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The Locus of Implicit Causality Effects in Comprehension

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Implicit causality might enable readers to focus on the imputed cause of an event and make it the default referent of a following pronoun. Alternatively, its effects might arise only when a following explicit cause is integrated with a description of the event. In three probe recognition experiments, in which the participants in the events were of the same sex, the only reliable effect—apart from the advantage of first mention—was that of whether implicit and explicit causes were the same. This effect was independent of whether the probe named the referent of the pronoun. In a fourth experiment, in which the two participants were of different sexes, there was no simple effect of implicit causality, but there was an advantage for the pronoun's referent. These results are consistent with the view that implicit causality has its effects at integration. We discuss their broader implications for theories of comprehension.

There is a growing consensus that mental representations of the content of text take the form of discourse models (e.g., Garnham, 1981, 1987; Johnson-Laird & Garnham, 1980; Greene, McKoon, & Ratcliff, 1992; Stenning, 1978; Webber, 1979) and that the primary goal of a theory of text comprehension is to specify the nature of such models and of the processes that construct them. Discourse models contain representations of people, things, events (in the broad sense of that term used in semantic theory; see e.g., Frawley, 1992, in which it covers acts, actions, states, and processes), and so on, in the real, or an imaginary, world. However, beyond this basic specification, there is considerable disagreement about their nature and about the mental processes that build them. One important issue is the extent to which discourse models are elaborated using information that is not explicit in a text, but which must be derived inferentially (see e.g., McKoon & Ratcliff, 1992, vs Garnham, 1992, and Glenberg & Ma-

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thew, 1992). Another set of issues, and one that has received less attention in the psychological literature, concerns the internal structure of discourse models. These issues, which can loosely be dubbed ''issues of focus,'' are crucial to online theories of text comprehension, because the internal structure of discourse models determines which parts of those models are most available in memory. It is one of these issues that we address in this paper.

Some of the things mentioned in a text are in focus and, therefore, readily available for later reference, and others are not. Both local, sentence level, and global, discourse level, mechanisms may contribute to whether an item is in focus and hence can readily be referred to again (e.g., using a pronoun). However, the details of these mechanisms remain, for the most part, to be determined. One unresolved issue is: How powerful are focus mechanisms? According to some theorists (e.g., Gordon, Grosz, & Gilliom, 1993; Greene, McKoon, & Ratcliff, 1992) these mechanisms typically ensure that at each point in a well-written text, though not necessarily in a text in a psycholinguistic experiment, one entity enjoys a privileged status, so that a pronoun will refer to that entity by default. An alternative view is that focusing need not be so constrained, but that a pronoun, for example, can find its referent among a (usually small) set of recently mentioned items. In this paper we examine the hypothesis that *implicit causality* contributes to local focusing by giving increased salience to one participant in each event mentioned in a text—the implicit cause of that event.

Causality and Implicit Causality

Computing causal relations is a major component of building discourse models for narrative texts. A reader who fails to recognize those causal relations cannot be said to understand the text fully. The causal relations in a narrative often form complex *causal chains* that link events in the text. For many people, the central question about causality is how these causal chains are computed (e.g., Fletcher & Bloom, 1988; Myers & Duffy, 1990; Trabasso & van den Broek, 1985; van den Broek & Trabasso, 1986). The question of implicit causality, however, arises in the simpler case of representing a single event and may affect the interpretation of text that explicitly presents another event as its cause.

Consider a sentence such as

Betty punished Diane three weeks ago because she didn't do the dishes.

Here the main clause introduces an event, and the subordinate, *because,* clause presents another event as the cause of the first. The word *because* is an *explicit* indication that a causal relation is intended, and the interpretation of the two clauses of the sentence is straightforward. The sentence, however, has an interesting property. As far as its morphosyntactic properties go, the pronoun *she* is referentially indeterminate. Simply by knowing its form, we cannot tell whether it refers to Betty or to Diane. In this respect the sentence above contrasts with the following, similar, one:

Betty punished Roger three weeks ago because he didn't do the dishes.

In this sentence the morphosyntactic properties of the pronoun effectively determine its referent to be Roger, at least in this written form and where there is no preceding context.[1]

The fact that a pronoun's form leaves it referentially indeterminate does not mean that, in its sentential context, it is actually referentially indeterminate. Most people take *she* to refer unambiguously to Diane, not Betty. In this case the names are merely place-fillers. Nothing is known about the people with those

[1] With emphasis on the pronoun and an accompanying pointing gesture (in the spoken version), or in context, the reference of the pronoun can be something not mentioned in the sentence itself:

Betty punished Diane three weeks ago because SHE ordered her to.

The snow queen entered the room imperiously.

The servants punished the little girl because she ordered them to.

names, so background knowledge about the probable gender of people with those names, about the kinds of events described, and about the likely relations between them determines the probable referent of the pronoun. In other cases, specific knowledge about people or things may also play a role in determining to whom or to what a pronoun refers.

Implicit causality is one part of the background knowledge that may be used in deciding who did what (Garvey & Caramazza, 1974). In the kind of sentence we have been discussing, the implicit cause of the event described in the main clause may influence the interpretation of the explicit statement of the cause in the subordinate clause. In particular, it may affect the assignment of reference to the pronoun in that clause. The idea is that, in an event that has been described as *Betty punished Diane three weeks ago,* it is more likely that one participant in the event (in this case Diane) did something, or had some characteristic, that precipitated the event. In other words, although this clause says nothing *explicit* about the cause of the event it portrays, it nevertheless implies, simply by the way it describes the event, what its cause was. Since implicit causality has the effect of making *one* of several participants in an event the cause of that event, it could act as the kind of focusing mechanism described above, at least in narrative texts. If it did, it would *both* affect the representation of particular events in the discourse model, by focusing attention on a particular participant, *and* affect later pronoun resolution, by providing a default referent for an upcoming pronoun. However, the effect on pronoun resolution would probably depend on whether the pronoun-containing clause was perceived as explicitly stating the cause of the event. Ehrlich (1980) showed that effects of implicit causality disappear if the subordinating conjunction *because* is replaced by *and* or *but.*

Two Views about Implicit Causality

In addressing the question of whether implicit causality acts as a focusing mechanism we need only to assume that causes are unambiguously imputed. This is fortunate, because there is considerable disagreement about the underlying source of implicit causality. Indeed, there are two different, though not entirely divorced, perspectives on implicit causality, which have yet to be properly integrated (see e.g., Edwards & Potter, 1993). The original perspective of Garvey and Caramazza was a (psycho)linguistic one. From this perspective, the focus is naturally on *language.* So, although Garvey and Caramazza were somewhat guarded in their original claims about the source of implicit causality, their presentation is in terms of verbs imputing cause, with other factors, such as the social status of the participants, influencing or attenuating the basic effect (1974, p. 462). In later writings (Caramazza, Grober, Garvey, & Yates, 1977; Garvey, Caramazza, & Yates, 1975; Grober, Beardsley, & Caramazza, 1978) this emphasis on verbs is accentuated.

When considering events described in simple clauses of the form *xV-edy,* where *x* and *y* are arbitrary proper names (or simple NPs describing people with arbitrary relations to the event: *The grocer punished the fishmonger*), the tendency to ascribe implicit causality to verbs is a natural one. The referents of the proper names or NPs have little role in suggesting the probable cause of the event described in the clause. Furthermore, if implicit causality is seen primarily as a property of verbs, it becomes natural to talk of verbs as implicitly ascribing causality to one or other of the *participants* in the type of event denoted by the verb. However, since Caramazza and his co-workers were primarily concerned with simple active affirmative clauses with a subject NP and an object NP, they classified verbs as having a bias toward imputing causality to the first (subject) NP (NP1 biased verbs) or to the second (object) NP (NP2 biased verbs). The use of the term *bias* is a reflection of the fact that a following *because* clause might impute a cause to the (referent of the) nonpreferred NP (assignment *incongruent* with the bias of the verb). Caramazza

et al.'s claim was that, in such cases, comprehension should be measurably more difficult than when the completion was *congruent* with the bias.

In their original article, however, Garvey and Caramazza had explicitly noted the possibility that part of a clause other than the verb might play a role in determining the implicit causality of the event described by a clause. Furthermore, Oakhill and Garnham (unpublished) showed that in sentences containing verbs of transfer, such as

Sandra sold her tent to Tracy because she . . . ,

the nature of the object transferred can have a strong influence on implicit causality, as measured in a sentence completion task. In this sentence for example, the completions often made *she* refer to Tracy, even though *sell* is usually an NP1 verb. These observations suggest that the proper account of implicit causality is in terms of the mental representation of the complete event described by a clause. Nevertheless, verbs make a strong contribution to this representation, and a particular verb may denote an event that is most typically precipitated by something that a particular participant in the event has previously done.

The second perspective on implicit causality is a social psychological one, and in particular, that of attribution theory. Furthermore, within the social psychological approach there are some theorists who focus strongly on language (e.g., Au, 1986; Brown & Fish, 1983; Fiedler & Semin, 1988) and others who focus on social interaction (e.g., Edwards & Potter, 1993; Hilton, 1990). The social psychological approach has produced some useful insights about why verbs have NP1 or NP2 biases. For example, Brown and Fish (1983) argued that, with action verbs, the agent tends to be seen as the cause, rather than the patient (in *Ted helps Paul,* Ted is seen as the cause), and that with mental state verbs the stimulus tends to be seen as the cause, rather than the person experiencing the mental state (the experiencer). On this view, action verbs impute the cause to their subject (in active sentences), but mental state verbs may impute the cause to either the subject or the object, because some of these verbs (e.g., *amaze*) have the stimulus as subject and others (e.g., *admire*) have the experiencer as subject. However, Au (1986) noted (as Garvey & Caramazza, 1974, already had, though only implicitly) that some actions verbs (e.g., *punish,* see above) impute causation to the patient, not the agent, so the overall picture is not as straightforward as Brown and Fish (1993) suggest. Au follows Fillmore (1977) in suggesting that the imputed cause depends on the ''scenes'' that a verb brings to mind and notes that this view is compatible with Johnson-Laird's (1983) theory of mental models of discourse.

