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Measuring Inhibition and Facilitation from Pronouns

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Two cross-modal experiments investigated changes in activation levels for pronominal referents and nonreferents. Subjects heard sentences with and without pronouns and responded to visual probe words that appeared at variable intervals during sentence presentation. The gender of potential referents was controlled in Experiment 1 so that the pronoun unambiguously referred to one sentence participant, and Experiment 2 contained both unambiguous and ambiguous reference conditions. In both experiments, responses to probes corresponding to nonreferents were slower in the presence of an unambiguous pronoun compared to the no-pronoun condition, suggesting that pronouns inhibit nonreferents. Responses to referents were speeded by unambiguous pronouns compared to the no-pronoun condition in Experiment 2. Neither of these effects appeared at probe positions immediately after the pronoun, indicating that assignment of a referent to an unambiguous pronoun took a measurable amount of time, and a substantially longer amount for an ambiguous pronoun. An additional probe condition in Experiment 1 indicated that these effects were not due to differences in overall processing load. These results were interpreted in light of discourse shifts from establishment of pronominal reference, and in terms of the sensitivity of probe response tasks to a variety of influences.

An important issue in the study of pronoun comprehension is the question of how a pronoun affects the mental representation of its referent. Typically, investigations of the effect of pronouns on mental representations have presented sentences containing a referent and a pronoun, such as *John went to the store and he bought cookies,* and then measured responses to a visual probe word appearing during or after presentation of the sentence. On some trials the probe corresponds to the referent, in this case *John,* while on other trials the probe is some other word (that is, a baseline condition). Studies using a variety of response tasks have shown that, compared to subjects' performance in the baseline condition, subjects' responses are faster to a probe corresponding to the referent of a pronoun. This difference between referent and baseline conditions has been found in a probe naming task (Leiman, 1982), in a lexical decision task (Cloitre & Bever, 1988; Nicol, 1988), and in a task in which subjects judge whether the probe word had appeared in the sentence (Chang, 1980; Cloitre & Bever, 1988; Emmorey, Norman, & O'Grady, 1989; Gernsbacher, 1989; Stevenson, 1986). These findings have been interpreted to indicate that the processes that form a link between a pronoun and its

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referent result in an increase in the activation level of the referent in the mental representation, thereby producing faster response times in a probe task.

A theory which claims that the establishment of coreference produces changes in activation levels leads naturally to the question of why this phenomenon exists. One possible answer to this question is that there may simply be something inherent in the language processing system such that the process of finding a referent for a pronoun has the side effect of changing activation levels of that referent. Alternatively, the phenomenon might be part of a more general process in which shifting activation levels are caused by encoding shifts in discourse focus. When a previously mentioned concept or person is re-mentioned with an anaphor such as a pronoun, it signals that the speaker or writer is shifting the discourse focus toward the previously mentioned entity. Changes in activation levels might therefore reflect the language comprehension system's tendency to keep focused elements at high levels of activation. On this view, it is the encoding of discourse focus shifts that produces changes in activation levels, and the establishment of coreference between a referent and a pronoun is just one of many signals to the perceiver (including emphatic stress and cleft constructions) that the speaker is shifting the discourse focus.

It is not immediately clear how to decide between these two explanations of activation level changes. Because use of a coreferential pronoun usually produces discourse focus shift, it is difficult to create conditions to tease apart the predictions made by the two accounts. It is actually quite possible that both explanations are partially correct—they are not mutually exclusive accounts. Our own approach will not be to try to decide between these two explanations but rather to explore further the relationship between pronominal reference and shifts in discouse focus, with the goal of working toward a more comprehensive view of changes in activation levels during coreference processing and language comprehension in general.

With this view about coreference and discouse shifts, a number of interesting predictions emerge. If focus shifts are the cause of changes in activation levels, and if pronominal reference is a signal of focus shifts, then it could be the case that the establishment of coreference does more than increase the activation level of a pronoun's referent, it also decreases the activation level of nonreferents. That is, when the referent becomes more prominent in the discouse and acquires a higher activation level in the perceiver's mental representation, everything else in the discouse necessarily becomes less prominent, resulting in lowered activation levels. Translating this hypothesis into a prediction about probe response times, we should find that response times to a *nonreferent* probe should be slower following a (non-coreferential) pronoun than in a baseline condition.

This paper will investigate whether pronouns can in fact produce two changes in activation levels so that they not only facilitate their referents but also inhibit nonreferents. A number of researchers have studied facilitation effects for referents, and Gernsbacher (1989) has argued that inhibition effects for nonreferents not only exist but are stronger than facilitation effects. Our own reading of the many studies that have measured probe response times leads us to the conclusion that neither the facilitation nor inhibition effects can be inferred from probe response data in a straightforward way. A major concern is that facilitation and inhibition effects can only be seen in reference to some baseline condition, and it is not obvious exactly what the correct baseline condition should be. Many different baselines have been used in previous work, and it is important to examine the consequences of different baselines before embarking on our own investigation of facilitation and inhibition effects.

Interpreting Probe Response Times

It is easy to see that the pronoun priming

methodology has its roots in semantic priming studies (e.g. Meyer, Schvaneveldt, & Ruddy, 1974). The basic methodology in that work involves comparisons of response times to a target such as *butter* following either an associated prime, such as *bread,* or a neutral prime word. The correct choice for the neutral prime has been a topic of much discussion in that literature (e.g. Neely, 1977), and the problem may be at least as difficult in the case of pronouns. A second major issue in the semantic priming literature concerns the effects of the task that the subject performs on the target word (e.g., Seidenberg, Waters, Sanders, & Langer, 1984). Cloitre and Bever (1988) have argued that the choice of probe task may have large consequences in studies of probe response times with pronoun sentences. We will not pursue that issue here but will instead focus on the baseline issue.

Throughout our discussion of baselines, we will use the terms *referent probe* and *nonreferent probe* to refer to two specific visual probes presented in conjunction with a sentence containing a pronoun (or an anaphoric noun phrase). A referent probe is a probe word that corresponds to the noun in the sentence that was the pronominal referent, and nonreferent probes correspond to nouns in the sentence that were not referenced by a pronoun. In the sentence *John and Mary went to the store and he bought cookies,* the referent probe would be *John* and the nonreferent probe would be *Mary.* A third probe type, which we will term a *control probe,* will also emerge in the course of this discussion. This probe corresponds to a word that could not have been the referent, either because it never appeared in the stimulus sentence (for the example above, *Fred,* or *book* could be the control probe), or because it was the kind of word that could not denote a pronominal referent (e.g., an adjective or verb like *went* in the sentence above). The distinction between a nonreferent and a control probe is an important one: The nonreferent in the sentence is a noun that might have been the referent, but was not (e.g., because the pronoun and the nonreferent did not match in gender or number), while the control probe corresponds to a word that could not have been the pronominal referent.

Referent versus nonreferent comparisons. In one of the earliest pronoun facilitation studies, Chang (1980) used comparisons between referent and nonreferent probe response times to argue for facilitation effects for referents from pronouns. He presented sentences such as *John and Mary went to the store and he/she bought cookies,* and he manipulated the gender of the pronoun, so that either *John* or *Mary* was the referent. He found that responses to referent probes were faster than to nonreferent probes. That is, responses to *John* were faster when *he* was the pronoun than when *she* was the pronoun, and the effect was reversed when the probe word was *Mary.* Chang argued that these referent-nonreferent differences indicate that pronouns facilitate their referents, but his conclusion is not a necessary one. The problem with the referent-nonreferent comparison is that neither condition is a neutral baseline; it is impossible to tell whether the reaction time differences are really due to facilitation of the referent, inhibition of the nonreferent, or to some combination of the two processes.

The no-pronoun baseline. Another technique is to compare probe response times following a pronoun sentence to probe responses after a matched sentence that contains no pronoun. This technique was first employed by McKoon and Ratcliff (1980; Dell, McKoon, & Ratcliff, 1983), whose sentences contained noun phrase anaphors rather than pronouns. They presented a short passage with a noun such as *burglar* in the first sentence and either an anaphor (*thief*) or nonanaphor (*cat*) in the last sentence. They found faster responses to the referent *burglar* following the anaphor sentence than following the no-anaphor condition. Leiman (1982) used a similar technique with pronouns. He presented short passages in which the second sentence either did or did not contain a pronoun refer-

ring to a word in the first sentence. For example, a pronoun passage was *The rock was very heavy. We could hardly throw it,* and the corresponding no-pronoun passage had the identical first sentence and *We were very surprised* as the second sentence. Leiman found that naming time for a referent probe (e.g., *rock*) was faster in the pronoun condition than in the no-pronoun condition. These results support findings with noun phrase anaphors (McKoon & Ratcliff, 1980; Dell et al., 1983) in that they suggest that an anaphor can increase the activation level for its referent. None of these studies measured nonreferent response times, but there is nothing in the paradigm that would prevent investigation of nonreferents as well.

The use of the no-pronoun baseline is not without problems, however, because pronoun and no-pronoun sentences may have differences beyond the presence or absence of a pronoun. These differences might produce additional changes in probe response times, making it difficult to draw any conclusions from a given pattern of response times. For example, consider the problem of matching the pronoun and baseline (no-pronoun) sentences for comprehension difficulty. This control is essential because probe response times are certainly sensitive to sentence comprehension difficulty. It is reasonable to assume that comprehending a sentence and responding to a probe simultaneously is a divided attention task, so that if sentence comprehension becomes more difficult, probe response times will slow down for reasons that may have nothing to do with coreference. The most common response to this potential problem is to use an additional control condition in the probe words to assess whether the materials are in fact balanced for difficulty. For example, Leiman (1982) used a control probe condition in which subjects named probes that had not appeared in the stimulus passages. Similarly, Dell et al. (1983) measured recognition times to a probe of a word that had appeared in the passage but was not related to the referent. The fact that neither of these studies found any differences in these control probe response times indicates that differences in the pronoun and baseline sentences were not affecting all probe responses, just probe responses to the referents of the anaphoric expressions.

