachusetts, Amherst, were given course credit or were paid $7 to participate in the experiment. All had normal or corrected-to-normal vision, and all were naïve to the purpose of the experiment.

Materials

Twenty-four sets of sentences like (9a-d) were constructed.

(9) a. Though the maid arrived and mopped the floor would not get clean.
b. Though the maid arrived and mopped, the floor would not get clean.
c. Though the maid mopped the floor would not get clean.
d. Though the maid mopped, the floor would not get clean.

Versions a–d will be referred to, respectively, as the *coordination no comma* condition, the *coordination comma* condition, the *no coordination no comma* condition, and the *no coordination comma* condition. Unlike in Experiment 1, there was no second sentence. The full set of materials is presented in the Appendix.

Two main criteria were used in constructing these materials. First, the subject noun phrase of the second clause was selected to be a very plausible object for the final verb of the initial clause (e.g., *mopped the floor*, *fight the enemy*), in order to induce a tendency to misanalyze this noun phrase as the verb's direct object. Second, the sentences were constructed in such a way that the "right node raising" analysis (Postal, 1974), in which a single noun phrase is the direct object of both verbs in a coordinate structure (e.g., *Barbara likes to collect and analyze data*), was very implausible upon reaching the ambiguous noun phrase. For almost half of the items, the initial verb in the verb-and-verb construction was a pure intransitive, either an unaccusative (e.g., *blossom*, *arrive*)

or an unergative (*lie*, *sprint*; see Levin & Rappaport Hovav, 1995, for detailed discussion of this distinction and criteria for classification). With these verbs, a direct object is prohibited in all but a few special constructions, and as a result, the right node raising analysis could be ruled out on the basis of ungrammaticality (e.g., **blossom their leaves*, **arrived the floor*, **lie the money*, **sprint the barrier*). For the remaining items, this initial verb did allow a transitive use, but the ambiguous noun phrase was (with the exceptions noted below) a highly implausible direct object (e.g., *traveled their songs*, *shop the dinner*, *stay the enemy*, *speak the files*). For those items in which the initial verb did allow a direct object in principle, the critical verb also tended to be intransitive-biased. Nine of these verbs appear in the corpus-based norms collected by Gahl, Jurafsky, and Roland (2004) or the production norms collected by Connine, Ferreira, Jones, Clifton, and Frazier (1984) or Pickering and Traxler (2003), and based on these sources, they have a mean probability of appearing with a direct object of .09, ranging from 0 to .23.

After the fact, it was noted that for two of the 24 items the right node raising analysis did have at least some degree of plausibility at the point of reaching the ambiguous noun phrase in the *coordination no comma* condition (i.e., *Because Alan likes to walk and contemplate the forest is his favorite place*, and *Most people think that if you relax and rest a sprained ankle will heal fast*). Subsequent examination of the eye movement data revealed that these two items did not differ notably from the overall patterns.

To assess whether the parallelism preference does in fact result in a preference for an intransitive verb at the end of the subordinate clause in a sentence like (9a), compared to (9c), the materials designed for the eye movement study were included together with the materials from Experiment 1 in the written completion norming study discussed above. No participant who participated in this off-line study took part in the present eye movement experiment. Participants were provided with each of the experimental items up to, but not including, the critical subordinate clause verb, half with and half without coordination (e.g., a participant would receive either *Though the maid arrived and* or *Though the maid*). A small pilot study suggested that including the critical verb in the fragment produces ceiling effects in terms of the number of intransitive completions, since participants interpreted the end of the fragment as the end of the clause. The materials were counterbalanced so that each item was completed by eight participants in each of its two versions. Participants were instructed to complete each fragment with the first response that came to mind.

Participants began the completion with a verb phrase 94% of the time in the *coordination* condition and 95% of the time in the *no coordination* condition. A completion was scored as intransitive only if the participant ended the subordinate clause with a intransitive verb; e.g., a verb followed by a prepositional phrase or adverbial modifier was not scored as intransitive. In the *coordination* condition, 61% of all verb phrase completions were intransitive, compared to 45% in the *no coordination* condition. This difference was significant by both participants and items ($t_1(15) = 2.44$, $p < .05$; $t_2(23) = 2.52$, $p < .02$). It is worth noting that these means include a single participant who was an extreme outlier in the opposite direction from the main trend, completing the subordinate clauses with an intransitive verb 11% of the time in the *coordination* condition, compared to 75% of the time in the *no coordination* condition. Excluding this participant, 65% of verb phrase completions in the *coordination* condition were intransitive, compared to 44% in the *no coordination* condition. In sum, the norming data clearly demonstrate that the preference for parallelism in coordinate structures does result in a relative preference for the subordinate clause to end with an intransitive verb, at least in a written production task.

For the purpose of analysis of the eye movement data, each sentence was divided into five regions. This division is shown below, with a slash between regions and optional material in parentheses:

(10) Though the maid (arrived and)/mopped(,)/the floor/would not/get clean.

