Avoiding the Garden Path: Eye Movements in Context

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Pragmatic factors, such as referential context, influence the decisions of the syntactic processor. At issue, however, has been whether such effects take place in the first or second pass analysis of the sentence. It has been suggested that eye movement studies are the only appropriate means for deciding between first and second pass effects. In this paper, we report two experiments using ambiguous relative/complement sentences and unambiguous controls. In Experiment 1 we show that referential context eliminates all the first pass reading time differences that are indicative of a garden path to the relative continuation in the null context. We observe, however, that the context does not eliminate the increased proportion of regressions from that disambiguating continuation. We therefore introduce a regression-contingent analysis of the first pass reading times and show that this new measure provides an important tool for aiding in the interpretation of the apparently conflicting data. Experiment 2 investigated whether the results of Experiment 1 were an artifact of the kinds of questions about the contexts that were asked in order to encourage subjects to attend to the contexts. The results demonstrated that the use of explicitly referential questions had little effect. There was some small evidence for a garden path effect in this second experiment, but the regression-contingent measure enabled us to locate all garden path effects in only a small proportion of trials and to conclude that context does influence the initial decisions of the syntactic processor.

There is considerable evidence both for and against the hypothesis that contextual information can influence the decisions of the syntactic processor. Although it is universally agreed that context affects the final interpretation of a sentence, at issue is whether such effects take place in first or second pass analysis. The "garden path" theory of syntactic processing (e.g., Clifton & Ferreira, 1989; Ferreira & Clifton, 1986; Frazier, 1979; Frazier, 1987; Rayner, Carlson, & Frazier, 1983) proposes that context exerts its influence only in the second pass reanalysis of a sentence, with first pass effects being exclusively syntactic. Thus, syntactic ambiguity is initially resolved on the basis of purely structural principles such as minimal attachment and late closure. Subsequent revision of this first pass analysis may be made on the basis of incompatibility with either the syntactic or pragmatic context, and hence the eventual context-sensitivity of the ambiguity resolution process. The "Incremental Interactive" theory (e.g., Altmann & Steedman, 1988; Steedman & Altmann, 1989; Altmann, 1989) proposes, contrary to the garden path theory, that context does influence the first pass analysis.

Much of the discussion has focused on the effects of referential context, which are supposed, in the incremental interactive theory, to determine the resolution of many ambiguities that garden path theorists explain in terms of the minimal attachment strategy (but see Clifton & Ferreira, 1989). One such ambiguity is the relative/complement ambiguity illustrated in examples (1) and (2).

This research was supported by SERC/MRC/ESRC Grant No. SPG8920151 awarded to GA and AG, and a SERC postgraduate studentship awarded to YD. We thank Don Mitchell for first drawing our attention to the unambiguous relative clause materials that were employed in this study. In addition, we are grateful to Judith Henstra and four anonymous reviewers for advice and comments on earlier versions of this paper. Correspondence and reprint requests should be sent to Gerry T. M. Altmann, Laboratory of Experimental Psychology, University of Sussex, Brighton BN1 9QG, UK.
(1) The fireman told the woman that he had risked his life for to install a smoke detector.

(2) The fireman told the woman that he had risked his life for many people in similar fires.

The garden path theory predicts that the interpretation of a noun phrase as either a simple noun phrase (as in example 2) or the head of a complex noun phrase (as in example 1) is resolved in favor of the simple noun phrase interpretation by virtue of its simpler phrase structure. The incremental interactive theory proposes that the resolution of this ambiguity in context depends on whether a unique referent for the referring expression can or cannot be found. If it cannot, the subsequent material ("that he had . . .") in examples 1 and 2 will be interpreted as a post-nominal modifier, providing additional restrictive information by which to successfully identify a unique referent (the principle of referential support—Altmann & Steedman, 1988). That is, the noun phrase will be interpreted as the head of a complex. If, on the other hand, a unique referent can be found, then the principle of parsimony (Altmann & Steedman, 1988; Crain & Steedman, 1985) predicts that the simple noun phrase interpretation will be adopted. Thus, whereas the garden path theory predicts that example (1) will always induce a garden path, whether in or out of context, the referential hypothesis predicts that garden paths in both examples can either be induced or avoided depending on the referential nature of the contexts (see Altmann, 1989, for an account of the incremental interactive hypothesis as applied to the case where there is no explicit prior context).

The theoretical underpinnings of the respective theories, and some of their shortcomings, have been discussed extensively elsewhere (see, for example, Clifton & Ferreira, 1989; Steedman & Altmann, 1989). The purpose of the present paper is to present new empirical evidence which bears on the subject and to consider some methodological issues that have accompanied the debate about which model most correctly describes the behavior of the human sentence processing mechanism.

As we stated at the outset, the crucial issue is not whether context exerts an influence on the syntactic processor, but when such influence is exerted. Central to this debate has been the distinction between first and subsequent pass parsing effects. Eye tracking provides a methodology that is to some extent sensitive to this distinction, insofar as the left-to-right movements of the eyes during reading can be divided into those that occur when a region is read for the first time and those that occur when that region is revisited for a second or subsequent time (or when the eyes have travelled back to that region from a later region). The eye movement measures that have commonly been used when studying syntactic ambiguity include first pass reading times per character in a region, total pass reading times per character in a region (i.e., first and subsequent pass reading times), and the number of regressions out of a region (see Rayner et al., 1989, for review). Any effect which manifests itself only in the pattern of second pass reading times cannot be said to be a first pass parsing effect, while differences occurring in the first pass reading times may be due to first pass parsing effects. Rayner et al. (1989) suggest, in fact, that a range of measures are required in order to argue that an observed effect reflects an initial analysis process as opposed to a reanalysis process (henceforth, we use the latter terms to refer to the first and second pass parsing effects which concern us here, in order to avoid any potential confusion between first pass parsing effects, and first pass reading times).

In addition to using the appropriate measures of reading time, it is important to make appropriate comparisons across different experimental conditions. Rayner et al. (1989) review a variety of ways in which such comparisons can be made. One way is to compare sentences which, according to
some theory, should be easy to analyze with sentences which should be difficult. The question relevant to the present study would be whether the provision of appropriate contexts eliminates any difference that would otherwise be observed between the two kinds of sentence. Another way is to use an unambiguous control in which the syntactic processor is assumed to pursue a particular analysis. Any difference from this baseline in the experimental conditions suggests that the processor has pursued some other analysis.\(^1\) Better still is to use both kinds of contrast. If both converge on the same interpretation of the data then whatever conclusions are made will be strengthened.

Thus far, none of the studies which favor the incremental interactive theory—which predicts effects of context on the initial analysis—have used eye movements to demonstrate such effects, and the one eye movement study which attempted to test the referential hypothesis (Ferreira & Clifton, 1986, Experiment 2) has been criticized for using contexts that did not allow a true test of the referential hypothesis (see Altmann & Steedman, 1988; Clifton & Ferreira, 1989; Steedman & Altmann, 1989, for discussion). Moreover, this study failed to utilize the control conditions which are so crucial to the interpretation of the eye movement record. It is important, therefore, that suitable controls be constructed for materials such as (1) and (2), so that the predictions of the referential hypothesis can be tested.

The referential hypothesis predicts a variety of effects, under different contextual conditions, for sentences such as (1) and (2), repeated below.

\begin{quote}
(1) The fireman told the woman \textit{that he} had risked his life for to install a smoke detector.
\end{quote}

\begin{quote}
(2) The fireman told the woman \textbf{that he} had risked his life for many people in similar fires.
\end{quote}

Like the garden path theory, it predicts that in the absence of any context (the so-called null-context—Crain & Steedman, 1985) the italicized sequences in both the ambiguous complement (2) and the ambiguous relative (1) will be interpreted as part of a complement clause (see Crain & Steedman, 1985, Altmann & Steedman, 1988, and Altmann, 1989, for variations on the underlying theory). It follows that a garden path should be experienced on “to install” in example (1), given that this continuation is only compatible with the relative clause interpretation of the ambiguous sequence. Eye movements should thus indicate a processing difficulty at this point in example (1), with no corresponding difficulty in the corresponding region “many people” in example (2). Because both the referential hypothesis and the garden path theory make the same prediction, these two conditions do not allow the theories to be distinguished.

The second prediction of the referential hypothesis is that by preceding the ambiguous relative by a relative-supporting referential context (introducing more than one possible referent for the referring expression “the woman”), the garden path on “to install” can be avoided: The ambiguous string will now be interpreted as a relative clause. The garden path theory predicts that there should still be a garden path in the initial stages of analysis for the ambiguous relative. Preceding the ambiguous complement by a complement-supporting referential context (just one antecedent to the critical referring expression) will, on both accounts, lead to interpretation of the ambiguous string as a complement clause.

