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Testing the shared resource assumption in theories of text processing ☆

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Abstract

Eight experiments evaluated a core assumption of several theories of text processing, the shared resource assumption, which states that component text processes share limited processing resources. Short texts each contained two critical sentences that together warranted a causal inference. The syntactic structure of the second sentence was either more or less difficult to parse. Results from a lexical decision task suggested that readers formed the causal inferences when the syntactic structure was less difficult to parse but that inferencing was constrained when syntactic structure was more difficult. Follow-up experiments suggested that this interference was not due to inferior output of the syntactic parser nor to the increased demands of difficult syntax interfering with maintenance of information needed to form the inference. The results suggest insufficient resources were available for the operation of inference processes due to the increased demands of syntactic parsing, consistent with the shared resource assumption.
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1. Introduction

Text processing is a highly complex cognitive task, in that its successful completion depends upon the coordinated operation of several component processes. At a minimum, text processing is widely assumed to involve components that identify the words in a text and establish the concepts they denote (i.e., lexical processes), components that identify the syntactic relationships between words and establish the phrase and clause structure of a sentence (i.e., syntactic parsing processes), components that identify the semantic relationships between concepts to establish the ideas expressed within a sentence (i.e., semantic parsing processes), and components that identify the semantic relationships between ideas both within and between sentences (i.e., integration processes), often involving the use of general world knowledge to identify relationships that are implied rather than stated explicitly in the text (i.e., inference processes). Over the past three decades, many theoretical accounts and models of the particular component processes have been developed, and a wealth of empirical work has been directed at understanding how each of these component processes operates (e.g., Duffy, Morris, & Rayner, 1988; Ferreira & Clifton, 1986; Frazier, 1987; Graesser, Singer, & Trabasso, 1994; McKoon & Ratcliff, 1992; Rayner & Frazier, 1989).

By comparison, although more general theoretical accounts of text processing have been forwarded, minimal research has directly explored the coordinated operation of the component processes (e.g., Keller, Carpenter, & Just, 2001). That is, whereas research has been directed at understanding how particular component processes operate, empirical research exploring how they operate together as a system is scant. Certainly, research exploring the operation of particular components is necessary for a complete understanding of text processing, but it is not sufficient. Accordingly, the present research investigates a key aspect of the system within which component text processes must cooperate.

Specifically, the major goal of this paper is to empirically evaluate a core assumption of general theories of text processing, referred to hereafter as the *shared resource assumption*. Several theories assume that the various components involved in text processing depend upon limited processing resources, either for their operation, for the maintenance of their output, or both (e.g., Just & Carpenter, 1992; Kintsch, 1988; Millis & Simon, 1994; Perfetti, 1988). For example, according to Perfetti's (1988) Verbal Efficiency Theory (VET), "the assembly of propositions and their integration occurs within a limited-capacity processing mechanism" (p. 111). As these components are assumed to share the same limited capacity, VET predicts that the processing demands of one component may influence the extent to which other component processes can operate successfully. Similarly, according to Just and Carpenter's (1992) Capacity-Constrained Comprehension theory, text processing depends upon "a pool of operational resources that perform the symbolic computations and thereby generate the intermediate and final products" (p. 122), the maintenance of which is also dependent upon those resources. Just and Carpenter further propose that this pool of resources is limited such that increasing maintenance or operational demands will impose constraints on the successful operation of all processes when demands exceed available resources.

However, the shared resource assumption does not meet with complete consensus. Other theories propose instead that different resources support the operation and/or information maintenance of the various text processing components. For example, based on patterns of language processing deficits and preservation across several patients with neurological damage, Martin and Romani (1994) concluded that "within the language processing domain, there are separate capacities for the retention of phonological, semantic, and syntactic information"

(p. 519). Caplan and Waters (1999) proposed a separate-sentence-interpretation-resource (SSIR) theory, according to which "part of the verbal working memory system is specialized for interpretive aspects of sentence comprehension, specifically, assigning syntactic structure and using it to determine the meaning of a sentence" (p. 79). According to SSIR theory, the resources that are dedicated to these sentence interpretation processes are separate from those available to post-interpretive processes, which include remembering sentence content, using sentence meaning to draw inferences, and planning action.