Obviously, reading time differences would be expected on the initial region, due to increased length in the *coordination* conditions. On the next region (*mopped(,)*), referred to as the *verb region*, clause wrap-up effects (Hirotani et al., 2006, Rayner et al., 2000) were expected in the *comma* conditions, in the form of increased regressions and longer go-past times. On the next region (*the floor*), which will be referred to as the *ambiguous region*, no specific predictions were made, though a possible landing position effect was anticipated, with an earlier initial landing position in this region in the *no comma* conditions (Hirotani et al., 2006; Rayner et al., 2000). The hypothesized reanalysis on this region in the *coordination no comma* condition was assumed to be very minor.

The critical regions for testing the hypotheses under consideration were the *disambiguating region* (*would not*) and the *final region* (*get clean*). Signs of early processing difficulty were expected to appear in the *no comma* conditions, not modulated by the coordination manipulation. Facilitation of reanalysis in the *coordination no comma* condition was expected to appear on later measures, consistent with the results of Experiment 1.

As in Experiment 1, four lists were created from the 24 sets of experimental sentences, so that each list con-

tained six sentences of each type, and one version of each item. The experimental sentences were intermixed with 118 filler items, for a total of 142 items. The sentences were presented in an individually randomized order to each participant.

Procedure

The procedure was identical to Experiment 1. Average accuracy on the post-sentence comprehension questions was 94%, with no participant scoring below 80%. As in Experiment 1, the entire experiment lasted approximately 30 min.

Results

The same four basic reading time measures were computed as in Experiment 1, with the same supplementary analyses of reading times on the final region. Less than 4% of trials were excluded due to track losses, and less than 2.5% of the remaining fixations were excluded due to falling outside the 80–800 ms range. The same statistical analyses were carried out as in Experiment 1. Table 3 presents the participant means for each of the principal measures, for each region, together with standard errors, and Table 4 presents the *F* statistics. Fig. 4 displays the go-past reading times in each condition for regions 2–5. The regions are discussed individually below.

Initial region

As expected, first pass time (and, consequently, go-past time) were longer in the *coordination* conditions than in the *no coordination* conditions, due to the fact that two additional words appeared in these conditions (1373 vs. 930 ms; 95% confidence interval of the difference from 394 to 492 ms). No other effects approached significance.

Verb region

There were significantly more regressions from the clause-final verb when a comma was present at the clause boundary (14.7 vs. 4.2%; 95% confidence interval of the difference from 6.5 to 14.5%), consistent with previous findings of increased regressions before a clause-final comma (Hirotani et al., 2006; Rayner et al., 2000). As a result, go-past time was also longer in the comma conditions (386 vs. 337 ms; 95% confidence interval of the difference from 19 to 79 ms).

There was also a significant effect of coordination on first pass time, with shorter first pass times in the absence of coordination (300 vs. 325 ms; 95% confidence interval of the difference from 4 to 46 ms). This effect

Table 3
Experiment 2 participant mean reading times, in milliseconds, and percent regressions

Measure	Initial region (though the maid (arrived and))	Verb region (mopped(,))	Ambiguous region (the floor)	Disambiguating region (would not)	Final region (get clean.)
First fixation duration					
Coord no comma	213 (5.8)	283 (9.9)	277 (9.3)	295 (10.3)	304 (12.6)
Coord comma	217 (7.2)	279 (10.1)	268 (7.0)	280 (9.9)	293 (10.5)
No coord no comma	213 (6.4)	264 (5.6)	276 (7.2)	293 (11.3)	299 (8.6)
No coord comma	211 (4.6)	273 (9.2)	265 (6.2)	268 (7.7)	301 (9.5)
First pass time					
Coord no comma	1382 (49.8)	324 (12.4)	401 (25.6)	370 (16.7)	403 (19.5)/*433 (35.3)
Coord comma	1363 (60.2)	326 (14.8)	374 (16.9)	350 (14.1)	384 (15.2)/*421 (25.7)
No coord no comma	929 (36.9)	299 (10.9)	418 (16.6)	391 (16.3)	384 (16.4)/*418 (28.6)
No coord comma	931 (48.9)	301 (14.3)	388 (16.8)	350 (14.9)	408 (21.2)/*418 (18.2)
Go-past time					
Coord no comma	1382 (49.8)	339 (15.4)	420 (25.4)	440 (30.5)	528 (39.0)/**94 (30.4)
Coord comma	1363 (60.2)	392 (23.0)	411 (17.2)	377 (17.7)	478 (27.0)/**68 (13.8)
No coord no comma	929 (36.9)	334 (17.1)	446 (17.9)	476 (44.6)	678 (53.9)/**230 (44.1)
No coord comma	931 (48.9)	379 (21.3)	426 (20.2)	401 (21.3)	535 (42.5)/**97 (25.7)
Percent regressions					
Coord no comma	0	3.0 (1.17)	3.7 (1.16)	10.6 (2.76)	30.1 (5.69)
Coord comma	0	14.8 (3.09)	5.2 (1.75)	5.8 (2.02)	26.3 (4.13)
No coord no comma	0	5.3 (2.11)	4.6 (1.42)	9.8 (2.25)	40.2 (4.64)
No coord comma	0	14.5 (3.03)	4.6 (1.42)	8.7 (2.35)	30.5 (5.10)

Note: Standard error of the mean is in parentheses. A single asterisk (*) is used to denote first pass time on the final region based on trials on which first-pass reading of this region was not terminated by a regressive eye movement. Two asterisks (**) denote time spent to the left of the final region after entering this region, but before leaving it to the right. See the text for discussion of these analyses.