Implicit Causality and Focusing

In this paper we are not primarily concerned with which is the correct perspective on implicit causality, but with its on-line effect during comprehension. Caramazza and his colleagues have shown that there are strong effects in *off-line* tasks, such as sentence completion (Garvey et al., 1975; Grober et al., 1978), as, indeed, there must be if the bias of individual verbs (or clauses) is to be established. In on-line tasks the picture is less clear. Here the question has been whether a sentence that is completed in a way that is congruent with the bias of the verb is easier to process than one that is completed incongruently. Congruent and incongruent endings are often spoken of as going *with* or *against* the bias of the verb. Caramazza et al. (1977) report clear effects (of congruity with bias) in referent naming tasks, in which subjects had to read a sentence silently and then say out loud the name of the pronoun's referent. For example, responses were faster in the first of the following sentences, in which the verb, *scold,* is an NP2 verb:

Tom scolded Bill because he was annoying.
Tom scolded Bill because he was annoyed.

In self-paced reading experiments, Vonk (1985) reported clear effects of implicit causality: *Because* clauses were read more quickly when they were congruent with the bias of the verb. However, Garnham and Oakhill (1985) report less clear effects of congruity, which, in a post hoc analysis, were significant only when there was also a gender cue. Garnham, Oakhill, and Cruttenden (1992) also report mixed findings using a self-paced reading paradigm, though when subjects were asked to judge whether the *because* clause was a sensible continuation from the main clause the effect of congruity was reliable. However, that effect tended to be stronger when the inference needed to connect the two clauses was simple. This finding goes some way in explaining discrepancies in the previous literature: Where effects have been found, the inferences have usually been simple. Garnham et al. (1992) also found evidence that the effects of congruity were stronger in the absence of a gender cue, a more intuitive result than that reported by Garnham and Oakhill (1985).

The principal question addressed in this paper is whether implicit causality has a focusing effect, an effect that would manifest itself as soon as the verb of the main clause (and its arguments) has been processed (the *focusing hypothesis*), or whether its effects are not focusing effects at all, but are seen only when a statement about the explicit cause of an event (in a following subordinate clause) is integrated with the description of the event itself (the *integration hypothesis*). We investigated this question using two-clause sentences such as

(a) David approached Brian after school because he wanted some advice.

(b) David approached Brian after school because he looked friendly.

(c) Sherry envied Evette all the time because she had a fast car.

(d) Sherry envied Evette all the time because she had no money.

Approach is an NP1 verb and *envy* is an NP2 verb, so the endings in (a) and (c) are congruent with the bias of the verbs in the main clause, and those in (b) and (d) are incongruent. We used a probe task in which subjects had to say whether a name (the name of one of the participants in the crucial cases) had appeared in the sentence so far. With this task, strong effects of first mention have been reported (see Gernsbacher, 1990, for a summary). The effects described below, if they appeared, would be modulations of this first mention effect.

The focusing hypothesis and the integration hypothesis are both compatible with the effects of the *congruity* reported in the previous literature. They would not be worth considering seriously if they were not. However, they make *different* predictions about the way implicit causality information (the *bias* of the verb) is used in comprehension. According to the focusing hypothesis, implicit causality acts to ''highlight'' one participant in the event denoted by the verb. If the cause is a person introduced by a proper name, that proper name should be more readily available than the names of the other participants in the event. In addition, if the implicit cause is focused, and if a following clause contains a pronoun, the implicit cause should be the default referent of the pronoun. An explicit gender cue on the pronoun will confirm or disconfirm this assignment, after which implicit causality information can be discarded. However, if there is no gender cue, the default assignment of the implicit cause as the referent of the pronoun should maintain, if not accentuate, the differential activation of the implicit cause and the other participants, until the content of the second clause makes clear to whom the pronoun refers.

The integration hypothesis predicts that there should be no differential activation of the names of the participants in the main event, with differently biased verbs, until it is known whether the subordinate clause is congruent or incongruent with the bias of the verb in the main clause. When the pronoun cannot be resolved from its morphology, information about congruity becomes available

only toward the end of the subordinate clause and, thus, congruity effects can manifest themselves only when the end of the second clause is read. However, when the form of the pronoun determines its referent, and hence whether the subordinate clause is congruent or incongruent with the bias of the previous verb, congruity effects, or more likely referent effects, should manifest themselves at that point.

EXPERIMENT 1

The first experiment investigated the influence of verb bias on the activation and availability of sentence participants when readers encounter a pronoun that is, at least initially, referentially indeterminate. To investigate this influence, the names of the participants were used as probe words immediately before and immediately after such pronouns.

Methods

Subjects. The subjects were 160 undergraduates at the University of Oregon. As in all the following experiments, the subjects participated as one means of fulfilling an introductory psychology course requirement; they were all native (American) English speakers, and no subject participated in more than one experiment.

Materials and design. Sixty-four experimental sentences were constructed. Many of the sentences were modifications of those used by Garvey, Caramazza, and their collaborators (see Caramazza, et al., 1977; Garvey et al., 1976; Grober et al., 1978). All sentences contained two clauses, mentioned two participants in the first clause (NP1 and NP2), and contained a pronoun in the second clause that referred to one of the participants from the first clause. Pronouns were separated from the second participant by at least two words; all sentences contained a filler phrase, which was always an adverbial phrase of time or place, and the word *because* (as in Example 1). Half of the experimental sentences contained verbs that encourage most readers to interpret a following pronoun in a *because* clause as referring to the first participant in the sentence (NP1 verbs, as in Example 1), and half the sentences contained verbs that encourage most readers to interpret such a pronoun as referring to the second participant (NP2 verbs, as in Example 2).

Example 1: Walter apologized to Ronald this morning because he . . .

Example 2: Jeff believed Paul yesterday because he . . . .

The NP1 verbs were *apologize, approach, call, confess to, confide in, confuse, kill, lie, phone,* and *question.* The NP2 verbs were *admire, believe, blame, congratulate, envy, fear, praise, punish,* and *scold.* A full list of the materials appears in the Appendix.

Finally, the second clause of half the sentences agreed with the verb's bias (congruent endings, as in Example 3), and the second clause of half the sentences disagreed with the verb's bias (incongruent endings, as in Example 4).

Example 3, Version 1: Walter apologized to Ronald this morning because he damaged the car. (NP1 verb, Congruent ending)

Example 3, Version 2: Walter apologized to Ronald this morning because he demanded an apology. (NP1 verb, Incongruent ending)

Example 4, Version 1: Jeff believed Paul yesterday because he believed everything. (NP2 verb, Incongruent ending)

Example 4, Version 2: Jeff believed Paul yesterday because he gave a convincing performance. (NP2 verb, Congruent ending)

In congruent sentences, the implicit cause of the event in the first clause (as determined by the bias of the verb) was the referent of the pronoun in the second clause. In incongruent sentences, the implicit cause was not the referent of the pronoun. As Examples 3 and 4 illustrate, congruent and incongruent endings follow the same first clause, so that length and frequency of the names, and hence the probe words, were not confounded with congruity.

To ensure that the information in the second clauses identified a unique antecedent, the fol-

lowing normative data were collected. Forty-nine subjects at the University of Oregon, who were not otherwise involved with any of the experiments reported here, read the experimental sentences. The subjects indicated to which of the two participants the pronouns referred. Only sentences that elicited more than 90% agreement with the experimenter were used in the experiment. These are the sentences listed in the Appendix.

In each sentence, the two participants' names were typical American first names commonly ascribed to only one gender (names such as ''Pat'' and ''Chris'' were avoided). Across all the sentences, half the names were stereotypically female, and half were stereotypically male. But within each sentence, the two names were of the same gender. Within each sentence, the names were matched for perceived familiarity and length in letters.

To encourage comprehension, each experimental sentence was followed by a two-alternative WH-question. Roughly half the questions were about the first clause, one-quarter were about the second clause, and one-quarter were about information in the filler phrase. This served the purpose of discovering whether subjects understood the sentences. An example question for the first clause in Example 3 is ''Who apologized to somebody this morning?'' As a finer division, half the questions about the first clause queried the first-mentioned participants' activity (e.g., ''Who apologized to somebody this morning?''), and half queried the second-mentioned participants' activity (e.g., ''Who got an apology this morning?''). The question for the filler phrase in Example 5 was ''When did Walter apologize to Ronald?'' Each question was accompanied by two answer choices (e.g., ''Walter'' and ''Ronald'' for the *who* questions and ''this morning'' and ''this afternoon'' for the *when* question).

Sixty-four lure sentences were constructed. A lure sentence was one in which the probe name did not occur in the sentence the subjects had just read. The lure sentences were similar to the experimental sentences. They contained two clauses, mentioned two participants in the first clause, and contained a pronoun in the second clause that referred to one participant from the first clause. Pronouns were separated from the second participant by at least two words; all sentences contained a filler phrase and the word *because*. The lure sentences contained the same verbs as the experimental sentences. However, the lure sentences contained participants' names, fillers, and endings different from those of experimental sentences.