A more troublesome problem may be matching the pronoun and no-pronoun sentences for discourse focus, because there is ample reason to believe that changes in discourse focus produce changes in activation levels. Because the intent of these studies is to determine that the presence of a pronoun is producing changes in activation levels, then it is important that the pronoun and no-pronoun sentences differ in discourse focus only to the extent that the pronoun re-mentions a sentence participant and the no-pronoun sentence does not. Since the pronoun must be replaced with *something else* in the baseline sentence, matching for discourse focus may prove very difficult. O'Brien, Duffy, and Myers (1986) investigated precisely this issue. They examined response times to a probe that appeared after the subject had read a short passage that contained no pronouns. The probe corresponded to a word that had occurred in the first sentence of the passage, and O'Brien et al. manipulated whether or not the last sentence of the passage introduced a new topic. When a new topic was introduced, response times to the probe word were slowed compared to a condition in which no new topic was introduced. O'Brien et al. concluded that topic shifts can produce interference effects for previously mentioned concepts; this result raises the possibility that previous findings for facilitation in anaphor conditions were contaminated by interference from topic shifts in no-anaphor conditions. In the worst case, a pattern of reaction times that had been considered to indicate pronominal facilitation effects might have been caused by the supposedly neutral no-pronoun condition itself shifting discouse focus through the introduction of a new topic.

In other studies, however, O'Brien et al. found evidence that reaffirms the claim that anaphoric reference can produce facilita-

tion effects. They examined responses to referent probes in an anaphor condition, in comparison to probe responses in a series of no-anaphor conditions in which new topics were not introduced. They found clear evidence for anaphor facilitation effects that were not dependent on discourse topic shifts. A second reassuring finding is that Dell et al. (1983) found no differences in response times to their control probe (which had appeared in the sentence but was unrelated to the referent). This result suggests that there were no large topic shifts in their materials: If the no-anaphor condition had produced topic shifts, those shifts should have slowed responses to the control probe compared to responses in the anaphor condition.

The alternative probe word baseline. In the discussion of the no-pronoun baseline above, we mentioned that it is desirable to have a control probe word to compare across pronoun and no-pronoun sentences to monitor for unwanted differences between the two sentence types. Given this manipulation, one could also compare responses to different probes within each sentence type. For example, one might expect greater differences between a referent probe and a control probe in a pronoun condition compared to the no-pronoun condition, because of a facilitation effect to the referent. In our view, this comparison is not desirable: If the control probe is of a noun contained in the sentence, then it is essentially a nonreferent probe and carries the objections outlined for referent-nonreferent comparisons above. If it is a probe of some word that cannot be a pronominal referent (e.g., a verb or function word), or if it is a word that was not in the sentence, then a comparison with the referent probe is still not ideal, because it is not known how the other differences between the referent and control probes might influence response times.[1]

A variation of the referent vs. control probe comparison that Nicol (1988) used may avoid some of these objections. To this point, all probe words have corresponded exactly to words that appeared in the sentence (e.g., if *John* was the referent of the pronoun in the sentence, then *John* was the referent probe word). Nicol's variation was to measure lexical decision times to semantic associates of referents and nonreferents and compare these response times to matched nonassociate probe words. For example, she presented a sentence containing the words *janitor* and *fireman* and a pronoun that unambiguously referred to *janitor*. Nicol found that response times to the probe *clean*, which is an associate of the referent *janitor*, were faster than to the nonassociate probe *score*, suggesting facilitation effects from the pronoun to its referent. In contrast, there was no difference in response times to an associate of the nonreferent (the probe was *smoke* for the nonreferent *fireman*) and a nonassociate probe. Though Nicol did not intend the paradigm to be an investigation of inhibition effects, these results might be taken as an indication that pronouns produce only facilitation for their referents, and not inhibition for nonreferents. Note however that this paradigm could tend to increase facilitation effects and reduce inhibition effects. This tendency is due to the fact that even without any pronoun in the sentence, it is probable that associates of a word that was in the sentence (e.g., the associate *clean* for the word *janitor* in the sentence) should be faster than for a word that was not associated with anything in the sentence. Nicol's results are strengthened by the fact that she found fast referent-associate responses only for probe position shortly *after* the pronoun was presented and not before it,

[1] Given these criteria, it is unclear whether the control probe condition used by Dell et al. (1983) was actually a nonreferent probe, since on at least some trials this 'control' probe was a noun, and thus conceivably could have been a potential referent for the anaphoric noun phrase. Perhaps a slightly different definition of "control" versus "nonreferent" probes may be necessary when noun anaphors are used, as in the Dell et al. study.

but it is not clear how much effect the pronoun is having in this paradigm. Since the nonreferent is also a word in the sentence, an inhibition effect for this word would require slower responses to its associate than to some completely unrelated word, and this result would seem difficult to obtain.

The pre-pronoun baseline. We noted above that Nicol (1988) added probe positions in which the probe appeared before the pronoun to create an additional baseline condition. Gernsbacher (1989) also used this pre-pronoun baseline and looked for both facilitation and inhibition effects with this manipulation. She presented subjects with sentences containing two names and a pronoun, such as *Bill handed John some tickets to a concert, but he took the tickets back immediately* and presented referent and nonreferent probes (*Bill* and *John*, respectively). A probe word appeared either immediately before the pronoun *he* (baseline condition) or at the end of the sentence (pronoun condition).[2] She found that responses to the referent probe *Bill* in the sentence-final position (i.e., the pronoun condition) did not differ from probe responses to *Bill* in the pre-pronoun baseline. In contrast, responses to the nonreferent probe *John* in sentence-final position were slower than in the pre-pronoun baseline condition.

Gernsbacher (1989) interpreted her results as showing that pronouns inhibit nonreferents more than they facilitate referents. Her interpretation is not a necessary one, however, because the pre-pronoun baseline is also subject to alternative interpretations. One concern is that the pre-pronoun probe can form a grammatical continuation of the sentence (e.g., *but* followed by the probe *John*), while the probes in other positions do not form a continuation. It is not known whether this situation affects probe recognition times, though other tasks such as probe naming are affected (Marslen-Wilson & Tyler, 1980). Another difficulty is that measures of probe response times at different points in the sentence face the problem that activation levels could decline with increasing distance between the appearance of a word in the sentence and the appearance of the probe of that word. For example, Jarvella (1971) noted that words becomes less accessible as new words are read or heard, and Gernsbacher and Hargreaves (1988) found faster responses to probes of words occurring in a current clause than in a previous clause. Gernsbacher's (1989) finding of lower activation levels for the nonreferent probe in sentence final position compared to the pre-pronoun baseline could therefore reflect simply a "natural" decline in activation levels by the end of the sentence rather than any inhibition from the pronoun, or perhaps a combination of these two influences. Similarly, the finding of no differences in referent probe response times at the two probe positions could reflect the opposing forces of facilitation from the pronoun and a decline in activation levels by the end of the sentence.

If such a "natural" decline in activation levels exists, the problems it presents for the interpretation of inhibition effects are different from the problems presented for interpreting facilitation effects. Studying inhibition effects with this baseline could be quite problematic, because declining activation levels would contribute to an inhibition effect, and it will not be clear how much, if any, of the slowed response times is due to pronoun inhibition and how much to declining activation levels late in the sentence. The problem for studying facilitation effects for the referent is somewhat different, in that the effects would not be difficult to interpret, only difficult to find. This is because the declining activation levels would be working to slow response times in comparison to times at earlier probe positions (i.e., pre-pronoun baseline positions), and what is needed to claim facilitation effects is actually faster response times late in

[2] A position 150 ms after the pronoun was also tested, but it did not yield results that were different from the baseline condition.

the sentence.[3] In sum, using the pre-pronoun baseline, which might inflate inhibition effects and hide facilitation effects, Gernsbacher found only inhibition and not facilitation. On the other hand, Nicol, using a paradigm that might inflate facilitation and hide inhibition, found just facilitation, and not inhibition.

A second problem with the pre-anaphor control is that whereas most other paradigms allow sentence presentation to continue uninterrupted by the probe word (that is, any remaining words in the sentence continue to be presented to the subject while the probe appears on the screen), it is necessary to stop the presentation of the sentence at the point of the probe in paradigms using the pre-pronoun baseline. For example, with the sentence *John went to the store and he bought cookies,* presentation of the sentence must stop at or before the word *and,* whereas any pronoun conditions could be presented any time after *he,* including, as in Gernsbacher (1989), after the entire sentence had been presented. The reason for this restriction when using the pre-pronoun baseline is that what makes the pre-pronoun condition a baseline condition is that the subject has not yet heard or read the pronoun at the time that the probe appears, and so the sentence must stop to make this condition a valid one. It is not known whether the procedures that establish noun-pronoun coreference operate differently midsentence (when more potentially useful information for coreference assignment might be arriving) compared to at the end of the sentence, nor whether stopping the sentence presentation results in unnatural operations. There exists the possibility (and we stress that it is just a possibility at this point) that trying to compare midsentence response times to end-of-sentence response times may be trying to compare apples and oranges, both because the coreference assignment operations may be different at these two points and because a probe response might be executed in a very different way when the sentence is incomplete compared to when it has ended.