In principle, then, one need only compare four conditions: the ambiguous relative and the ambiguous complement in the null context (to demonstrate that the experimental measure is sensitive to the garden

\(^1\) We would argue, similarly, that an appropriate baseline against which to compare sentences in which a garden path is expected would be an ungrammatical control condition, because both kinds of sentence (garden path and truly ungrammatical) include a point at which a local ungrammaticality is experienced.
path effect) and the same two targets in their respectively 'felicitous' contexts (where "felicity" is defined informally in terms of satisfying the presuppositions associated with the target sentences—see Altmann & Steedman, 1988). We would expect, under the referential hypothesis, to observe a garden path effect in the null context, but not in the felicitous context. However, if we were to find evidence of some increased processing complexity to the relative clause target in context relative to the complement clause target, this need not be due solely, or at all, to a garden path effect: The difference may simply be a reflection of the fact that the relative clause analysis requires a more complex search of the discourse model than that necessitated by the complement clause analysis. Moreover, and given that the disambiguating phrase "to install" signals the offset of the relative clause, it is conceivable that differences in processing complexity might arise at that point. We thus need an unambiguous relative clause which is as close in wording as possible to the ambiguous version. Such a sentence is easily constructed by replacing the main verb "told" in example (1) with a verb like "asked" which does not permit a that-complement clause in object position:

(3) The fireman asked the woman that he had risked his life for to install a smoke detector.

According to the referential hypothesis, there should be no difference in the first pass reading times between the unambiguous and ambiguous relatives when both are embedded in the same relative-supporting context. In both cases, the material "that he had" should be interpreted as a relative. According to the garden path theory, only in the unambiguous case will a garden path be avoided. Any difference, in felicitous contexts, between the ambiguous relative and its unambiguous control would pose a problem for the referential hypothesis. Similarly, a total lack of any such difference in the first pass data would pose a problem for the garden path theory.

Some researchers (Ferreira & Henderson, 1990; Mitchell, 1987, 1989) have suggested that the subcategorization information which prohibits a verb like "asked" to take a that-complement is ignored in the initial phases of parsing. If this were true, then sentence (3) would be less obviously appropriate as a control for sentences (1) and (2). This is because the sequence "that he had" would not be interpreted initially as a relative, but would be analysed as such only subsequently, once the subcategorization information became available. We shall defer further discussion of this point until after Experiment 1, which will show whether reading time data support the contention that reprocessing takes place in the ambiguous region following "asked."

Experiment 1

This first experiment was designed to test the predictions of the referential hypothesis and the garden path theory in the null context and felicitous context conditions. Given the immediate concerns of the paper, namely the factors influencing the initial selection among alternative analyses, this experiment (like Experiment 2) is intended to explore only first pass patterns of eye movements. The contexts corresponding to the complement, relative, and control targets (i.e., their felicitous contexts) are given in Table 1.

For the purposes of the analysis, the targets were segmented as follows:

(4) He / told / the woman / 1 2 3 that he had risked his life for / 4 to install / a smoke detector. 5 6

We shall refer to region 4 as the "ambiguous region," to region 5 as the "disambiguating region," and to region 6 as the "final region."

According to both the garden path theory and the referential hypothesis, evidence of a garden path should be observed, in the null context, in the disambiguating region
TABLE 1

EXAMPLE ITEM FROM EXPERIMENT 1

<table>
<thead>
<tr>
<th>Complement-supporting context</th>
<th>Relative-supporting context</th>
<th>Unambiguous control</th>
</tr>
</thead>
<tbody>
<tr>
<td>An off-duty fireman was talking to a man and a woman. He was telling them how serious the situation had been when their house had caught fire. The fireman had risked his life to rescue the woman while the man had waited outside.</td>
<td>He / told / the woman / that he'd risked his life for / many people / in similar fires.</td>
<td>He / asked / the woman / that he'd risked his life for / to install / a smoke detector.</td>
</tr>
</tbody>
</table>

context between the two ambiguous targets, because in both cases this region should be interpreted as part of a complement clause. On the other hand, we do expect increased reading times in the equivalent region for the unambiguous relative, simply because of the infelicity of the relative clause construction in the null context (cf. Crain & Steedman, 1985, and see below where we discuss these predictions in the light of Mitchell's claim, 1989, that subcategorization information is initially ignored). In a relative-supporting context, the relative clause is felicitous, and if we were to compare reading times to the unambiguous relative in and out of context, we should observe reading times for the relative clause dropping in the felicitous context. We shouldn't necessarily expect to see much change in reading times for the following complement clause "to install," as this provides new information in both the null and felicitous contexts. We might thus expect differential effects of context on the different parts of the sentence and even for the "corresponding" parts of the different types of sentence. The complexities of such interactions mean that care is needed in interpreting our results, and in reporting them we shall concentrate mainly on the comparisons between the sentence types (and, in particular, between the ambiguous and unambiguous relatives), although we shall comment, where appropriate, on comparisons within sentence types across the different context conditions.

Method

Subjects. Forty-two members of the University of Sussex were paid £4 an hour to participate in the experiment. All subjects had normal uncorrected vision or wore contact lenses.

Apparatus. Subjects' eye movements were recorded using an infrared limbus eye-tracking system (Optoelectronic Developments type 54), and the horizontal signals were sampled every 5 ms. A complete record of eye location, fixation duration, and fixation sequence was stored for later anal-
ysis. Viewing was binocular, although signals were recorded from one eye only. The distance from the eye to the screen was approximately 60 cm. At this distance, the eye tracker has a resolution of one character.

**Materials.** 36 experimental passages such as the one in Table 1 were presented to subjects randomly intermixed with 34 filler passages. The fillers were constructed so that they resembled the experimental items to different degrees. Thus, six of the fillers had contexts that were similar to the relative-supporting contexts in Table 1, with a further two fillers having contexts that introduced a number of different objects (the final sentences of these passages did not resemble those of the experimental passages). The fillers were designed in this way to minimize the likelihood that subjects could adopt a strategy of the form "If two Xs are encountered, then expect subsequently to encounter one of the Xs modified by a relative clause."

Where a target sentence was preceded by a context, the context was presented one sentence at a time, with the subject pressing a response button to initiate the display of the next sentence. All sentences were centered vertically on the screen. Thus, successive sentences replaced the preceding sentence on the screen. Any context sentence that was longer than 80 characters was split across two lines of the display. No target sentence exceeded 80 characters.

**Design.** There were six versions of each passage (3 targets × 2 contexts—the null context, or a felicitous context). The design was a fully factorial repeated measures design incorporating a Latin square. Six stimuli sets were constructed with each item represented in each set in just one of its versions. Each subject was thus exposed to all items and to all experimental conditions but never saw more than one version of any individual item. There were two versions of each stimulus set: one starting with all the referential context conditions and ending with all the null context conditions. Thus, context condition was blocked, with half the subjects receiving the null context conditions first and half receiving them second.  

**Procedure.** Subjects' head movements were minimized using a head restraint and a bite bar that was prepared beforehand for each subject. The experimenter explained the procedure to the subject and initiated a brief practice session to ensure the subject's comfort and familiarity with the procedure. The eye tracking system was calibrated prior to approximately 60% of the trials. This procedure lasted 30 s. Calibrations were made prior to all experimental items and approximately 12% of the filler items (to ensure that subjects could not distinguish the experimental trials from the fillers). In the referential context conditions, subjects pressed a button to view the next sentence in the context. Each sentence was replaced by an aligning prompt prior to the presentation of the following sentence (or question, following the target sentence). All the experimental and filler items were followed by a simple yes/no question that was included to induce subjects to pay attention to the target. In the referential context conditions, an additional question was included which could only be answered correctly if subjects had read the context (e.g., "Was the fireman talking to two women?"). Subjects responded to the questions by pressing one of two response buttons in front of them. Subjects were free to come off the bite bar and pause at any stage in the experiment, although they were encouraged to do so only between trials.

**Scoring regions.** The target sentences were divided into regions for the purposes of scoring as outlined above. Only the ambiguous, disambiguating, and final regions were included in the data analyses.

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2 No effect of blocking was found in the data, and we therefore excluded this variable from the results we report below.
Results

Results are reported in terms of both first pass reading times per character in a region and the probability of a first pass regression to a point outside (and to the left) of that region. The first pass reading time is the time spent in a region until the subject first makes an eye movement out of that region (whether left- or rightwards). A first pass regression is simply a regression out of a region when there has been no prior fixation in any region to its right (in other words, any regression made on a second pass sweep of the region is excluded). The probability of making a first pass regression is calculated as the proportion of trials on which a first pass regression occurs (i.e., it is the number of trials, across subjects and items, on which a first pass regression occurs, divided by the total number of trials, across subjects and items). The mean first pass reading times per character, and the probability of making a first pass regression, are shown in Fig. 1 and Table 2, respectively. Three-way ANOVAs (2 Contexts x 2 Sentence Types x 3 Regions) were performed on the data.