Table 4
Experiment 2 F values for tests of main effects and interaction effect

Measure	Initial region (though the maid (arrived and))	Verb region (mopped(,))	Ambiguous region (the floor)	Disambiguating region (would not)	Final region (get clean.)
First fixation duration					
Coordination	Fs < 1.5	$F_1 = 2.96$, $p = .10$ $F_2 = 2.38$, $p = .14$ Min$F'(1, 46) = 1.32$, $p = .26$	Fs < 1.5	Fs < 1.5	Fs < 1.5
Comma	Fs < 1.5	Fs < 1.5	$F_1 = 3.42$, $p = .07$ $F_2 = 2.87$, $p = .11$ Min$F'(1, 46) = 1.56$, $p = .22$	$F_1 = 9.40$, $p < .01$ $F_2 = 7.13$, $p < .02$ Min$F'(1, 45) = 4.05$, $p = .05$	Fs < 1.5
Coord × comma	$F_1 = .65$, $p = .43$ $F_2 = 1.74$, $p = .20$ Min$F'(1, 49) = .47$, $p = .50$	Fs < 1.5	Fs < 1.5	Fs < 1.5	Fs < 1.5
First pass time					
Coordination	$F_1 = 342.18$, $p < .001$ $F_2 = 302.94$, $p < .001$ Min$F'(1, 47) = 160.68$, $p < .001$	$F_1 = 6.06$, $p < .02$ $F_2 = 6.88$, $p < .02$ Min$F'(1, 50) = 3.22$, $p = .08$	$F_1 = 2.57$, $p = .12$ $F_2 = 3.53$, $p = .08$ Min$F'(1, 51) = 1.49$, $p = .23$	$F_1 = .79$, $p = .38$ $F_2 = 1.53$, $p = .23$ Min$F'(1, 51) = .52$, $p = .47$	Fs < 1.5
Comma	Fs < 1.5	Fs < 1.5	$F_1 = 6.01$, $p < .05$ $F_2 = 6.86$, $p < .02$ Min$F'(1, 50) = 3.20$, $p = .08$	$F_1 = 13.75$, $p < .01$ $F_2 = 5.35$, $p < .05$ Min$F'(1, 35) = 3.85$, $p = .06$	Fs < 1.5
Coord × comma	Fs < 1.5	Fs < 1.5	Fs < 1.5	Fs < 1.5	$F_1 = 3.71$, $p = .06$ $F_2 = .83$, $p = .37$ Min$F'(1, 29) = .68$, $p = .42$
Go-past time					
Coordination	$F_1 = 342.18$, $p < .001$ $F_2 = 302.94$, $p < .001$ Min$F'(1, 47) = 160.68$, $p < .001$	Fs < 1.5	$F_1 = 3.36$, $p = .08$ $F_2 = 2.68$, $p = .12$ Min$F'(1, 46) = 1.49$, $p = .23$	$F_1 = 1.19$, $p = .28$ $F_2 = 2.13$, $p = .16$ Min$F'(1, 51) = .76$, $p = .39$	$F_1 = 7.01$, $p < .02$ $F_2 = 13.85$, $p < .01$ Min$F'(1, 51) = 4.65$, $p < .05$
Comma	Fs < 1.5	$F_1 = 10.93$, $p < .01$ $F_2 = 8.47$, $p < .01$ Min$F'(1, 45) = 4.77$, $p < .05$	$F_1 = 1.70$, $p = .20$ $F_2 = 1.15$, $p = .30$ Min$F'(1, 43) = .69$, $p = .41$	$F_1 = 10.14$, $p < .01$ $F_2 = 9.15$, $p < .01$ Min$F'(1, 47) = 4.81$, $p < .05$	$F_1 = 10.73$, $p < .01$ $F_2 = 9.35$, $p < .01$ Min$F'(1, 47) = 5.00$, $p < .05$
Coord × comma	Fs < 1.5	Fs < 1.5	Fs < 1.5	Fs < 1.5	$F_1 = 3.22$, $p = .08$ $F_2 = 6.21$, $p < .05$ Min$F'(1, 51) = 2.12$, $p = .15$
Percent regressions					
Coordination	N/A	Fs < 1.5	Fs < 1.5	Fs < 1.5	$F_1 = 3.19$, $p = .09$ $F_2 = 3.08$, $p = .10$ Min$F'(1, 48) = 1.57$, $p = .22$
Comma	N/A	$F_1 = 29.20$, $p < .001$ $F_2 = 25.33$, $p < .001$ Min$F'(1, 47) = 13.56$, $p < .001$	Fs < 1.5	$F_1 = 2.13$, $p = .15$ $F_2 = 1.71$, $p = .21$ Min$F'(1, 46) = .95$, $p = .36$	$F_1 = 2.93$, $p = .10$ $F_2 = 3.43$, $p = .08$ Min$F'(1, 50) = 1.58$, $p = .22$
Coord × comma	N/A	Fs < 1.5	Fs < 1.5	Fs < 1.5	$F_1 = .97$, $p = .33$ $F_2 = 2.61$, $p = .12$ Min$F'(1, 49) = .71$, $p = .40$

Note: For participants analyses, $df = (1, 32)$; for items analyses, $df = (1, 20)$. Results of supplementary analyses of reading times for the final region are included in the text.