The repeated name comparison. Finally, we turn to one more comparison condition, one that is really more of an extreme coreference condition than a neutral baseline. On the view that some processing must be accomplished to determine that some noun or pronoun is indeed a remention, it is possible to examine the effects of this type of reference against another remention condition in which there is little or no extra processing involved to determine that a remention is taking place. This condition is presented through repetition of a name in the sentence, as in Gernsbacher's (1989) sentence *Bill handed John some tickets to a concert, but Bill took the tickets back immediately.* If rementioning produces facilitation and inhibition effects, then these effects should be clearest in this repeated name condition, and a comparison of this baseline with pronoun conditions should reveal how the additional processing unique to pronouns modulates facilitation and inhibition effects. Several researchers have employed this condition in conjunction with other baseline measures such as referent-nonreferent comparisons (Chang, 1980; Corbett & Chang, 1983) and pre-anaphor probe positions (Gernsbacher, 1989). Gernsbacher's results are representative: In sentences like the one given above, end of sentence referent responses were faster with a repeated name anaphor compared to responses at the pre-anaphor probe position, and nonreferent responses slowed at the end of the sentence compared to the earlier probe position. Gernsbacher contrasted these results with those obtained in her sentences containing pronouns and ar-

[3] Dell et al. (1983) did find facilitation effects in post anaphor positions compared to a pre-anaphor baseline, so the task is not impossible. However, several sentences separated the appearance of the critical word in the passage and the probe of that word in any of the probe positions, and so activation levels were probably already at some low asymptote for all of the probe positions in this case.

gued that the more specific the anaphor, the more facilitation and inhibition effects will be found for referents and nonreferents, so that only repeated names can produce stronger facilitation and inhibition effects than pronouns can.

The repeated name data do support the hypothesis that inhibition and facilitation are consequences of establishing coreference, but there are some concerns about this condition. Cloitre and Bever (1988) have pointed out that facilitation effects for the referent in repeated name conditions may in fact be a repetition priming effect for a probe word that the subject has just seen twice before, and need not reflect any facilitation from discourse shifts and establishing coreference relations. Moreover, it is clear that pronoun and repeated name conditions are not matched for discourse focus, because repeated full noun phrases in a sentence result in a very marked discourse status (Li & Thompson, 1975), and are used only in special circumstances, such as to counter presuppositions. Comparisons between repeated name and pronoun conditions thus do not necessarily reflect only the distinction between an unambiguous remention and a pronoun.

Summary. In our review, we mentioned five options for baseline conditions with which to investigate pronoun facilitation and inhibition effects. Although we believe that the research reviewed here has been conducted very carefully, it is clear that no single baseline measure is an ideal choice. The first baseline mentioned, the referent versus nonreferent comparison, cannot distinguish facilitation from inhibition. The no-pronoun baseline and the repeated name condition both run the risk of changing discourse focus when the sentences are altered. The pre-pronoun probe position has the problem of declining activation levels at different probe positions, so that inhibition effects may be magnified. The use of control probe conditions may help to assess whether the baseline conditions are in fact working properly, but direct comparisons between probe words of very different types (e.g., probes of nouns vs. probes of function words) may not yield interpretable results.

Despite these concerns about each baseline used individually, there have been so many examinations of facilitation effects from pronouns, many in studies that used multiple baselines, that it is possible to arrive at a consensus that pronouns do facilitate their referents. The picture for inhibition effects is much less clear, as they have received far less attention. The relative importance and time course of these two hypothesized processes also remain unclear.

The two experiments reported here address these issues in a cross-modal probe response task, in comparison to several baseline conditions. The major baseline is a no-pronoun sentence. We expect that referent responses will be faster in the pronoun condition than in the no-pronoun condition, reflecting pronoun facilitation effects, and if inhibition effects also exist, then nonreferent responses should be slower in the pronoun sentence compared to the no-pronoun baseline. As a check for unwanted differences in sentence difficulty or discourse shifts across the pronoun and no-pronoun conditions, we included a control probe word in Experiment 1; if we have matched things properly, we expect that responses to this word should not change across sentence type. All of our probe positions appear in midsentence in order to avoid problems associated with end- vs. midsentence comparisons. We have not included a pre-pronoun baseline, because we wanted to have subjects continue to hear the sentences while the probe word is on the screen. Instead, we use three probe positions after the pronoun is presented to track the time course of any facilitation and inhibition effects that we might find. We expect that this combination of baselines and checks on the baselines will allow us to assess the existence and time course of fa-

cilitation and inhibition effects from pronominal reference.

EXPERIMENT 1

All sentences in Experiment 1 contained one male and one female proper name, and could appear in both pronoun and neutral no-pronoun versions. We had subjects perform a probe recognition task and probed with one of three words on each trial: the referent of the pronoun (the *referent* probe), the other name in the sentence (the *nonreferent* probe), and another word in the sentence, such as a verb, that could not be the referent of the pronoun (the *control* probe). Note that the terms "referent" and "nonreferent" will continue to be used for the two names probed in the sentence, even though the distinction is not meaningful when there is no pronoun in the sentence. Pronouns appeared near the middle of the sentence, and three levels of Probe Delay (the interval between the offset of the pronoun and the onset of the probe) were chosen so that the probe appeared before the sentence ended.

We would predict that, at a probe position appearing at the offset of the pronoun, the presence or absence of the pronoun will have no effect on responses to any probe, since the referent of the pronoun will not have been computed at this point. This result would replicate Gernsbacher's (1989) findings of no facilitation or inhibition effects immediately after the pronoun. In the later delays, however, any facilitation effects for the referent should produce faster response times to the referent probe in the pronoun condition compared to the no-pronoun condition. Inhibition effects for the nonreferent would be indicated by slower response times to the nonreferent probe in the pronoun condition compared to the no-pronoun condition. By looking at these effects at three different intervals after the pronoun, we should be able to see whether they follow the same time course or have different rise and fall times. Finally, comparison of the control probe in the pronoun and no-pronoun sentences should reveal whether processing load and discourse focus were matched in the two conditions.

Method

Subjects. Subjects were 36 students enrolled in psychology classes at Carnegie Mellon University. All were native speakers of English and participated for course credit.

Materials. This experiment manipulated three independent variables. The presence or absence of a pronoun in the second clause was the *Second Clause* variable. This variable had two levels: pronoun and no-pronoun. The *Probe* variable had three levels: referent, nonreferent, and control. The third variable, *Probe Delay,* also had three levels—probe words appeared 0, 250, or 500 ms following presentation of the pronoun. Example stimuli are presented in Table 1, and all stimuli are contained in the Appendix.

The 90 experimental sentences all contained two clauses, conjoined with either *and* or *but*. These conjunctions were chosen because they have been shown to limit the influence of the verb's "implicit causality" on the selection of a pronominal referent (Caramazza, Grober, Garvey, & Yates, 1977). By controlling implicit causality we could better control the plausibility of pronominal reference across items. All

TABLE 1
EXAMPLE STIMULI, EXPERIMENT 1

First clause	Just before dawn, Lisa was fishing with Ron in the boat,
Second clause no pronoun	and lots of big trout were biting.
Second clause pronoun	and she caught a big trout right away.

Note. The probe words for this item were as follows: Referent probe: LISA; nonreferent probe: RON; control probe: FISHING.

first clauses of the experimental stimuli contained 11 words and began and ended with a three-word prepositional phrase. Words 4 and 8 of the first clause were always common English first names, one male and one female. Word 4 was always the subject of the sentence. No names were repeated across any of the experimental sentences; names with diminutive or casual forms (e.g., *Bernard–Bernie*) appeared in only one form.

Two second clauses were constructed for each first clause; the pronoun version contained a pronoun (*he* or *she*) coreferential with the first name (Word 4), and the no-pronoun version contained no pronoun and no other reference to either name mentioned in the first clause. Word 13 was always a function word in the no-pronoun condition, typically a quantifier such as *some*. The length of the pronoun and no-pronoun clauses averaged 9.72 and 9.96 words, respectively. The referent and the pronoun were always the subjects of their clauses and were always Words 4 and 13, respectively. These manipulations were designed to control for two other factors that have been shown to influence the difficulty of selecting a referent: (1) the grammatical role of the referent and pronoun (Ehrlich, 1980), and (2) the number of words intervening between the referent and the pronoun (Clark & Sengul, 1979). A third reason for having the referent be the subject is that it aids in matching the pronoun and no-pronoun sentences for discourse focus. If no topic shifts are introduced, the discourse focus in the no-pronoun condition will tend to remain on the subject of the sentence, and thus a comparison of this condition with the condition in which the pronoun refers to the subject will tend to produce the best match of discourse focus.

The three probe words for the experimental sentences were the referent (Word 4), the nonreferent (Word 8), and the control probe (Word 6). The only restriction for Word 6 when constructing the sentences was that this word could not be an animate, singular noun that might be considered as a referent for the pronoun. Because the control probe class is made up of a variety of word types, and because the purpose of this probe is to monitor for unwanted changes across the pronoun and no-pronoun conditions, this probe condition will be analyzed separately from the two more homogeneous name probe conditions, the referent and nonreferent probes.

Half of the 102 filler sentences contained one or two names; 24 of these contained a pronoun that was not coreferential with the subject of the sentence. None of the names used in the fillers were used in the experimental sentences. Most probes selected for the filler sentences were *false* probes; that is, they had not occurred in the sentence. The proportion of false probes was such that subjects saw true probes on 58% of the trials and false probes on 42% of the trials (all experimental stimuli had true probes). False probes were either names that were similar to names that had been in the sentence or were synonyms of a word that had been in the sentence.