First pass reading times. Overall, there were main effects of Context ($F_1(1,41) = 54.93, p < 0.001; F_2(1,35) = 77.98, p < 0.001$) and Region ($F_1(2,82) = 5.29, p < 0.01; F_2(2,70) = 9.05, p < 0.001$). The main effect of Sentence Type was significant on the by-items analysis but just failed to reach significance on the by-subjects analysis ($F_1(2,82) = 3.07, p < 0.06; F_2(2,70) = 3.23, p < 0.05$). There was a significant Region x Sentence Type interaction ($F_1(4,164) = 5.44, p < 0.001; F_2(4,140) = 7.59, p < 0.001$) and a significant three-way interaction between Region, Sentence Type, and Context ($F_1(4,164) = 3.23, p < 0.02; F_2(4,140) = 3.69, p < 0.01$). No other interactions were significant. Planned comparisons in the disambiguating region revealed that in the null context the difference between the relative and the control was significant ($F_1(1,164) = 19.80, p < 0.001; F_2(1,140) = 22.66, p < 0.001$) as was the difference between the relative and the complement ($F_1(1,164) = 31.55, p < 0.001; F_2(1,140) = 36.10, p < 0.001$). There was no significant difference between the control and the complement ($F_1(1,164) = 1.36, p > 0.2; F_2(1,140) = 1.56, p > 0.2$). In addition, the unambiguous relative control was significantly slower than the ambiguous complement and relative targets in the ambiguous region ($F_1(1,164) = 7.75, p < 0.01; F_2(1,140) = 8.87, p < 0.005$). In the final region of the target, again in the null

![Graph](image-url)
TABLE 2

THE PERCENTAGE OF TRIALS IN EXPERIMENT 1 ON WHICH A FIRST PASS REGRESSION OUT OF EACH REGION OCCURRED

<table>
<thead>
<tr>
<th>Region</th>
<th>Null context</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ambiguous</td>
<td>Disambiguating</td>
<td>Final</td>
</tr>
<tr>
<td>Comp</td>
<td>9 (91)</td>
<td>21 (78)</td>
<td>69 (25)</td>
</tr>
<tr>
<td>Rel</td>
<td>7 (93)</td>
<td>44 (56)</td>
<td>76 (23)</td>
</tr>
<tr>
<td>Control</td>
<td>17 (83)</td>
<td>25 (72)</td>
<td>64 (34)</td>
</tr>
<tr>
<td>Referential context</td>
<td>9 (91)</td>
<td>19 (79)</td>
<td>69 (24)</td>
</tr>
<tr>
<td>Comp</td>
<td>8 (91)</td>
<td>34 (64)</td>
<td>69 (23)</td>
</tr>
<tr>
<td>Control</td>
<td>9 (91)</td>
<td>21 (77)</td>
<td>66 (26)</td>
</tr>
</tbody>
</table>

Note. Figures in parentheses show the percentage of trials on which a first pass regression did not occur. (The two do not necessarily add up to 100 because of the (few) trials on which a zero reading time was recorded for that region. In such cases the trial was eliminated from the regression-contingent measures described below (and treated as a missing value which was replaced by the Subject x Condition, or Item x Condition, cell mean). Zeros resulted when the eyes skipped a region entirely, although the majority of zeros occurred in the final region, when subjects pressed the response button before having reached the final region. As expected, no zeros were recorded for trials on which a first pass regression was observed. For the overall reading times, it made virtually no difference whether zeros were included in the cell means or were treated as missing values. The figures showing overall reading times graph the cell means which constituted the by-subjects analyses (and which treated zeros as real data—that is, as reflecting the contribution of each region to the overall processing time across all subjects). The observed patterns did not change depending on which of several possible methods of calculating the cell means was used.)

context, only the difference between the relative and the control was significant ($F_1(1,164) = 5.16, p < 0.03; F_2(1,140) = 5.91, p < 0.02$). In the referential context condition, the only significant difference on the pairwise comparisons was between, once again, the relative and control targets in the final region ($F_1(1,164) = 4.65, p < 0.04; F_2(1,140) = 5.32, p < 0.03$).

Looking only at the ambiguous relative and the control in the ambiguous and disambiguating regions, we found a significant three-way interaction between Region, Sentence Type, and Context ($F_1(1,41) = 14.06, p < 0.001; F_2(1,35) = 18.40, p < 0.001$). There were significant main effects of Context ($F_1(1,41) = 45.84, p < 0.001; F_2(1,35) = 41.93, p < 0.001$) and Region ($F_1(1,41) = 11.00, p < 0.002; F_2(1,35) = 17.86, p < 0.001$) and a Sentence Type x Region interaction ($F_1(1,41) = 15.99, p < 0.001; F_2(1,35) = 11.71, p < 0.002$). No other effects were significant. Separate two-way ANOVAs within each Sentence Type revealed a significant Context x Region interaction for the control ($F_1(1,41) = 17.29, p < 0.001; F_2(1,35) = 33.34, p < 0.001$), although there was no such interaction for the ambiguous relative target ($F_1$ and $F_2 < 1$). The main effect of Context was highly significant for both the ambiguous relative ($F_1(1,41) = 24.68, p < 0.001; F_2(1,35) = 29.23, p < 0.001$) and the unambiguous control ($F_1(1,41) = 31.56, p < 0.001; F_2(1,35) = 35.86, p < 0.001$). A main effect of region was only found for the ambiguous relative ($F_1(1,41) = 22.80, p < 0.001; F_2(1,35) = 24.64, p < 0.001$).

First pass regressions. There were main effects of Sentence Type ($F_1(2,82) = 14.51, p < 0.001; F_2(2,70) = 10.43, p < 0.001$) and Region ($F_1(2,82) = 223.98, p < 0.001; F_2(2,70) = 735.57, p < 0.001$) but only marginal effects of Context ($F_1(1,41) = 3.36, p < 0.08; F_2(1,35) = 4.74, p < 0.04$). The only significant interaction was between Sentence Type and Region ($F_1(4,164) = 11.73, p < 0.001; F_2(4,140) = 12.76, p < 0.001$). The difference in the disambiguating region between the relative target and the other two targets was significant both in the null context ($F_1(1,164) = 45.68, p < 0.001; F_2(1,140) = 46.51, p < 0.001$) and in the referential context ($F_1(1,164) = 21.29, p < 0.001; F_2(1,140) = 21.68, p < 0.001$). Whereas the referential context completely eliminated any differences in reading times to the three targets in the disambiguating region, the same was not true for first pass regressions. There were more regressions out of the disambiguating region of the relative than out of the equivalent region of
the control, irrespective of context (although there were significantly more regressions out of this region in the null context than out of the same region in the referential context—44% versus 34%, $F_1(1,164) = 7.92, p < 0.01$; $F_2(1,140) = 8.06, p < 0.01$).

**Questions.** In the two conditions in which the target sentences were preceded by an explicit context, approximately 94% of the yes/no context questions were answered correctly. 88% of the questions about the target sentence were answered correctly.

**Discussion of Experiment 1**

The difference in the null context between the ambiguous relative and its unambiguous counterpart is clear evidence of a garden path effect. The fact that the unambiguous control evokes longer reading times in the ambiguous region than the ambiguous complement was expected (see above) and is easily explained in terms of the referential hypothesis. As Crain and Steedman (1985) observe, the use of a relative clause presupposes a number of things, such as the existence of more than one woman (in the current examples), the existence of additional information by which to distinguish between these women (that the fireman had saved the life of one of the women), and so on. Use of the complement clause, on the other hand, presupposes none of these things, and one might therefore suppose that in the null context, the increased reading times to the relative clause signal the greater processing cost associated with the violation of the presuppositions underlying the usage of a relative. Interestingly, this residual difference in processing complexity between the unambiguous relative and the complement is completely eliminated once a felicitous context which satisfies these presuppositions is provided.

This latter result is important because it also provides evidence against the idea that the subcategorization features of "asked" are ignored in the initial stages of analysis (cf. Mitchell, 1989). If they were ignored, then there should be evidence of reanalysis in the ambiguous region following "asked." While the increased reading times for this region in the null context could conceivably be attributed to such reanalysis, we should also expect to see a similar increase in the context condition. However, reading times for the ambiguous regions of all three targets in context do not differ. We therefore believe that "asked" does disambiguate the ambiguous region in the manner predicted and was, therefore, an appropriate control condition for the present study.

In accord with the predictions of the referential hypothesis, the provision of a felicitous referential context completely eliminated the reading time difference which had been observed in the null context between the ambiguous relative and the unambiguous control.

As we predicted, the provision of a felicitous context had different effects on the different regions of the unambiguous control (specifically, the regions corresponding to the ambiguous and disambiguating regions). However, while there was a significant interaction of context with region for the unambiguous control, there was no such interaction for the ambiguous relative. This might suggest that the only effect of context on the ambiguous relative was a general lowering of first pass reading times across all regions. However, a more detailed examination of the data shows that this lack of interaction should be explained in terms of the differential effects of context on the different regions of the ambiguous relative. First, reading times for the disambiguating region are slower in the null context than in the felicitous context because in the null context the garden path is noticed in this region, whereas there is no garden path in the felicitous context (according to the referential hypothesis). Reading times for the ambiguous region are slower in the null context than in the felicitous con-
text for a different reason. The ambiguous region is interpreted as a complement in the null context (according to both the referential hypothesis and the garden path theory), and the corresponding region of the true complement is read more slowly in the null context than in the felicitous context. This latter finding may reflect the fact that in context the complement clause repeats information already contained in the context, although another explanation is that new information is easier to integrate into the discourse model when the model already contains information to which it can be anchored.

The finding that there is no interaction between Region and Context is, as we have just claimed, compatible with the referential hypothesis. However, it should be noted that finding an interaction would also be compatible, because we have no a priori reason for supposing that the increase in reading times due to the garden path on the disambiguating region will be the same as the increase on the ambiguous region due to the increased difficulty of processing the ambiguous region in the null context.

It is because of this uncertainty about the effects of context on the different regions of the sentences that the crucial comparison is not between the ambiguous relative in and out of context, but between the difference between the ambiguous relative and the unambiguous relative in and out of context. Given the close match between the two targets, the elimination of this difference in the referential context supports the contention that the garden path has been eliminated.