Eight material sets each containing 64 experimental sentences and 64 lure sentences were created. Individual subjects read only one version of each experimental sentence. Within a material set, there were 4 experimental sentences in each of the 16 experimental conditions. Across material sets, each experimental sentence occurred in all 8 of its experimental conditions (verb bias was a between-items manipulation). Twenty subjects were randomly assigned to each material set; thus, each subject was exposed to an experimental sentence in only one of its conditions. The lure sentences occurred in the same randomly selected order in each material set.

Procedure. The stimulus sentences appeared word-by-word in the center of a video display monitor. How long each word remained on the screen was a function of its length plus a constant. The function was 16.667 ms per character, and the constant was 300 ms. For example, a five-letter word was shown for 383.3 ms. These timing parameters were based on the reading times produced by 12 subjects, who were otherwise uninvolved with the experiment and who read self-paced, word-by-word through the experimental materials. Even the slowest of these 12 subjects read comfortably faster than the rate produced by the above function.

Each trial began with a warning signal, which was a plus sign that appeared for 750 ms in the center of the screen. After that, each word of the sentence appeared with an interword interval of 150 ms. When the probe names were tested, they appeared in capital letters at the top of the screen. When the probe

names were tested before the pronouns, they appeared 150 ms after the offset of the word immediately prior to the pronouns. When they were tested immediately after the pronouns, they appeared 150 ms after the offset of the pronouns. The probe names remained on the screen until either the subjects responded or 2.5 s had elapsed.[2] Subjects responded with their dominant hand, pressing one key with their index finger and another with their middle finger. After the probe name disappeared from the screen, the presentation of the sentence continued.

After each experimental sentence, the word ''Test'' appeared for 750 ms toward the bottom of the screen to warn subjects that a comprehension question would appear next. Appearing along with the comprehension question were its two answer choices. One answer choice appeared in the bottom left corner, and the other in the bottom right corner. The answer choice in each corner was correct half the time. The questions and answer choices remained on the screen until either the subjects responded by pressing one of two response keys or 10 s had elapsed. They pressed the key on the right to choose the answer presented to the right of the screen and the key on the left to choose the answer presented to the left. After responding, the subjects were given feedback about their accuracy at answering the questions.

Subjects were replaced if they failed to meet the following criteria: 90% accuracy in responding to experimental probe names (requiring a ''yes'' response), 90% accuracy in responding to lure probe names (requiring a ''no'' response), and 85% accuracy in answering the two-choice comprehension questions.[3]

[2] The number of responses lost because subjects took more than 2.5 s to respond was well below 1% in all four of the experiments reported in this paper: Experiment 1, 0.15%; Experiment 2, 0.11%; Experiment 3, 0.09%; Experiment 4, 0.05%.

[3] The number of subjects rejected averaged 8.5% across the four of the experiments reported in this paper: Experiment 1, 12%; Experiment 2, 9%; Experiment 3, 5%; Experiment 4, 8%.

Results

The following is true of all the analyses reported for this and the following experiments: The correct response times and the number of correct responses were analyzed in two sets of analyses of variance (ANOVAs). In the first set, subjects was treated as a random effect; in the second, items was treated as a random effect. In all the experiments there was an effect of verb bias (NP1 vs NP2) on response times that was significant by subjects, but not by items, with responses to probe names following NP2 bias verbs being faster than those to probe names following NP1 bias verbs. Since different sets of probe names were used for the two sets of verbs, the most parsimonious explanation of this effect is that is it a materials effect, and it will not be discussed further.

For Experiment 1, the design of both sets of ANOVAs was 2 (Verb Type: NP1 bias vs NP2 bias) $\times$ 2 (Sentence Ending: congruent vs incongruent) $\times$ 2 (Test Point: before vs after the pronouns) $\times$ 2 (Probe Name: NP1 vs NP2). In the subjects' analysis, all four factors were within-subjects. In the items' analysis, verb bias (NP1 vs NP2) was a between-items factor.

We chose NP1 and NP2 as the appropriate levels of the probe name variable in this and the subsequent experiments, rather than (actual) referent and nonreferent of the pronoun, because at many of our test points, including both of those used in Experiment 1, subjects had not yet read the information that would have allowed them to assign a referent to a pronoun. In Experiment 1, subjects could not disambiguate pronouns before they saw the probe words, because disambiguating information was contained in the second clause and probe names were presented immediately before and after the pronouns. Furthermore, it was the disambiguating information in the second clause that was either congruent or incongruent with the bias of the verb. Since the probes were presented before this information had been read, subjects could not have been

TABLE 1

PROBE RESPONSE TIMES (ms) AND PERCENTAGE CORRECT RESPONSES (IN PARENTHESES) TO PROBES IN EXPERIMENT 1

	Sentence ending				
	Congruent		Incongruent		
	Probe before pronoun	Probe after pronoun	Probe before pronoun	Probe after pronoun	
Probe NP1					
NP1 bias verb	828 (97.5)	828 (95.5)	821 (97.5)	826 (96.0)	826 (96.6)
NP2 bias verb	820 (95.6)	836 (95.5)	821 (96.2)	822 (95.5)	825 (95.7)
Probe NP2					
NP1 bias verb	904 (94.9)	902 (94.5)	903 (93.3)	920 (92.5)	908 (93.8)
NP2 bias verb	889 (94.5)	888 (93.9)	874 (94.9)	901 (93.1)	888 (94.1)
	860 (95.6)	864 (94.8)	855 (95.5)	862 (94.3)	

influenced by it in their responses to the probe words in Experiment 1.

Table 1 shows the response times to the probe words and the percentage of correct responses to the probes in Experiment 1.

Response times. One main effect was reliable: Subjects responded more quickly to NP1 probe names ($M = 825$) than NP2 probe names ($M = 898$), $F1(1,159) = 151.25$, $p < .0001$, $MSE = 22186$; $F2(1,62) = 102.87$, $p < .0001$, $MSE = 6712$. No interactions were reliable.

Accuracy. One main effect was reliable: Subjects responded more accurately to NP1 probe names ($M = 96.2\%$) than NP2 probe names ($M = 94.0\%$), $F1(1,159) = 13.99$, $p < .001$, $MSE = 0.357$; $F2(1,62) = 11.16$, $p < .001$, $MSE = 2.275$. In addition, there was an effect of test point that was significant by subjects, but not by items. Subjects responded slightly more accurately to probes before the pronouns than to probes after the pronoun (95.5 vs 94.6%), $F1(1,159) = 6.17$, $p < .01$, $MSE = 0.165$; $F2(1,62) = 3.08$, $.05 < p < .1$, $MSE = 1.583$. No interactions were reliable.

Discussion

The faster and more accurate responding to NP1 probes is most naturally interpreted as a first mention effect (see Gernsbacher, 1990). Although the NP1 probes and NP2 probes were in fact different names, the names were assigned to subject (NP1) and object (NP2) positions at random from pairs matched in length and perceived frequency (using norms collected by Gernsbacher). The effects in this study are similar in magnitude to those found in studies systematically investigating first mention effects (e.g., Gernsbacher & Hargreaves, 1988; Gernsbacher, Hargreaves, & Beeman, 1989; Carreiras, Gernsbacher, & Villa, 1995) in which the position of the names was systematically varied. There is no question of the first mention effect reported here being a materials effect. Gernsbacher's Structure Building Framework provides a ready explanation for first mention effects, since it assumes that first-mentioned items form the focal point around which discourse models are built.

There was no evidence for differential activation of the two NPs as a function of the bias of the verb, either immediately before or immediately after the pronoun. The interaction between probe name (NP1 vs NP2) and verb bias (NP1 vs NP2) was not significant. These results do not support the focusing hypothesis and suggest that implicit causality does not act as a focusing mechanism. If it did, an NP1 verb would speed responses to NP1 probes and an NP2 verb would speed responses to NP2 probes.[4] However, there is no evidence that the bias of a verb enhances the activation of the argument of the verb designated as the implicit cause. This finding suggests that previously reported effects of implicit causality, in other experimental paradigms, occur when the information in the two clauses of sentences like the ones we used is integrated. However, accepting this conclusion would be premature, since we have not yet presented evidence that the probe task is sensitive to effects of congruity.

EXPERIMENT 2

Experiment 2 was identical to Experiment 1 except that the before-the-pronoun test point was replaced by an end-of-sentence test point. In Experiment 2, end-of-sentence probes were presented 150 ms after the offset of the last word in the sentence. The after-the-pronoun test point was identical to that in Experiment 1. Thus, in this experiment we measured the times to respond to the probe names at two test points: immediately after the pronouns and at the ends of the sentences.

Methods

The only methodological difference between Experiment 2 and Experiment 1 was the change of one of the two test points from immediately before the pronoun to the end of the sentence. One hundred sixty subjects participated.

Results

Table 2 shows the response times to the probe words and the percentage of correct responses to probes in Experiment 2.

Response times. In Experiment 2, three main effects were reliable. Subjects' probe-response times were faster when reading sentences with congruent endings (964 ms) than sentences with incongruent endings (983 ms), $F1(1,159) = 12.37$, $p < .0006$, $MSE = 17630$; $F2(1,62) = 9.18$, $p < .005$, $MSE = 4359$. Subjects' probe-response times were faster after the pronoun (953 ms) than at the end of the sentence (993 ms), $F1(1,159) = 46.15$, $p < .0001$, $MSE = 22210$; $F2(1,62) = 44.00$, $p < .0001$, $MSE = 4500$. As in Experiment 1, subjects responded more rapidly to NP1 probe names (928 ms) than NP2 probe names (1018 ms), $F1(1,159) = 149.4$, $p < .0001$, $MSE = 34646$; $F2(1,62) = 83.39$, $p < .0001$, $MSE = 12686$.