Comprehension questions were prepared for half of the experimental and filler sentences. The information necessary to answer these questions was contained in the first clause of the sentence. Each question was phrased to allow a yes/no answer.

The stimulus sentences were digitized for auditory presentation. Digitization was performed using a low-pass filter with a sharp cutoff at 9 KHz and a sampling rate of 20 KHz. The experimental sentence stimuli were prepared in several stages. First, every sentence was recorded twice on cassette tape, once each with the pronoun and no-pronoun endings. Sentences were recorded at a slow to normal rate of speech with a short, natural-sounding pause between the two clauses. Next, one of the two recordings of the first clause was selected to be digitized—approximately half of the selected first clauses came from the sentence ending in the pronoun second clause, and half from the no-pronoun version. The

two second clauses were then digitized. Each experimental item was thus stored as three files of digitized speech: one first clause, the pronoun second clause, and the no-pronoun second clause. During playback, when a first clause file was followed immediately by one of the second clause files, a natural-sounding sentence resulted with no indication of a splice.

Wave-form displays of each second clause were inspected, and the end of Word 13 (the pronoun in the pronoun condition) was marked in the digitized data. The mark had no audible effect on playback and was used to vary Probe Delay. During playback, the visual probe appeared on the screen at 0, 250, or 500 ms following the mark. Each filler sentence was recorded and digitized in its entirety. The mark controlling the appearance of the probe was set in a variety of locations for the filler sentences.

Procedure. Subjects were tested individually, seated before a CRT with a loudspeaker positioned to the right of the screen. Presentation of sentences, probes, and comprehension questions was controlled by computer. Each trial began with a READY signal in the center of the screen, which was replaced after 1000 ms by a rectangular box 12 characters long. Subjects were instructed to fixate on the box, as it indicated where the probe word would appear. Playback of a sentence through the speaker began with the appearance of the box on the screen. At some point during each sentence, a probe word replaced the box. Probes appeared in lower case with appropriate capitalization of names. Subjects pressed a YES or NO key with the right hand to indicate whether the probe had appeared in the sentence. Incorrect responses and responses longer than 1800 ms produced a message on the screen indicating the occurrence of an error and/or of a long response time.

Comprehension questions appeared on the CRT following the probe response for half of the stimuli. Subjects used the same two buttons to answer these questions, and incorrect answers were indicated by a message on the screen. Following 10 practice trials, the experimental and filler stimuli were presented in random order. Subjects completed the experiment in a 35-min session without a break.

Results and Discussion

Overview. The reaction time data produced a complex pattern of effects. At the 250-ms delay there was the predicted inhibition of the nonreferent by the pronoun, and this effect persisted as a trend at the 500-ms delay. However, there was inhibition for the referent in the pronoun condition at 0-ms delay. Analyses of the control probe revealed no effects, indicating that processing load was correctly balanced across the pronoun and no-pronoun conditions. There was also some evidence that our concern about "natural" declines in activation levels with increasing delay was not unfounded: Response times slowed nonsignificantly with increasing probe delays, and response errors increased significantly as probe delay increased. Each of these effects is examined in detail below.

Reaction time analyses. Only correct responses to the probe were analyzed. Before analysis, a two-step trimming procedure was employed. First, all responses greater than 1800 ms or less than 200 ms were removed. Next, the mean and standard deviation for response times were calculated for each subject, and all responses that were more than 2.5 *SD* above a subject's mean were discarded. This procedure removed less than 4% of the data.

Response times to all probes are shown in Fig. 1. For the two name probes, there was a significant Probe Word × Second Clause × Probe Delay interaction, $F_1(2,70) = 6.12$, $MSe = 6898$, $p < .005$, $F_2(2,176) = 5.82$, $MSe = 10{,}770$, $p < .005$, indicating a changing pattern of effects of the pronoun on the referent and nonreferent at the three probe delays. Further examination revealed that there was a Probe Word × Sec-

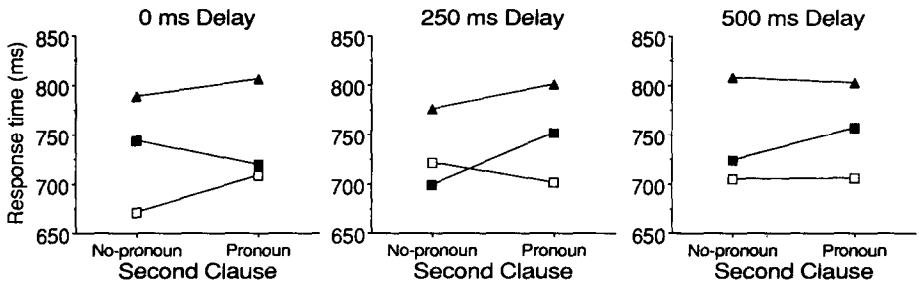

FIG. 1. Response times to probes of referents (open squares), nonreferents (filled squares), and control words (triangles), Experiment 1.

ond Clause interaction at both the 0-ms probe delay ($F_1(1,35) = 7.14$, $MSe = 4812$, $p < .02$, $F_2(1,88) = 4.88$, $MSe = 10{,}3667$, $p < .05$), and at the 250-ms delay ($F_1(1,35) = 7.70$, $MSe = 5973$, $p < .01$, $F_2(1,88) = 7.00$, $MSe = 10164$, $p < .01$). There was no interaction at the 500-ms delay, Fs < 1.5.

The interaction at the 250-ms delay was produced by a pattern of data consistent with the hypothesis (Gernsbacher, 1989) that inhibition results from establishing coreference between a pronoun and its referent. Responses to the nonreferent probe were significantly slower in the presence of the pronoun, compared to nonreferent responses in the no-pronoun condition, $F_1(1,35) = 6.87$, $MSe = 7345$, $p < .02$, $F_2(1,88) = 6.72$, $MSe = 9866$, $p < .02$. This pattern for nonreferent responses appears to continue to the 500-ms delay condition, although statistically the 33 ms difference was only a trend, $F_1(1,35) = 3.31$, $MSe = 6024$, $p < .10$, $F_2(1,88) = 3.20$, $MSe = 10{,}165$, $p < .10$.

We predicted that some facilitation effects for the referent would be found in the pronoun condition compared to the no-pronoun condition, but this prediction was not supported. Responses to the referent were faster in the pronoun condition than in the no-pronoun condition at the 250-ms delay, but this difference did not approach significance at this delay or at the 500-ms delay, Fs < 1. Thus, like Gernsbacher (1989), we found no clear evidence for facilitation effects for the referent of a pronoun.

These data can be examined in another way, comparing referent and nonreferent responses at each of the two levels of the Second Clause factor. As we pointed out above, this referent-nonreferent comparison cannot indicate whether observed effects are caused by facilitation or inhibition; this comparison can only indicate whether the pattern of responses to the two probes changes in the presence of a pronoun. When the sentence contained a pronoun at the 250-ms delay, referent probe responses (702 ms) were significantly faster than nonreferent responses (752 ms), $F_1(1,35) = 7.32$, $MSe = 6186$, $p < .02$, $F_2(1,88) = 8.11$, $MSe = 8952$, $p < .01$, while responses to these two probes did not differ in the no-pronoun condition, (721 and 699 ms for referent and nonreferent responses, respectively, $F_1(1,35) = 1.59$, $MSe = 5157$, $p > .20$). Similarly, at the 500-ms delay, referents were faster than nonreferents when a pronoun was present (706 vs. 756 ms, respectively, $F_1(1,35) = 5.83$, $MSe = 8545$, $p < .05$, $F_2(1,88) = 3.15$, $MSe = 16{,}874$, $p < .10$). In the no-pronoun condition at this same delay, there was no difference in response times between referents (705 ms) and nonreferents (724 ms), Fs < 1. In sum, the pattern of results that emerges at the 250- and 500-ms delays from these four combinations of Second Clause and Probe factors is that three conditions produce roughly the same response times, but one is different. The one that appears to be different is the nonreferent probe when the sentence contains a pronoun—this condition is reliably slower than all the others, $F_1(1,35) = 12.58$, $MSe = 2094$, $p < .001$, $F_2(1,88) = 13.17$, $MSe = 2973$, $p < .001$, but the other three condi-

tions do not differ among themselves, $F < 1$. Thus the pronoun does appear to produce a real inhibition effect for the nonreferent at these two delays.

This conclusion must remain tentative, however, because the pattern of results producing the interaction at the 0-ms delay is a very different one from the pattern at the later delays. At the 0-ms delay, nonreferent probes were not affected by the presence of a pronoun, $F_1(1,35) = 1.68$, $MSe = 5931$, $p > .20$). At the same time there was a significant inhibition effect from the pronoun for its referent $F_1(1,35) = 7.79$, $MSe = 3389$, $p < .01$, $F_2(1,88) = 4.10$, $MSe = 9731$, $p < .01$. In the presence of the pronoun at this delay, referent response (708 ms) did not differ from nonreferent responses (720 ms), Fs < 1. In the no-pronoun condition, however, referent responses (671 ms) were significantly faster than nonreferent responses (744 ms), $F_1(1,35) = 13.59$, $MSe = 7123$, $p < .01$, $F_2(1,88) = 8.79$, $MSe = 12{,}951$, $p < .01$. We will return to a discussion of these results below.