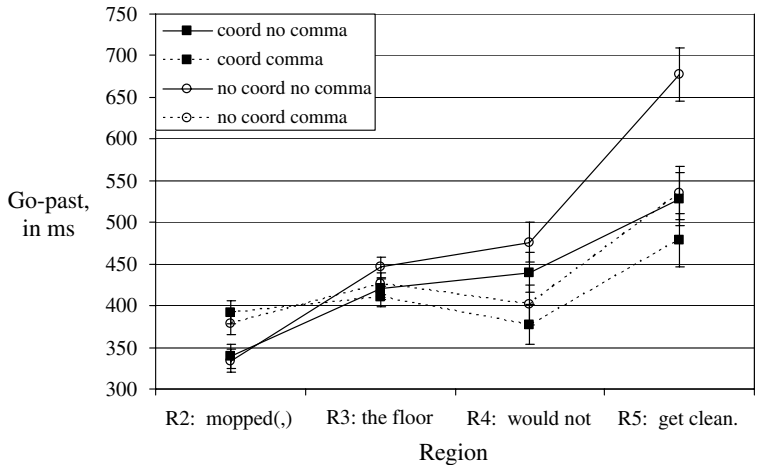

Fig. 4. Experiment 2 Go-past reading times for regions 2–5, in milliseconds. *Note:* Error bars reflect the standard error of the within-participant mean, computed according to the Masson and Loftus (2003) method.

was not predicted. However, it has a very plausible explanation in terms of a low-level (i.e., non-linguistic) factor. In the *coordination* conditions, the word that preceded the verb was always *and*, which, due to its length, is very likely to be skipped (e.g., Drieghe et al., 2005). As a result the eyes may tend to land close to left edge of the verb, compared to the *no coordination* conditions in which the word that preceded the verb was sometimes short and sometimes long. If there is in fact a landing position difference, this could have resulted in more refixations of the verb in the *coordination* conditions. In fact, a *post hoc* analysis suggests that this is likely to be the correct account. The mean position of the first fixation was 2.52 characters into the region in the *coordination* conditions, and 2.86 characters into the region in the *no coordination* conditions ($F_1(1,32) = 6.38$, $p < .02$; $F_2(1,20) = 6.66$, $p < .02$; Min$F'(1,49) = 3.26$, $p = .08$; 95% confidence interval of the difference from .06 to .62 characters). Readers made an average of 1.13 first pass fixations in the *coordination* conditions, versus 1.06 in the *no coordination* conditions; this difference was marginal by participants and significant by items ($F_1(1,32) = 3.20$, $p = .08$; $F_2(1,20) = 6.88$, $p < .02$; Min$F'(1,51) = 2.18$, $p = .15$). In sum, the effect of coordination on first pass reading time on the verb region seems to be due to the influence of oculomotor factors, rather than linguistic ones.

Ambiguous region

The only significant effect on this region was an effect of the comma on first pass time, with shorter times in the presence of a comma (381 vs. 410 ms; 95% confidence interval of the difference from 5 to 53 ms). As in Experiment 1, this is plausibly attributed to a well-documented landing position effect, with a later landing position after a comma (Hirotani et al., 2006; Rayner et al., 2000). The initial landing position was 4.82 characters into the ambiguous region when the comma was present, and 4.50 characters into the region when the comma was absent ($F_1(1,32) = 5.05$, $p < .05$; $F_2(1,20) = 4.58$, $p < .05$; Min$F'(1, 48) = 2.40$, $p = .13$; 95% confidence interval of the difference from .02 to .62 characters). It appears that, as was the case with the effect of coordination on first pass times on the verb region, the effect of the comma on first pass times on ambiguous region may be due to oculomotor factors.

As Table 4 indicates, there were several other marginal effects on the ambiguous region. However, because there were no main effects or interaction effects that reached significance at the .05 level in either the participants or the items analyses, these effects will not be discussed here.

Disambiguating region

Essentially the same pattern emerged on the first fixation, first pass, and go-past measures on the disambiguating region. There were significant effects of the comma on all three of these measures, with shorter reading times when the comma was present (First fixation: 274 vs. 294 ms; 95% confidence interval of the difference from 7 to 33 ms. First pass: 350 vs. 381 ms; 95% confidence interval of the difference from 14 to 48 ms. Go-past: 389 vs. 458 ms; 95% confidence interval of the difference from 41 to 97 ms.). The effect of coordination and the interaction effect did not approach significance on any measure. There were no significant effects of the experimental manipulations on the percent regressions measure.

In light of the role of initial landing position in producing the patterns of reading times on the previous regions, it is important to note that the effect of the comma on reading times on the disambiguating region cannot be due to landing position effects. The first fixation in this region was an average of 3.63 characters into the region in the *no comma* conditions, and 3.55 characters into the region in the *comma* conditions (*p*s > .65).

To the extent that these values differ at all, they differ in the direction that would be expected to produce more fixations, and therefore longer reading times, in the *comma* conditions. In fact, reading times were consistently longer in the *no comma* conditions.