The regression data, however, suggest otherwise: The data from the referential context conditions indicate that a regression out of the disambiguating region was significantly more probable for the ambiguous relative than for the unambiguous control. The two sources of data are thus at odds with one another: The reading time data suggests that the garden path has been eliminated by the provision of referential contexts, and the regression data suggests that there is still some increased processing complexity associated with the relative target.

There are at least two interpretations of this result. First, it could be argued that there is a garden path at the disambiguating region of the relative target in the referential context, as evidenced by the regression data, but that it is easier to recover from the garden path in the referential context and there is consequently less of a cost (indeed, no observable cost in the absence of a regression) in the context condition. Under this interpretation, first pass reading times derived from eye movement data are unreliable indicators of garden path phenomena, insofar as garden path phenomena may not be manifested as increases in first pass reading times. But if the regression data alone are taken to indicate a garden path in the referential context, then some explanation must be given for the 66% of trials on which there was no first pass regression out of the disambiguating region of the relative. Either the regression data are also an unreliable index of garden paths (to the extent that they do not capture the majority of occasions on which a garden path occurs) or the discrepancy between the reading time and regression data suggests that the regression data reflect a minority of occasions on which subjects garden path—a minority which shows up as an increase in the proportion of trials on which a regression takes place, but which is overshadowed in the reading time data by the majority of occasions on which subjects did not garden path. Clearly, closer inspection of the regression data is required.

The high proportion of regressions from the final region (see Table 2) reflects in part the tendency of subjects to move back to the beginning of the line, perhaps to prepare to read the next display before pressing the response button. More interesting, though, is the fact that in the referential context the disambiguating region of the ambiguous relative caused only 13% more first pass regressions than did the same re-
EYE MOVEMENTS IN CONTEXT

Fig. 2. Mean first pass reading times per character (ms) in the absence of a regression, with standard errors, for the ambiguous (ambig), disambiguating (dis), and final (final) regions (Experiment 1).

region of the unambiguous control. Moreover, on the majority of trials, there were no regressions out of the disambiguating region. That is, whereas on 34% of trials there was a regression out of the disambiguating region of the ambiguous relative in context, on 66% of trials there was no such regression. In the null context, only 44% of the trials involving the relative resulted in a first pass regression out of the disambiguating region, even though this is where both the referential hypothesis and the garden path theory predict the majority of the garden paths to occur. If the general tendency in the null context is for subjects to garden path in the ambiguous region of the relative, then first pass reading times for the disambiguating region in the absence of a regression (i.e., 66% of the trials) should reflect the processing complexities that accompany the garden path, even though there has been no regression out of this region (if a garden path occurs on the majority of trials, but regressions only occur on a minority of trials, then we must expect evidence of a garden path even when there

Fig. 3. Mean first pass reading times per character (ms) prior to a regression, with standard errors, for the ambiguous (ambig), disambiguating (dis), and final (final) regions (Experiment 1).
has been no regression). In order to test this prediction, we divided the reading time data according to whether a regression out of a region did or did not occur (we shall subsequently refer to this procedure as a regression contingent analysis of the first pass reading times).

When subjects first move into a region, they can either remain in that region and then leave it with a rightwards saccade, or they can leave it with a leftwards saccade (a regression). We have suggested that trials in which there has been no regressive eye movement out of a region should still indicate a garden path effect in the null context. Reading times on trials in which a regression does occur (that is, reading times prior to a regression) may reflect the processing complexities of a garden path, but they may also reflect other complexities (which, given that we see regressions from all regions of the sentence, will not necessarily be related to the garden path phenomenon). We would also expect such reading times to be contaminated by noise due to the relatively small number of observations from which they are calculated (between 19% and 44% in the disambiguating region—see Table 2). Figures 2 and 3 show the first pass reading times for each region broken down into those in the absence of a regression from that region, and those prior to a regression from that region.3

In Fig. 2 we see a pattern that is very similar to the overall first pass reading times shown in Fig. 1. Even though the data for any one region reflect only those trials on which no first pass regression occurred, we see clear evidence of a garden path effect in the null context which is completely eliminated in the referential context.4 In addition, we also see an interaction between Region and Context for both the ambiguous relative and the unambiguous control (cf. the earlier discussion on the differential effects of context on different regions of different target sentences).5 In Fig. 3, on the

4 There were main effects of Context \((F_{(1,14)} = 51.31, p < 0.001; F_{(1,35)} = 19.01, p < 0.001)\) and Region \((F_{(2,82)} = 24.08, p < 0.001; F_{(2,70)} = 90.94, p < 0.001)\). There was no significant effect overall of Sentence Type \((F_{(2,82)} = 2.65, p < 0.08; F_{2} < 1)\). There was a significant Region \(\times\) Sentence Type interaction \((F_{(4,164)} = 6.35, p < 0.001; F_{(4,140)} = 3.65, p < 0.01)\) and Region \(\times\) Context interaction \((F_{(4,164)} = 7.77, p < 0.001; F_{(4,140)} = 5.45, p < 0.01)\) and a significant three-way interaction between Region, Sentence Type, and Context \((F_{(4,140)} = 6.71, p < 0.001; F_{(4,140)} = 7.60, p < 0.001)\). No other interactions were significant. Planned comparisons in the disambiguating region revealed, in addition, that in the null context the difference between the relative and the control was significant \((F_{(1,164)} = 31.89, p < 0.001; F_{(1,140)} = 13.07, p < 0.001)\) as was the difference between the relative and the complement \((F_{(1,164)} = 48.78, p < 0.001; F_{(1,140)} = 23.15, p < 0.001)\). There was no significant difference between the control and the complement \((F_{(1,164)} = 1.79, p < 0.2; F_{(1,140)} = 1.43, p < 0.3)\). In addition, the unambiguous relative control was significantly slower than the ambiguous complement and relative targets in the ambiguous region \((F_{(1,164)} = 7.15, p < 0.01; F_{(1,140)} = 4.25, p < 0.05)\). In the final region of the target, again in the null context, the difference between the relative and the control was significant \((F_{(1,164)} = 5.36, p < 0.03; F_{(1,140)} = 6.47, p < 0.02)\). The difference between the relative and the complement was marginal \((F_{(1,164)} = 3.69, p < 0.06; F_{(1,140)} = 15.15, p < 0.001)\). In the referential context condition, there were no significant differences on any of the pairwise comparisons (within a region).

5 For the relative: \(F_{(1,41)} = 16.85, p < 0.001; F_{(1,35)} = 9.94, p < 0.005\). For the unambiguous control: \(F_{(1,41)} = 7.19, p < 0.02; F_{(1,35)} = 9.54, p < 0.005\).

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3 Three-way ANOVAs (described below) were performed on the two regression contingent measures. In each case, however, some of the by-subjects or by-items cell means were missing. Figures 2 and 3 exclude missing cells, with standard errors being calculated across the remaining cells. However, for the purposes of the statistical analyses, missing cells were replaced according to the procedure described in Winer (1962) for repeated measures designs (and see Boland et al., 1990). For the reading times in the absence of a regression, 11.5% of the by-subject means (across the three regions of interest) and 4% of the by-item means were missing. For reading times prior to a regression, 27% of the by-subject means and 22% of the by-item means were missing. The analyses should thus be treated with caution.
other hand, we see a very different pattern. In the null context, the pattern is similar to that found overall and in the absence of any regression (although there is considerable difference in the absolute reading times)—in all cases there is evidence of a garden path to the relative target. However, whereas overall, and in the absence of any regression, we find that the referential context completely eliminates this garden path, this is not the case for the reading times prior to a regression—the time spent in the disambiguating region prior to a regression is greater for the ambiguous relative than it is for the unambiguous control (and the complement). It would appear, then, that the regression contingent measures support the view that the referential context eliminates all but a minority of garden paths.

The claim that a small number of garden paths still occur in the felicitous context merits some comment. These occurrences can be attributed to a variety of causes, two of which we mention here. First, the subject's concentration may wander and they either fail to build the correct representation of the discourse or else they lose information during the course of the trial. If this happens, and information about the possible referents is lost, then the relative-supporting context acts more like the null or complement-supporting context (and hence the garden path, predicted by both

6 There were no main effects of Context ($F_1$ and $F_2 < 1$) or Sentence Type ($F_S(2,82) < 1; F_S(2,70) = 1.53, p < 0.3$). There was a significant effect of Region ($F_1(2,82) = 70.34, p < 0.001; F_2(2,70) = 87.96, p < 0.001$). There was a significant Region x Sentence Type interaction ($F_S(4,164) = 7.31, p < 0.001; F_2(4,140) = 12.16, p < 0.001$) and Region x Context interaction ($F_1(4,164) = 7.27, p < 0.001$; $F_2(4,140) = 5.39, p < 0.01$) and only a marginal three-way interaction between Region, Sentence Type, and Context ($F_S(4,164) = 2.20, p < 0.08; F_2(4,140) = 3.70, p < 0.01$). No other interactions were significant. Planned comparisons in the disambiguating region revealed, in addition, that in the null context the difference between the relative and the control was significant ($F_1(1,164) = 7.23, p < 0.01$; $F_2(1,140) = 22.18, p < 0.001$) as was the difference between the relative and the complement ($F_1(1,164) = 7.39, p < 0.01; F_2(1,140) = 21.76, p < 0.001$). There was no significant difference between the control and the complement ($F_1$ and $F_2 < 1$). In addition, the unambiguous relative control was significantly slower than the ambiguous complement and relative targets in the ambiguous region ($F_S(1,164) = 11.24, p < 0.001; F_2(1,140) = 16.47, p < 0.001$). The apparent difference in Fig. 3 between the complement and the relative in the ambiguous region was not significant ($p > 0.1$). In the final region of the target, again in the null context, there were no significant differences between any of the sentence types (all $p > 0.1$). In the referential context condition, there were no differences between the sentence types in the ambiguous region (all $F < 1$). In the disambiguating region, the difference between the relative and both the complement and the control was significant ($F_1(1,164) = 5.42, p < 0.03; F_2(1,140) = 18.10, p < 0.001$). In the final region there were no significant differences between any of the sentence types on the

by-subjects analyses (all $p > 0.1$), although on the by-items analyses the differences between the relative and the complement and between the relative and the control were significant ($F_2(1,140) = 5.19, p < 0.03$ and $F_2(1,140) = 8.48, p < 0.003$, respectively). The discrepancy between the by-subjects and by-items is presumably due to the procedure for replacing missing cells described earlier.