Despite the debate surrounding the shared resource assumption and its importance to several prominent theories of text processing, few studies have directly tested the assumption. Among the relevant studies, evidence has suggested that the resource demands of syntactic parsing can influence the maintenance of verbal information. Carpenter and Just (1989) reported that when individuals read a list of unrelated sentences and then reported the final word in each sentence, memory for the final words decreased as the syntactic complexity of the sentences increased (for related results, see King & Just, 1991). This finding suggests that syntactic parsing requires processing resources, and that those demands can interfere with maintaining a memory load imposed by a secondary task external to the sentence processing task itself. However, other researchers have challenged the interpretation and robustness of these findings. Caplan and Waters (1999) note several related studies that failed to find differences in syntactic processing as a function of memory load, and they suggest that the positive findings reported in previous research may have been due to strategic effects or costs associated with task switching. Of particular importance for present purposes, each of these studies examined interference (or the lack thereof) between sentence processing and the maintenance of a memory load external to text processing itself. Previous research has not directly tested whether the processing demands of one component text process can influence the operation of other components involved in the processing of connected discourse.

Given the paucity of research exploring resource dependence between text processing components, the present research was specifically designed to evaluate the shared resource assumption. The basic approach was to manipulate the difficulty of one component process and then examine the extent to which the successful operation of another component process was compromised. If the assumption that different component processes rely on the same limited processing resources is correct, then manipulations influencing the resource demands of one text process should affect the performance of another.

As means to this end, the two processes examined in the present experiments include syntactic parsing processes and causal inferencing (i.e., establishing a causal relationship implied by explicit text content). Specifically, each critical text contained two sentences that supported a causal inference. For example, consider the following sentences:

> Mary tapped on the front of a cage.
>
> The animal that was curled up in the corner jumped forward suddenly

One may reasonably infer that the animal jumped forward because Mary scared it when she tapped the cage. A prevalently used method for evaluating whether people make an inference on-line is to present a probe word related to the inference after the target sentence for a speeded response task (e.g., a lexical decision task in which the participant must decide whether the probe forms an English word). Response times for inference words are then compared to response times for matched control words unrelated to the target sentence. For example, immediately after the second sentence in the pair above, the inference probe word SCARED would be presented. In the control condition, a control word that was unrelated to the target sentence but that matched the inference probe word along important dimensions (e.g., length, frequency) would be presented instead (e.g., CARVED). Faster response time to the inference probe word than to the control probe word is taken as evidence that the inference was made (e.g., Long, Golding, & Graesser, 1992; Millis & Graesser, 1994; Whitney, Ritchie, & Crane, 1992).

The important manipulation for present purposes concerns the syntactic structure of the second sentence in each pair (hereafter referred to as the "target sentence"). All target sentences contained a relative clause. Two versions of each target sentence were written such that the relative clause structure was either unambiguously marked or was temporarily ambiguous. In the example above, the relative clause is unambiguously marked (e.g., "The animal *that was* curled up in the corner jumped forward suddenly"). In the ambiguous version of this sentence, the marker was removed (e.g., "The animal curled up in the corner jumped forward suddenly"). The sentence is temporarily ambiguous at the verb "curled," because the sentence could legally continue with "curled" in a relative clause or with "curled" as a main verb (e.g., "The animal curled up in the corner."). A wealth of research has shown that upon encounter of an ambiguous verb, readers typically adopt a main verb interpretation and then must reanalyze if subsequent content indicates that a relative clause interpretation is correct (e.g., Binder, Duffy, & Rayner, 2001; Britt, Perfetti, Garrod, & Rayner, 1992; Ferreira & Clifton, 1986). Thus, arriving at the correct interpretation of ambiguous sentences is generally more demanding than interpreting sentences with unambiguously marked relative clauses, because the former typically require syntactic reanalysis in addition to initial syntactic analysis.