Final region

There were no significant effects of the experimental manipulations on the first fixation and first pass measures on this region. As in the analysis of Experiment 1, first pass time for trials on which there was no regression from the region was also computed; however, there were still no significant effects. On the regressions measure there were marginal effects of both factors, with more regressions in the *no coordination* and *no comma* conditions. The interaction effect was not significant. On the go-past measure, there were significantly shorter times in the *coordination* conditions (503 vs. 607 ms; 95% confidence interval of the difference from 41 to 167 ms). There were also significantly shorter times when the comma was present (507 vs. 603 ms; 95% confidence interval of the difference from 36 to 156 ms). The interaction of the two factors was significant by items, and marginal by participants; the comma reduced go-past time by 143 ms in the *no coordination* conditions, but by only 50 ms in the *coordination* conditions (interaction effect of 93 ms; 95% confidence interval from −13 to 199 ms).

As in the analysis of Experiment 1 the regression path left measure was used to isolate reanalysis processes on the final region. There were shorter times on this measure in the *coordination* conditions (81 vs. 164 ms; $F_1(1, 32) = 5.75$, $p < .05$, $F_2(1, 20) = 18.12$, $p < .001$, $\mathrm{Min}F'(1, 47) = 4.36$, $p < .05$; 95% confidence interval of the difference from 13 to 153 ms), and shorter times in the *comma* conditions (83 vs. 162 ms; $F_1(1, 32) = 10.92$, $p < .01$, $F_2(1, 20) = 8.01$, $p < .02$, $\mathrm{Min}F'(1, 44) = 4.62$, $p < .05$; 95% confidence interval of the difference from 30 to 128 ms). The comma effect was 133 ms in the *no coordination* conditions, and only 26 ms in the *coordination* conditions, resulting in a significant interaction (interaction effect of 107 ms; $F_1(1, 32) = 6.19$, $p < .02$, $F_2(1, 20) = 6.49$, $p < .02$, $\mathrm{Min}F'(1, 49) = 3.17$, $p = .08$; 95% confidence interval from 19 to 195 ms).

Discussion

The pattern of results from this experiment is remarkably similar to the pattern from Experiment 1. On the disambiguating region, which consisted of the first two words after the point of disambiguation, there was a clear garden path effect when the comma was absent. All three reading time measures were inflated when the comma was absent, with the main difference from Experiment 1 consisting of a fully significant first fixation effect on this region. On none of these measures was there a significant interaction between the effect of the comma and the effect of coordination; the presence of a verb-and-verb structure in the subordinate clause did not significantly reduce the size of the garden path effect on the disambiguating region. This suggests that the probability of adopting the incorrect direct object analysis was not reduced by the presence of the verb-and-verb structure in the subordinate clause. But the verb-and-verb structure seems to have helped readers to resolve more easily the difficulty resulting from their initial misanalysis. Reading times for the *coordination no comma* condition were only very slightly inflated on the final region, compared to the *coordination comma* condition. By contrast, there was substantial processing difficulty on the final region in the *no coordination no comma* condition, compared to the *no coordination comma* condition. As in Experiment 1, on the final region there was a significant interaction on the regression path left measure between the effect of coordination and the effect of the comma.

It appears that readers do initially analyze *the floor* as the object of *mopped* in both (9a) and (9c). Because the next word is a verb that cannot be attached into the phrase marker on this analysis, processing difficulty results. But this difficulty is short-lived in (9a), compared to (9c), as it appears that readers are able to recover, or re-activate, the intransitive analysis of *mopped* that may have been constructed at an earlier point in the sentence. Unlike in Experiment 1, the results of Experiment 2 cannot be due to the presence of a specific lexical item that facilitates reanalysis in the *coordination no comma* condition.

General discussion

Because of the similarities in the results from Experiments 1 and 2, these results are easy to summarize. Clear garden path effects were observed on the first one or two words following disambiguation, in the form of increased reading times in the *no comma* conditions compared to the *comma* conditions. These initial garden path effects were never significantly (or even marginally) modulated by the manipulation of the other factor, the presence of *either* in Experiment 1 and the presence of a verb-and-verb structure in the subordinate clause in Experiment 2. On the other hand, processing difficulty arising after the eyes entered the next (and last) region of the sentence was significantly modulated by this other factor. When *either* was present in Experiment 1, and when the intransitive verb-and-verb structure was present in Experiment 2, re-reading of earlier portions of the sentence after entering this final region was significantly reduced.

It is very important to note that in both experiments, the critical interaction effect on the regression path left measure was obtained despite an inherent bias in the

materials against this finding. In both experiments the ambiguous condition in which there was more re-reading after entering the final region was shorter than the ambiguous condition in which there was less re-reading; this length difference was one word in Experiment 1 (the word *either*) and two words in Experiment 2 (*verb and*). If re-reading were purely random, more re-reading time would accrue in the longer sentences than in the shorter sentences, simply because there is more material to re-read in these sentences. In fact, the pattern went in the opposite direction.

A plausible interpretation of these results is that reanalysis was indeed facilitated when the reader constructed, then abandoned, the ultimately correct analysis prior to being garden-pathed by the incorrect analysis. It appears that this fleeting initial analysis was, in some sense, still present in the system at the point at which it became necessary to revise the incorrect analysis, and was accessible to reanalysis mechanisms.

