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Processing Arguments and Adjuncts in Isolation and Context: The Case of *By*-Phrase Ambiguities in Passives

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Two eye-tracking experiments examined processing of sentences like *The shrubs were planted by the apprentice/greenhouse that morning,* where the *by* phrase is locally ambiguous between an agent and a location. Experiment 1 found a preference to initially interpret the *by* phrase agentively in the absence of context. In Experiment 2, a context like *The head gardener decided [who should]/[where to] plant the shrubs* induced an expectation that either an agent or a location would subsequently be specified. After agentive contexts, locatives were harder to process than agentives. After locative contexts, both sentences were easy to process. The authors argue that the verb and interrogative words (*who, where*) activate thematic roles, which can be associated with corresponding phrases. Phrases that express activated roles are easy to process. Phrases that might express activated roles but are subsequently shown not to express those roles require reanalysis.

This article reports two experiments concerned with the processing of sentences containing a *by* phrase that is locally ambiguous between expressing an agent and a location. Experiment 1 considered the processing of such sentences in isolation, and Experiment 2 considered whether context can affect how they are processed. In particular, we used these sentences to investigate differences between the processing of *argument* and *adjunct* phrases. Much linguistic theory assumes a fundamental distinction between arguments and adjuncts (Chomsky, 1981; Kaplan & Bresnan, 1982; Pollard & Sag, 1987).

Arguments are defined as constituents that are expressed as part of a word's lexical entry. In this article, we are primarily concerned with cases where this word is a verb. We therefore refer to verbs and their arguments, although some nouns (e.g., *report* in *the report of the disaster*) also license arguments. Semantically, arguments of a verb correspond to participants in the event described by the verb. For example, in *John sneezed yesterday,* the verb *sneezed* describes an intransitive event involving one participant, the sneezer. John serves as the participant in the sneezing event, and therefore *John* is the argument of *sneezed.*

In contrast, adjuncts are not requisite components of a word's lexical entry. Semantically, adjuncts of a verb do not correspond to participants in the event described by the verb. In *John sneezed yesterday,* the word *yesterday* does not refer to a participant in the sneezing event and is therefore an adjunct.

More formally, arguments are specified in the lexical entry for a verb in two ways, the subcategorization frame and the thematic grid. Both of these may vary for different senses of a verb (Chomsky, 1965). The subcategorization frame specifies the syntactic categories of the verb's arguments. For example, the frame for *devour* specifies two noun-phrase arguments, which can be filled, for instance, by *Mary* and *the food,* as in *Mary devours the food.* The thematic grid specifies the thematic roles associated with these arguments, thereby indicating the roles that the arguments play in the action denoted by the verb (Stowell, 1981). The grid for *devour* contains an *agent* thematic role, which is associated with an argument (e.g., *Mary*) that corresponds to the agent in an act of devouring, and also contains a *patient* thematic role, which is associated with an argument (e.g., *the food*) that corresponds to the patient in an act of devouring. A consequence is that the verb partly determines the overall semantic contribution that an argument makes to the sentence.

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Exactly one constituent may serve as each argument, filling a single slot within the verb's thematic grid. A thematic grid is *saturated* if all slots are filled, as in the sentence *Mary devours the food.* In this case, both arguments are obligatory; if either argument is omitted, the sentence is ungrammatical. In contrast, the object argument of *eats* is optional, so that *Mary eats* is grammatical. Under standard assumptions, the lexical entry for *eat* specifies a thematic role for the object argument, but also specifies that it need not be filled. In *Mary eats,* the patient role is not filled, and it is said to be *open* (Carlson & Tanenhaus, 1988).

An agentive *by* phrase can serve as an argument that fills the agent role. In Sentence 1, *by the apprentice* is an optional argument if it is interpreted as an agent (specifying the person who planted the shrubs):

1. *The shrubs were planted by the apprentice that morning.*

As a verb's lexical entry can contain only one agent role, Sentence 2 is ungrammatical (as indicated by asterisk) if both *by* phrases are agents:

2. **The shrubs were planted by the apprentice, by the gardener.*

Only passive verbs license an agentive *by*-phrase argument. In *John was sleeping by the apprentice,* the *by* phrase cannot be interpreted agentively.

Both syntactically and semantically, adjuncts are less closely linked to the verb than arguments (e.g., Pollard & Sag, 1987). Unlike arguments, they are not specified as part of a verb's lexical entry. In *Mary devours food in the garden,* the locative expression *in the garden* has the thematic role *location,* but this is not provided by the verb. Instead, it is made available by the preposition *in.* Hence, the sentence *Mary devours the food* is saturated and does not contain an open location role. Because adjuncts do not correspond to slots in a verb's thematic grid, a verb may be associated with more than one adjunct bearing a particular thematic role. Adjuncts are always optional. For example, if a locative expression such as *in the garden* is an adjunct, it is always optional. In addition, a particular adjunct will always make a more or less uniform semantic contribution to a sentence, such as specifying time or location, regardless of the verb.

A locative *by* phrase can serve as an adjunct that fills the location role:

3. *The shrubs were planted by the greenhouse that morning.*

In this sentence, *by the greenhouse* is optional. It can also appear with other locative adjuncts. For example, in Sentence 4, both *by the new door* and *by the greenhouse* specify where the shrubs were planted:

4. *The shrubs were planted by the greenhouse, by the new door.*

The meaning of *by the greenhouse* is invariant across sentences. For example, it makes the same semantic contribution to *John was sleeping by the greenhouse* and *Mary ate a picnic by the greenhouse* as it does to Sentences 3 and 4. In each case, its location role is determined by the preposition *by* and the noun *greenhouse.*

The distinction in the interpretation of the *by* phrase between Sentences 1 and 3 is reflected in the argument versus adjunct distinction. In contrast, the two sentences do not appear to differ in terms of phrase structure (e.g., Bock & Loebell, 1990). Both sentences contain a passive verb and a prepositional phrase. In standard linguistic analyses, the verb phrase contains the verb *were planted,* together with the *by* phrase and the temporal phrase *that morning,* but the analysis is identical whether the *by* phrase is agentive or locative.

Processing Arguments and Adjuncts in Isolation

We now consider whether preceding context could affect the processing of arguments and adjuncts. Because the thematic roles for both obligatory and optional arguments are specified in the verb's lexical entry, the verb is, in a sense, seeking phrases that can fill these roles. In contrast, the verb is not seeking phrases that can serve as adjuncts. We might therefore predict that the processor preferentially interprets ambiguous phrases as arguments over adjuncts. If so, the processor would find it easier to process the agentive *by* phrase in Sentence 1 than the locative *by* phrase in Sentence 3:

1. *The shrubs were planted by the apprentice that morning.*
3. *The shrubs were planted by the greenhouse that morning.*

We briefly discuss the issue of whether an argument preference should occur during initial processing. We then contrast an account of thematic processing that incorporates an argument preference with an alternative in which interpretative preferences are based on statistical information.

Abney (1989; cf. Crocker, 1996; Pritchett, 1992) proposed that the processor initially resolves syntactic ambiguities "in favor of theta-attachment" (p. 133), which he regarded as synonymous with argument attachment. This predicts an initial preference for interpreting ambiguous phrases as arguments rather than adjuncts. If a verb is unsaturated, and the processor encounters a phrase of the appropriate syntactic category, then it would initially interpret it as an argument. If the phrase turned out to be an adjunct, reanalysis would be necessary. This predicts that *by the greenhouse* in Sentence 3 would initially be misinterpreted, and hence, it should cause processing difficulty in comparison with *by the apprentice* in Sentence 1.

Alternatively, thematic processing may be delayed until after initial syntactic processing. Rayner, Carlson, and Frazier (1983) proposed that thematic roles provide an interface between syntax, discourse, and general knowledge. They are used by a thematic processor, which is separate from the syntactic processor. It is at this level that any preference for treating a constituent as an argument over an adjunct would operate. Rayner et al. assumed that initial parsing preferences are determined by the syntactic processor, and that the thematic processor affects only reanalysis.

Clifton, Speer, and Abney (1991) provided some evidence that thematic processing is delayed in comparison with syntactic processing. They considered sentences such as

Sentence 5 to contain a potential attachment ambiguity for a prepositional phrase:

5. *The man expressed his interest in a wallet during the storewide sale at Steigers.*

Clifton et al. compared sentences like Sentence 5, in which the phrase *in a wallet* attaches to the noun phrase *his interest,* with sentences where the prepositional phrase attaches to a verb. They also manipulated whether the prepositional phrase was an argument, as in Sentence 5, or an adjunct. They found an immediate preference for verb attachment over noun attachment and a subsequent preference for attachment as an argument over attachment as an adjunct. These findings are more compatible with the findings of Rayner et al. (1983) than with those of Abney (1989).