According to the shared resource assumption, the various cognitive processes involved in reading (including syntactic processes and inference processes) are dependent upon the same limited processing resources. Thus, the increased demands of processing syntactically ambiguous sentences (due to the need for syntactic reanalysis) are predicted to interfere with the success of causal inferencing. Specifically, the shared resource assumption predicts an interaction between the syntactic structure of the target sentence (ambiguous or unambiguous) and kind of probe word (inference or control), such that the advantage in response times for inference over control probe words should be significantly smaller after ambiguous target sentences than after unambiguous sentences. Alternatively, if syntactic processes and inference processes are each supported by dedicated pools of processing resources, then only a main effect of probe word would be predicted to obtain. To preview, Experiments 1a–1c demonstrated basic patterns of results predicted by the shared resource assumption and ruled out alternative interpretations of the findings that are theoretically uninteresting for present purposes. Experiments 2a–2c provided further replication and evaluated a theoretically important alternative interpretation of the effect. Experiments 3–4 provided converging evidence for the shared resource assumption and more closely examined the nature of the resource dependence between processes.

2. Experiment 1a

2.1. Method

2.1.1. Participants and design

Seventy-six undergraduates participated to partially satisfy course requirements in Introductory Psychology. The two within-subject variables were target sentence (ambiguous or unambiguous) and probe word (inference or control).

2.1.2. Materials

Two pilot experiments were conducted to develop appropriate materials. To develop the critical sentence pairs, forty candidate sentence pairs were written or adapted from extant research. Each pair was presented to 15–45 pilot participants, who were undergraduates at University of Colorado participating to partially satisfy course requirements in Introductory Psychology. For each pair, participants were instructed to write a sentence that explicitly described the causal relationship between the two sentences (cf. Millis, Morgan, & Graesser, 1990). For each pair, responses were grouped according to the inferred causal relationship, and the most frequently generated causal relationship was identified. The sixteen pairs with the highest agreement among respondents were selected as critical pairs.[1]

For each critical pair, the key content word that was most frequently generated to express the inference was selected as the inference probe word. For example, for the sentence pair "Mary tapped on the front of a cage. The animal that was curled up in the corner jumped forward suddenly," most participants wrote either that Mary *scared* the animal or that Mary *startled* the animal. These responses would be grouped together as expressing the same inferred relationship, although *scared* was explicitly written more often and was thus chosen as the inference probe word. Across the 16 critical pairs selected, 79% of all responses for a pair expressed the same relationship, and 59% of all responses explicitly stated the inference probe word. For each inference probe word, a control word was selected that had the same number of letters and syllables, was the same part of speech, and had a similar word frequency (mean occurrences per 1,000,000 words was 58 with $SD = 64$ for both inference and control words, based on the norms from Kucera & Francis, 1967). The 16 critical sentence pairs along with their corresponding probe words are presented in Appendix A.

A second pilot experiment involving an additional 40 undergraduate volunteers was conducted to confirm that the inference and control probe words were suitably matched. The inference and control probe words were embedded in a list of filler words and non-words, and participants were asked to make a speeded lexical decision to each (as in the main experiments, described in detail below). For correct responses, mean response time was 583 ms ($SEM = 12$) for inference probes and 588 ms ($SEM = 12$) for control probes, $t(39) = 0.55$.

Each of the sixteen critical sentence pairs selected from the pilot experiment was embedded in an appropriate short story context. A sample text is presented in Table 1, along with the corresponding probe words. Across participants, assignment of text to condition was counterbalanced so that each text appeared in the four conditions an equal number of times and thus any subtle differences between items would not be confounded with the manipulations of interest. An additional 48 filler texts were written that were similar in style and length

[1] With some of the critical sentence pairs, one might be concerned that the causal link may be inferable from the first sentence in the pair alone, which constitutes a predictive inference. However, this is not problematic for present purposes for several reasons. First, previous research shows that predictive inferences are usually not fully represented during on-line text processing. Second, when they are formed, they are extremely fragile and are usually only incorporated into the representation if supported by subsequent explicit text content. In this case, even if a predictive inference were tentatively made after reading the first sentence, integration of that inference into the representation would likely depend on processing of the second sentence, and thus syntactic processing could still influence the completion of inference processes. Third, even if the predictive inference was fully represented prior to reading the second sentence, this would work against the hypothesis being examined, as the syntactic structure of the second sentence would then be less likely to interfere with inference processing.