7 One reviewer suggested an alternative procedure in which the data for each region were selected contingent on the presence of a regression out of the disambiguating region. Thus its would be included from the ambiguous or final regions irrespective of whether a regression occurred in those regions and dependent only on whether there had been a regression out of the disambiguating region. The rationale would be that this would best pick out those occasions on which subjects garden pathed (as evidenced by the presence of a regression at the disambiguating region). But given that a regression from the disambiguating region is not evidence per se of a garden path (in the null context we see a garden path effect in the absence of any such regression), it follows that we would at best be picking out a subset of occasions on which a garden path occurred. Our intention, however, is not to identify exclusively those cases in which a garden path occurred. It is, instead, to demonstrate a majority of cases where there is no evidence of any such effect. We favor the original contingency because it allows us to assess the processing cost associated with each region when that particular region is read without interruption by a regressive eye movement (however caused) and because we have observed that this no-regression component is sensitive to garden paths in the null context.
the alternative hypotheses). The fact that on a small minority of occasions subjects responded incorrectly to the context questions suggests this may have occurred. The second possibility is that subjects may on occasion give one of the referents (for instance, one of two women mentioned in the context) more prominence than the other. Thus, one of the referents may be more focused than the other and the subject may take the focused individual to be the referent of the critical (simple) noun phrase, thereby obviating the need for interpreting the subsequent material as a relative clause (and hence the garden path). Why these effects occur is beyond the scope of this paper. It is enough to demonstrate that the architecture of the HSPM does generally permit contextual information to interact with the parser to avoid the garden path in the cases we examine here. Moreover, it is important to demonstrate that this effect shows up in the first pass reading times. Such a demonstration is not readily compatible with the garden path theory.

In Experiment 1 we have demonstrated the usefulness of the regression-contingent measure of first pass reading times as a means for reconciling the non-contingent first pass reading time data with the first pass regression data. The strong effects of referential context illustrated in Figs. 1 and 2 could reflect, however, the fact that the referential nature of these contexts was made explicit to the subjects by virtue of the yes/no questions that were asked of subjects. These questions explicitly asked whether, to use the example already given, the fireman was talking to two women, or to a man and a woman. Have we somehow biased towards a processing strategy which, although sensitive to referential context, is not the norm? In Experiment 2, we repeat Experiment 1 exactly, only this time the context questions focus on any aspect of the context except the referential aspect. Experiment 2 also serves as a replication of Experiment 1 with respect to the usefulness of the regression-contingent measure of first pass reading times.

**Experiment 2**

**Method**

This experiment was identical in all respects to Experiment 1, the only difference being that the yes/no questions asked of the Contexts did not require attention to the referential details for a correct answer. A typical example is the following:

(5) Was the fireman off-duty?

The questions asked of the targets were the same as those used in Experiment 1.

**Results**

To facilitate the interpretation of the results, we superimpose in Fig. 4 the first pass reading times from this experiment on the equivalent data from Experiment 1. Figure 5 displays the data from Experiment 2 alone.

**First pass reading times per character.**

Four-way ANOVAs introducing Experiment as a between-subjects within-items factor revealed no effect of Experiment and no interactions with the Experiment factor, whether on the by-subjects or by-items analyses. Three-way ANOVAs on the data from Experiment 2 alone revealed the following: Overall, there were main effects of Context \(F_1(1,41) = 54.93, p < 0.001; F_2(1,35) = 59.67, p < 0.001\), Region \(F_1(2,82) = 12.31, p < 0.001; F_2(2,70) = 49.97, p < 0.001\), and Sentence Type \(F_1(2,82) = 10.75, p < 0.001; F_2(2,70) = 8.29, p < 0.001\). There was a significant Region × Sentence Type interaction \(F_1(4,164) = 7.95, p < 0.001; F_2(4,140) = 9.34, p < 0.001\) and Region × Context interaction \(F_1(2,82) = 4.17, p < 0.02; F_2(2,70) = 6.22, p < 0.005\). There was a significant three-way interaction between Region, Sentence Type, and Context \(F_1(4,164) = 3.40, p < 0.02; F_2(4,140) = 2.97, p < 0.03\). There was no Context ×
Fig. 4. Mean first pass reading times for the ambiguous complement, the ambiguous relative, and the unambiguous relative control in Experiments 1 and 2. The dotted lines indicated Experiment 1, and the solid lines Experiment 2.
Sentence Type interaction. Planned comparisons in the disambiguating region revealed, in addition, that in the null context the difference between the relative and the control was significant ($F_1(1,164) = 8.08, p < 0.01; F_2(1,140) = 7.06, p < 0.01$) as was the difference between the relative and the complement ($F_1(1,164) = 43.38, p < 0.001; F_2(1,140) = 37.88, p < 0.001$) and the control and the complement ($F_1(1,164) = 14.02, p < 0.001; F_2(1,140) = 12.24, p < 0.001$). In the ambiguous region, the unambiguous relative control was significantly slower than the ambiguous complement and relative targets ($F_1(1,164) = 13.53, p < 0.001; F_2(1,140) = 11.82, p < 0.001$). In the final region of the target, again in the null context, the difference between the relative and the control was marginally significant ($F_1(1,164) = 4.07, p < 0.05; F_2(1,140) = 3.55, p < 0.07$). But neither of the other two comparisons in that region approached significance. In the referential context condition, the complement and the control were different in the ambiguous region ($F_1(1,164) = 4.07, p < 0.05; F_2(1,140) = 3.55, p < 0.07$). But neither of the other two comparisons in that region approached significance. In the referential context condition, the complement and the control were different in the ambiguous region ($F_1(1,164) = 4.07, p < 0.05; F_2(1,140) = 3.55, p < 0.07$). But neither of the other two comparisons in that region approached significance. In the referential context condition, the complement and the control were different in the ambiguous region ($F_1(1,164) = 4.07, p < 0.05; F_2(1,140) = 3.55, p < 0.07$). But neither of the other two comparisons in that region approached significance. In the referential context condition, the complement and the control were different in the ambiguous region ($F_1(1,164) = 4.07, p < 0.05; F_2(1,140) = 3.55, p < 0.07$). 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In the referential context condition, the complement and the control were different in the ambiguous region ($F_1(1,164) = 4.07, p < 0.05; F_2(1,140) = 3.55, p < 0.07$). But neither of the other two comparisons in that region approached significance.
TABLE 3
THE PERCENTAGE OF TRIALS IN EXPERIMENT 2 ON WHICH A FIRST PASS REGRESSION OUT OF EACH REGION OCCURRED

<table>
<thead>
<tr>
<th>Region</th>
<th>Ambiguous</th>
<th>Disambiguating</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null context</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp</td>
<td>10 (90)</td>
<td>18 (81)</td>
<td>75 (22)</td>
</tr>
<tr>
<td>Rel</td>
<td>13 (87)</td>
<td>36 (63)</td>
<td>81 (18)</td>
</tr>
<tr>
<td>Control</td>
<td>15 (85)</td>
<td>26 (72)</td>
<td>68 (27)</td>
</tr>
<tr>
<td>Referential context</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp</td>
<td>7 (92)</td>
<td>13 (85)</td>
<td>73 (25)</td>
</tr>
<tr>
<td>Rel</td>
<td>9 (91)</td>
<td>23 (74)</td>
<td>70 (28)</td>
</tr>
<tr>
<td>Control</td>
<td>8 (92)</td>
<td>16 (78)</td>
<td>69 (27)</td>
</tr>
</tbody>
</table>

Note. Figures in parentheses show the percentage of trials on which a first pass regression did not occur.

= 9.26, p < 0.005). As with Experiment 1, there were more regressions out of the disambiguating region of the relative than out of the equivalent region of the control, irrespective of context (although there were significantly more regressions out of this region in the null context than out of the same region in the referential context—36% versus 23%, $F_1(1,164) = 12.31, p < 0.001$; $F_2(1,140) = 12.61, p < 0.001$).