These findings might suggest that effects due to thematic analysis would always be delayed. Hence, we might expect that Sentence 3 would be hard to process in comparison to Sentence 1, but that the effect would occur after the processor had initially encountered the *by* phrase. However, this is not necessarily the case. It may be that the effects of thematic processing are delayed only if the processor has already had to deal with a phrase-structure ambiguity, as in Clifton et al.'s (1991) sentences, but if there is no such ambiguity, the effects may be extremely rapid. If so, we might expect to find an immediate preference for agentive *by* phrases over locative *by* phrases.

In any case, we predict fairly rapid effects of thematic processing, leading to an advantage for optional and obligatory arguments over adjuncts. Let us now adopt the thematic account of Carlson and Tanenhaus (1988; Tanenhaus & Carlson, 1989), and set aside issues of syntactic processing. In this account, when the processor encounters a verb, associated thematic grids are immediately activated. Hence, the verb's thematic roles become available for assignment to its arguments. Assignment takes place within a discourse model that includes thematic information. Thematic roles for preverbal arguments are assigned immediately upon encountering the verb. If the processor then encounters a phrase after the verb that is a potential argument of the verb, then the phrase is assigned a thematic role before it is semantically evaluated. If semantic evaluation suggests that the thematic role assignment is correct, then comprehension proceeds unhindered. However, if semantic evaluation suggests that the correct thematic role is an adjunct role, such as the location role in Sentence 3, then reanalysis will be required.

In the case of *by*-phrase ambiguities, we would therefore expect a preference for the agentive interpretation in Sentence 1 over the locative interpretation in Sentence 3. When the passive verb is processed, it makes available an obligatory patient role (assigned to the subject noun phrase which has already been processed) and an optional agent role which can then be assigned to the ambiguous *by* phrase immediately after it is encountered. A location role, however, would be available only after the preposition at the earliest, because it is the preposition that makes available the location role. Hence, we would predict that the processor would initially assign an ambiguous *by* phrase to the agent role. If this assignment is correct, as in Sentence 1, then no processing difficulty would occur. However, if it subsequently turns out to be incorrect, as in Sentence 3, then the processor must reanalyze and assign the more appropriate location role, with an associated processing cost soon after encountering the disambiguating noun (*greenhouse*).

Many parsing accounts make no predictions about the relative difficulty of Sentences 1 and 3. Assuming that these sentences do not differ in phrase structure, the principles of *minimal attachment* and *late closure* (Frazier, 1979) make no predictions. Similarly, the *referential theory* (Altmann & Steedman, 1988; Crain & Steedman, 1985) predicts no differences between them. This theory predicts whether the processor will favor an analysis containing a simple noun phrase or one containing a complex noun phrase. However, the ambiguity in Sentences 1 and 3 above is not dependent on having a simple or a complex noun phrase.

In contrast, constraint-based theories may make predictions about the relative difficulty of Sentences 1 and 3. These theories assume that processing preferences are determined by the interaction of multiple constraints, such as frequency and plausibility, and that the different analyses compete for activation in parallel (e.g., MacDonald, 1994; MacDonald, Pearlmutter, & Seidenberg, 1994; Spivey-Knowlton, Trueswell, & Tanenhaus, 1993; Trueswell, Tanenhaus, & Garnsey, 1994; Trueswell, Tanenhaus, & Kello, 1993; cf. Mitchell, Cuetos, Corley, & Brysbaert, 1995; Taraban & McClelland, 1988; Tyler & Marslen-Wilson, 1977). Such accounts might predict that the agentive interpretation of ambiguous *by* phrases receives more activation than the locative interpretation, and hence that the agentive interpretation is processed more easily. The critical issue is the likelihood of the competing analyses, which is determined by how often people have encountered each analysis. There might be an agentive preference (a) because agentive *by* phrases are more frequent than locative *by* phrases, (b) because prepositional phrases following passive verbs are more frequently agentive than locative, or (c) because *by* phrases following passive verbs are more frequently agentive than locative (e.g., Hanna, Spivey-Knowlton, & Tanenhaus, 1996).

Experiment 1 below considered the comprehension of the ambiguous *by* phrase in sentences like Sentences 1 and 3. Previous studies designed to test constraint-based accounts have used sentence completion to obtain an indication of whether a preference should exist for an ambiguity during comprehension (Hanna et al., 1996; Trueswell et al., 1993, 1994). The assumption is that the frequency of the alternatives should be reflected in the completion data. Hence, we also conducted a completion study that used the same items as Experiment 1 did, up to the preposition *by.* If this completion study showed a preference for argument completions, then both constraint-based accounts and the thematic-processing account would predict that sentences like Sentence 1 containing an optional argument would be easier to process than sentences like Sentence 3 containing an adjunct. This difference should have been apparent soon after the disambiguating noun in the *by* phrase was encountered.

Experiment 1

Method

Participants. Forty native English speakers from the University of Glasgow were paid to participate in the experiment. All had normal or corrected-to-normal vision. No participant took part in more than one of the experiments, prescreens, or completions reported in this article.

Stimuli. We constructed 24 pairs of items like Sentences 1 and 3, repeated below (see Appendix):

1. *The shrubs were planted by the apprentice that morning.* (agentive)
3. *The shrubs were planted by the greenhouse that morning.* (locative)

The items consisted of an initial noun phrase, the verb, a prepositional phrase comprising the preposition *by* and a noun phrase, and a temporal expression. The intention was that the prepositional phrase would be interpreted as an agentive expression in one condition and as a locative expression in the other condition (see below). Except for the prepositional phrase, the sentences were identical. We constructed two lists of 24 items, comprising 12 items from each condition, such that one version of each item appeared in each list.

The prepositional objects contained in the locative and agentive forms of each item were matched for length and frequency according to the Celex database (Baayen, Piepenbrock, & van Rijn, 1993): Mean agentive frequency was 29.4 words per million (i.e., all instances of the word, including any homographs); mean locative frequency was 33.1 words per million. An analysis of variance (ANOVA) based on item variability showed no significant difference ($F < 1$). Also, because an agentive sentence may potentially be interpreted as a locative sentence, a prescreen was carried out. Twenty-four participants judged whether the prepositional phrase in each sentence described who was performing the action, where the action occurred, or whether they were unsure. After each decision, they indicated how plausible the sentence was on a scale from 1 (*highly implausible*) to 7 (*highly plausible*). Participants selected the expected interpretation on 98.0% of occasions. The agentive and locative sentences were also exactly matched for plausibility (mean agentive plausibility = 5.8; mean locative plausibility = 5.8; $F_2 < 1$).

Sentence-completion study. We first performed a sentence-completion study to determine whether agentive or locative sentences were more likely in production. This study also determined the predictions of the constraint-based account. Thirty-two participants wrote completions to 24 sentence fragments like *The shrubs were planted by* . . . (together with 56 other fragments). These fragments were the beginnings of the experimental items, up to the preposition *by*. After writing all their responses, participants indicated for each experimental item whether their completion described who or what was performing the action (agentive completion), where the action occurred (locative completion), or whether they were unsure. (We also judged the participants' responses and found 97.8% agreement between our judgments and those of the participants.) According to the participants' judgments, participants completed the sentences as agentives 95.8% of the time and as locatives 3.3% of the time, $F_1(1, 31) = 3{,}225$, $p < .05$, $MSE = 0.004$; $F_2(1, 23) = 79.6$, $p < .05$, $MSE = 0.013$. Hence, there was a substantial bias in favor of the agentive sentences in language production. This finding confirms that the predictions of the constraint-based account are similar to those of the thematic-processing account.

Procedure. The computer displayed each experimental list of 24 items in a fixed random order, together with 32 filler sentences like *The announcement about the lucky penalty goals excites the man* and 16 additional sentences of various syntactic types. All sentences were displayed on a single line.

We monitored eye movements using a (SRI) Dual Purkinjc Generation 5.5 eye tracker made by Fourward Technologies under license to SRI. The eye tracker has an angular resolution of 10 degrees of arc. Participants used both eyes to read, but the tracker monitored only the right eye's gaze location. Items were presented on a visual display unit (VDU) at a distance of 70 cm from participants' eyes. The VDU displayed four characters per degree of visual angle. The tracker monitored participants' gaze location every millisecond, and the software sampled the tracker's output to establish the sequence of eye fixations and participants' start and finish times.