Clearly, there are other possible accounts of the present data. One such alternate account might claim that in fact the parser does not have consistent attachment preferences with respect to the ambiguous material in these experiments; rather, the parser has some probability of adopting each of the possible analyses, as in a "variable choice" model such as the unrestricted race model of van Gompel and colleagues (van Gompel, Pickering, & Traxler, 2000, 2001; van Gompel, Pickering, Pearson, & Liversedge, 2005). Perhaps the presence of *either* in Experiment 1 and the presence of a verb-and-verb structure in Experiment 2 simply reduced the probability of adopting the incorrect analysis of the ambiguous material, so that reanalysis occurred less frequently in these conditions. In other words, what was affected by the critical manipulations was the frequency of reanalysis, not its severity. The chief difficulty for this account stems from the fact that while late measures of the garden path effect were modulated by the critical manipulations, early measures of the garden path effect were not.

There is another alternate account of the present data that may be considered more plausible. As noted in the discussion of Experiment 1, it could have been the presence in memory of the specific lexical item *either* that facilitated reanalysis in that experiment. There is no analogous explanation for the very similar results of Experiment 2; there was no lexical item in the *coordination no comma* condition that could have alerted the parser, during the reanalysis stage, to the possibility of an intransitive analysis. Still, it is possible that both the presence of *either* in Experiment 1 and the presence of coordination in Experiment 2 facilitated reanalysis simply by making it easier for the reader to construct the correct analysis after being garden-pathed, rather than by inducing the reader to fleetingly construct the correct analysis in the first place, prior to being garden-pathed. This account would emphasize the indirect nature of the evidence in favor of the claim that the ultimately correct analysis was, in fact, adopted prior to the main point of ambiguity in the critical conditions. This evidence comes from previous studies (Frazier et al., 2000; Staub & Clifton, 2006) that were not explicitly designed to investigate the parser's analysis at the relevant points (i.e., at the point of reading *or* in Experiment 1, and at the point of reading the subordinate clause verb in Experiment 2), and from sentence completion studies carried out in association with the present eyetracking experiments which found, first, that when sentence-initial *either* was present, *or* is about two-and-a-half times as likely to be treated as a clausal coordinator as when *either* was absent, and second, that a completion with a subordinate clause-final verb phrase was significantly more likely to consist of a simple intransitive verb when this verb phrase was preceded by *verb and*.

Such an account cannot be ruled out altogether. The chief argument against it is that it is not at all clear, on existing accounts of reanalysis, how the presence of *either* in Experiment 1 and the presence of an intransitive verb-and-verb structure in Experiment 2 would faciliate the reanalysis process. For example, neither an account of reanalysis difficulty that emphasizes differences between different kinds of structural revisions (e.g., Sturt et al., 1999) nor an account that emphasizes the length of time over which the incorrect analysis is held (e.g., Tabor & Hutchins, 2004) would predict the present findings, since the presence of *either* or a verb-and-verb structure does not change the required structural revisions, and the ambiguous region was always identical across conditions.

It may also be noted that the claim that in the critical conditions the correct analysis is adopted, then abandoned, then re-adopted contradicts the notion that reanalysis is a last resort (Fodor & Frazier, 1980; Schneider & Phillips, 2001; Sturt, Pickering, Scheepers, & Crocker, 2001). According to this view, which has been supported by several self-paced reading studies (Schneider & Phillips, 2001; Sturt et al., 2001), when local attachment preferences can be applied only by revising the parser's current analysis, preservation of the current analysis wins out. But the present account claims that in Experiment 1 readers adopted a clausal coordination analysis in the *either no comma* condition, upon reaching *or*, then abandoned it when they encountered the subsequent noun phrase, even though the clausal coordination analysis could have been preserved at this point. Similarly, the present account claims that in Experiment 2 readers adopted an intransitive analysis of the subordinate clause-final verb in the *coordination no comma* condition, then revised this analysis upon encountering the subsequent noun phrase, though the intransitive analysis could have been preserved.

It is notable that the empirical studies supporting the "reanalysis as a last resort" principle have explored only one structure, in which a particular type of local attachment preference (i.e., the preference to analyze the most recent noun phrase as the subject of an ambiguous verb phrase) is pitted against a particular type of revision (i.e., the revision from a direct object analysis to a sentence complement analysis). The generality of the reanalysis as a last resort principle can be established only through further studies in which a range of local attachment preferences are pitted against a range of potential reanalyses. Clearly, the present account assumes that reanalysis is not *always* a last resort. It may be that when plausibility very strongly supports a local attachment preference, and the revision that would be required is not very difficult in any event (because, e.g., the initial analysis was held only very briefly), then the parser does indeed undertake an unforced reanalysis.

However the present findings are interpreted, it is important to note that they can be seen as the first clear demonstration in the literature of effects of syntactic manipulations prior to the point of ambiguity on ease of reanalysis. (Several studies have found that reanalysis can be affected by non-syntactic manipulations prior to the point of ambiguity, such as the animacy of the head noun in a reduced relative construction; e.g., Clifton et al., 2003; Ferreira & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994.) In the present experiments, the sentences that varied in reanalysis difficulty were identical from the beginning of the ambiguous region to the end of the sentence. The finding that reanalysis processes are sensitive to earlier syntactic manipulations is of substantial interest.