Questions. In the two conditions in which the target sentences were preceded by an explicit context, approximately 94% of the yes/no context questions were answered correctly. Approximately 91% of the target questions were answered correctly.

Discussion of Experiment 2

Experiment 2 replicated in almost every detail the results from Experiment 1. However, a crucial difference between the two sets of results is that in Experiment 2, a residual difference in the disambiguating region between the relative and its unambiguous control was found (although there was no significant difference between the relative and the complement in the disambiguating region). As with Experiment 1, the proportion of regressions from the disambiguating region of the relative in the referential context was low (23%). We can thus ask, as before, whether the data in the referential context merely reflect a minority of
occasions on which subjects garden pathed. In Figs. 6 and 7 we plot the two regression-contingent measures which were introduced earlier: reading times in the absence of a regression and reading times prior to a regression.

In Fig. 6, which plots for each region the first pass reading times for those trials in which the subject departed from the region with a rightwards movement (the majority of the data), we see a clear garden path effect in the null context for the relative (and see our earlier explanation for why the control is significantly slower than the complement). In the referential context, however, all the differences observed in the null context disappear, as predicted by the referential hypothesis.\(^8\) In Fig. 7, which plots for each region the reading times for those trials in which the subject departed from the region with a regressive eye movement, we

\[^{3.37}, p < 0.02; F_2(4,140) = 2.51, p < 0.05\] but no
Region \times Context interaction \((F_2(4,164) = 1.98, p < 0.2; F_2(4,140) = 2.10, p < 0.2). The three-way interaction between Region, Sentence Type, and Context was significant by subjects only \((F_2(4,164) = 4.77, p < 0.005; F_2(4,140) = 1.29, p < 0.3). No other interactions were significant. Planned comparisons in the disambiguating region revealed, in addition, that in the null context the difference between the relative and the complement was significant \((F_2(4,164) = 37.72, p < 0.001; F_2(4,140) = 12.43, p < 0.001), although the difference between the relative and the control was only marginally significant \((F_2(4,164) = 6.50, p < 0.02; F_2(4,140) = 3.57, p < 0.07). The difference between the control and the complement was significant by subjects only \((F_2(4,164) = 12.89, p < 0.001; F_2(4,140) = 2.68, p < 0.2). The unambiguous relative control was slower than the ambiguous complement and relative targets in the ambiguous region on the by-subjects analysis \((F_2(4,164) = 7.52, p < 0.01; F_2(4,140) = 3.44, p < 0.07). In the final region of the target, again in the null context, there were no significant differences between the three targets. In the referential context condition, the only significant pairwise difference within a region was between the relative and complement in the final region \((F_2(4,164) = 3.96, p < 0.05; F_2 < 1).
see roughly similar data in the null context, but very different data in the referential context. It would appear that the residual differences observed in the referential context for the data overall can be accounted for exclusively by the data from these small numbers of trials in which a regression occurred (24% of trials for the relative).

The original motivation for Experiment 2 was to ensure that the results from Experiment 1 were not simply an artifact of an artificially induced processing strategy which arose because of the referential nature of the context questions. In Experiment 2 more general context questions were asked and, although the referential context did not completely eliminate the garden path effect found in the null context, the regression-contingent data suggest that this effect is restricted to only a small minority of occasions. Thus, whether or not subjects are encouraged to pay attention to the referential aspects of the contexts leads to only a very small difference in the pattern of results—a difference which does not threaten the validity of the referential hypothesis.

**General Discussion**

Two experiments have been reported which explored the predictions of two contrasting theories of syntactic processing. The garden path theory predicted that the garden path effect observed in ambiguous relative clause targets could not be avoided by the provision of referential contexts: Such contexts should not eliminate the evidence in the first pass eye movement record for the garden path. The referential hypothesis predicted that such contexts would eliminate the garden path. The experiments used a number of different eye movement measures. We distinguished between first pass reading times corresponding to fixations in a region which are followed by a leftwards movement out of the region, and first pass reading times corresponding to fixations in a region followed by a rightwards movement out of the region. The standard measure of first pass reading times, which is not contingent on whether there is or is not a first pass regression out of the region, consists of these two components. We were able to demonstrate that the residual differences in reading times between the relative and the other two targets were due entirely to the reading times which occurred when the disambiguating region was left by a regressive movement. There was no hint of a difference in reading times for those trials (the majority, in fact) in which the subject departed from the disambiguating region with a rightwards...
movement. We conclude that, but for a small minority of occasions, felicitous referential context eliminates the garden paths that are otherwise found with the ambiguous relatives in the null context.

One interpretation of the data, however, is that they are nonetheless fully consistent with the garden path theory. All that must be postulated is that the minimally attached complement clause analysis is initially selected even when the ambiguous relative is embedded in a felicitous context, but that the infelicity of this analysis in the relative-supporting context is realized very soon, leading to a prompt reanalysis of the ambiguous sequence, thereby avoiding the garden path when the disambiguating relative clause continuation is encountered. In other words, given that the present materials disambiguate late in the sentence, relative to when the ambiguity first occurs, the processor may realize its initial mistake early on, and complete its reanalysis of the ambiguous sequence before the disambiguating region. If such reanalysis did take place, one would expect it to show up as an increase in first pass reading times (whether contingent or not on the regression data) for the ambiguous region of the ambiguous relative, as compared to the ambiguous region of the ambiguous complement. The fact that there was no such difference at all suggests that no such reanalysis did take place (see Figs. 1 to 3 and 5 to 7—in neither experiment, and on none of the measures, was there any significant difference between the relative and the complement). Nonetheless, there does exist contrary evidence.

Mitchell, Corley, and Garnham (1992) report a reading time study which employed materials similar in structure to (6) and (7) below:

(6) The fireman told the woman that had been in the blazing house with him that she was very lucky.
(7) The fireman told the woman that he had been in the blazing house with several other firemen.

The subject-relative (6) is disambiguated early, immediately after the ambiguous complementizer/relative pronoun “that.” The object-relative in (7) disambiguates late, at the second occurrence of “that.” Mitchell et al. showed in the null context that reading times to “had been” were longer in the subject-relative than in the object-relative, indicating a garden path at this early position. In a referential context, however, they found no evidence that this garden path was eliminated, contrary to what would be expected on the referential hypothesis. There are a number of problems with this study, not least being the lack of any robust effect of context (the effect of context on the garden path to the second occurrence of “that” in (7), relative to the equivalent region in (8), was nonsignificant by items and significant at 0.06 by subjects). In other words, the referential contexts may not have been sufficiently felicitous and may instead have biased toward the complement interpretation. Nonetheless, this study demonstrates the manner in which the referential hypothesis could in principle be distinguished from a garden path account based on prompt reanalysis, and further studies are under way, using eye movements and regression contingent analyses of first pass reading times, which go some way to resolving the issue.

One further aspect of the present study which warrants discussion is that research which has investigated effects of non-syntactic factors on the initial stages of syntactic ambiguity resolution may have failed to find such effects in the past simply because noncontingent first pass reading times can hide the disambiguating effects of these factors. In Experiment 2 the difference in the referential context between the
ambiguous relative and the unambiguous relative control could have been interpreted as a garden path effect. However, by separating the noncontingent reading times into the two regression-contingent components, we found that this difference was due solely to the minority of occasions on which the subject departed from the disambiguating region with a regressive eye movement. Had the contingent analyses not been computed, we might have concluded that context did not overcome the garden paths that are observed in the null context.

It follows that it is an empirical matter whether there were, after all, any contextual effects in the Ferreira and Clifton experiments (1986) described earlier. Similarly, Ferreira and Henderson's (1990) failure to find any effects of lexical bias on syntactic ambiguity resolution may have, again, been due to the noncontingent reading time measure they employed, rather than to the nonexistence of the effect. Although the Ferreira and Henderson materials were single sentences, they are not comparable to the null context materials in the present study, where the contingent analyses made no crucial difference. Lexical bias is, by its nature, a within-sentence phenomenon, and it may have had an effect on some proportion of the trials. More generally, it is an open question whether the contingent analyses we have employed will be useful in the investigation of other influences on syntactic ambiguity resolution.

While the present study provides further evidence in support of the influence of, in this case, referential factors on ambiguity resolution, it has not tested one crucial prediction of the referential hypothesis, namely, that garden paths can be induced in referentially inappropriate contexts and in cases where no garden path would be predicted under the minimal attachment hypothesis. In terms of the experiments described here, such cases would occur if the ambiguous complement target were preceded by a relative-supporting context, or if the ambiguous relative target were preceded by a complement-supporting context. Considerable debate on the informativeness of this "crossed-context" design has taken place (see Altmann & Steedman, 1988; Clifton & Ferreira, 1989; Ferreira & Clifton, 1986; and Steedman & Altmann, 1989). Much of the debate has centered on the use of these designs with reading time methods which conflate initial analysis and reanalysis processing times (see Clifton & Ferreira, 1989). The regression contingent measures which we introduced in the present study do to some extent help tease apart these two components of processing time, and future research will determine the efficacy of using regression contingent reading times to explore the crossed-context predictions of the referential hypothesis.