Participants read a set of instructions that told them to read at their normal rate and to try to comprehend the sentences to the best of their ability. They were seated at the eye tracker, and a bite bar and a head restraint were used to minimize head movements. They then participated in a short calibration procedure. Sentences were presented one at a time on the screen. Before each trial, a small + symbol appeared near the upper left-hand corner of the screen. Immediately after participants fixated the + symbol, the computer displayed a target sentence, with the first character of the sentence replacing the + on the screen. The + also served as an automatic calibration check, because the computer did not display the text until it detected a stable fixation on the +. If a stable fixation on the + did not occur at the beginning of any trial, the experimenter recalibrated the eye tracker before continuing. The experimenter also recalibrated the equipment halfway through the experiment. Normally, recalibration occurred three or four times during the experiment. The experiment took about 30 min.

When participants finished reading each sentence, they pressed a key, and the computer either displayed a comprehension question on one third of the experimental and filler trials, balanced across conditions (e.g., *Were the shrubs planted next to a greenhouse?*), or proceeded to the next trial. Half of these questions had "yes" answers, half had "no" answers. Participants pressed a key to answer the questions and received no feedback.

Analyses. An automatic procedure pooled short contiguous fixations. The procedure incorporated fixations of less than 80 ms into larger fixations within one character, and then deleted fixations of less than 40 ms that fell more than three character spaces away from any other fixation. Following Rayner and Pollatsek (1989), we presume that readers did not extract much information during such brief, isolated fixations.

For purposes of analysis, we divided our experimental sentences into five regions, indicated by slashes as follows: *The shrubs/ were planted/ by the/ apprentice/ that morning. First-pass time* is the sum of the fixations occurring within a region before the point of fixation exited the region, either to the right or to the left. However, if the eye fixated a point beyond the end of a region before landing in the region for the first time, then the first-pass time for that region was zero. *Total time* is the sum of all fixations in a region. A *first-pass regression* is any saccade from the rightmost fixation so far to an earlier region in the text. (In Experiment 2, the second line of text was regarded as being to the right of the first line.)

Before analyzing the eye-movement data, we eliminated the occasional trial in which the participant did not read the sentence or in which tracker loss ensued. More specifically, we removed trials in which two or more adjacent regions had a first-pass time of zero. This procedure removed 1.5% of the data.

We conducted two sets of analyses. In the millisecond-per-character analysis, we divided the sum of the fixation durations by

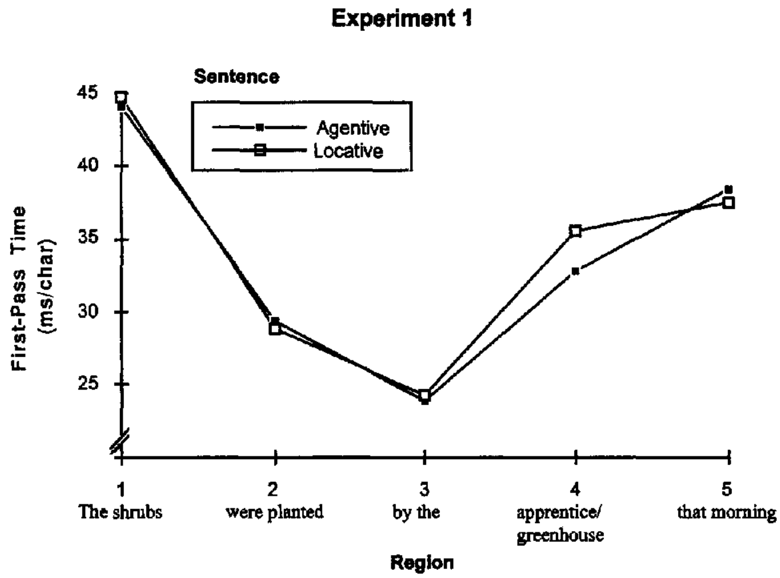

Figure 1. For Experiment 1, mean first-pass time by region and condition for an example sentence. Region 4 corresponds to the word *apprentice* in Sentence 1 and to *greenhouse* in Sentence 3. char = character.

the number of characters in the region. In the untransformed analysis, we simply considered the sum of the fixation durations in a region. Note that Trueswell et al. (1994) criticized the use of the millisecond-per-character analysis, on the grounds that it can distort results when comparing regions of different lengths (because the measure erroneously assumes that longer regions ought to take proportionally longer to read than shorter regions). Our experiment is not subject to this criticism, because our regions were identical in length (across conditions). In addition, our critical regions were relatively long (mean length = 12.2 characters). Under these conditions, Trueswell et al. noted that the millisecond-per-character analysis should not present problems. However, the untransformed and transformed analyses do make different assumptions about the weightings of long versus short pairs of items, and it is unclear which weighting is more appropriate. Hence, we conservatively conducted both sets of analyses. We report the transformed analyses below. Unless both transformed and untransformed analyses were significant at the .05 alpha level (by both subjects and items), we also report the untransformed analyses.

Results

Figures 1 and 2 show the first-pass time and the total time, respectively, for the five regions of the agentive and locative sentences. We conducted ANOVAs with sentence type (agentive vs. locative) as a within-subjects and within-items variable, treating subjects and items as random variables. For brevity's sake, we report only p values that exceed the .05 level. During the first pass, participants spent more time reading the critical Region 4 of the locative sentences (mean = 35.5 ms/character) than the agentive sentences (mean = 32.7 ms/character), $F_1(1, 39) = 6.96$, $MSE = 22.7$; $F_2(1, 23) = 12.2$, $MSE = 8.44$. For untransformed analyses, the mean locative was 463 ms, and the mean agentive was 430 ms, $F_1(1, 39) = 3.33$, $p < .08$, $MSE = 6{,}680$; $F_2(1, 23) = 7.54$, $MSE = 1{,}846$.[1] There were no other significant differences between the agentive and locative sentences for any region during first pass (all Fs < 1). There were no differences between the number of first-pass regressions that participants made from Region 4 in each condition (both Fs < 1.5).

For total time, there were no reliable differences between the conditions. For Regions 1, 2, and 5, all Fs < 1. Effects did not achieve significance for Region 3: The mean locative was 36.7, and the mean agentive was 33.7, $F_1(1, 39) = 3.73$, $p < .07$, $MSE = 47.6$; $F_2(1, 23) = 1.77$, $p < .20$, $MSE = 64.7$. As Region 3 comprised the same words *by the* in both conditions for all items, the untransformed analyses had F values identical to the transformed analyses. Likewise, effects did not achieve significance for Region 4: The mean locative was 46.3 ms/character, and the mean agentive was 43.8 ms/character, $F_1(1, 39) = 1.72$, $p < .21$, $MSE = 77.4$; $F_2(1, 23) = 3.12$, $p < .10$, $MSE = 29.5$. For untransformed analyses, the mean locative was 606 ms, and the mean agentive was 574 ms, $F_1(1, 39) = 1.37$, $p < .25$, $MSE = 15{,}549$; $F_2(1, 23) = 3.04$, $p < .10$, $MSE = 4{,}475$. The difference between the conditions for the complete *by* phrase, defined as a new single region, was marginally significant (for these analyses, we removed all trials with a zero first-pass time, because we assumed that participants had to fixate this extended region to process it properly): $F_1(1, 39) = 3.09$, $p < .10$, $MSE = 34.9$; $F_2(1, 23) = 2.98$, $p < .11$, $MSE = 23.1$. The mean locative was 42.6 ms/character, and the mean agentive was 40.3 ms/character.

[1] First-pass time was zero on 1.7% of the trials included in the analyses: 1.3% of the trials were in the locative condition, and 2.1% were in the agentive condition.