If the present results are indeed interpreted as reflecting the continued influence of an abandoned initial parse on later processing, they are clearly consistent with the emerging body of literature discussed in the Introduction demonstrating the influence of an initial parse on the final interpretation of a sentence (Christianson et al., 2001), on the production (van Gompel et al., 2006) and comprehension (Kaschak & Glenberg, 2004) of subsequent sentences, and on the acceptability of a sentence containing a disfluency (Lau & Ferreira, 2005). The present results (on the interpretation adopted here) add to this literature in at least three ways. First, they demonstrate that an initial parse has an influence even if it is extremely short-lived; indeed, the posited initial parse in the present experiments is so transitory that it is not introspectively apparent. Second, they demonstrate an influence of this parse on later syntactic processing of the same sentence. Finally, they demonstrate that this parse has an influence even when there is compelling evidence that it was, in fact, abandoned in favor of an alternate parse. It is the presence of a garden path effect on the disambiguating region of the critical sentences in both experiments that establishes this point. More generally, both the present study and the related studies discussed above may be seen as confirming the well-established point from the literature on structural priming in language production (e.g., Bock, 1986; Bock & Griffin, 2000; Branigan, Pickering, & Cleland, 2000) that language users retain abstract syntactic structures in a robust form of memory representation, even on the basis of brief exposure.

Turning to the theoretical implications of the present findings for models of the parsing process, it may appear that a parallel parsing model is best positioned to handle facilitation of reanalysis from a previously abandoned parse; such a model can straightforwardly account for the effect of an abandoned parse on reanalysis by supposing that this parse retains some level of activation. At the point of disambiguation, this activation could be increased, which is presumably an easier and faster process than the process of constructing the correct analysis from scratch and raising its activation level above that of the incorrect analysis. However, a parallel model may have trouble accounting for other aspects of the data. Specifically, a parallel model would have to explain why the initial garden path effect is not modulated by the continued activation of the correct parse. It is natural to assume that if the correct parse remains active while the ambiguous region is being read, the disambiguating material should be easier to integrate into the phrase marker, essentially as soon as it is encountered.

It would almost certainly be possible to set the parameters of a parallel computational model to predict just the pattern of results obtained here, i.e., at the point of disambiguation the amount of disruption in the eye movement record is unaffected by the continued activation of the correct parse, but later on, the amount of regressive re-reading is affected. But is not obvious how such parameter settings would be interpreted in theoretical terms, or whether the same parameter settings would account for a range of other data (e.g., the robust finding that reading times are not inflated on an ambiguous region itself; Traxler et al., 1998; van Gompel et al., 2005; cf. Green & Mitchell, 2006).

A fully serial model, on its own, would have an even harder time accounting for the present data. Such a model would assume that the incorrect analysis that is adopted upon reading the ambiguous material fully replaces any previous analysis. However, a serial model along the lines proposed by Lewis and Vasishth (2005; Lewis, 2000) would have less difficulty with these results; in fact, given certain plausible assumptions it would seem to predict data patterns like the ones obtained here. The Lewis and Vasishth model allows that multiple analyses may be generated at a point of ambiguity, though it is serial in the sense that the parser only pursues and maintains a single analysis. The model distinguishes between easy and hard reanalyses by way of a set of assumptions about which constituents of the parse

tree (“chunks,” in Lewis and Vasishth’s terminology) are available in working memory, and thus are accessible to an operation that undoes (or “snips”) incorrect attachments. The reanalysis required in Experiment 2 is explicitly identified by Lewis (1998, 2000) as a difficult one; essentially, the explanation is that the verb phrase node containing the incorrect attachment (see Fig. 3b) is not in working memory when the main clause is being processed. An identical account would apply to the reanalysis required in Experiment 1. When the incorrect attachment cannot be snipped, the parser must re-analyze a large portion of the input, either forwards or backwards, in the manner of the “backtracking” model discussed by Frazier and Rayner (1982), who associated regressive re-reading with such backtracking.

Crucially, the architecture of the Lewis and Vasishth (2005) model (which is based on the ACT-R architecture, e.g. Anderson & Lebiere, 1998) allows the products of sentence processing to decay gradually in memory. One way to explain the results of the present experiments would be to suppose that, due to the short lag between the time at which the correct analysis was initially abandoned and the time at which it was necessary to retrieve it, this analysis still retained a sufficient level of activation for retrieval to be relatively easy, compared to the conditions in which this analysis was not present in memory at all.

In sum, either a parallel or a serial parsing model could, in principle, account for the finding that reanalysis is facilitated when the correct parse was briefly adopted prior to the main point of ambiguity. Given the fact that this finding emerged so clearly in two completely different types of sentences, it would seem to be an important finding for modelers to take on.

Conclusions

The eyetracking experiments presented here were designed to ask whether very briefly adopting a correct parse, prior to adopting an incorrect parse, would facilitate the process of settling on the correct parse after the ultimate point of disambiguation. The answer is an unequivocal yes. In both of the experiments, which involved very different types of structural ambiguity, readers were garden-pathed by a plausible but incorrect local attachment even when the correct analysis was likely to have been entertained at a previous point; however, reanalysis was substantially easier when the correct parse was constructed earlier, as measured by the amount of regressive re-reading of the sentence.