Table 1
Experiment 1: sample text with corresponding probe words

When Fred got off the phone, his wife noticed the look on his face and asked who he had been talking to. He told her that it was Steve, one of the guys from work. *Steve was organizing a group to make signs and to contact the press. The workers [who were] presented the last offer from management had been insulted.* ##### Steve asked him if he would join the group. Fred told him he wanted to think it over and would get back to him.
Inference probe word: STRIKE
Control probe word: SCREEN
Comprehension question: Did the workers present the offer?

Note: The two sentences warranting a causal inference are italicized. In the second of the two sentences, the words in brackets were included in the unambiguous version and omitted in the ambiguous versions (sentences shown to participants did not include brackets or italics). The ##### symbol indicates the location at which the probe word was presented.

to the critical texts. The filler texts were included so that only a minority of texts included a reduced relative clause, so as to minimize the possibility that participants would "guess" what the study was about and/or adopt task-specific strategies. The decision to limit the number of critical texts to 16 was made to satisfy this criterion and to keep the overall length of the experiment less than an hour to minimize adverse effects of participant boredom or fatigue. For each text, a short comprehension question was written. For the critical texts, the question tested whether the target sentence had been parsed correctly (in most cases assessing whether the relative clause had been correctly interpreted).

2.1.3. Procedure

Experimental instructions and materials were presented on a computer. During the first phase of the experiment, participants were given instructions and practice with the lexical decision task. Participants were told that on each trial, a string of letters would appear on the screen and that they were to decide whether or not the letters spelled an English word (without rearrangement). A go/no-go version of the lexical decision task was used (Perea, Rosa, & Gómez, 2002). The go/no-go version of the lexical decision is preferable to the yes/no version of the task, because it is less demanding, yields more correct responses, and yields faster response times (which reduces concerns about task-specific strategies such as context checking influencing performance of the task).[2] When the letters spelled a word, participants were told to quickly press the spacebar. When the letters did not spell a word, participants were

[2] Lexical decision was selected for use here rather than naming (another common speeded response task in which participants simply read the probe word aloud as quickly as possible), because previous research has suggested that naming may be a less sensitive measure of the activation of inference concepts than lexical decision (e.g., Lucas, Tanenhaus, & Carlson, 1990; Whitney et al., 1992). The potential trade-off is that lexical decision may be more susceptible to the influence of context checking, in which the semantic consistency of the probe with the preceding context is used as evidence when making a response (Potts, Keenan, & Golding, 1988). The concern is that differences in response times between target and control conditions may not reflect the extent to which readers formed the inference during reading, but rather the speed with which they can identify a semantic relationship between the probe word and the preceding context at the time of test. However, McKoon and Ratcliff (1989) have argued that the kind of information needed to support context checking is not available early enough to influence speeded responses in the range of 600–700 ms (as in the present research). Furthermore, Whitney et al. (1992) suggest that "concerns over context checking in the lexical decision task that originate from studies of single-word priming … may not generalize to the use of lexical decision to study information primed by sentences" (p. 426). To foreshadow, this issue will be revisited during discussion of the results of Experiment 1a, which also weigh against a context checking account.

told not to press any key and the letters would disappear from the screen after two seconds. The experimenter then confirmed that the participant understood the instructions and emphasized that responses were to be as quick and accurate as possible. Next, participants practiced the lexical decision task with a list of 40 filler probe strings (20 words and 20 non-words) presented one at a time in random order.