As mentioned earlier, responses to the two name probes were analyzed separately from the control probe responses because the words in the control condition were not proper names and were expected to have longer and more variable response times. In fact, this is exactly what happened. The mean response times for the referent, nonreferent, and control probes were 702, 732, and 797 ms, respectively, with standard deviations of 133, 143, and 152 ms. Responses to the control probe, which were words that could not be a pronominal referent, did not differ in the pronoun and no-pronoun versions of the sentence, and there was no interaction with Second Clause and Delay for this probe (all Fs < 1.5). This result indicates that the pronoun and no-pronoun second clauses did not differ in processing load.

In order to assess whether there was a general decline in activation levels with increasing probe delay, we examined overall response times across delay. Response times slowed with increasing probe delay, but this effect was not robust ($F_1(2,70) = 1.39$, $MSe = 5029$, $p > .25$).

Error analyses. Subjects' accuracy rates responding to the probe are presented in Table 2. There were no interactions to give any evidence of speed/accuracy tradeoffs, but accuracy did decline as probe delay increased, $F_1(2,70) = 4.05$, $MSe = 0.0080$, $p < .05$, $F_2(2,176) = 3.92$ $MSe = 0.0103$, $p < .05$. This result is consistent with the hypothesis that a word would become less available as the time increased between the initial presentation of a word and the probe of that word. Control probe responses were less accurate than responses to the two name probes, $F_1(2,70) = 10.12$, $MSe = 0.0094$, $p < .001$, $F_2(2,176) = 7.76$, $MSe = 0.0162$, $p < .001$.

Summary. This study provides evidence for inhibition of nonreferents at the 250- and 500-ms delays, but these results are paired with an inhibition effect for the referent at the 0-ms delay. One possible explanation is that at the 0-ms delay, the correct referent has not been found for the pronoun, and response times at this point indicate some confusion while the correct referent is being sought. Our original expecta-

TABLE 2
PERCENTAGE OF CORRECT RESPONSES TO PROBE, EXPERIMENT 1

Second clause	Referent	Probe word Nonreferent	Control
Probe delay = 0 ms			
No-pronoun	98.3	98.3	95.0
Pronoun	96.1	100	95.6
Probe delay = 250 ms			
No-pronoun	96.7	99.4	91.0
Pronoun	95.6	97.8	95.0
Probe delay = 500 ms			
No-pronoun	95.6	96.1	93.3
Pronoun	93.9	96.5	93.2

tion was for no effects at the 0-ms delay, a result which would have replicated Gernsbacher (1989). Our own results will be tested again in the next experiment, but it would also be useful to explore further the idea that there could be a refractory period between the time when a pronoun has been encoded and the time when its referent has been found. The stimuli in Experiment 1, which were designed to make referent selection as easy as possible, created the smallest possible window of time in which to observe the processes before the assignment of coreference. Accordingly, Experiment 2 was designed to gather further information. Half of the trials provided a replication of Experiment 1, with unambiguous referents to the pronouns, whereas the other half presented sentences with ambiguous pronoun reference. This ambiguity will make the referent selection process more difficult and extend the time between when the pronoun is encoded and when it is assigned a referent. The ambiguous condition should therefore provide a greater opportunity to observe processing during the period when a pronoun has not yet been assigned a referent.

Experiment 2

In Experiment 2 we manipulated referential ambiguity for the pronoun simply by changing one word of the sentence, so that the two names in the first clause were either different genders, reproducing the conditions of Experiment 1, or they were the same gender, creating an ambiguity. In Experiment 1 we designed the stimuli so that gender was the primary cue to coreference and constructed the stimuli to eliminate potentially conflicting cues like implicit causality (Caramazza et al., 1977). When gender cues are eliminated from these stimuli, very little is left to guide the selection of a pronominal referent.

We do not claim that this new condition with two names of the same gender is perfectly ambiguous, merely that is substantially more difficult to choose a referent in these sentences without gender information. This manipulation should thus extend the time between when a pronoun is perceived and when it is assigned a referent. We predict that unambiguous pronouns (i.e., those that are disambiguated by gender information) should produce inhibition effects for nonreferents compared to the no-pronoun condition, but when gender information is unavailable, the effect of pronouns should be very different. Not only should there be no inhibition effects typical of the unambiguous condition, but there might even be a general slowing of responses in all pronoun conditions as subjects are faced with additional processing load in the task of determining the referent for an ambiguous pronoun.

Method

Subjects. Forty-eight college students were paid for their participation in the experiment. An additional three subjects were tested and were rejected for error rates over 20% on comprehension questions.

Materials and procedures. The procedures for digitizing and presenting the stimuli were identical to those used in Experiment 1. Filler and practice stimuli and comprehension questions were also identical to those used in Experiment 1.

The experimental materials were developed from those used in the previous experiment. The major change in the materials from Experiment 1 was the addition of the manipulation of the ambiguity of the pronominal reference, via the manipulation of gender in the first clause of the sentence. On half the experimental trials, subjects heard sentences with one male and one female name—the *Unambiguous Reference* condition. On the remaining trials both names in the first clause were of the same gender, producing the *Ambiguous Reference* condition in which either name could be the referent of the pronoun. To keep our terminology consistent, we will continue to call the first name in the sentence the "referent" and the second the "nonreferent," even though both names are com-

patible in gender with the pronoun in the ambiguous condition.

In order to maintain a reasonable number of observations per cell with the addition of the new Ambiguity factor, the Control Probe condition used in the previous experiment was eliminated in Experiment 2. The present experiment thus employed a 2 × 2 × 2 × 3 design. The four factors were Ambiguity (the referent of the pronoun was disambiguated by gender or it was not), presence or absence of a pronoun in the second clause, Probe Word (referent/Word 4 or nonreferent/Word 8), and Probe Delay (0, 250, or 500 ms following the 13th word of the sentence). Six new experimental sentences were constructed to produce a balanced design of all the factors in this experiment. These new sentences appear at the end of the Appendix.

All 96 experimental sentences appeared at both levels of the Ambiguity factor across subjects, but within each level, sentences were randomly assigned to a male-first or female-first pattern of names. That is, 48 sentences were assigned a male-female order of names in the Unambiguous Reference condition and two male names in the Ambiguous Reference condition, while the other half of the sentences had a female-male order and two female names at the two levels of Ambiguity. Pairs of sentences were yoked so that the same four names would be used in all conditions for those sentences. For example, a subject who was presented a sentence containing the names *Lisa* and *Ron* in the Unambiguous Reference condition would also hear an Unambiguous Reference sentence containing the names *Danny* and *Penny*, whereas subjects who heard these sentences in the Ambiguous Reference condition would hear one sentence containing the names *Lisa* and *Penny*, and another containing *Danny* and *Ron*. Thus all subjects heard each name only once.

Results and Discussion

Response time analyses. Response times to probe words in all conditions are presented in Fig. 2 with Unambiguous Reference results in the top panel and Ambiguous Reference below. Before analysis, response times were trimmed as in Experiment 1. There was a four-way interaction of Ambiguity, Second Clause, Probe Word, and Probe Delay, $F_1(2,94) = 5.11$, $MSe = 9091$, $p < .01$, $F_2(2,190) = 3.89$, $MSe = 19197$, $p < .05$. We further investigated this effect first by examining responses in the Unambiguous Reference and Ambiguous Reference trials independently, and second by examining the effects of Second Clause and Ambiguity at each of the three probe delays.

The stimuli in the Unambiguous Reference trials were identical to the stimuli in the previous experiment, save for the addition of six new stimulus items, but inhibition effects appeared earlier in the Experiment 1 than in this experiment. Considering just the Unambiguous Reference trials, there was a significant Second Clause × Probe × Delay interaction $F_1(2,94) = 3.36$, $MSe = 9488$, $p < .05$, $F_2(2,190) = 3.33$, $MSe = 16703$, $p < .05$. The source of this interaction is obvious in the top panel of Fig. 2: Pronouns began to affect the referent and nonreferent in different ways only at the 500-ms delay. There was no Second Clause × Probe Word interaction at the 0-ms delay, $F_1(1,47) = 1.87$, $MSe = 6705$, $p > .15$, nor at the 250-ms delay, $F < 1$. At the 500-ms delay, however, this interaction was robust, $F_1(1,47) = 14.35$, $MSe = 9582$, $p < .001$, $F_2(1,95) = 14.77$, $MSe = 16521$, $p < .001$. As can be seen from the graph for the Unambiguous Reference condition at the 500-ms delay, the pronoun produced a significant 57-ms facilitation effect for the referent in the pronoun condition compared to the no-pronoun baseline, $F_1(1,47) = 7.91$, $MSe = 9736$, $p < .01$, $F_2(1,95) = 4.78$, $MSe = 19217$, $p < .05$. The pronoun simultaneously inhibited nonreferent probe responses so that they were 50 ms slower in the pronoun condition than in the no-pronoun condition, $F_1(1,47) = 9.07$, $MSe = 6716$, $p < .01$, $F_2(1,95) = 8.29$, $MSe = 18870$, $p < .01$.