Our demonstration that context can affect the initial parsing decisions of the human sentence processor is another in a series of demonstrations that factors other than pure syntactic structure can influence the initial stages of the parsing process (e.g., Boland, Tanenhaus, & Garnsey, 1990; Holmes, Stowe, & Cupples, 1989; Stowe, 1986; Tanenhaus, Carlson, & Trueswell, 1989; Tanenhaus, Garnsey, & Boland, 1990; Taraban & McClelland, 1988; Trueswell, Tanenhaus, & Garnsey, cited in Tanenhaus et al., 1989). The majority of these studies have concentrated on the effects of intra-sentential information on syntactic parsing. The present study adds to the increasing evidence that extra-sentential information can also influence syntactic ambiguity resolution (see Trueswell & Tanenhaus, 1991, for recent evidence on the influence of temporal fac-

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10 A similar study by Kennedy et al. (1989) also found no effect of verb bias. See Holmes et al. (1989) for the earlier subject-paced word-by-word reading version of these studies on lexical influences on syntactic ambiguity resolution, and Rayner and Frazier (1987) for a version of the Ferreira and Henderson (1990) study without the lexical bias variable.
tors, and Marslen-Wilson & Tyler, 1987, and Tyler & Marslen-Wilson, 1977, for earlier examples of extra-sentential effects). The general picture of the human sentence processing mechanism that emerges is of a fast, efficient, highly interactive system in which parsing is inextricably linked to interpretation. Although there is a tendency to consider the two processes as separate, it is becoming increasingly apparent that the distinction has little empirical value when applied to the resolution of local syntactic ambiguity by the human sentence processor.

**APPENDIX: Experimental Items from Experiments 1 and 2**

Note that | denotes the region boundaries for the purposes of the analyses only.

**Complement context.**

A householder had just had his new house completely refurbished. He was talking about the bill to the builder and the electrician. The householder had arranged to pay the builder but couldn’t afford to pay the electrician.

*Ambiguous complement.*

He | told | the builder | that he’d arranged to pay | his large bill | in a fortnight.

**Relative context.**

A householder had just had his new house completely refurbished. He was talking about the bill to the two builders. The householder had arranged to pay one of the builders but couldn’t afford to pay the other.

*Ambiguous relative.*

He | told | the builder | that he’d arranged to pay | that the bill | was very fair.

*Unambiguous relative.*

He | thanked | the builder | that she had consulted | and handed him | the project.

A man had witnessed an assault on a young girl. He was taken to the police station to give a detailed statement to a policeman and a policewoman. The man had been talking about the assault to the policewoman but had yet to talk about it to the policeman.

He | told | the policewoman | that he’d been talking to | the young girl | earlier.

A man had witnessed an assault on a young girl. He was taken to the police station to give a detailed statement to two policewomen. The man had been talking about the assault to one of the policewomen but had yet to talk about it to the other.

He | told | the policewoman | that he’d been talking to | that he felt | horrified.

A doctor was making his daily ward round at the hospital. He remembered that he had to see a patient and a nurse about some X ray results. The doctor had some good news about the patient but some rather gloomy news for the nurse.

He | told | the patient | that he had some good news about | the X ray | they’d done.

A doctor was making his daily ward round at the hospital. He remembered that he had to see two patients about some X ray results. The doctor had some good news about one of the patients but some rather gloomy news for the other.

He | told | the patient | that he had some good news about | that the X ray | was clear.

A captain was stationed close to enemy occupied territory. He tried to radio the base to report his position to the colonel and the lieutenant. The captain managed to make contact with the colonel just after talking to the lieutenant.

He | told | the colonel | that he had some good news about | the enemy forces | and was advancing.

A captain was stationed close to enemy occupied territory. He tried to radio the base to report his position to the two colonels. The captain managed to make contact with one of the colonels just after talking to the other.

He | told | the colonel | that he had contacted | if the enemy | was now advancing.

A barmaid was serving a man and a woman in a pub. As she poured their drinks they made comments about her clothes. The barmaid found the man’s comments very insulting but thought that the woman was quite complimentary.
She told the man that she'd been insulted by | the nature | of his remarks.

A barmaid was serving two men in a pub. As she poured their drinks they made comments about her clothes. The barmaid found one of the men's comments very insulting but thought that the other was quite complimentary.

She told the man that she'd been insulted by | to take | a running jump.

She asked the man that she'd been insulted by | to take | a running jump.

A manager had received replies from a woman and a man to his job advertisement. After interviewing the candidates he talked to them informally. The manager felt confident about the suitability of the woman but was doubtful about the man.

He told the woman that he was confident about | her chances of | getting the job.

A manager had received replies from two women to his job advertisement. After interviewing the candidates he talked to them informally. The manager felt confident about the suitability of one of the women but was doubtful about the other.

He told the woman that he was confident about | to return | in a fortnight.

He invited the woman that he was confident about | to return | in a fortnight.

A minister was reviewing controversial proposals for a new airport. He had been asked to meet a councillor and an environmentalist to discuss their latest plans. The minister agreed to see the councillor and was to telephone the environmentalist.

He told the councillor that he had agreed to see | the plans | during lunch.

A minister was reviewing controversial proposals for a new airport. He had been asked to meet two councillors to discuss their latest plans. The minister agreed to see one of the councillors and was to telephone the other.

He told the councillor that he had agreed to see | to submit | further details.

He asked the councillor that he had agreed to see | to submit | further details.

A woman had crashed her car into a wall on her way home from a party. She was being questioned about the incident by a policeman and a solicitor. The woman was trying to avoid the policeman but was willing to talk to the solicitor.

She told the policeman that she'd been trying to avoid | driving into | a lamp post.

She had crashed her car into a wall on her way home from a party. She was being questioned about the incident by two policemen. The woman was trying to avoid one of the policemen but was willing to talk to the other.

She told the policeman that she'd been trying to avoid | to contact | her lawyer.

She asked the policeman that she had been trying to avoid | to contact | her lawyer.

A bank manager was giving financial advice to a man and a woman. They were asking about the benefits of a high-interest savings account. The bank manager had misunderstood the woman's question about the account but understood the man perfectly.

He told the woman that he'd misunderstood | the nature | of her question.

A bank manager was giving financial advice to two women. They were asking about the benefits of a high-interest savings account. The bank manager had misunderstood one of the women's questions about the account but understood the other perfectly.

He told the woman that he'd misunderstood | to repeat | her last question.

He asked the woman that he'd misunderstood | to repeat | her last question.

A teenager had been charged with breaking and entering. He had been ordered to make weekly visits to a probation officer and a social worker at a local remand center. The teenager had only been meeting the probation officer as he had developed an instant dislike for the social worker.

He told the officer that he'd been meeting | his commitments | and had changed.

A teenager had been charged with breaking and entering. He had been ordered to make weekly visits to two probation officers at a local remand center. The teenager had only been meeting one of the probation officers as he had developed an instant dislike for the other.

He told the officer that he'd been meeting | that gradually | he was changing.

He rang the officer that he'd been meeting | and arranged | to visit him.

A driving instructor was talking to a man and a woman. He was discussing their progress in view of the forthcoming driving test. The driving instructor had been impressed by the woman's driving abilities but felt that the man needed more lessons.

He told the woman that he'd been impressed by | her skills and | wished her luck.

A driving instructor was talking to two women. He was discussing their progress in view of the forthcoming driving test. The driving instructor had been impressed by one of the women's driving abilities but felt that the other needed more lessons.

He told the woman that he'd been impressed by | to ensure | she drove with care.

He asked the woman that he'd been impressed by | to ensure | she drove with care.

A solicitor was asked to defend a man and a woman
believed to be involved in an armed robbery. After accepting the case he collected statements from them to use as evidence. The solicitor had doubts about the alibi given by the woman but felt sure that the man was telling the truth.

He told the woman that he had doubts about the details of her statement.

A solicitor was asked to defend two women believed to be involved in an armed robbery. After accepting the case he collected statements from them to use as evidence. The solicitor had doubts about the alibi given by one of the women but felt sure that the other was telling the truth.

He told the woman that he had doubts about the details of her statement.

A headmistress was waiting in her office after school. She had arranged to see a boy and a girl about the standard of their schoolwork. The headmistress was worried about the boy’s poor standard of work but was delighted with the standard attained by the girl.

She told the boy that she was worried about the standard of his schoolwork.

A headmistress was waiting in her office after school. She had arranged to see two boys about the standard of their schoolwork. The headmistress was worried about one of the boys’ standard of work but was delighted with the standard attained by the other.

She told the boy that she was worried about the standard of his schoolwork.

A sales assistant was helping a man and a woman. They’d been complaining to her about some faults in their purchases. She had dealt with the man’s complaints but felt that the manager should deal with the woman.

She assured the man that she’d dealt with the small faults and offered a refund.

A sales assistant was helping two men. They’d been complaining to her about some faults in their purchases. She had dealt with one of the men’s complaints but felt that the manager should deal with the other.

She assured the man that she’d dealt with the faults would be repaired.

She asked the man that she’d dealt with to contact her the following day.

A journalist was talking to a man and a woman over lunch. He had just finished a report on the Young Royals. The journalist had been working on the report with one of the women but only knew the other from social events.

He told the woman that he’d been working with to outline their next case.

He asked the woman that he’d been working with to outline their next case.

A doctor was treating a man and a woman at his surgery. They both had illnesses which the doctor believed could be cured with the help of positive attitudes. The doctor was worried about the attitude of the woman but felt that the man was very positive.