In the second phase of the experiment, participants were given instructions for the main task and then practiced with two sample texts (along with probe words and comprehension questions, as in the experimental trials described below). Before starting the experimental trials, the experimenter confirmed that the participant understood the instructions. The experimenter emphasized that participants were to read at their own pace but to make sure they understood the story as they progressed through the sentences and that they were to respond as quickly and accurately as possible to the lexical decision probes when they appeared.

During each experimental trial, the text was presented one sentence at a time. After reading a sentence, the participant pressed the spacebar to advance. After the target sentence in a critical text was read and removed from the screen, a warning signal (#####) appeared on the screen for 750 ms followed by either the inference or control probe word for the go/no-go lexical decision task. After the lexical decision probe was removed from the screen, the next sentence of the text was presented and so on, until the participant reached the end of the text. After the last sentence of the text, the comprehension question was presented and participants were to respond "Yes" or "No" by pressing the "Y" or "N" key, respectively. Participants were allowed to respond to the comprehension question at their own pace (in contrast to the lexical decision task, in which they were explicitly instructed to respond as quickly as possible). For the filler texts, the lexical decision probe was either a word or a non-word (with an equal number of each across all texts), presented after a randomly selected sentence in the text. Filler texts were also followed by a comprehension question, with an equal number of correct "Yes" and "No" answers across all texts. For each participant, six randomly selected filler texts were presented during the first six experimental trials to allow participants further practice with the main task before any critical texts were encountered. The 16 critical texts and the remaining filler texts were then presented in random order for each participant.

2.2. Results and discussion

Data from one participant were lost due to computer error. In all experiments, analyses of variance (ANOVAs) over subjects are of primary interest (see Raaijmakers, Schrijnemakers, & Gremmen, 1999) but ANOVAs over items are also included for interested readers (reported as F_1 and F_2, respectively).

As a manipulation check, reading times for target sentences were examined. Reading times (in ms) were longer for ambiguous sentences ($M = 5019$, $SEM = 206$) than for unambiguous sentences ($M = 4127$, $SEM = 128$) [$F_1(1,74) = 27.95$, $MSE = 1068175.87$, $p < .001$; $F_2(1,15) = 5.72$, $MSE = 602577.34$, $p = .03$], suggesting that syntactic processing was more demanding for sentences with reduced relative clauses.

2.2.1. Response times

Mean times for correct responses to lexical decision probe words (97.3% of trials) are reported in Table 2. A repeated measures ANOVA yielded a main effect of probe word

Table 2
Mean response times to lexical decision probe words (correct responses only) for Experiments 1a, 2a, 2c, and 4

	Inference probes	Control probes	Difference
Experiment 1a			
Unambiguous clause	611 (15)	700 (19)	89
Ambiguous clause	656 (20)	674 (16)	18
Experiment 2a			
Unambiguous clause	594 (13)	668 (22)	74
Ambiguous clause	621 (19)	653 (19)	32
Experiment 2c			
Unambiguous clause	620 (19)	706 (29)	86
Ambiguous clause	642 (20)	725 (28)	83
Experiment 4			
Unambiguous clause	612 (16)	649 (17)	37
Ambiguous clause	610 (20)	696 (22)	86

Note. Response times are reported in milliseconds. Standard errors are reported in parentheses.

[$F_1(1,74) = 22.24$, $MSE = 9775.61$, $p < .001$; $F_2(1,15) = 3.43$, $MSE = 18492.48$, $p = .08$] and no main effect of target sentence, Fs < 1. Most important, the interaction predicted by the shared resource assumption was significant [$F_1(1,74) = 5.07$, $MSE = 18307.01$, $p < .03$; $F_2(1,15) = 6.25$, $MSE = 3561.27$, $p < .03$]. Paired comparisons showed that after unambiguous sentences, response times were faster to inference probe words than to control probe words [$F_1(1,74) = 28.67$, $MSE = 10365.39$, $p < .001$; $F_2(1,15) = 7.24$, $MSE = 11249.87$, $p < .02$], suggesting that readers made the causal inferences in this condition. In contrast, after ambiguous sentences, response times for inference and control probe words did not significantly differ (Fs < 1), suggesting that the increased demands of syntactic processing in this condition interfered with inference processing.