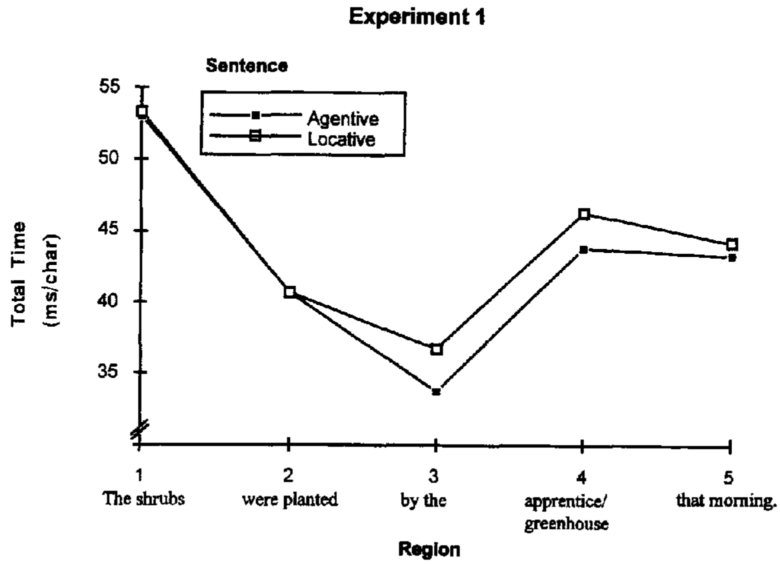

Figure 2. For Experiment 1, mean total time by region and condition for an example sentence. Region 4 corresponds to the word *apprentice* in Sentence 1 and to *greenhouse* in Sentence 3. char = character.

For untransformed analyses, the mean locative was 862 ms, and the mean agentive was 809 ms, $F_1(1, 39) = 3.86$, $p < .06$, $MSE = 14{,}441$; $F_2(1, 23) = 3.56$, $p < .08$, $MSE = 9{,}022$.

Discussion

Experiment 1 demonstrated that participants found agentive sentences easier to process than locative sentences as soon as they encountered the disambiguating noun. The effect occurred as soon as the argument structure difference became apparent. It was localized to the disambiguating noun, and the small and unreliable total-time differences between the conditions suggest that recovery was fairly straightforward.

These results accord with the prediction of the thematic-processing account that optional arguments should be easier to process than adjuncts. They also accord with the predictions of constraint-based accounts, because the sentence-completion study showed a statistical bias in favor of agentive over locative *by* phrases. The results are not predicted by the garden-path theory or by the referential theory.

Processing Arguments and Adjuncts in Context

Experiment 1 demonstrated that participants initially interpreted ambiguous *by* phrases as agentives rather than as locatives. However, the sentences were presented in isolation, and it is possible that discourse context could have had an immediate effect on processing. Some studies have suggested that initial processing preferences may be influenced by a preceding context (Altmann, Garnham, & Dennis, 1992; Altmann, Garnham, & Henstra, 1994; Altmann & Steedman, 1988; Britt, 1994; Britt, Perfetti, Garrod, & Rayner, 1992; Spivey-Knowlton et al., 1993; Trueswell & Tanenhaus, 1991), though others have suggested that they can affect only reanalysis (Clifton & Ferreira, 1989; Ferreira & Clifton, 1986; Mitchell, Corley, & Garnham, 1992; Murray & Liversedge, 1994; Rayner, Garrod, & Perfetti, 1992). If context can have an immediate effect, then it may be possible to construct a context that induces an expectation that a location will be specified. This could then induce an expectation for a location role in a subsequent sentence. However, all of the above studies manipulated the preference for or against a simple or complex noun phrase. The agentive–locative ambiguity does not involve ambiguity about the form of the noun phrase, and any context effects would have to act in a hitherto unexplored way.

Carlson and Tanenhaus's (1988) account of thematic processing offers an account of how context might affect thematic processing. The processor enters open thematic roles into a discourse model. These roles can then be associated with appropriate constituents in following sentences. Carlson and Tanenhaus compared sentences in which an optional argument was expressed with ones in which it was not expressed. For instance, consider Sentences 6 and 7:

6. *The fire was extinguished by the fireman.*
7. *The fire was extinguished.*

Their account predicts that when the processor accesses a passive verb like *was extinguished,* an agent role corresponding to the optional *by*-phrase argument is made available in both Sentence 6 and Sentence 7. In Sentence 6, this thematic role is assigned to *the fireman,* and so Sentence 6 is saturated, but in Sentence 7, the optional argument is not expressed, and so the agent role is not assigned to a constituent. Instead, it remains in the discourse model as an open role, awaiting further elaboration.

Some empirical evidence supports this account. Tanenhaus, Burgess, Hudson D'Zmura, and Carlson (1987) examined sentences like Sentences 8–10 below.

8. *John had difficulty running fast to catch his plane.*
9. *John had difficulty loading his car.*
10. *The suitcases were very heavy.*

In Sentence 8, the thematic grid of *run* is saturated, but in Sentence 9, no argument corresponding to the patient role of *load* is expressed, so an open patient role is entered into the model. In Sentence 10, *the suitcases* can fit into the model by filling this patient role. In accordance with this, Tanenhaus et al. found that participants made grammaticality judgments about Sentence 10 faster and more accurately following Sentence 9 than following Sentence 8. However, there may be alternative explanations for the findings (e.g., differences in the inferences required under the two conditions).

Mauner, Tanenhaus, and Carlson (1995) found within-sentence effects that are compatible with Carlson and Tanenhaus's (1988) proposal. They compared sentences like Sentences 11 and 12 that contained rationale clauses:

11. *The game show's wheel was spun to win a prize and lots of cash.*
12. *The game show's wheel spun to win a prize and lots of cash.*

The rationale clause *to win a prize and lots of cash* involves an understood subject, which adopts the agent thematic role of the verb *win*. Neither Sentence 11 nor Sentence 12 contains an explicit entity that could appropriately act as the agent of the rationale clause. However, the account predicts that the passive in Sentence 11 introduces an agent role, which can act as the implicit agent of the rationale clause, but that Sentence 12 does not. In accordance with this, participants were more likely to judge that Sentence 11 made sense than that Sentence 12 made sense.

Carlson and Tanenhaus's (1988) account predicts that preceding context might affect the processing of subsequent sentences, by introducing open roles with the expectation that they will be filled by a subsequent constituent. However, they considered only contexts in which an optional argument of a verb was not overtly expressed. We suggest that their account can be extended to include contexts involving a class of constituents that are overtly expressed but that otherwise act as free variables in need of further specification. These constituents are interrogative *wh-* words like *who* and *where*. Consider Sentences 13 and 14 below:

13. *The gardener wondered who should plant the shrubs.*
14. *The gardener wondered where to plant the shrubs.*

In Sentence 13, *who* is assigned the agent role specified in the thematic grid of *plant;* in Sentence 14, *where* is assigned an adjunct location role associated with *plant*. In each case, however, the word that receives the role is semantically almost vacuous, with *who* referring to an unspecified human and *where* referring to an unspecified location. Both *wh-* words invite further specification. Intuitively, they anticipate that subsequent discourse will identify a referential noun phrase associated with them.

We therefore suggest that the thematic roles associated with interrogative *wh-* words are entered into the discourse model in the same way as the thematic roles associated with unexpressed arguments discussed by Carlson and Tanenhaus (1988). After encountering Sentence 13, the processor introduces an unspecified agent role, indexed with respect to that specific event of planting, into the discourse model. After encountering Sentence 14, the processor introduces an unspecified location role in the same way. The role will be available for association with a suitable constituent in subsequent discourse. Roles specified in this way need not be the only roles available in the discourse model, as other roles may be specified by a verb within the subsequent discourse. The processor should have no difficulty associating a constituent with any role expressed in the model.

Let us now consider what this account predicts for the processing of agentive- and locative-target sentences such as Sentences 1 and 3 when they are preceded by context sentences such as Sentences 13 and 14. We assume that Sentence 13 is felicitous with an agentive target (as in Sentence 15), and that Sentence 14 is felicitous with a locative target (as in Sentence 17):

15. *The gardener wondered who should plant the shrubs. In fact, the shrubs were planted by the apprentice that morning.* (agentive context, agentive target)
16. *The gardener wondered who should plant the shrubs. In fact, the shrubs were planted by the greenhouse that morning.* (agentive context, locative target)
17. *The gardener wondered where to plant the shrubs. In fact, the shrubs were planted by the apprentice that morning.* (locative context, agentive target)
18. *The gardener wondered where to plant the shrubs. In fact, the shrubs were planted by the greenhouse that morning.* (locative context, locative target)

In each of the Sentence Pairs 15–18, the context sentence makes available an unspecified thematic role that invites subsequent elaboration: In Sentence Pairs 15 and 16, *who* introduces an unspecified agent role into the discourse model; in Sentence Pairs 17 and 18, *where* introduces an unspecified location role. When participants encounter the verb *planted* in the target sentence, the processor introduces an agent role associated with the verb's optional agentive argument. Hence, processing of the agentive-target sentences in Sentence Pairs 15 and 17 should be unproblematic, regardless of context. Processing of the locative target sentence in Sentence Pair 18 should also be unproblematic, because the context provides an unspecified location role associated with planting. In contrast, processing the locative-target sentence in Sentence Pair 16 should be difficult. Both the context sentence and the target verb introduce an agent role. Hence, the *by* phrase is initially assigned an agent role. When it becomes clear that this assignment is incorrect, thematic reanalysis must be initiated, resulting in a processing cost. Experiment 1 suggested that thematic processing effects can be rapid, so we would also predict rapid effects in Experiment 2.