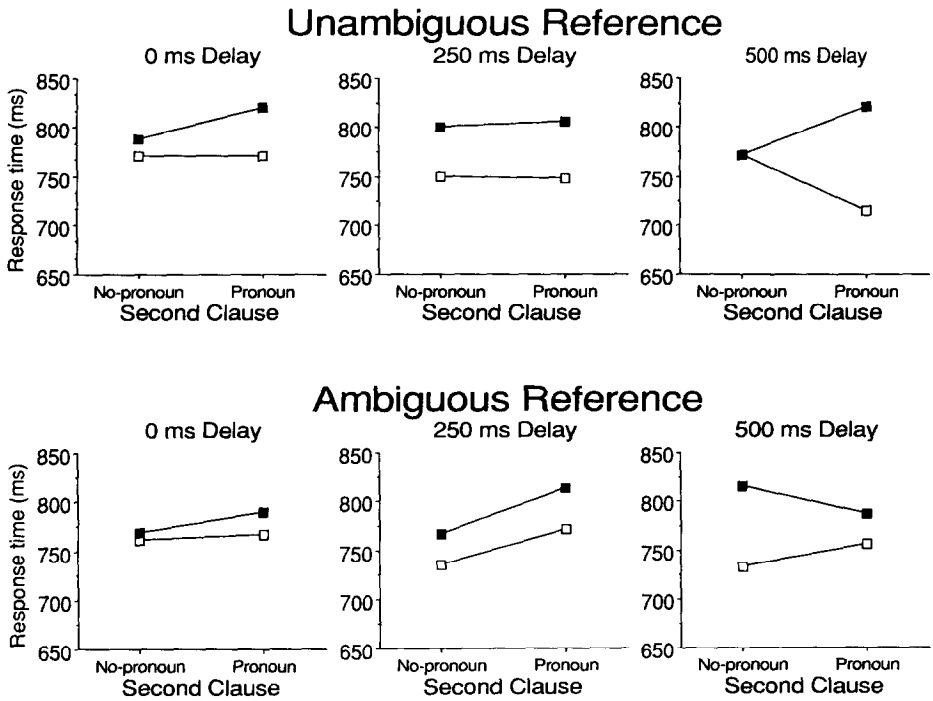

FIG. 2. Response times to probes of referents (open squares) and nonreferents (filled squares) in Unambiguous and Ambiguous Reference conditions, Experiment 2.

The Ambiguous Reference conditions showed a different pattern of response times. There was a trend for a Second Clause × Delay interaction, suggesting that the effect of the pronoun was changing over time, $F_1(2,94) = 3.09$, $MSe = 7461$, $p < .06$, $F_2(2,190) = 2.71$, $MSe = 21476$, $p < .07$. Examination of Fig. 2 shows that this interaction was produced by a very different pattern of data than that found in the Unambiguous Reference conditions. Most notably, the presence of the pronoun significantly slowed reaction times to probes in comparison to responses in the no-pronoun trials in the Ambiguous Reference condition, $F_1(1,47) = 5.85$, $MSe = 7157$, $p < .05$, $F_2(1,95) = 6.81$, $MSe = 13107$, $p < .05$. The slowing did not interact with Probe Word (Fs < 1), indicating that probes of both names were slowed equally in the presence of the pronoun. These results show the sensitivity of the probe task to variations in processing load. Subjects in the Ambiguous Reference condition had no gender information to help them establish the referent of the pronoun, and so they had to look for other clues and/or delay the assignment of coreference, producing additional load and thus slower response times in the probe task. As would be expected if disambiguating gender information made coreference assignment easier, there was no slowing effect on overall response times from the pronoun in the Unambiguous Reference condition, Fs < 1.

By examining the data in another way, it is possible to see how gender information influenced responses over time. At the 0-ms delay, the graphs in the Unambiguous Reference and Ambiguous Reference conditions are nearly identical. Ambiguity did not interact with any of the other factors at this delay, suggesting that gender information was not yet available. The pronoun had not been fully processed yet, and so there are no differences between conditions in which one or two names are potential referents.

At the 250-ms delay, it is obvious from the graphs that subjects are slowed by the pronoun in the Ambiguous Reference condition. In the Unambiguous Reference condition, however, they do not seem to be having this difficulty, even though facilitation and inhibition effects have not yet appeared. The statistical analyses support this account of the data: There was a Second Clause × Ambiguity interaction at this delay ($F_1(1,47) = 6.49$, $MSe = 5348$, $p < .05$, $F_2(1,95) = 6.11$, $MSe = 14508$, $p < .05$), but there was no three-way interaction with these factors and Probe Word, Fs < 1. That is, the presence or absence of a pronoun in the second clause was affecting responses to *every* probe word as a function of the pronoun's ambiguity, but referents and nonreferents were not yet distinguished by the gender information. This result is exactly what would be expected if the ambiguous pronoun was causing difficulty in the Ambiguous Reference conditions but was being resolved in the Unambiguous Reference conditions. Thus the 250-ms delay shows the difference between an unambiguous and ambiguous pronoun before any priming effects have appeared.

Finally, at the 500-ms delay, there is a strong three-way interaction of Ambiguity, Second Clause, and Probe Word, $F_1(1,47) = 13.10$, $MSe = 11673$, $p < .001$, $F_2(1,95) = 12.56$, $MSe = 21044$, $p < .001$. As noted above, in the Unambiguous Reference condition there was significant facilitation of the referent and inhibition of the nonreferent at this delay. The effects are much different in the Ambiguous Reference condition, when gender information is unavailable. It is clear from Fig. 2 that subjects at this delay did not resolve the pronoun in the same way as they did in the Unambiguous Reference condition. There was a trend for a significant Second Clause × Probe Word interaction for the Ambiguous Reference conditions, $F_1(1,47) = 4.64$, $MSe = 7161$, $p < .05$, $F_2(1,95) = 2.48$, $MSe = 21905$, $p < .15$. As can be seen in Fig. 2, however, the pattern of interaction at this delay is unlike the interaction found in the Unambiguous Reference condition.

While both experiments reported here found inhibition effects for nonreferents, they appeared at 250 ms in Experiment 1, but did not appear until 500 ms in Experiment 2. We cannot be sure of the reason for this difference (and indeed we will see below that there are many different time courses that have been found for pronominal facilitation effects), but it is interesting to note that these delayed effects in Experiment 2 were accompanied by overall slower response times in this experiment compared to Experiment 1. Response times to referents and nonreferents in Experiment 1 were 702 and 732 ms, respectively, whereas responses to these two probes in the identical (unambiguous) conditions in Experiment 2 were 754 and 796 ms, respectively. It is possible that the subject populations were different enough to cause these effects—Carnegie Mellon students participated for course credit in Experiment 1, but the Experiment 2 subjects were summer school students at a variety of colleges who were paid for participating. Another factor that might also have contributed to slower response times and delayed pronoun effects in Experiment 2 is the increased overall processing load arising from the 48 difficult Ambiguous Reference trials.

Error analyses. The pattern of errors in the probe response tasks, presented in Table 3, is consistent with the reaction time data. There was an interaction of the Second Clause and Probe factors such that responses were more accurate to the referent probe in the presence of a pronoun, while nonreferent responses were more accurate in the no-pronoun condition, $F_1(1,47) = 4.53$, $MSe = 0.0044$, $p < .05$, $F_2(1,95) = 5.27$, $MSe = 0.0094$, $p < .05$. This result demonstrates that the inhibition and facilitation effects found in the reaction time data were not the result of speed/accuracy tradeoffs. Overall responses to the nonreferent were somewhat more accurate (98.4% correct) than to the referent (97.5%),

TABLE 3
PERCENTAGE OF CORRECT RESPONSES TO PROBE, EXPERIMENT 2

	Probe delay = 0 ms			
	Unambiguous reference		Ambiguous reference	
Second clause	Referent	Nonreferent	Referent	Nonreferent
No-pronoun	97.4	99.5	95.8	99.5
Pronoun	97.9	95.8	99.0	98.4
	Probe delay = 250 ms			
	Unambiguous reference		Ambiguous reference	
Second clause	Referent	Nonreferent	Referent	Nonreferent
No-pronoun	98.4	97.9	96.4	99.5
Pronoun	99.0	98.4	97.9	98.4
	Probe delay = 500 ms			
	Unambiguous reference		Ambiguous reference	
Second clause	Referent	Nonreferent	Referent	Nonreferent
No-pronoun	96.4	97.9	97.0	97.9
Pronoun	97.9	97.9	97.3	100

$F_1(1,47) = 3.93$, $MSe = 0.0060$, $p < .10$, $F_2(1,95) = 5.03$, $MSe = 0.0092$, $p < .05$.

Summary. Response times in the Unambiguous and Ambiguous Reference conditions show how different results can be obtained from sentences that are identical save for the change of one word. In one sense the Ambiguous Reference condition can be thought of as yet another baseline, in that it reveals the effects of an ambiguous vs. an unambiguous remention of sentence participants. When there is an ambiguity in pronominal reference, subjects show no evidence of having assigned a referent to the pronoun within the 500 ms interval explored here. However, when the first name in the sentence is unambiguously rementioned with a pronoun, subjects can move on to process the pronoun, activate the referent and deactivate the nonreferent. The Ambiguous and Unambiguous conditions represent extremes of a continuum of pronoun resolution difficulty. Had we added information to make one name the more plausible referent in the absence of gender information, as others have done (Corbett & Chang, 1983; Gernsbacher, 1989; Hirst & Brill, 1980), we would expect to find evidence of the establishment of coreference at points intermediate between the Unambiguous and Ambiguous conditions tested here.