No interactions were significant both by subjects and by items. The interaction between probe name (NP1 vs NP2) and verb bias (NP1 vs NP2) was reliable by subjects, but marginal by items, $F1(1,159) = 12.15$, $p < .0006$, $MSE = 16501$; $F2(1,62) = 2.88$, $p < .10$, $MSE = 12686$. This pattern of results arose because the effect of first mention was greater for NP1 verbs (108 ms) than for NP2 verbs (70 ms). The interaction between test point and congruity (whether the end of the sentence confirmed or contradicted the verb bias) was reliable by items, but marginal by subjects, $F1(1,159) = 2.71$, $p < .10$, $MSE = 17533$; $F2(1,62) = 4.45$, $p < .04$, $MSE = 3235$. As one would expect, subjects' response times were not affected by congruity immediately after the pronoun, $F1(1,159) = 2.23$, $p < .14$, $MSE = 3483$. However, at the ends of sentences, subjects responded more rapidly when the sentence ending was congruent (980 ms) than when the sentence ending was incongruent (1002 ms), $F1(1,159) = 11.77$, $p < .001$, $MSE = 3322$, $F2(1,62) = 13.64$, $p < .0005$, MSE

[4] It is important that the match of or the failure to match the probe name with the bias of the verb is not confused with congruity, which is the match of or failure to match the ending of the sentence, and hence the referent of the pronoun, with the bias of the verb.

TABLE 2

PROBE RESPONSE TIMES (ms) AND PERCENTAGE CORRECT RESPONSES (IN PARENTHESES) TO PROBES IN EXPERIMENT 2

	Sentence ending				
	Congruent		Incongruent		
	Probe after pronoun	Probe at end of sentence	Probe after pronoun	Probe at end of sentence	
Probe NP1					
NP1 bias verb	906	919R	920	949	924
	(96.8)	(95.7R)	(97.1)	(94.4)	(96.0)
NP2 bias verb	916	945	915	959R	934
	(95.5)	(94.9)	(95.6)	(95.2R)	(95.3)
Probe NP2					
NP1 bias verb	993	1052	1008	1072R	1031
	(94.2)	(90.5)	(94.7)	(90.6R)	(92.5)
NP2 bias verb	980	1005R	991	1049	1006
	(94.1)	(92.4R)	(94.9)	(94.9)	(94.0)
	949	980	959	1049	
	(95.2)	(93.3)	(95.6)	(93.8)	

Note. R, probing a referent that subjects have sufficient information to establish.

= 1951. The interaction between probe name (NP1 vs NP2) and test point (after the pronoun vs end of sentence) was marginally significant in both analyses. The advantage of the first-mentioned participant was greater at the end of the sentence (101 ms) than immediately after the pronoun (78 ms), $F1(1,159) = 3.52$, $p < .06$, $MSE = 23213$; $F2(1,62) = 3.66$, $p < .06$, $MSE = 5088$.

Accuracy. Two main effects were reliable. Subjects responded more accurately to NP1 probe names (95.6%) than to NP2 probe names (93.2%), $F1(1,159) = 18.60$, $p < .0001$, $MSE = 0.324$; $F2(1,62) = 16.53$, $p < .0001$, $MSE = 2.251$. Subjects responded more accurately to probe names after the pronoun (95.4%) than to probe names at the end of the sentence (93.6%), $F1(1,159) = 15.61$, $p < .0001$, $MSE = 0.226$; $F2(1,62) = 17.28$, $p < .0001$, $MSE = 1.131$.

One interaction, that between verb bias and test point, $F1(1,159) = 7.54$, $p < .01$, $MSE = 0.176$; $F2(1,62) = 5.42$, $p < .05$, $MSE = 2.251$, was reliable. The decreased accuracy at the end of the sentence was greater for NP1 verbs (2.9%) than for NP2 verbs (0.7%). In addition, the interaction between verb bias and probe name was significant by subjects, but not by items, $F1(1,159) = 5.24$, $p < .05$, $MSE = 0.270$; $F2(1,62) = 3.78$, $.05 < p < .1$, $MSE = 2.251$. This interaction is discussed in detail below, as it is relevant to the focusing hypothesis.

Discussion

In this experiment there was some indication of a focusing effect, both in response times and in response accuracy, as indexed by the interaction between probe name and verb bias. This interaction, which in both analyses was reliable only by subjects, provides the only evidence for the focusing hypothesis in the four experiments reported in this paper. An NP1 biased verb favors NP1 and therefore enhances any first mention effect, whereas an NP2 verb favors NP2 and counteracts a first mention effect. This finding might appear to indicate that implicit causality can determine which participant in an

event is focused, as well as have an effect at the point of integration.

However, the focusing hypothesis does not merely claim that these effects occur, it claims that they reflect the way the main clause is represented, and that they should, therefore, occur immediately and should be detectable at the test point following the pronoun. There was no three-way interaction among probe name, verb bias, and test point either for response times or for accuracy. Nevertheless, both response time and accuracy effects were stronger at the end of sentence than at the test point following the pronoun (Response times: after pronoun, $F1(1,159) = 2.88$, $.05 < p < .1$, $MSE = 12522$, $F2(1,62) = 1.05$, $MSE = 11312$; end of sentence, $F1(1,159) = 9.93$, $p < .01$. Accuracy: after pronoun, $F1(1,159) = 1.48$, $MSE = 0.180$, $F2(1,62) = 1.20$, $MSE = 1.581$; end of sentence, $F1(1,159) = 3.84$, $p < .05$, $MSE = 0.354$, $F2(1,62) = 3.28$, $.05 < p < .1$, $MSE = 2.307$). This aspect of the results again suggests that effects are arising primarily at the point of integration of the two clauses and that if the results provide any support for the focusing hypothesis, it is only very weak support.

By contrast, there was a clear effect on response times of the congruity of the end of the sentence with the bias of the verb in the main clause. Subjects responded faster to *either probe name* when the ending of the sentence was congruent with the bias of the verb in the first clause. This effect was found primarily at the end of the sentence. In the sentences used in this experiment, which had referentially indeterminate pronouns, it is only at the end of the sentence that congruity or incongruity with the bias becomes apparent and that a plausible referent for the pronoun can be selected (using information in the subordinate clause). Thus, the results of this experiment are compatible with the integration hypothesis.

At the end of sentence test point, subjects in this experiment could determine the referent of the pronoun. It therefore makes sense to ask whether probes that named the referent were responded to more quickly than those that named the nonreferent. A main effect of referent versus nonreferent is statistically equivalent to three-way interaction among probe name (coded as NP1 vs NP2), verb bias, and sentence ending. The marking of the referent and nonreferent probes in Table 5 makes this fact apparent. The overall advantage for the referent of the pronoun (probe RT 970 ms) over the nonreferent (976 ms) in this experiment was very small and statistically nonsignificant ($F1(1,159) = 1.53$; $F2 < 1$). And, although the referent effect was numerically larger at the end of the sentence (10 vs 3 ms), it remained nonsignificant [$F1$ and $F2$ both < 1 immediately after the pronoun; $F1(1,159) = 1.88$, $F2(1,62) = 1.12$ at the end of the sentence].

Gernsbacher (1989; Experiment 3) found a stronger pattern of differential activation of referents and nonreferents of pronouns in an experiment that was in many ways similar to the present one. The present experiments were carried out in the same laboratory and with subjects from the same population as those reported by Gernsbacher (1989). It is, therefore, most unlikely that the explanation of the difference lies in the experimental procedures. However, there are at least three differences between the materials used in the present study and those used by Gernsbacher that might explain the different results. First, although the pronouns in Gernsbacher's experiment could not be resolved from their number and gender, the inferences needed to resolve them were considerably simpler than the ones required of our subjects. More specifically, the sentences did not have competing sets of cues (such as verb bias and sentence ending) to the antecedents of the pronoun. Compare, for example:

(a) Bill handed John some tickets to a concert but he took the tickets back immediately.

with

(b) Sandra lied to Elaine during the trial because she was gullible.

Presumably, in making complex inferences, as in (b), subjects have to engage in more elaborate processing, which will typically maintain the activation of the two possible antecedents at an equal level, until a resolution is achieved. If the nonantecedent has been relatively highly activated, it will probably take some time for that activation to die away or be suppressed. Second, in Gernsbacher's (1989) sentences the pronoun's referent was (virtually) certain before the end of the sentence (before *immediately* in sentence (a) above). In our sentences the referent often remained unclear until the last word of the sentence had been read (*gullible* in the sentence above could have been *scared*, for example). This aspect of the materials is even clearer in Gernsbacher's (1989) Experiment 4. In a passage such as

Bill lost a tennis match to John.
Accepting the defeat, he walked slowly to the showers.

it is clear that *he* refers to Bill as soon as the pronoun is read, despite the lack of a gender cue. Third, and perhaps most importantly, Gernsbacher's sentences typically presented two events in their correct temporal order. If a sentence of this kind occurs in narrative text, and if the second clause mentions Bill, but not John, it is likely (though not certain) that later events will involve Bill but not John. Our sentences presented the cause of an event after the event itself. If the sentence about Sandra and Elaine were part of a narrative, it is quite likely that Sandra would continue to be important in the following events. In such sentences, the suppression of the nonreferent of the pronoun, as described by Gernsbacher, may not be what is required of the language understanding system. Thus, in Experiment 2, the effects detected by Gernsbacher may have been slower to manifest themselves, they may have been masked by a relatively high level of activation of the nonreferent that lasted to the end of the sentences, or they may not have been present at all. Experiment 3 sheds further light on this issue.