Note that referential theory (Altmann & Steedman, 1988; Crain & Steedman, 1985) makes no predictions for these passages, because the ambiguity does not concern the issue of whether the processor should favor an analysis containing a simple noun phrase or one containing a complex noun phrase. The predictions of constraint-based theories depend on the results of a completion study, just as in Experiment 1. However, we know that Sentence Pairs 15–18 manipulate two constraints, a contextual constraint that supports one interpretation or the other, and a sentence-internal constraint (presumably due to the verb) that supports the agentive completion. The target sentence in the agentive–agentive condition (Sentence Pair 15) should be easier to process shortly after disambiguation than any of the other three conditions, because this is the only condition in which both constraints support the correct interpretation. Conversely, the target sentence in the agentive–locative condition (Sentence Pair 16) should be harder to process than any of the other three conditions at the same point, because this is the only condition in which neither constraint supports the correct interpretation. In the locative–agentive condition (Sentence Pair 17), sentence-internal constraints support the correct interpretation, whereas contextual constraints support the wrong interpretation. In the locative–locative condition (Sentence Pair 18), sentence-internal constraints support the wrong interpretation, whereas contextual constraints support the correct interpretation. The relative difficulty of these two conditions depends on the strength of the competing constraints. This can be assessed by the completion study.

Hence, a clear difference emerges between the predictions of the two accounts. The thematic-processing account predicts that the agentive–locative condition should involve reanalysis and therefore should cause processing difficulty. None of the other three conditions should involve reanalysis, and therefore they should be equally easy to process. Constraint-based accounts predict that the agentive–agentive condition should be easiest, because both constraints support the correct interpretation, and these accounts predict that the agentive–locative condition should be hardest, because neither constraint supports the correct interpretation; the other conditions fall between these two in difficulty. Assuming that the agentive–locative condition is hard, the two types of accounts make different predictions for the agentive–agentive condition. If it is easiest, constraint-based accounts are supported, but if it is as easy as the locative–locative and locative–agentive conditions, then the thematic-processing account is supported.

We now report the findings of an eye-tracking experiment that examined the processing of ambiguous *by* phrases in discourse context. As in Experiment 1, our main experiment was preceded by a completion study that tested whether our contextual manipulation would be likely to be effective. It also indicated how the comprehension data should pattern according to constraint-based accounts.

Experiment 2

Method

Participants. Thirty-two native English speakers at the University of Nottingham were paid to participate in the experiment. All had normal or corrected-to-normal vision.

Stimuli. We constructed 24 items like Sentence Pairs 15–18 above (see the Appendix). The target sentences comprised a connecting phrase like *In fact* followed by the 24 sentences used in Experiment 1. For each target sentence, we constructed a pair of context sentences. One of these induced an expectation that an agent would subsequently be specified, by explicitly raising the issue of who might carry out an action in the context sentence. The other induced an expectation that a location would subsequently be specified, by explicitly raising the issue of where an event might occur in the context sentence. None of the context sentences used the passive construction, so that any experimental effects could not be caused by syntactic priming (Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995). We constructed four lists of items containing six items from each condition, such that one version of each item appeared in each list.

Sentence-completion study. We first performed a sentence-completion study to determine whether the contexts affected the types of completions that participants produced. We assumed that if the contexts affected completions, then they were inducing the types of expectations required of them in Experiment 2. This study also determined the precise predictions of constraint-based accounts. Twenty-four participants wrote completions to 24 items comprising either an agent- or a location-inducing context sentence from Experiment 2 and a target fragment like *The shrubs were planted by . . .* (together with 61 other fragments). Participants received one of two files containing 12 agent-inducing and 12 location-inducing contexts, constructed such that each file contained one version of each context sentence. After writing all their responses, participants indicated for each experimental item whether their completion described who was performing the action (agentive completion), where the action occurred (locative completion), or whether they were unsure. (We also judged the participants' responses and found 95.8% agreement between our judgments and those of the participants.) After an agentive context, participants produced 96.2% agentive completions and 2.8% locative completions. After a locative context, participants produced 56.9% agentive completions and 40.3% locative completions.

ANOVAs showed that participants produced more agentive than locative completions, $F_1(1, 23) = 101$, $MSE = 0.072$; $F_2(1, 23) = 137$, $MSE = 0.053$. More important, the interaction between context type and completion was significant, $F_1(1, 23) = 52.6$, $MSE = 0.067$; $F_2(1, 23) = 65.9$, $MSE = 0.054$. This suggested that the contextual manipulation was potentially strong enough to affect comprehension of the target sentence. Planned comparisons indicated that the differences between all four cells were reliable.

After an agentive context, the pattern of agentive and locative completions was almost identical to that obtained in the completion study in Experiment 1 (96.2% vs. 95.8% agentive completions, and 2.8% vs. 3.3% locative completions for Experiments 1 and 2, respectively). After a locative context, there was still a preference to produce agentive completions (56.9%) rather than locative completions (40.3%), but the magnitude of this effect was greatly reduced. The completion data indicate the pattern of reading times that constraint-based theories predict immediately after the processor reaches the disambiguating noun. The agentive–agentive condition should be easiest, followed in order by the locative–agentive, the locative–locative, and the agentive–locative conditions, though the differences between the locative–agentive and locative–locative conditions may be quite small. Assuming that any differences can be detected, the agentive–agentive condition should be the easiest, and the agentive–locative condition should be the hardest.

Procedure. The experimental procedure was the same as that in Experiment 1, except in the following respects. The computer displayed each experimental list together with 12 filler items of varying types, and 32 filler items like *In a retirement home/ All of the residents were in the TV room during/ Brookside. Few of the*

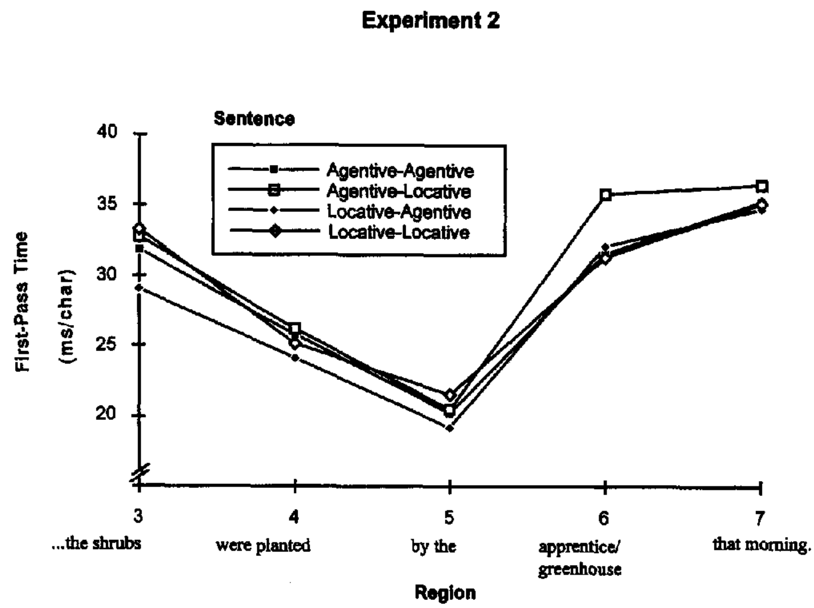

Figure 3. For Experiment 2, mean first-pass time by region and condition for an example sentence. Region 6 corresponds to the word *apprentice* in Sentences (7A and 7B) and to *greenhouse* in Sentences 7C and 7D. char = character.

residents were bored with the plot,/ so they watched intently when the programme began (the slashes indicate line breaks). All experimental items were displayed on two lines separated by a single blank line, with the line break occurring immediately before, during, or immediately after the connecting phrase. The experiment took about 25 min. A yes–no question followed one third of the experimental items and eight of the fillers.