In addition to providing additional information about the period of time before a referent is assigned to a pronoun, the Ambiguous condition provides evidence against an alternative explanation of facilitation and inhibition effects. This alternative notes that probe words might be read more quickly when they are immediately preceded by a gender-matched pronoun and more slowly when preceded by a gender mismatched pronoun, as compared to the no-pronoun condition. According to the alternative account, facilitation and inhibition effects are not due to anaphoric reference but instead to nondiscourse priming effects or the interactions of these effects with reductions in processing load caused by a superficial gender match between a pronoun and a proper name probe. However, this account is ruled out by the data obtained in the Ambiguous condition in Experiment 2. In this condition a probe of either name presents a sequence of gender-matched pronoun and probe. This should lead to faster response times for either probe in the pronoun condition compared

to the no-pronoun control. Instead, what we have found is that, in the Ambiguous Pronoun condition, response times to both probes are generally slower than in the no-pronoun control, a result which we have attributed to the increased difficulty of finding a referent without the aid of gender cues.

General Discussion

In these experiments, we found inhibition effects for nonreferents of a pronoun and, at the 500-ms delay in the unambiguous reference condition of Experiment 2, facilitation effects for referents. The use of the comparison with the no-pronoun sentence and multiple probe delays allowed us to disentangle these effects from possible declines in activation levels that might be found when comparing probe responses early and late in the sentence. There were, in fact, no significant increases in response times over probe positions in the 500-ms interval that we tested, but this is not to say that slowing would not appear in more widely spaced probe positions. Indeed, response accuracy did show some evidence of declining activation levels over time: Accuracy rates decreased with increasing probe delay in Experiment 1, though the effect was not significant in Experiment 2.

Before relating these results to those of other pronoun studies and to more theoretical issues, two findings in the present experiments deserve mention. The first finding is the inhibition effect for the referent at the 0-ms Delay in Experiment 1. This effect was not replicated in Experiment 2, and so we conclude that the result was probably a spurious one. The second finding that deserves mention is that a facilitation effect for referents at the unambiguous 500-ms delay was found in Experiment 2 but not Experiment 1. Facilitation effects have appeared elsewhere in studies that compare pronoun and no-pronoun conditions (Emmorey et al., 1989; Leiman, 1982; MacDonald, 1986). Our failure to find this effect reliably could be due to the fact that we always made the referent the first name in the sentence. The first of two participants in the same clause of a sentence generally has a higher activation level, resulting in faster reaction times to probes of the first name (Gernsbacher & Hargreaves, 1988). Figures 1 and 2 show that we replicated this subject preference effect—responses for first names/referents are generally faster than for nonreferent/second names in all conditions. Perhaps there was a floor effect here; it could be that the activation levels of the first names were high enough that further facilitation from the pronoun could not be easily observed.

The present research demonstrates that the time course of facilitation and inhibition effects is dependent on ease of resolving pronominal reference. Because our crucial comparison is not across time, but across pronoun conditions, our results further show that inhibition effects are not to be confused with "natural" declines in activation levels. Neither the present studies nor the Gernsbacher (1989) studies found any inhibition for nonreferents or facilitation for referents at probe positions immediately after the pronoun (Gernsbacher's earliest probe position after the pronoun was actually at a 150-ms delay). Apparently these early probe positions measured responses at a point before the referent had been found for the pronoun. The results from the Ambiguous Reference conditions in Experiment 2 show that this interval can be extended for longer periods if there are few cues to the correct referent.

The observation that it is possible to tap a point after a pronoun has been perceived but before it has been assigned a referent has been reported in other work. MacDonald (1986), using a self-paced reading and probe recognition task with similar sentences to those employed in the present experiments, found no facilitation effects before a 500-ms interval, and when the syntax of the sentences became more difficult, facilitation effects did not appear until a 1000-ms probe position. In an experiment with

videotaped American Sign Language sentences and probes, Emmorey et al. (1989) compared referent and nonreferent probes in pronoun and no-pronoun conditions and found facilitation effects for referents at a 1000-ms delay, but not at a 0-ms delay. Similarly, Stevenson (1986) found a facilitation effect one word after the pronoun in a self-paced reading task. Given the nature of self-paced reading, this interval was probably about 300–400 ms after the pronoun, and this result is thus consistent with other findings. On the other hand, Marslen-Wilson and Tyler (1980) found no differences in probe responses to referents and nonreferents within three words of the pronoun in a cross-modal task using probes that were semantic associates of the referent. Their failure to find an effect at this relatively late probe delay is somewhat surprising, but Tanenhaus, Carlson, and Seidenberg (1985) suggest that the type of associate probes Marslen-Wilson and Tyler used may have limited their ability to find facilitation effects.

In contrast to the work reviewed above, all of which suggested that finding the referent for a pronoun takes a measurable amount of time, there are a few experiments that have shown facilitation effects at a 0-ms probe delay (Leiman, 1982; Cloitre & Bever 1988; Nicol, 1988). With the exception of Nicol's (1988) work (which we suggested earlier might tend to amplify facilitation effects), all of these experiments employed stimuli such that the pronoun was the last word of the sentence, a feature that is not shared by any of the experiments discussed in the previous paragraph. While experiments directly comparing pronoun resolution at the end and in the middle of sentences have yet to be done, it is reasonable to hypothesize that the processes might not be identical in the two cases. Certainly one difference is that the task is easier when the pronoun is the last word of the stimulus, because there are no more incoming words to be interpreted, and thus more resources are available for resolving the pronominal reference. It is therefore reasonable to expect that effects might appear earlier with sentence-final pronouns.

A second factor that separates groups of studies is the nature of the referent noun phrase. Some studies, including the present ones, have used proper name probes (Chang, 1980; Corbett & Chang, 1983; Gernsbacher, 1989; MacDonald, 1986; Stevenson, 1986), whereas others have used common nouns such as the actress and the policeman (Cloitre & Bever, 1988; Emmorey et al., 1989; Leiman, 1982; Marslen-Wilson & Tyler, 1980; Nicol, 1988). There is no reason to believe that one type of stimulus is somehow more "natural" than the other—perceivers encounter both common and proper nouns very frequently—but it is possible that the procedures for maintaining common and proper names in short term memory might not be identical. Indeed, McDonald and MacWhinney (1988) conducted a cross-modal pronoun study comparing proper names and common nouns and found earlier facilitation effects for proper names than for common nouns. They interpreted this in terms of the additional processing time involved in activating the images and associations linked to common nouns. Clearly, this issue deserves further research.

Taken together, the present studies and those reviewed above suggest that probe response data can provide information about the effects of pronominal reference, but that probe responses can also be influenced by variations in processing load and by the degree to which the probed concept is prominent in the discourse. In our view, the activation levels of elements in the comprehender's representation of the discourse are continuously changing as additional inputs are processed. The probe response task used here is a measure of activation levels, and anaphoric reference is just one of many processes that might change these levels. Other influences, such as overall processing load, share in the process of

shaping the time course of these changes. The sensitivity of the probe task to multiple influences presents both a challenge for methodological analysis and an opportunity for constructing experiments that tap a large variety of psycholinguistic processes.

Appendix

Stimulus Sentences for Experiments 1 and 2

Pronoun second clauses are followed by no-pronoun second clauses. Items 91–96 were used only in Experiment 2.

1. After this speech, Carol will easily beat Burt in the election, and she is expecting an early victory. /and all the supporters are sensing victory.
2. In the bar, Hal bought drinks for Jennifer for several hours, and he decided to call a taxi for the ride home. /and all the liquor was beginning to have an effect.
3. Until lunch time, Tina always plays with Nick in the yard, and she usually doesn't want to go in for lunch. /and all the games are noisy ones.
4. Sometime this spring, Gary will go with Cathy to the mountains, and he will camp out in the woods. /and all the gang will camp in the woods.
5. Just before halftime, Marilyn got popcorn for Bernie from a vendor, and she missed the most exciting play of the game. /and some guy in line spilled soda all over the place.
6. In the laundry, Ernest borrowed bleach from Denise for one wash, and he really faded some new jeans. /and some new blue jeans got ruined.
7. All winter long, Joe shovelled snow with Bridget in the driveway, and he was amazed at how hard the work was. /and some days the work lasted for hours.
8. In the alley, Valerie gave envelopes to Max containing secret documents, and she was punished by the police. /and then some money changed hands.
9. With the scissors, Ben cut material that Sherri bought for costumes, and he made a big mess on the table. /and some of the pieces were ruined.
10. For a joke, Besty put frogs on Jimmy during math class, and she got into big trouble with the principal. /and two teachers got very angry about the mess.
11. For several months, Steve had practiced with Linda for the parade, and he knew the marches perfectly now. /and all the difficult steps were easy now.
12. After several minutes, Ellen caught sight of Harold in a tree, and she waved and shouted to the others. /and all the kids were there too.
13. On the radio, Craig heard news that Brenda had been rescued, and he told everyone right away. /and all the people cheered at the news.
14. Behind the garage, Sally was hiding from Ken for an hour, and she was too scared to come out. /and three boys finally discovered the spot.
15. On the beach, Mitch gathered driftwood with Cindy for the fire, and he found a large shell under a log. /and some hot dogs were roasted right away.
16. At the mall, Wendy saw books by Kevin out on display, and she bought two for Christmas gifts. /and none looked very exciting or fun.
17. In the truck, Sam got lost with Julie somewhere in Texas, and he drove around for hours in the desert. /and even the map was no use.
18. Just before dawn, Lisa was fishing with Ron in the boat, and she caught a big trout right away. /and lots of big trout were biting.
19. Right after lunch, Frank overheard discussions with Ruth about the robbery, and he called the police right away. /and then the police came rushing in.
20. During the movie, Sharon became angry with Brad about the seats, and she left the theater before the film ended. /and then everyone was unhappy for the rest of the night.
21. During lunch hour, Scott cashed checks for Ann at the bank, and he was careful to save the receipts. /and all the lines were really long.
22. Throughout the year, Angela would often help Fred with the project, and she learned many things about research. /and some of the pictures came out very well.
23. On Tuesday afternoon, Robert had lunch with Allison near work downtown, and he picked up the check for the meal. /and all the fruit salads were delicious.
24. Every Sunday afternoon, Susan watches sports with Allen at the track, and she usually picks the winning team. /and all the shouting can be heard for blocks.
25. Early one morning, Josh was walking with Tracy through the zoo, and he got some film to put in the camera. /and none of the animals were very playful.
26. During the holidays, Amy was skiing with Earl somewhere up north, and she broke a leg on the second day. /and some days were really beautiful.
27. After the play, Walter probably will invite Connie over for cocoa, and he has cleaned the apartment all day. /and maybe for some oatmeal cookies too.
28. After the accident, Melissa really watched over David in the hospital, and she always brought along some books and magazines. /and those visiting hours were never long enough.
29. From the window, Bill saw wasps near Emily in the garden, and he ran to get the bug spray. /and all the buzzing was really loud.
30. On the airplane, Esther found out that Stan was a

writer, and she asked for an autograph. /and all the passengers gathered around for an autograph.