These findings suggest that an abandoned syntactic analysis remains present, in a functionally relevant sense, for some non-trivial period of time. This complements similar findings obtained in a variety of paradigms (Christianson et al., 2001; Kaschak & Glenberg, 2004; Lau & Ferreira, 2005; van Gompel et al., 2006). In the terms of a parallel parsing model, the present findings could be interpreted as reflecting gradually decreasing activation of the abandoned parse. In the terms of a serial model, they could be interpreted as reflecting the retention of an abandoned parse in a memory store, and the ability of the reanalysis mechanism to access this store.

Appendix A. Experiment 1 items

Optional material is in parentheses. As described in the text, the second sentence in each stimulus was presented on a separate line, and was included primarily for uniformity with an unrelated experiment with which these materials were intermixed.

(Either) John borrowed the rake(,) or the shovel turned out to be sufficient. Later the kids jumped in the leaves.

(Either) Ms. Haywood planned a picnic(,) or a barbecue was preferred by the kids. They planned to play a game of touch football as well.

(Either) the bill arrived in the Senate(,) or the House delayed it again. We’ll have to watch the news to find out.

(Either) Linda bought the Chevrolet(,) or the Buick was forced on her by the dealer. She did get a new car, for sure.

(Either) Dr. Wendell will perform the surgery(,) or the procedure will be postponed. The doctor who was originally supposed to do it is out of town.

(Either) Liza will perform her famous song(,) or her dance number will end the show. Everyone will go home happy.

(Either) the boys will use the skis(,) or the sled will make the deliveries. The snow has been really hard to deal with.

(Either) the batter got a hit(,) or a walk was issued intentionally. Somehow he ended up on first base.

(Either) William discovered a cure(,) or a vaccine stopped the disease. In any event, there are no more new cases.

(Either) the natives will keep their land(,) or their villages will be taken over. It’s too early to say for sure.

(Either) the space aliens destroyed the ship(,) or the shield remained effective. We won’t know which until the radio transmission is received.

(Either) Louise talked to the children(,) or the parents scolded them. The kids have been very disobedient.

(Either) the child put on the jacket(,) or the sweater turned out to be warm enough. In any case(,) he didn’t complain.

(Either) the factory emitted the waste sludge(,) or the chemicals damaged the river. You can’t swim there anymore.

(Either) the tourists visited the shrine(,) or the monastery kept their attention. They’ll see the ancient ruins tomorrow.

(Either) the gambler visited the casino(,) or the racetrack proved too much fun. He’s got a serious problem.

(Either) the team took the train(,) or the subway turned out to be a better option. They did get to the meet on time, though.

(Either) the lawyer will play the recording(,) or the videotape will sway the jury. The defendant will definitely be found not guilty.

(Either) Rachel wrote a poem(,) or an essay filled the space in the magazine. We finished working on it this afternoon.

(Either) the ants ate through the door(,) or the window was left open. Now the ants are everywhere.

(Either) the animals slept on the straw(,) or the leaves were more comfortable. We need to clean out the stable next week.

(Either) Richard bought the necklace(,) or the bracelet was a better deal. His wife really likes jewelry.

(Either) the farmers fixed the barn(,) or the outhouse was more important. They did not have time to work on both buildings.

(Either) my dog will chase the ball(,) or the frisbee will keep his attention. He is still a frisky puppy.

Experiment 2 items

Optional material is in parentheses.

The vet said that because the dog (slept and) ate(,) the medicine had its effect.

John said that if the soldiers (stay and) fight(,) the enemy will soon leave.

If Tom has time to (sit and) write(,) the book will certainly turn out great.

Julie said that if the students (stand and) perform(,) the show will be a hit.

If the kids (work and) study(,) the next book will be their choice.

As the plants (blossom and) grow(,) their leaves turn yellow.

If Barbara intends just to (stop and) visit(,) her relatives will be disappointed.

Because the Hollywood star wants to (act and) direct(,) the play will be a failure.

As the Beatles (traveled and) played(,) their songs became known everywhere.

When the Prime Minister (came and) visited(,) the people felt better.

The chief said that if the reactor (cools and) restarts(,) the process will be safe.

Most people think that if you (relax and) rest(,) a sprained ankle will heal fast.

After the store (opened and) advertised(,) the merchandise sold out.

Because the sea birds tend to (congregate and) attack(,) ships should be careful.

Though the adult animals just (hibernate and) feed(,) their young remain active.

When the chef finishes (shopping and) cooking(,) the dinner will be fantastic.

When the demonstrators (get up and) leave(,) the building will be locked.

Because the Senator (lied and) stole(,) the money is no longer available.

Though the maid (arrived and) mopped(,) the floor would not get clean.

Because Alan likes to (walk and) contemplate(,) the forest is his favorite place.

If the politician (strategizes and) plans(,) the campaign will go well.

Though the recruits tried to (sprint and) jump(,) the barrier was just too high.

Mary thought that if she (waited and) saved(,) her money would be sufficient.

When it was time to (speak and) summarize(,) the files were missing.

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