Analyses. We first identified which line participants were reading. Occasionally, the point of fixation was on the blank line, and so we assumed that such fixations were on the same line as their neighbors. As in Experiment 1, we removed trials where two or more adjacent regions had a zero first-pass time. This procedure removed 7.8% of the data. For purposes of analysis, we divided our experimental sentences into seven regions. The context sentence was Region 1, the connecting phrase was Region 2, and Regions 3–7 corresponded to Regions 1–5 in Experiment 1. We adopt the same convention for reporting transformed and untransformed analyses as in Experiment 1.

Results

Figures 3 and 4 show first-pass time and total time, respectively, for Regions 3–7 under the four conditions: We conducted 2 (target sentence type: agentive target vs. locative target) × 2 (context sentence type: agentive context vs. locative context) ANOVAs. During the first pass, there was a significant interaction between target sentence type and context sentence type for the critical Region 6 (e.g., *apprentice* or *greenhouse*), $F_1(1, 31) = 4.86$, $MSE = 40.3$; $F_2(1, 23) = 5.35$, $MSE = 29.5$. Planned comparisons showed that the interaction was due to longer reading time for the agentive-context/locative-target condition (mean = 35.8 ms/character) than for (a) the agentive-context/agentive-target condition (mean = 31.6 ms/character), $F_1(1, 31) = 6.70$; $F_2(1, 23) = 7.24$; (b) the locative-context/agentive-target condition (mean = 32.1 ms/character), $F_1(1, 31) = 5.27$; $F_2(1, 23) = 4.98$; or (c) the locative-context/locative-target condition (mean = 31.3 ms/character), $F_1(1, 31) = 7.99$; $F_2(1, 23) = 7.91$. The other three conditions did not differ from each other (all *F*s < 1).

We also conducted an analysis to determine the power of the eye-movement experiment to detect the difference in reading time that the constraint-based theory would have predicted on the basis of the differences observed in the sentence-completion experiment. From the completion data, we computed that the difference between the proportion of locative completions that participants produced after an agentive context and the mean of the proportion of agentive and locative completions that participants produced after a locative context is 45.8%. In the first-pass time data for the disambiguating region, the corresponding difference (between the agentive-context/locative-target condition and the mean of the two locative-context conditions) is 4.1 ms/character. The completion data also showed that the difference between the proportion of agentive completions after an agentive context and the mean of the proportion of agentive and locative completions that participants produced after a locative context is 47.6%. On this basis, constraint-based theories predict a 4.1 × 45.8/47.6 = 4.3 ms/character difference in first-pass time for the disambiguating region between these conditions.

We then computed the effect size *d*, using the formula $d = (\mu_1 - \mu_2)/\sigma_{x_1-x_2}$, where $\mu_1 - \mu_2$ is the expected mean difference in first-pass times, and $\sigma_{x_1-x_2}$ is the standard deviation of difference scores drawn from the two populations of reading times. We know that $\mu_1 - \mu_2$ is 4.3

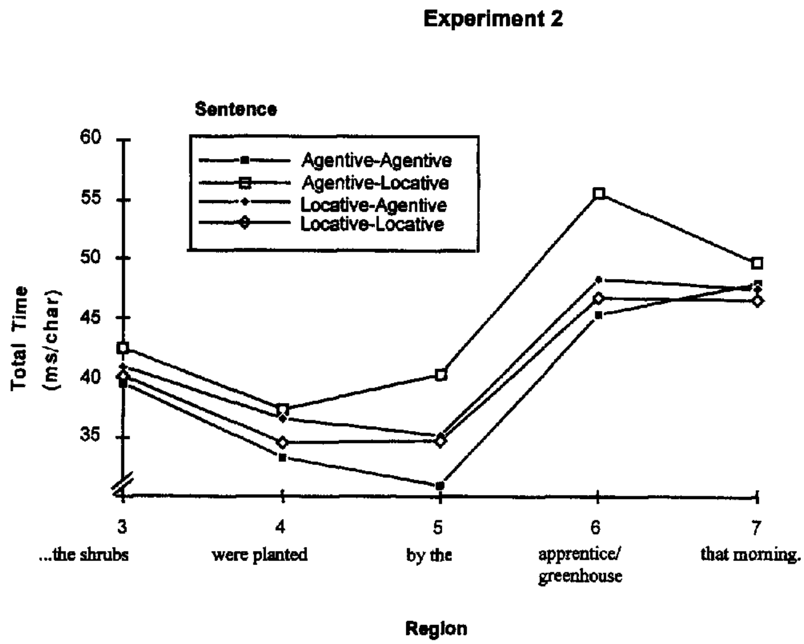

Figure 4. For Experiment 2, mean total time by region and condition. Region 6 corresponds to the word *apprentice* in Sentences 7A and 7B and to *greenhouse* in Sentences 7C and 7D. char = character.

ms/character, and because the effect sizes of 4.3 ms/character and 4.1 ms/character are approximately the same, we are able to obtain a good estimate of $\sigma_{x_1-x_2}$, from the differences between the mean first-pass times for the disambiguating region of locative-target sentences after an agentive context and the mean first-pass times for the disambiguating region of agentive and locative target sentences after locative contexts (estimated $\sigma_{x_1-x_2}$, = 11.1). From this, we calculate that the effect size d is .385. This is regarded as a small to medium size effect (Cohen, 1988). We combined the effect size with the sample size ($N = 32$), using the formula $\delta = d\sqrt{N}$, to give $\delta = 2.2$. This indicates that at a significance level of $\alpha = .05$, the power of the eye-movement experiment to detect a difference of the magnitude predicted by constraint-based theories on the basis of the completion study was .6. Hence, if there was a difference of the predicted magnitude between the agentive-context/agentive-target condition and the mean of the two locative-context conditions, with 32 participants, we would find a significant effect 60% of the time.

The untransformed analyses for Region 6 on the first pass showed a similar interaction between target sentence type and context sentence type, $F_1(1, 31) = 5.82$, $MSE = 5{,}101$; $F_2(1, 23) = 4.16$, $p < .06$, $MSE = 6{,}207$. Planned comparisons showed that the interaction was due to longer reading time for the agentive-context/locative-target condition (mean = 471 ms) than for (a) the agentive-context/agentive-target condition (mean = 414 ms) $F_1(1, 31) = 10.3$; $F_2(1, 23) = 6.69$; (b) the locative-context/agentive-target condition (mean = 418 ms), $F_1(1, 31) = 8.99$; $F_2(1, 23) = 4.93$; or (c) the locative-context/locative-target condition (mean = 414 ms), $F_1(1, 31) = 10.23$; $F_2(1, 23) = 6.34$. The other three conditions did not differ from each other (all Fs < 1).[2]

There were no differences between the number of first-pass regressions that participants made from Region 6 in each condition (all Fs < 1).

For total time, there was a main effect of target sentence type in Region 6, with locative-target sentences (mean = 51.2 ms/character) taking longer than agentive-target sentences (mean = 46.8 ms/character), $F_1(1, 31) = 5.71$, $MSE = 106$; $F_2(1, 23) = 6.59$, $MSE = 81.4$. An interaction between target and context sentence type occurred in Region 6, $F_1(1, 31) = 6.25$, $MSE = 166$; $F_2(1, 23) = 5.87$, $MSE = 152$. Planned comparisons showed that the interaction was due to longer reading time for the agentive-context/locative-target condition (mean = 55.6 ms/character) than for (a) the agentive-context/agentive-target condition (mean = 45.5 ms/character), $F_1(1, 31) = 9.71$; $F_2(1, 23) = 9.26$; (b) the locative-context/agentive-target condition (mean = 48.1 ms/character), $F_1(1, 31) = 5.36$; $F_2(1, 23) = 4.93$; or (c) the locative-context/locative-target condition (mean = 46.8 ms/character), $F_1(1, 31) = 7.47$; $F_2(1, 23) = 6.78$. The other three conditions did not differ from each other (all Fs < 1).

On the untransformed analyses, the main effect of sentence type was significant by items but not by subjects (mean

[2] First-pass time was zero on 3.0% of the trials included in the analyses: 3.4% of the trials were in the locative-context/locative-target condition, 0.6% were in the locative-context/agentive-target condition, 3.4% were in the agentive-context/locative-target condition, and 4.7% were in the agentive-context/agentive-target condition.

locative = 667 ms; mean agentive = 613 ms), $F_1(1, 31) = 1.53$, $p > .20$, $MSE = 63{,}360$; $F_2(1, 23) = 5.52$, $MSE = 15{,}299$. The interaction between target and context sentence type approached significance, $F_1(1, 31) = 3.56$, $p < .07$, $MSE = 27{,}868$; $F_2(1, 23) = 3.59$, $p < .08$, $MSE = 26{,}622$. Planned comparisons suggested that the marginal interaction was due to longer reading time for the agentive-context/locative-target condition (mean = 713 ms) than for (a) the agentive-context/agentive-target condition (mean = 603 ms), $F_1(1, 31) = 7.03$, $F_2(1, 23) = 6.76$; (b) the locative-context/agentive-target condition (mean = 622 ms), $F_1(1, 31) = 4.76$, $F_2(1, 23) = 3.98$, $p < .06$; or (c) the locative-context/locative-target condition (mean = 622 ms), $F_1(1, 31) = 4.84$, $F_2(1, 23) = 4.31$. The other three conditions did not differ from each other (all Fs < 1).