The interpretation of the present results is, therefore, that, when the probe word is presented, the pronoun's referent is not differentially activated compared to the nonreferent, even at the end of the sentence. The most plausible interpretation of the congruity effect is, therefore, one that does not depend on the idea of enhancement and suppression of activation. The probe task paradigm can be regarded as a special case of the dual task paradigm, with comprehension as one task and responding to the probe as the other (which, if either, is perceived to be primary depends on, among other things, the instructions to the subjects). Noncongruent endings make the subordinate clauses more difficult to integrate with the main clauses: They make the comprehension task harder. This difficulty of processing then affects the ease with which the other task, responding to the probe word, can be performed. Differential activation and interference from a concurrent task are not, of course, mutually exclusive explanations of the speed of responding in a probe task. Indeed, we believe that both types of process are at work. We take the first mention effect, in particular, to require an explanation in terms of activation.

EXPERIMENT 3

We surmised that the lack of a referent effect in Experiment 2 might be explained by the fact that both the referent and the nonreferent remained activated to the end of the sentence. We also gave reasons for thinking that the referent might subsequently be favored over the nonreferent (if both had to remain active until complex inference processes were complete) or that both the referent and the nonreferent might continue to remain active (because both were plausible topics in any following narrative). To examine these possibilities we repeated the experiment, but introduced a delay of 1850 ms between stimulus offset and onset of probe names. This delay should have provided sufficient time for the referent of the pronoun to be computed and hence for a differential effect on the activation of the referent

TABLE 3

PROBE RESPONSE TIMES (ms) AND PERCENTAGE CORRECT RESPONSES (IN PARENTHESES) TO PROBES IN EXPERIMENT 3

	Sentence ending				
	Congruent		Incongruent		
	Probe after pronoun	Probe at end of sentence	Probe after pronoun	Probe at end of sentence	
Probe NP1					
NP1 bias verb	737 (95.5)	761R (94.2R)	729 (96.3)	780 (93.6)	752 (94.9)
NP2 bias verb	725 (96.1)	751 (95.0)	734 (96.3)	764R (94.1R)	744 (95.4)
Probe NP2					
NP1 bias verb	856 (94.9)	863 (91.0)	844 (94.9)	902R (89.9R)	866 (92.6)
NP2 bias verb	843 (95.5)	849R (92.4R)	824 (94.4)	883 (92.4)	850 (93.6)
	790 (95.5)	806 (93.1)	783 (95.4)	832 (92.5)	

Note. R, probing a referent that subjects have sufficient information to establish.

and the nonreferent to appear. The delay was introduced both at the end of the sentence and, for purposes of comparability, immediately after the pronoun. It comprised a blank screen for 500 ms followed by the words TEST NAME for 1350 ms.

Methods

The only methodological difference between Experiment 3 and Experiment 2 was the addition of a delay between stimulus offset and probe name onset. One hundred sixty subjects participated.

Results

Table 3 shows the response times to the probe words and the percentage of correct responses in Experiment 3.

Response times. The response times in this experiment were considerably faster than those in the other three experiments reported in this paper. We attribute this speeding up to the additional time in which subjects were able to prepare their responses.

In Experiment 3, two main effects were reliable. Subjects responded to probes more quickly after the pronouns (786 ms) than at the end of the sentence (819 ms), $F1(1,159) = 33.63$, $p < .0001$, $MSE = 21381$; $F2(1,62) = 30.96$, $p < .0001$, $MSE = 4982$. As in Experiments 1 and 2, subjects responded more rapidly to NP1 probe names (747 ms) than NP2 probe names (857 ms), $F1(1,159) = 272.25$, $p < .0001$, $MSE = 28642$; $F2(1,62) = 419.80$, $p < .0001$, $MSE = 4177$. In addition, subjects were marginally faster when reading sentences with congruent endings (798 ms) than when reading sentences with incongruent endings (807 ms), $F1(1,159) = 3.21$, $p < .08$, $MSE = 16953$; $F2(1,62) = 3.50$, $p < .07$, $MSE = 6451$.

As in Experiment 2, the interaction between test point (after the pronoun vs end of sentence) and sentence ending (congruent vs incongruent) was reliable, $F1(1,159) = 16.11$, $p < .0001$, $MSE = 11136$; $F2(1,62) = 7.05$, $p < .01$, $MSE = 3719$. Again, subjects' responses were not affected by congruity imme-

diately after the pronoun (−7 ms), $F1(1,159) = 1.51$, $p < .22$, $MSE = 3005$; $F2 < 1$. However, at the ends of sentences, subjects responded more rapidly when the sentence ending was congruent than when the sentence ending was incongruent (26 ms), $F1(1,159) = 13.42$, $p < .0005$, $MSE = 4018$; $F2(1,62) = 7.67$, $p < .01$, $MSE = 3178$. No other interactions were reliable.

Accuracy. Two main effects were reliable. Subjects responded more accurately to NP1 probe names (95.1%) than NP2 probe names (93.1%), $F1(1,159) = 15.55$, $p < .0001$, $MSE = 0.261$; $F2(1,62) = 4.55$, $p < .05$, $MSE = 4.29$. Subjects responded more accurately to probe names after the pronoun (95.5%) than to probe names at the end of the sentence (92.8%), $F1(1,159) = 29.72$, $p < .0001$, $MSE = 0.243$; $F2(1,62) = 8.81$, $p < .01$, $MSE = 2.68$.

Discussion

In this experiment, unlike in Experiment 2, there was no evidence for any effect of bias on the activation level of the names of the participants (NP1 and NP2) in the event described in the main clause, either in the response time data or in the accuracy data. The interaction between verb bias (NP1 vs NP2) and probe name (NP1 vs NP2) was not significant in either analysis. Given the nonsignificance of this interaction, the nonsignificance of the corresponding interaction in Experiment 1, and the fact that the effect of verb bias on the two types of probe name (NP1 and NP2) in Experiment 2 was confined to the end of the sentence, we feel confident in concluding, from Experiments 1–3, that implicit causality does not act as a focusing device that highlights the implicit cause of an event and makes it the default referent for a following pronoun. The focusing hypothesis is incorrect. Even with nearly 2 s between the offset of the pronoun and the onset of the probe word, there was no evidence for any focusing effect of implicit causality immediately after the pronoun.

In this experiment the effect of implicit causality was restricted to an effect of congruity at the point (the end of the sentence) where integration of the information in the two clauses was taking place. However, even 1850 ms after the end of the sentence, there was still no evidence for differential activation of the referent and the nonreferent. This finding suggests that the referent/nonreferent differences found by Gernsbacher (1989; Experiment 3, see above) arose because the nonreferent of the pronoun was unlikely to be the topic of a following sentence, and its activation was, therefore, suppressed. In our sentences, the nonreferent could still be a plausible topic. This aspect of the results is considered in more detail in the General Discussion.

EXPERIMENT 4

Experiment 4 was also identical to Experiment 2, except that the experimental sentences were altered so that one participant was female and the other was male. Thus, the pronoun in each sentence was no longer ambiguous, even when only its morphological form was considered. As in previous experiments, sentence participants were matched for number of letters, syllables, and familiarity. In half of the experimental sentences, the first NP was female and the second NP was male; in the other half, the first NP was male and the second NP was female.

Recall that in the previous three experiments the end of the second clause of each sentence contained the only information that could specify unambiguously to whom the pronouns referred. In this experiment, two factors determined the referents of the pronouns: the end of the sentence and the gender of the pronoun itself. Because only one of the sentence participants matched the pronoun's gender, each pronoun (presumably) could refer to only one of the participants. In addition, the end of the sentence and the gender of the pronoun always suggested the same referent for the pronoun (otherwise the sentence would be anomalous), though that referent could be incongruent with the bias of the verb. In this experiment the referent of the pronoun, therefore, can be determined immediately after the

TABLE 4

PROBE RESPONSE TIMES (ms) AND PERCENTAGE CORRECT RESPONSES (IN PARENTHESES) TO PROBES IN EXPERIMENT 4

	Sentence ending				
	Congruent		Incongruent		
	Probe after pronoun	Probe at end of sentence	Probe after pronoun	Probe at end of sentence	
Probe NP1					
NP1 bias verb	891R	914R	912	931	912
	(96.3R)	(93.9R)	(96.3)	(93.8)	(95.0)
NP2 bias verb	913	893	899R	914R	905
	(95.6)	(97.4)	(96.1R)	(95.8R)	(96.2)
Probe NP2					
NP1 bias verb	975	1039	975R	1006R	991
	(92.8)	(94.2)	(94.9R)	(92.2R)	(93.5)
NP2 bias verb	940R	993R	966	1013	978
	(94.9R)	(92.2R)	(95.5)	(92.4)	(93.7)
	922	960	938	966	
	(94.9)	(94.4)	(95.7)	(93.5)	

Note. R, probing a referent that subjects have sufficient information to establish.

pronoun has been read and before the reader knows whether the ending of the sentence is congruent or incongruent with the bias of the verb in the first clause. Therefore, we can expect to see referent effects at the early test point, which are independent of the congruity of the sentence's ending with the bias of the verb in the main clause.