He told the woman that he was worried about her negative view of the illness.

A doctor was treating two women at his surgery. They both had illnesses which the doctor believed could be cured with the help of positive attitudes. The doctor was worried about the attitude of one of the women but felt that the other was very positive.

He told the woman that he was worried about to be positive about the illness.

He asked the woman that he was worried about to be positive about the illness.

An electrician was repairing a fuse for a woman and her husband. As he worked he explained why the fuse had burned out. The electrician was impressed by how much the woman knew about electrical systems but was surprised by how little her husband understood.

He told the woman that he was impressed by how much she knew about the system.

An electrician was repairing a fuse for two women. As he worked he explained why the fuse had burned out. The electrician was impressed by how much one of the women knew about electrical systems but was surprised by how little the other understood.

He told the woman that he was impressed by to explain it all to her friend.

He asked the woman that he was impressed by to explain it all to her friend.

A teacher had been talking to the mother and father of one of the children in her class. She had asked if they would participate in a forthcoming school visit. The teacher had been shocked to find that the father lacked all interest in education but had been cheered by the mother’s enthusiasm.

She told the father that she was shocked by his poor attitude to education.

A teacher had been talking to the fathers of two of the children in her class. She had asked if they would participate in a forthcoming school visit. The teacher had been shocked to find that one of the fathers lacked all interest in education but had been cheered by the other’s enthusiasm.

She told the father that she was shocked by that his attitude was appalling.
She rang the father that she was shocked by to persuade him to participate.

A musician was listening to the performances of a guitarist and a drummer. He wanted to form a new pop group and was auditioning suitably talented youngsters. The musician was very impressed by the guitarist but didn't think much of the drummer.

He told the guitarist that he was impressed by his playing of the music.

A musician was listening to the performances of two guitarists. He wanted to form a new group and was auditioning suitably talented youngsters. The musician was very impressed by one of the guitarists but didn't think much of the other.

He told the guitarist that he was impressed by to audition again on Friday.

He invited the guitarist that he was impressed by to audition again on Friday.

A marriage guidance counsellor was counselling a man and his wife. He was saddened to hear about their marital problems. The counsellor was worried about the wife but wasn't particularly concerned about the man.

He told the wife that he was worried about the way that she blamed herself.

A marriage counsellor was counselling two wives. He was saddened to hear about their marital problems. The counsellor was worried about one of the wives but wasn't particularly concerned about the other.

He told the wife that he was worried about to come and visit more often.

He asked the wife that he was worried about to come and visit more often.

An off-duty fireman was talking to a man and a woman. He was telling them how serious the situation had been when their house had caught fire. The fireman had risked his life to rescue the woman while the man had waited outside.

He told the woman that he'd risked his life for many people in similar fires.

An off-duty fireman was talking to two women. He was telling them how serious the situation had been when their house had caught fire. The fireman had risked his life to rescue one of the women while the other had waited outside.

He told the woman that he'd risked his life for to install a smoke detector.

He asked the woman that he'd risked his life for to install a smoke detector.

An auctioneer was talking to a man and a woman. He was discussing the amount of commission he would claim for auctioning several antique objects. The auctioneer had just sold a painting for one of the women but had never dealt with the other before.

He told the woman that he had just sold a painting for to give him his fee.

He asked the woman that he had just sold a painting for to give him his fee.

A woman was drinking coffee in a quiet cafe when a man she knew entered with his girlfriend. She wanted some company so she invited them to join her. She was pleased to see the man but had never really got on with his girlfriend.

She told the man that she was pleased to see he'd got her another coffee.

A woman was drinking coffee in a quiet cafe when two men she knew entered. She wanted some company so she invited them to join her. She was pleased to see one of the men but had never really got on with the other.

She told the man that she was pleased to see to order her another coffee.

She asked the man that she was pleased to see to order her another coffee.

A Conservative politician was talking to a journalist and a photographer. He was commenting on the government's intention to privatize the water industry. The politician agreed with the views of the journalist but thought that the photographer was very naive.

He told the journalist that he agreed with what he had said on the subject.

A Conservative politician was talking to two journalists. He was commenting on the government's intention to privatize the water industry. The politician agreed with the views of one of the journalists but thought that the other was very naive.

He told the journalist that he agreed with to write a report on the subject.

He asked the journalist that he agreed with to write a report on the subject.

The Queen Mother was at a garden party talking to a comedian and an actor. They were telling her about their contributions to the 1989 Royal Variety Performance. The Queen Mother was amused by the comedian but she found the actor terribly boring.

She told the comedian that she was amused by his imitations of Prince Charles.

The Queen Mother was at a garden party talking to two comedians. They were telling her about their contributions to the 1989 Royal Variety Performance. The Queen Mother was amused by one of the comedians but she found the other terribly boring.

She told the comedian that she was amused by to impersonate the other guests.

She asked the comedian that she was amused by to impersonate the other guests.
A film director had just won a British Academy Award. After the ceremony he was invited to a party where he was introduced to an award-winning actress and her husband. The film director had heard of the actress before but knew nothing about her husband. He told the actress that he had heard of her qualities as a leading lady.

A film director had just won a British Academy Award. After the ceremony he was invited to a party where he was introduced to two award-winning actresses. The film director had heard of one of the actresses before but knew nothing about the other. He told the actress that he had heard of her. He invited the actress to audition for his next film.

A baker had been bent over a hot oven all morning. While he was taking his coffee break an old lady and a young mother entered the shop to collect their orders. The baker had baked a cake for the old lady and made a dozen scones for the young mother. He told the old lady that he’d baked a cake for a friend of hers only yesterday. He asked the old lady that he’d baked a cake for her friend.

A baker had been bent over a hot oven all morning. While he was taking his coffee break two old ladies entered the shop to collect their orders. The baker had baked a cake for one of the old ladies and made a dozen scones for the other. He told the old lady that he’d baked a cake for her. He asked the old lady that he’d baked a cake for her friend.

A couple were driving to the local General Hospital. They were going to visit a young boy and girl who had been involved in a nasty road accident. The couple had brought a gift for the boy but they hadn’t brought anything for the girl because they couldn’t afford it. They told the boy that they’d brought a gift for him to share with his friend.

A couple were driving to the local General Hospital. They were going to visit two young boys who had been involved in a nasty road accident. The couple had brought a gift for one of the boys but they hadn’t brought anything for the other because they couldn’t afford it. They told the boy that they’d brought a gift for him to share with his friend.

A man was talking to a woman and her boyfriend about an exhibition at a local museum. The exhibition included some paintings by his favourite artist. The man wanted to go with one of the women but didn’t want to go with her boyfriend. He told the woman that he wanted to go with a good friend that appreciated art.

A man was talking to two women about an exhibition at a local museum. The exhibition included some paintings by his favourite artist. The man wanted to go with one of the women but didn’t want to go with the other.

He told the woman that he wanted to go with him outside the museum. He asked the woman that he wanted to go with him outside the museum.

An antique dealer was inspecting a valuable painting. He was trying to buy the painting which had recently been inherited by a woman and her brother. The dealer was discussing the painting with the woman while her brother listened with interest. He told the woman that he was talking to another dealer in London.

An antique dealer was inspecting a valuable painting. He was trying to buy the painting which had recently been inherited by two women. The dealer was discussing the painting with one of the women while the other one listened with interest. He told the woman that he was talking to another dealer.

A photographer was taking the last reel of film out of his camera. He had just finished photographing a top model and a well-known sports personality. The photographer was sure he’d taken bad photos of the model but was happy with those he’d taken of the sports personality. He told the model that he’d taken bad photos of many top models in the past.

A photographer was taking the last reel of film out of his camera. He had just finished photographing two top models. The photographer was sure he’d taken bad photos of one of the models but was happy with those he’d taken of the other. He told the model that he’d taken bad photos of to pose again the next day.

A social worker had been allocated a small group of at-risk children. She decided to visit the father and mother of one of the children in her care. The social worker was horrified by how aggressive the father was towards his children whereas the mother seemed quite kind. She told the father that she was horrified by his attitude to children.

A social worker had been allocated a small group of at-risk children. She decided to visit two of the fathers of the children in her care. The social worker was horrified by how aggressive one of the fathers was towards his children whereas the other seemed quite kind.
A ski instructor was asked to give skiing lessons to a girl and a boy who had never skied before. He decided to give them their first lesson on the beginners slope. The ski instructor was happy with the ability of one of the girls but was a little worried about the other.

He told the girl that he was happy with the way she controlled her skis.

A ski instructor was asked to give skiing lessons to two girls who had never skied before. He decided to give them their first lesson on the beginners slope. The ski instructor was happy with the ability of one of the girls but was a little worried about the other.

He told the girl that he was happy with it to try a more difficult slope.

He invited the girl that he was happy with it to try a more difficult slope.

A young boy was being bullied by two older girls at school. He tried to be brave but was eventually reduced to tears. He was frightened of what the teacher would do to them.

A young boy was being bullied by an older boy and girl at school. He tried to be brave but was eventually reduced to tears. He was frightened of the girl but wasn’t too worried about the boy.

He told the girl that he was frightened of what the teacher would do to them.

He begged the girl that he was afraid of to bully someone her own age.

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(Received March 11, 1991)

(Revision received December 28, 1991)