The only other significant results occurred in Region 5 on the total-time measure. The effect of target sentence type was significant by subjects and approached significance by items (mean locative = 37.5 ms/character; mean agentive = 33.1 ms/character), $F_1(1, 31) = 5.56$, $MSE = 109$; $F_2(1, 23) = 3.49$, $p < .08$, $MSE = 144$. More interestingly, this region showed an interaction between target and context sentence type, $F_1(1, 31) = 6.13$, $MSE = 130$; $F_2(1, 23) = 4.81$, $MSE = 140$. The mean reading times were as follows: the locative-context/locative-target condition was 34.7 ms/character; the locative-context/agentive-target condition was 35.3 ms/character; the agentive-context/locative-target condition was 40.3 ms/character; and the agentive-context/agentive-target condition was 30.9 ms/character. Because Region 5 comprised the same words *by the* in all conditions for all items, the untransformed analyses had F values identical to the transformed analyses. Planned comparisons were not in general reliable. In addition, total time was zero on 24.5% of the trials, which is clearly a considerable proportion of the data.[3]

We also conducted reading-time analyses on the complete *by* phrase. (As in Experiment 1, for these analyses we removed all trials on which there was a zero first-pass time for the complete *by* phrase.) During the first pass, the effect of target sentence type was significant by items only: The mean locative was 31.2 ms/character, and the mean agentive was 28.9 ms/character, $F_1(1, 31) = 2.92$, $p < .10$, $MSE = 55.3$; $F_2(1, 23) = 4.40$, $MSE = 28.0$. For the untransformed analyses, the mean locative was 633 ms, and the mean agentive was 586 ms, $F_1(1, 31) = 1.37$, $p > .20$, $MSE = 50{,}707$; $F_2(1, 23) = 4.37$, $MSE = 11{,}548$. More interestingly, there was an interaction between target and context sentence type, $F_1(1, 31) = 8.52$, $MSE = 27.1$; $F_2(1, 23) = 5.57$, $MSE = 31.3$. The mean reading times were as follows: the locative-context/locative-target condition was 29.4 ms/character; the locative-context/agentive-target condition was 29.8 ms/character; the agentive-context/locative-target condition was 33.0 ms/character; and the agentive-context/agentive-target condition was 28.0 ms/character. Planned comparisons showed that the complete *by* phrase of locative-target sentences after an agentive context took longer to read during the first pass than the same region of (a) locative-target sentences after a locative context, $F_1(1, 31) = 7.50$, $F_2(1, 23) = 4.90$; (b) agentive-target sentences after a locative context, $F_1(1, 31) = 5.75$, $F_2(1, 23) = 3.80$, $p < .07$; or (c) agentive-target sentences after an agentive context, $F_1(1, 31) = 14.34$, $F_2(1, 23) = 9.43$. The other three conditions did not differ from each other (all Fs < 2).

Total-time analyses for the complete *by* phrase revealed a main effect of target sentence type: The mean locative was 46.1 ms/character, and the mean agentive was 41.7 ms/character, $F_1(1, 31) = 9.91$, $MSE = 63.3$; $F_2(1, 23) = 12.5$, $MSE = 41.9$. For untransformed analyses, the mean locative was 930 ms, and the mean agentive was 843 ms, $F_1(1, 31) = 3.46$, $p < .08$, $MSE = 69{,}504$; $F_2(1, 23) = 10.4$, $MSE = 19{,}057$. Again, there was an interaction between target and context sentence type, $F_1(1, 31) = 10.4$, $MSE = 89.0$; $F_2(1, 23) = 7.45$, $MSE = 105$. The mean total times were as follows: the locative-context/locative-target condition was 42.5 ms/character; the locative-context/agentive-target condition was 43.4 ms/character; the agentive-context/locative-target condition was 49.8 ms/character; and the agentive-context/agentive-target condition was 40.0 ms/character. Planned comparisons again showed that total times for the full *by* phrase of locative-target sentences after an agentive context were longer than for the same region of (a) locative-target sentences after a locative context, $F_1(1, 31) = 9.64$, $F_2(1, 23) = 7.05$; (b) agentive-target sentences after a locative context, $F_1(1, 31) = 7.31$, $F_2(1, 23) = 5.31$; or (c) agentive-target sentences after an agentive context, $F_1(1, 31) = 13.2$, $F_2(1, 23) = 9.67$. The other three conditions did not differ from each other (all Fs < 2.1).

These analyses all support the claim that the agentive-context/locative-target condition caused processing difficulty as soon as the processor reached the disambiguating noun. In contrast, the other three conditions were easy to process and could not be distinguished. These results accord well with the predictions of the thematic-processing account but accord less well with constraint-based accounts.

General Discussion

Experiment 1 demonstrated that participants had less difficulty interpreting an ambiguous *by* phrase in a passive sentence as an agentive than as a locative, when reading that sentence in isolation. The effect appeared as soon as participants encountered the noun in the *by* phrase that pragmatically disambiguated the sentence and was highly localized. In accordance with these data, a completion study showed a strong preference for agentive over locative completions.

In Experiment 2, the agentive and locative sentences were preceded by contexts that suggested that either an agentive or a locative expression would be forthcoming. Participants had less difficulty with the agentive *by* phrase than with the locative *by* phrase following an agentive context, but after a locative context, both types of *by* phrase were easy to

[3] By condition, the percentages were as follows: 24.6% in the locative-context/locative-target condition, 22.6% in the locative-context/agentive-target condition, 19.9% in the agentive-context/locative-target condition, and 31.2% in the agentive-context/agentive-target condition.

process. Specifically, a locative-target sentence after an agentive context was harder to process than target sentences in the other three conditions, which were equally easy to process. For this conclusion, the most important data are the first-pass reading times immediately after disambiguation. As in Experiment 1, the effects were extremely rapid and highly localized. However, a completion study showed different effects: Agentive completions after agentive contexts were most common; locative completions after agentive contexts were least common; and locative completions after locative contexts and agentive completions after locative contexts fell in between. Hence, the disfavored completion was hardest to process, but importantly, the favored completion was no easier to process than the other two conditions.

We note that Hanna et al. (1996) recently reported an eye-tracking study in which they investigated the resolution of *by*-phrase ambiguities with stimuli similar to ours. They found that total time on the full *by* phrase for agentive-target sentences after an agentive context was shorter than that for both locative-target sentences after locative contexts and locative-target sentences after agentive contexts. However, there were no significant differences between conditions during the first pass. In contrast, our analyses indicate that our pattern of effects is likely to be reliable.

The thematic-processing account, developed from Carlson and Tanenhaus's (1988) research, explains our findings well. When the processor encounters a verb, it accesses the verb's thematic grid (we ignore cases of ambiguity). It seeks obligatory and optional arguments to fill these roles, so that the verb can be saturated. Because adjuncts are not specified in the verb's lexical entry, the processor does not seek them. When the processor encounters a passive verb, it enters an agent role into the discourse model. The lexical entry indicates that this role can be filled by an agentive *by*-phrase argument. At the verb, the processor does not enter a location role into the discourse model, so it does not seek a locative *by*-phrase adjunct. In Experiment 1, participants initially assumed that the *by* phrase was agentive. If pragmatic information subsequently indicated that it was in fact locative, then thematic reanalysis was necessary, and processing difficulty ensued.

In Experiment 2, the interrogative *wh-* word in the context sentence introduced either an agent or a location role into the discourse model associated with the described event. This role was unspecified, but could be specified in a subsequent sentence. When participants encountered the verb in the target sentence and determined that it described the same event as the verb in the context sentence, the processor gained access to this role. It also gained access to the agent role as in Experiment 1, because this is specified in the verb's lexical entry. Hence, the processor had no difficulty with the agentive *by* phrase or with the locative *by* phrase after the locative context, but after the agentive context, the locative role was not available, so the locative continuation necessitated thematic reanalysis and produced processing difficulty.