Methods

The only methodological difference between Experiment 4 and Experiment 2 was the addition of gender cues. One hundred sixty subjects participated.

Results

Table 4 shows the response times to the probe words and the percentage of correct responses in Experiment 4.

Response times. In Experiment 4, two main effects were reliable. As in the three previous experiments, subjects responded faster when the probe name was the first-mentioned participant (908 ms) than when the probe name was the second-mentioned participant (988 ms), $F1(1,159) = 144.57$, $p < .0001$, $MSE = 28295$; $F2(1,62) = 86.20$, $p < .0001$, $MSE = 10070$. Subjects also responded more quickly immediately after the pronoun (934 ms) than at the end of the sentence (963 ms), $F1(1,159) = 31.88$, $p < .0001$, $MSE = 17167$; $F2(1,62) = 30.85$, $p < .0001$, $MSE = 3924$.

Two interactions were reliable. As in Experiment 2, the advantage of the first-mentioned participant was greater at the end of the sentence (100 ms) than immediately after the pronoun (61 ms), $F1(1,159) = 10.87$, $p < .001$, $MSE = 22119$; $F2(1,62) = 11.55$, $p < .001$, $MSE = 5820$. Also, there was a three-way interaction among verb bias (NP1 vs NP2), end of sentence (congruent vs incongruent), and probe name, $F1(1,159) = 9.72$, $p < .01$, $MSE = 12571$; $F2(1,62) = 10.20$, $p < .02$, $MSE = 3413$. As we pointed out earlier, this three-way interaction corresponds to a main effect of referent probe versus nonreferent probe. The interaction is discussed in more detail below.

Accuracy. Two main effects were reliable. Subjects responded more accurately to NP1 probe names (95.6%) than NP2 probe names (93.6%), $F1(1,159) = 15.58$, $p < .0001$, $MSE = 0.266$; $F2(1,62) = 7.71$, $p < .01$, $MSE = 2.144$. Subjects responded more accurately to probe names after the pronoun (95.3%) than to probe names at the end of the sentence (94.0%), $F1(1,159) = 7.75$, $p < .01$, $MSE = 0.232$; $F2(1,62) = 8.61$, $p < .01$, $MSE = 1{,}243$.

The three-way interaction among verb bias, test point, and test name was reliable, $F1(1,159) = 7.38$, $p < .01$, $MSE = 0.252$; $F2(1,62) = 11.52$, $p < .001$, $MSE = 1.373$. The test point effect was largely confined to those conditions in which the probe name matched the bias of the verb. However, in this experiment interactions involving verb bias and test name cannot be taken as evidence for focusing, since both test points are beyond the point where integration of the two clauses can usefully begin.

In addition, the two-way interaction between sentence ending and test point was significant by items, but not by subjects, $F1(1,159) = 3.38$, $.05 < p < .1$, $MSE = 0.214$; $F2(1,62) = 5.96$, $p < .02$, $MSE = 1.028$. There was a greater decrease in accuracy across an incongruous ending (2.2%) than across a congruous ending (0.5%).

Discussion

In this experiment the effects of test point and probe name on response times were similar to those in Experiments 2 and 3. However, there was no overall effect of congruity. Nor was there a simple main effect of congruity at the end of the sentence. In the sentences used in this experiment, in which the pronoun bears a gender cue, there is no need to use information about congruity and verb bias to determine the referent of the pronoun. The morphosyntactic information provided by the pronoun itself is sufficient. It does not, of course, follow that verb bias information is not used by readers to help them understand the sentences used in this experiment. Indeed, the three-way interaction among verb bias, sentence ending, and probe name suggests that it does play a role. What the results do show is that responses to the test words were not affected by congruity in the same way that they are when there is no gender cue. In addition, they show that, with a gender cue, the pronoun's referent and nonreferent *are* differentially activated (941 vs 955 ms).[5] Interestingly, in the light of our explanation of the lack of a referent effect in Experiments 2 and 3, this referent effect, unlike that reported by Gernsbacher (1989), does not increase at the end of the sentence: The referent effect does not interact with test point. Thus, the results are compatible with a *local* effect, in which the activation of the nonreferent is temporarily, and slightly, suppressed relative to that of the referent, when the pronoun is resolved using straightforward morphosyntactic cues. As we argued earlier, it would be incorrect, with sentences of this kind, to allow the nonreferent to become greatly suppressed, since it is a plausible candidate for the topic of any ensuing sentence.

Although there is a significant main effect of referent versus nonreferent in this experiment, it cannot be concluded that referents are simply responded to more quickly than nonreferents. The reason is that, if probe word is coded as referent versus nonreferent, the main effect of referent is modulated by a three-way interaction among verb bias, sentence ending, and probe name (referent vs nonreferent). This interaction is equivalent to the main effect of probe word (coded as NP1 vs NP2) in the original analysis. The original three-way interaction is shown in Table 5. If there were a simple (unqualified) referent effect, the four numbers marked with an ''R'' in the table would be smaller than those

[5] The *F* values for this main effect are identical to those reported above for the three-way interaction among verb bias, sentence ending, and probe name, and hence the effect is significant, both by subjects and by items. However, the effect is not *simply* a referent effect, because in an analysis that encoded referent versus nonreferent as a factor, its main effect would be modulated by higher order interactions.

TABLE 5

THREE-WAY INTERACTION AMONG VERB BIAS, SENTENCE ENDING, AND PROBE NAME IN EXPERIMENT 4

	Verb bias			
	NP1		NP2	
	Congruent ending	Incongruent ending	Congruent ending	Incongruent ending
Probe NP1	930R++	921−−	903+−	906R−+
Probe NP2	1007+−	990R−+	966R++	990−−

Note. R, probing the referent; ++, congruent ending, probe is referent; +−, congruent ending, probe is nonreferent; −+, incongruent ending, probe is referent; −−, incongruent ending, probe is nonreferent.

not so marked. Even setting aside the first mention effect, it is clear that there is *not* a simple referent effect. As Table 5 shows, the basic pattern of NP1 probes eliciting faster responses than NP2 probes (first mention effect) is modulated in only two cases rather than in the four cases in which it should be modified if there were a simple referent effect. Responses to NP1 probes are slower than expected when an NP1 biased verb is followed by an ending that goes against its bias, and responses to NP2 probes are faster than expected when an NP2 biased verb is followed by an ending that is congruent with its bias. In the first of these cases the NP1 probe is the nonreferent, and in the second the NP2 probe is the referent, so these effects are in line with the idea that referents are faster than nonreferents. However, NP1 probes are not slowed when NP2 verbs are followed by congruent endings. And NP2 probes are not speeded when NP1 verbs are followed by incongruent endings.

In an attempt to clarify these findings, we have added some further annotations to Table 5, in the forms of plus and minus signs. For each condition, the first plus indicates whether the ending of the sentence is congruent or incongruent with the bias of the verb. Experiments 2 and 3 suggest that this factor is important, at least when there is no gender cue. The second plus indicates whether the probe is a referent or a nonreferent. We have not coded whether the bias of the verb favors the probed NP, because Experiments 1–3 provided little evidence that this factor was important.

The pluses and minuses suggest a useful redescription of the pattern of results in Table 5. Rapid responding to NP1 probes is disrupted only when several factors conspire against it (the only slow NP1 probe condition has two minuses). Thus, in the NP1 verb against-the-bias condition, the ending of the sentence is comparatively difficult to process, because it goes against the bias of the verb, and the probe word is not the referent of the pronoun. It is not enough that the ending of the sentence favors NP2, since that is also true in the NP2 with-the-bias condition. Nor is it enough that the NP1 probe is not the referent of the pronoun, since that is also true in the NP1 against-the-bias condition. Furthermore, when the pronoun does not carry a gender cue (Experiments 1–3), the referent of the pronoun does not become clear until the end of the sentence, and that is apparently not sufficient to interfere with the rapid responses to the NP1 probes.

To complete the argument, responses to NP2 probes are speeded only when several factors conspire to favor them (the only fast NP2 condition has two pluses). Thus, in the NP2 with-the-bias condition, the pronoun is coreferential with the NP2 probe, because of its gender. In addition, the ending of the sentence supports this interpretation, and it is easy

to process since it is congruent with the bias of the verb.

The results of this experiment are, in many ways, similar to those of McKoon, Greene, and Ratcliff (1993; Experiments 1–4). Using a similar procedure and sentences with two participants of different sexes, but with faster presentation and with probes only at the end of the sentence, those authors found a clear effect, in all four experiments, of whether the probe word was the antecedent of the pronoun (in their terms, an interaction between character name and pronoun). However, they found no consistent effects of implicit causality.[6] There were significant effects on some measures, but only in some of the experiments. McKoon et al. used only sentences with characters of different sexes and hence with gender disambiguation from the morphosyntactic properties of the pronoun. They have no data comparable with those from Experiments 1–3. Furthermore, they tested NP1 (their subject-initiating) and NP2 (their object-initiating) verbs in separate experiments and did not carry out analyses that might have revealed the further complexities in the referent effect, such as the ones we discussed above. Furthermore, because of the between-subject nature of some of McKoon et al.'s manipulations, it is difficult to make a detailed comparison between their data and our own. However, in their experiments with standard (i.e., not speeded) response instructions (their Experiments 1 and 3), subjects were slower than might be expected in the subject-initiating verb, test first character, inconsistent continuation (i.e., NP1 verb, NP1 probe, incongruent ending) condition and faster in the object-initiating verb, test second character, consistent continuation (i.e., NP2 verb, NP2 probe, congruent ending) condition, just as they were in our experiment.