31. One day soon, Larry will really scare Elizabeth in the woods, and he will probably get into trouble. /and all the gang will be watching.
32. While at school, Rachel will compete with Arthur in chess games, and she plans each move very carefully. /and all the matches should be close.
33. During the hike, Warren saw dogs chase Jill through a meadow, and he called to some farmers for help. /and some hunters were calling for help.
34. For many years, Eileen had worked for Howard in the store, and she wanted some time off for a vacation. /and never had there been such bad business.
35. Late last summer, Neil spent time with Debbie at the beach, and he plans a trip again next year. /and all the surfers were showing off.
36. On the weekends, Nancy always jogs with Roger at the track, and she has lost several pounds already. /and all that exercise is tiring.
37. For three weeks, Adam argued constantly with Vicki about the design, and he was unhappy all the time. /and some harsh words were exchanged several times.
38. Until prices fall, Michelle will not buy Jack a new car, and she will also keep the small apartment. /and so buses and bicycles will have to do.
39. As a favor, Paul did typing for Stephanie over the weekend, but he made a lot of mistakes on the paper. /but some pages contained a lot of mistakes.
40. In the meadow, Joan searched around with Anthony for some crickets, but she only found some ugly beetles. /but only some beetles could be found.
41. On the pier, Barry watched seagulls with Janet for 10 minutes, but he didn't think the birds were very exciting. /but none of the birds came very near.
42. In the story, Barbara steals things from Cliff all the time, but she really doesn't know why. /but none of the items were valuable.
43. From the roof, Mark could see that Natalie had driven away, but he stayed in hiding for several hours. /but several cars were still in the driveway.
44. Under the house, Judy found out where Joel had hidden things, but she didn't want to tell the others. /but none of the others could find the spot.
45. During every speech, Tim always noticed that Cheryl took many notes, but he thought that the talks were boring. /but no one else was interested in the topic.
46. On the balcony, Gail looked down at Jeremy on the lawn, but she did not wave or say hello. /but all the other kids were hiding.
47. Right after breakfast, Andrew should have taken Lynne on a picnic, but he could not find the thermos. /but some storm clouds filled the sky.
48. During the fall, Laura joined clubs with Henry for the dances, but she didn't know any of the steps. /but no one else went for very long.
49. On the ship, Martin got seasick with Becky right after dinner, but he didn't want any of the medicine. /but very few passengers were on deck at the time.
50. On the raft, Katie reached out for Leonard in the river, but she could not grab anyone soon enough. /but some branches were in the way.
51. At the studio, Albert recorded songs by Mary without any musicians, but he thought that everything sounded fine. /but none of the record companies would sponsor the album.
52. Under the bridge, Alice was digging with Teddy for buried treasure, but she soon went home for a nap. /but some men got mad at the kids.
53. Before the meeting, Phil got doughnuts with Marla at a bakery, but he didn't remember the coffee and tea. /but none of the glazed ones were very good.
54. In the apartment, Lucy unpacked boxes with Jeff all day long, but she didn't find the dishes or glasses. /but none of the dishes could be found.
55. At the meeting, Raymond had predicted that Pam would be president, but he was wrong about the election. /but elections are always hard to predict.
56. Almost every afternoon, Penny watches cartoons with Danny right after school, but she has violin lessons at school today. /but today the television is broken.
57. While in town, Alexander went along with Eve to the clinic, but he stayed in the waiting room. /but all the seats were taken in the waiting room.
58. For every lesson, Annette would always teach Doug a new song, but she forgot the music sheets at home. /but this piece was especially difficult.
59. In the gallery, Donald saw portraits of Christine near some statues, but he did not recognize the artist. /but none of the pictures were signed.
60. In the car, Shirley played songs for Eric on the harmonica, but she would not sing any of the lyrics. /but then some kids got mad about the noise.
61. In the cafeteria, Jerry ordered breakfast for Bonnie from the menu, but he did not feel like eating. /but somebody got the order mixed up in the kitchen.
62. Long after midnight, Sandra was talking with Carl about the news, but she didn't speak to anyone else. /but some of the events were still unclear.
63. Today in class, Harry passed notes to Maria during the film, but he did not get an answer. /but few of the messages got there.
64. After the movie, Meg worked puzzles with Wesley on the porch, but she got tired very quickly. /but many of the pieces were missing.
65. One rainy night, Matthew skidded right into Joanne on the highway, but he didn't do much damage to either car. /but no police ever showed up.
66. One Saturday morning, Tammy bought groceries

for Patrick at the market, but she forgot all about the milk. /but none of the vegetables looked good.

67. After the concert, Stuart borrowed money from Beverly for a taxi, but he actually took the bus home. /but all the cabs were taken by then.
68. On the trip, Doreen took pictures of Peter in the mountains, but she lost the roll of film. /but all of the film was ruined.
69. During the play, Brian constantly muttered to Greta about the plot, but he never disturbed anyone else in the audience. /but nobody else was disturbed by the noise.
70. While in Mexico, Betty bought souvenirs for George in some shops, but she could not make room in the suitcase. /but none of the gifts got through customs.
71. Twice a week, Tom studied math with Belinda at the library, but he failed every one of the exams anyway. /but this quarter the schedule was changed.
72. Over the weekend, Nicole should have given Jason a surprise party, but she didn't make any definite plans. /but no friends could attend that day.
73. One rainy day, Edward made coffee for Andrea after the rehearsal, but he forgot the sugar and the cups. /but all the mugs were dirty or broken.
74. At the party, Jessica would have told Charles a good joke, but she couldn't remember the punchline. /but all the guests were too noisy.
75. Late yesterday evening, Russell should have called Donna about the meeting, but he couldn't find the phone number. /but all the phones were out of order.
76. Almost every morning, Virginia almost spoke to Keith about a raise, but she never had enough courage. /but other things always seemed more important.
77. While in Boston, Wayne shopped around with Doris for some shirts, but he couldn't find any good sales. /but none were available in the right size.
78. At every meeting, Sarah always spoke to Conrad about the project, but she never got much support from the staff. /but this month the conference was cancelled.
79. If time allows, Todd usually meets with Mindy after the game, and he often brings along some friends. /and some friends often come along too.
80. Sometime before dawn, Diane set sail with Victor for the islands, and she plans to return tomorrow evening. /and now everyone at the pier is worried.
81. In the beginning, Grant believed rumors about Heather and the job, but he now knows the truth about the situation. /but now everyone knows the full truth.
82. On Friday night, Helen watched television with Lance for three hours, and she was really bored with the show. /and some of the shows were really terrible.
83. On Monday morning, Grace expected packages from Curtis in the mail, but she didn't get anything until the next day. /but nothing arrived until the next day.
84. During the vacation, Sid became lost with Marcia in the forest, and he couldn't find the compass or map. /and all the sounds in the woods were scary.
85. After the lecture, Melinda explained algebra to Ralph for several hours, but she got very tired of teaching after that. /but most of the equations were not really hard.
86. During the war, Bruce sent pamphlets to Charlotte about enemy spies, and he talked about sabotage to everyone. /and everyone was very worried about sabotage.
87. Almost every evening, Toby reads articles to Ruth from the newspaper, but he finds most of the stories very boring. /but none of the children ever listen.
88. Inside the tent, Kimberly saw squirrels scolding Guy in the trees, and she grabbed the camera for a picture. /and all the campers were laughing.
89. At the casino, Teresa played poker with Leo almost until dawn, and she was exhausted for two days afterward. /and some big fortunes were lost that night.
90. On the computer, Gregory wrote programs for Faith for two weeks, but he never was satisfied with any of the work. /but none of the executives were very impressed.
91. While in Europe, Barney wrote letters to Abbey twice a week, but he did not send any postcards. /but none of the mail got there.
92. During the rally, Sylvia looked everywhere for Darrell in the auditorium, and she finally went home alone. /and some friends helped in the search.
93. At the station, Christopher told things to Gloria about the job, and he talked about work until the train left. /and all the news was very exciting.
94. Every Monday morning, Nina tried to teach Herman about ancient Greece, but she couldn't make the lessons very interesting. /but none of the lessons were very interesting.
95. On Friday mornings, John almost always gives Molly rides to work, but he drives a different route now. /but now the car is broken.
96. Right after dinner, Jane spilled coffee on Mick in the cafeteria, and she was really embarrassed. /and all the kids at the table laughed.

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