Constraint-based accounts have some problems with these data. They straightforwardly predict the results of Experiment 1, because the completion study showed a preference for agentive completions over locative completions in isolation (and this preference presumably reflects the actual occurrence of the two constructions). Hence, the agentive analysis should be more activated than the locative analysis and should therefore be easier to process, as turned out to be the case. However, constraint-based accounts predict that two constraints should operate in Experiment 2, either mutually supporting each other or competing with each other. If the two constraints agree with the correct analysis, processing should be easiest; if the two constraints disagree with the correct analysis, processing should be hardest. The completion data are in accord with these predictions (and suggest that the verb constraint was a little stronger than the discourse constraint). In fact, the agentive–locative condition was hardest, as predicted, but the agentive–agentive condition was no easier than the other two conditions, even though both constraints support the correct interpretation. The power analysis indicates that had the agentive–agentive condition been easiest, we would have been able to detect an effect 60% of the time.

If we compare Experiments 1 and 2, we see that participants appear to have processed the target sentences following the agentive context in Experiment 2 very much like they processed the sentences in isolation in Experiment 1. The agentive context had little effect on ambiguity resolution, but the locative context appeared to make the locative target as easy as the agentive target. Hence, the locative context neutralized the preference found in isolation. More precisely, it produced *positive neutralization,* in that it caused the disfavored analysis to be processed like the favored analysis in isolation. (In contrast, *negative neutralization* would occur if an infelicitous context had caused the favored analysis to be as difficult as the disfavored analysis in isolation.) Importantly, context did not produce *override,* because the locative context did not make the locative target easier to process than the agentive target. According to our account, positive neutralization is predicted, because context makes the locative role available, but override is not predicted, because context does not remove the agentive role. Indeed, our account predicts that override should never occur with ambiguities that purely involve the question of whether a phrase is an argument or an adjunct (with no phrase-structure difference between the alternatives).

With such ambiguities, positive neutralization might occur, but override should not occur. This raises an interesting parallel with context effects in syntactic processing. Although the referential theory (Altmann & Steedman, 1988; Crain & Steedman, 1985) predicts contextual override, with the parser being directed toward the analysis that makes reference to the appropriate number of entities specified by the context, there are very few demonstrations of override during early processing in reading (but see Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995, for evidence of override effects during spoken language comprehension). Britt (1994) considered prepositional-phrase attachment ambiguities similar to those studied by Clifton et al. (1991), as in Sentence 5 above. She found that context could neutralize the initial preference for high attachment to a verb if the verb lacked an optional prepositional-phrase argument, but not if it lacked an obligatory prepositional-phrase argument. In other words, context effects on syntactic analysis in written language comprehension may depend on the verb's subcategorization properties. If thematic ambiguities are similar, then our context effects occurred only because the agentive *by* phrase is optional, not obligatory. This is an interesting topic for further research.

Experiments 1 and 2 showed that preferences based on differences in argument structure can occur as soon as a disambiguating word is encountered. Assuming there is no phrase-structure difference between the agentive and locative sentences, the processor must be able to make very rapid reference to thematic-role information. Hence, these experiments showed that a new aspect of language comprehension is performed in a very incremental manner.

This appears to conflict with the findings of Rayner et al. (1983) and Clifton et al. (1991), who argued that the effects of thematic processing are delayed. However, the critical aspect of these accounts is that thematic processing is delayed with respect to syntactic processing (i.e., processing based on phrase structure). If an ambiguity can be resolved using a syntactic strategy like minimal attachment, then as Rayner et al. and Clifton et al. suggested, thematic preferences have no bearing on the initial decision, but in our experiments, there was no syntactic ambiguity. Thematic-ambiguity resolution may have to queue behind syntactic-ambiguity resolution, but if there is no syntactic ambiguity to resolve, then thematic-ambiguity resolution may be immediate. Our findings are compatible with Rayner et al.'s and Clifton et al.'s, though they are also compatible with accounts in which there is no privileged status for phrase-structure information in ambiguity resolution.

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Appendix

Context and Target Sentence Pairs From Experiment 2

The first sentence of each pair is the context sentence, which was either agentive supporting (shown in the first pair of square brackets) or locative supporting (shown in the second pair of square brackets). The target sentence was either an agentive sentence (shown in the first pair of curly brackets) or a locative sentence (shown in the second pair of curly brackets). The target sentences in Experiment 1 were presented without the connecting phrase and started with the initial determiner of the sentence, which had a capital letter.

1. The emergency crew asked [who would treat the accident victim.]/[where to treat the accident victim.]
Skillfully the victim was treated by the {eager nurse}/{grass verge} immediately.

2. The head gardener decided [who should plant the shrubs.]/[where to plant the shrubs.]
In the end the shrubs were planted by the {apprentice}/{greenhouse} that morning.

3. The lawyer explained [who had found the lost document.]/[where to find the lost document.]
It seemed that the file was found by the {personnel manager}/{shredding machine} last night.

4. The lecturer did not know [who would find his lost wallet.]/[where to find his lost wallet.]
Luckily the wallet was discovered by the {student teachers}/{theatre entrance} last night.

5. The general announced [who would carry out the ambush.]/[where to carry out the ambush.]
As planned the convoy was ambushed by the {commando officers}/{deserted building} building the next day.

6. The student knew [who had performed the burial of the man.]/[where the burial of the man took place.]
Without doubt, the man was buried by the {bishop}/{chapel} twenty years ago.

7. The teacher decided [who should hide the prize.]/[where to hide the prize.]
After some thought the prize was hidden by the {intelligent pupil}/{grandfather clock} that afternoon.

8. The girl heard [who had discovered the body.]/[where the discovery of the body occurred.]
Sadly, the body was discovered by the {grieving cousin}/{isolated stable} that afternoon.

9. The manager decided [who should arrest the shoplifter.]/[where to arrest the shoplifter.]
Discreetly the shoplifter was arrested by the {security guard}/{changing rooms} very promptly.

10. The policeman wanted to know [who had carried out the stabbing]/[where the stabbing took place.]
Apparently, the youngster was stabbed by the {convicts}/{tenement} last week.

11. The mafia had decided [who was to detonate the bomb.]/[where to detonate the bomb.]
As intended, the bomb was detonated by the {nervous gangster}/{railway platform} during the night.

12. The driver asked [who would unload the delivery van.]/[where to unload the delivery van.]
In fact, the van was unloaded by the {bored assistant}/{empty warehouse} very quickly.

13. The newscaster described [who had carried out the attacks.]/[where the attacks took place.]
In fact the crimes were committed by the {sadistic mugger}/{desolate bridge} during the night.

14. The hotel staff wondered [who would find the lost girl.]/[where to find the lost girl.]
In the end the child was discovered by the {manageress}/{escalator} during the evening.

15. The florist enquired [who had sold the last of the flowers.]/[where to sell the last of the flowers.]

In fact, the flowers were sold by the {teenager}/{roadside} during the morning.

16. The producer announced [who would conduct the interview.]/[where to conduct the interview.]

As usual, the athlete was interviewed by the {anxious youth}/{running track} after the final.

17. The farmer asked [who had pitched the big tent.]/[where to pitch the big tent.]

Surprisingly, the tent was pitched by the {girl guide}/{deep river} last month.

18. The police identified [what had caused the accident.]/[where the accident happened.]

It turned out that the cyclist was knocked down by the {juggernaut}/{roundabout} that morning.

19. The owner pointed out [who had trained the horse.]/[where to train the horse.]

Unusually, the horse was trained by the {proud jockeys}/{muddy paddock} last year.

20. The admiral decided [who should moor the ship.]/[where to moor the ship.]

As ordered, the ship was moored by the {captain}/{harbour} straight away.

21. The cop noted [who assaulted the foreman.]/[where the assault of the foreman occurred.]

In fact, the foreman was assaulted by the {tattooed miner}/{colliery gates} that evening.

22. The police wondered [who would find the murder victims.]/[where to find the murder victims.]

At last the bodies were dug up by the {gardeners}/{riverside} the next day.

23. The duke decided [who should set up the huge marquee.]/[where to set up the huge marquee.]

As ordered, the marquee was set up by the {attendant}/{fountains} during the morning.

24. The supervisor asked [who would refuel the jumbo jet.]/[where to refuel the jumbo jet.]

Finally the plane was refuelled by the {tired pilots}/{empty hangar} late on Friday.

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