[6] That is to say, there were no consistent effects within the experiments reported in the McKoon, Greene, and Ratcliff (1993) paper. Those authors claim that differences between the results in that paper and results of other experiments can be explained by the fact that the verbs in the other experiments did not impute causes.

General Discussion

The experiments reported in this paper were designed to investigate the locus of implicit causality effects in comprehension. More specifically, they were designed to distinguish between two hypotheses about how implicit causality might have its effects: the focusing hypothesis and the integration hypothesis. According to the focusing hypothesis the implicit causality of a verb affects the way the content of a clause containing that verb is represented. In particular, implicit causality focuses attention on whichever participant in the event instigates it. The implicit cause, therefore, should be more available than the other participants, as measured, for example, in a probe word task. Furthermore, this effect should manifest itself at the end of the clause in which the relevant verb appears, at the latest. The implicit cause should also be the default referent of a pronoun in the immediately following clause. On this hypothesis, the effects of implicit causality should be seen at the end of the clause in which a verb occurs and when an immediately following pronoun is encountered. Furthermore, they should be manifest in differential activation of the NP favored by the bias of the verb and the one that is not favored.

The integration hypothesis claims that implicit causality has no immediate effect on the representation of a text. It, however, can be used when integrating later information with information in the clause in which the causality imputing verb appeared. Such effects are particularly likely to occur when, and may even be restricted to, cases in which the following clause presents an explicit cause of the event (see Ehrlich, 1980). On this view, implicit causality will have no effects until an attempt is made to integrate the information in the two clauses. Furthermore, it may have effects only at this point if it is needed to effect the integration. Thus, its effects will not appear at the end of the clause containing the causality imputing verb, but only in a later clause, if at all. The exact point at which the

effects appear will depend on how integration takes place. Very commonly, particularly when the following clause does present a cause, integration requires the resolution of a pronominal reference. If such a pronoun can be resolved on the basis of its number and gender, implicit causality may be relatively unimportant. An explicit cause that is congruent with the implicit cause may be easier to integrate than one that is not, but the integration process will not be crucial to determining who did what. However, when morphosyntactic cues are not available, the resolution of the pronoun must be based on an inference, which will typically depend on material later in the subordinate clause. In such a case, the effects of implicit causality will be deferred until later in the clause. However, they are likely to be stronger, since the inference will depend on the relation between the main event and the event in the subordinate clause. Thus, the difficulty of the inference will depend, in part, on the comparison of pronominal assignments that make the ending congruent or incongruent with the bias of the verb in the main clause. However, since congruity is only one of several factors contributing to the inference, any preference for (or enhanced activation of) the NP favored by the bias of the verb is likely to be weak. Furthermore, it will be confined to the end of the sentence. In addition, in the sentences we used, there is no reason to expect greater activation of the referent of the pronoun compared with its nonreferent. The pronoun cannot be resolved when it is encountered, and which participants are focused at the end of our sentences is not necessarily a simple function of which have most recently been mentioned or pronominalized.

In Experiments 1–3 we examined the interpretation of sentences such as

Walter apologized to Ronald this morning because he had damaged the car.

in which the pronoun could refer, on the basis of its form alone, to either of the people mentioned in the first clause. Even if we reject the idea that implicit causality is important in the encoding of the first clause, the implicit causality of the verb, in this case *apologized*, could, in principle, have been brought into play as soon as the pronoun *he* was read. In an isolated sentence such as this, the reader can be certain that *he* will refer to one of the people mentioned in the first clause. Nevertheless, we found no evidence that implicit causality information is used at this point. In Experiments 2 and 3, however, we did find clear evidence of implicit causality effects at the end of the sentences: Subjects responded faster to the probe words when the sentence ending was congruent with the bias of the verb than when it was not. This effect was independent of which name (referent of the pronoun or nonreferent) was probed. Although implicit causality information affected the processing of the sentence, there was no evidence that it was influencing the relative availability of referent and nonreferent, even 1850 ms after the end of the sentence (Experiment 3).

On their own, the results from Experiments 2 and 3 might be explained not in terms of the relation between the content of the main and subordinate clauses (congruent vs incongruent), but purely in terms of the content of the second clause. Perhaps the incongruent second clauses were more complex in structure or had more uncommon words and for that reason caused more disruption to the probe word task. Fortunately, this explanation, according to which congruity per se is not important, can be discounted, given the results from Experiment 4. When the pronoun carried a gender cue, a different pattern of results emerged. There was no simple effect of congruity on the time taken to respond to the probes, even at the end of the sentence, and even though the subordinate clauses were the same as those used in Experiments 2 and 3. There was, however, evidence that the pronoun's referent was recognized more rapidly than its nonreferent. The detailed pattern of results (Table 5) showed something more complex than a simple referent/nonreferent difference. The robust first mention bias in responding to the probes was modified only

when both pronominal reference and congruity conspired against it. Our results differ from those of Gernsbacher (1989; Experiments 3–5), who did find referent/nonreferent effects at the end of pronoun-containing clauses. We have already detailed the reasons why this difference arose. More generally, we believe that effects of this kind have two components. The first is a fast-acting (enhancement or suppression of the) activation component, similar in some respects to the activation of senses of ambiguous words postulated by Swinney (1979) and others.[7] Unfortunately, in the case of pronouns it is harder to define the set of possible meanings (corresponding to the senses of ambiguous words) and harder to show that context makes the unintended meaning irrelevant (the nonreferent of a pronoun is quite likely to be mentioned again soon; the rejected sense of an ambiguous word is not likely to be relevant soon). These problems may help to explain why previous attempts to find differential activation of pronominal referents and nonreferents have met with mixed success (Shillcock, 1982; Tyler & Marslen-Wilson, 1982). However, we believe that our Experiment 4, with its large number of subjects, does show such an effect. The second component is a focusing component. In Gernsbacher's studies, with a narrative moving forward in time, only one of the characters mentioned in the first clause is mentioned again in the second. That character is, therefore, likely to be the topic of any incoming sentences, whereas the other character is not. In our sentences, which can also be construed as snippets from narratives, an event is followed by its cause. However, even if the description of the cause focused on one of the participants in the (main) event, the narrative will resume from the main event, and either of the participants in it may be the topic. Thus, in Gernsbacher's texts the person mentioned in the second clause should be more strongly focused at the end of that clause, whereas in ours that person should not be.

Consistent with this idea is the fact that, although there was a hint of a referent effect (10 ms) at the end of the sentences in Experiment 2, there was no such hint (0 ms) in Experiment 3. The delay that we introduced, far from bringing out a referent effect as we originally suspected it might, eliminated it. The pattern of results is consistent with the idea of a fast-acting process that suppresses a pronoun's nonreferent (compared with its referent) as the referent is assigned to the pronoun. It is also consistent with the fact that any such differential activation is likely to be overridden, unless it is compatible with the focus structure of the surrounding discourse. In particular, a suppressed nonantecedent should not remain suppressed for long, if it is a strong candidate for reference in the following text.

Overall, our results strongly support the second of the two hypotheses about implicit causality, the integration hypothesis. In only one experiment, Experiment 2, did we find evidence, and then only weak evidence, of a focusing effect. In that experiment, there was a hint that the NP favored by the bias of the verb had its activation enhanced compared to that of the other NP. But even in that experiment, the effect was only significant at the end of the sentence, where its appearance is entirely compatible with a backward inferencing account of the effects of implicit causality. Immediately after the pronoun there is not enough information to determine whether the ending of the sentence is congruent with the bias of the verb or to determine the referent of the pronoun. An effect at this point would have been attributable to the implicit causality of the prior verb alone. However, the effect was not significant at this point in the sentence.

Our results are compatible with a model of text processing in which readers build discourse models of the events they are reading

[7] In the case of pronouns, however, both the referent and the nonreferent are almost always already activated when the pronoun is read, and the effect is one of enhancement or suppression of the already existing activations. Gernsbacher (e.g., 1989) argues that the effect of resolving a pronoun is primarily one of suppression of the activation of the nonreferent.

about, but do not engage in unnecessary elaboration of their representations of those events. Unless the cause of an event is important, perhaps because it is presented explicitly, there may be no need to worry about (implicit) causes suggested by the way the event is described. It is better to wait and see whether, for example, an explicit cause is given and to invoke the relevant causal information at that point. Indeed, it may be counterproductive to focus on the cause of an event. If ''Betty punished Diane three weeks ago'' is followed not by a cause, but by a description of an event that stands in a different relation to it—a consequential relation, for example, or a contrastive one—it is more likely that Betty, and not Diane, will be mentioned again. Of course, it is difficult to say what constitutes ''unnecessary'' elaboration in text comprehension. Different readers have different goals, as does the same reader on different occasions. Nevertheless, a plausible hypothesis within the discourse model framework (e.g., Garnham, 1989) is that, except under special circumstances such as skimming, readers attempt to construct a coherent representation of the events portrayed in a text, and that any processing required to establish that coherence will be carried out. In

Betty punished Roger three weeks ago because he didn't do the dishes.

the causal link between the events is signaled by *because* and the referential link between *he* and *Roger* by morphosyntactic information. A coherent representation can be set up without considering which participant in an event of punishing is *usually* the cause. In

Betty punished Diane three weeks ago because she didn't do the dishes.

the causal link is signalled in the same way. However, the referential link is not signalled morphosyntactically. To establish that link, the relative probabilities of Betty and Diane not doing the dishes have to be established, given that Betty punished Diane. In establishing these probabilities, the nature of events of punishing, and why they come about, has to be considered. In other words, implicit causality plays a role in establishing referential coherence in passages of this kind. What the present results suggest, when taken together with results that show effects of implicit causality in measures such as clause reading times, is that these effects arise only when information from the two clauses is integrated. There is no ''proactive'' component to these effects.

Appendix: Test Sentences

Verb Bias = NP1

Congruent:	Dawn confessed to Cher a couple of days ago because she felt guilty.
Incongruent:	Dawn confessed to Cher a couple of days ago because she would have found out the truth anyway.
Congruent:	Walter apologized to Ronald this morning because he damaged the car.
Incongruent:	Walter apologized to Ronald this morning because he demanded an apology.
Congruent:	Bill confessed to John a couple of days ago because he felt guilty.
Incongruent:	Bill confessed to John a couple of days ago because he would have found out the truth anyway.
Congruent:	Chuck apologized to Danny this morning because he damaged the car.
Incongruent:	Chuck apologized to Danny this morning because he demanded an apology.
Congruent:	Greg called Neil before breakfast because he needed to relay some information.
Incongruent:	Greg called Neil before breakfast because he needed to be called.
Congruent:	David approached Brian after school because he wanted

some advice.
Incongruent: David approached Brian after school because he looked friendly.
Congruent: Sandra lied to Elaine during the trial because she didn't want to be convicted.
Incongruent: Sandra lied to Elaine during the trial because she was gullible.
Congruent: Kate approached Joan after school because she wanted some advice.
Incongruent: Kate approached Joan after school because she looked friendly.
Congruent: Rob phoned Ted after supper because he had to cancel.
Incongruent: Rob phoned Ted after supper because he was next on the list of people who needed to be called.
Congruent: Jan confessed to Sue during lunch because she was sorry.
Incongruent: Jan confessed to Sue during lunch because she would have found out the truth anyway.
Congruent: Carol questioned Ellen a lot because she wanted some answers.
Incongruent: Carol questioned Ellen a lot because she came home late.
Congruent: Michelle killed Shirley last year because she was paid to.
Incongruent: Michelle killed Shirley last year because she needed to die.
Congruent: Alice called Jenny late last night because she felt like talking.
Incongruent: Alice called Jenny late last night because she needed to be called.
Congruent: Harold lied to Arnold on Saturday because he felt ashamed.
Incongruent: Harold lied to Arnold on Saturday because he didn't need to know the truth right now.
Congruent: Cindy approached Janet in the office because she wanted to ask for a favor.
Incongruent: Cindy approached Janet in the office because she looked lonely.
Congruent: Kay approached Bev in the office because she wanted to ask for a favor.
Incongruent: Kay approached Bev in the office because she looked lonely.
Congruent: Jim apologized to Don last week because he was sorry.
Incongruent: Jim apologized to Don last week because he looked offended.
Congruent: Sara killed Anna last year because she was paid to.
Incongruent: Sara killed Anna last year because she needed to die.
Congruent: Joel apologized to Kent last week because he was sorry.
Incongruent: Joel apologized to Kent last week because he looked offended.
Congruent: Brenda called Patsy before breakfast because she needed to relay some information.
Incongruent: Brenda called Patsy before breakfast because she needed to be called.
Congruent: Patty phoned Becky before supper because she had to cancel.
Incongruent: Patty phoned Becky before supper because she seemed like an interesting person.
Congruent: Susan confided in Nancy at the ballgame because she felt that the timing was right.
Incongruent: Susan confided in Nancy at the ballgame because she was a good listener.

Congruent: Herbert confused Andrew after dinner because he used big words.
Incongruent: Herbert confused Andrew after dinner because he was easy to confuse.
Congruent: Sharon phoned Debbie before supper because she had to cancel.
Incongruent: Sharon phoned Debbie before supper because she was next on the list of people who needed to be called.
Congruent: Tommy killed Ricky after lunch because he was paid to.
Incongruent: Tommy killed Ricky after lunch because he knew too much.
Congruent: Steven confided in Clarke before the meeting because he just had to tell someone.
Incongruent: Steven confided in Clarke before the meeting because he would understand.
Congruent: Amy confused Kim after dinner because she used big words.
Incongruent: Amy confused Kim after dinner because she was easy to confuse.
Congruent: Helen questioned Julie last night because she needed some information.
Incongruent: Helen questioned Julie last night because she came home late.
Congruent: Joanne confided in Pamela before the meeting because she just had to tell someone.
Incongruent: Joanne confided in Pamela before the meeting because she would understand.
Congruent: Cathy confused Donna during class because she talked too fast.
Incongruent: Cathy confused Donna during class because she was very easy to mix up.
Congruent: Bob confused Tim during class because he talked too fast.
Incongruent: Bob confused Tim during class because he was very easy to mix up.
Congruent: Lucy confided in Suzy at the ballgame because she felt the timing was right.
Incongruent: Lucy confided in Suzy at the ballgame because she was a good listener.

Verb Bias = NP2

Congruent: Jeff believed Paul yesterday because he gave a convincing performance.
Incongruent: Jeff believed Paul yesterday because he believed everything.
Congruent: Beth feared Gail for many years because she was mean.
Incongruent: Beth feared Gail for many years because she was small and weak.
Congruent: Alex believed Hank yesterday because he gave a convincing performance.
Incongruent: Alex believed Hank yesterday because he believed everything.
Congruent: Betty punished Diane three weeks ago because she didn't do the dishes.
Incongruent: Betty punished Diane three weeks ago because she wanted the behavior to stop.
Congruent: Deb envied Liz for a long time because she was popular.
Incongruent: Deb envied Liz for a long time because she had low self-esteem.
Congruent: Linda scolded Debra in the car because she had been bad.
Incongruent: Linda scolded Debra in the car because she believed in strict discipline.

Congruent:	Penny congratulated Wendy after the play because she had done well.
Incongruent:	Penny congratulated Wendy after the play because she thought it was good.
Congruent:	Dave congratulated Rick after the play because he had done well.
Incongruent:	Dave congratulated Rick after the play because he thought it was good.
Congruent:	Tom believed Ken during the conversation because he was telling the truth.
Incongruent:	Tom believed Ken during the conversation because he didn't know any better.
Congruent:	Lois blamed Rita after the game because she seemed like the logical person to blame.
Incongruent:	Lois blamed Rita after the game because she needed a scapegoat.
Congruent:	Heidi believed Anita during the conversation because she was telling the truth.
Incongruent:	Heidi believed Anita during the conversation because she didn't know any better.
Congruent:	Randy punished Jerry last month because he was naughty.
Incongruent:	Randy punished Jerry last month because he disapproved of shoplifting.
Congruent:	Sam scolded Ray at the supermarket because he threw food.
Incongruent:	Sam scolded Ray at the supermarket because he believed in strict discipline.
Congruent:	Sherry envied Evette all the time because she had a fast car.
Incongruent:	Sherry envied Evette all the time because she had no money.
Congruent:	Marty congratulated Harry on the beach because he won the contest.
Incongruent:	Marty congratulated Harry on the beach because he liked the performance.
Congruent:	Jane congratulated Mary on the beach because she won the contest.
Incongruent:	Jane congratulated Mary on the beach because she liked the performance.
Congruent:	Gina feared Judy for a while because she was mean.
Incongruent:	Gina feared Judy for a while because she couldn't defend herself.
Congruent:	Richard feared Charles for a while because he was mean.
Incongruent:	Richard feared Charles for a while because he couldn't defend himself.
Congruent:	Lilly scolded Denise at the supermarket because she threw food.
Incongruent:	Lilly scolded Denise at the supermarket because she believed in strict discipline.
Congruent:	Tina envied Lisa all the time because she had a fast car.
Incongruent:	Tina envied Lisa all the time because she had no money.
Congruent:	James blamed Keith after the game because he seemed like the logical person to blame.
Incongruent:	James blamed Keith after the game because he needed a scapegoat.
Congruent:	Abe blamed Roy after the accident because he seemed like the logical person to blame.
Incongruent:	Abe blamed Roy after the accident because he wanted to blame someone.
Congruent:	Phil envied Dick for a long time because he was popular.
Incongruent:	Phil envied Dick for a long

time because he had low self-esteem.

Congruent: Jill admired Ruth during the school year because she worked so hard.

Incongruent: Jill admired Ruth during the school year because she needed a role model.

Congruent: Ann praised Pam in the park because she was good.

Incongruent: Ann praised Pam in the park because she wanted to seem supportive.

Congruent: Peg admired Eve all quarter because she was so smart.

Incongruent: Peg admired Eve all quarter because she wanted someone to look up to.

Congruent: Doug punished Mark three weeks ago because he didn't do the dishes.

Incongruent: Doug punished Mark three weeks ago because he wanted the behavior to stop.

Congruent: Bobby admired Lloyd all quarter because he was so smart.

Incongruent: Bobby admired Lloyd all quarter because he wanted someone to look up to.

Congruent: Barb admired Lynn during the school year because she worked so hard.

Incongruent: Barb admired Lynn during the school year because she needed a role model.

Congruent: Alan punished Jack last month because he was naughty.

Incongruent: Alan punished Jack last month because he disapproved of shoplifting.

Congruent: Frank praised Wayne in the park because he was good.

Incongruent: Frank praised Wayne in the park because he wanted to seem supportive.

Congruent: Andy praised Gary for several weeks because he cleaned his room.

Incongruent: Andy praised Gary for several weeks because he wanted to seem supportive.

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