The unambiguous condition showed both an advantage for response times to inference probe words and a disadvantage for response times to control probe words, relative to the ambiguous condition. Although the latter finding was not anticipated, one plausible explanation is that it reflects a slight delay in responding to the lexical decision probes in the unambiguous condition due to some spillover of wrap-up processes involved in inferencing. More important, the pattern suggests that the processing demands (and potentially the timecourse of processing; see Experiment 4) differ for the two kinds of target sentence, and thus comparisons of probe response times across target sentence conditions may be less interpretable than comparisons of response times to the different probes within each target sentence condition. Nonetheless, when paired comparisons are conducted, the full set will be reported for purposes of completeness. These additional comparisons showed that response times to inference probes were faster in the unambiguous versus ambiguous condition [$F_1(1,74) = 6.70$, $MSE = 10967.74$, $p = .012$; $F_2(1,15) = 3.96$, $MSE = 3583.96$, $p = .065$], and that the trend for longer response times to control probes in the unambiguous versus ambiguous condition was not significant [$F_1(1,74) = 1.37$, $MSE = 18737.22$, $p = .25$; $F_2(1,15) = 2.07$, $MSE = 3520.15$, $p = .17$].

The significant interaction in response times rules out several potential interpretative concerns. Evidence for inferencing in the unambiguous condition is difficult to explain by appeal to a context-checking account or to a word-based priming account (e.g., Potts et al., 1988). Given that the sentences in the ambiguous and unambiguous conditions differed by only two function words in most cases, the inference probe was equally related to the context and to the content words of the target sentence in both conditions. Thus, faster response times to inference versus control probe words in both the ambiguous and unambiguous conditions would have been expected by these accounts. To foreshadow, Experiment 1b was conducted to provide further evidence against word-based priming accounts.

The pattern of response times also weighs against another interpretative concern, namely, that response times to inference probe words may have been delayed after ambiguous sentences due to spillover of syntactic reanalysis processing from the previous sentence. That is, no advantage in response times to inference probe words may have resulted not because readers did not make the inference, but because they were still engaged in syntactic reanalysis processing when the probe word appeared and were thus slower to respond to the probe. However, such spillover processing would also slow responses to control probe words, and thus response times to control probes would be slower in the ambiguous condition than in the unambiguous condition. Clearly, this pattern did not obtain, with the trend in the opposite direction.

2.2.2. Comprehension performance

As performance on the comprehension questions following the critical texts did not vary with probe word condition, results were collapsed across this variable. For each individual, mean performance was calculated. Mean performance across individual means was 68% ($SEM = 2$) for ambiguous sentences, which is consistent with levels of accuracy reported in previous research on syntactic ambiguity (e.g., Christianson, Hollingworth, Halliwell, & Ferreira, 2001; Ferreira & Clifton, 1986; Rayner, Carlson, & Frazier, 1983). Performance was significantly lower for ambiguous sentences than for unambiguous sentences ($M = 81\%$, $SEM = 2$), $F_1(1,74) = 19.23$, $MSE = 296.65$, $p < .001$; $F_2(1,15) = 16.79$, $MSE = 71.59$, $p = .001$. As many of the comprehension questions tapped understanding of the relative clause, this finding suggests that readers were less likely to arrive at the correct interpretation of the relative clause in the ambiguous condition than in the unambiguous condition.

Lower performance for ambiguous sentences raises the concern that readers may not have made inferences in this condition because they did not have all the information they needed to do so, rather than because they did not have enough processing resources to do so. This possibility illustrates another form of dependence between component processes (referred to hereafter as *output dependence*) in which the success of one component depends upon the quality of the information made available by another process. Although this form of dependence is suggested by several models of text processing and thus is also of theoretical interest, the purpose of the present research is to explore resource dependence.

To evaluate the output dependence account, a post hoc analysis of the probe word response times was conducted that included only those items for which the participant had correctly responded to the comprehension question (and also correctly responded to the lexical decision probe, as above). When only those items that were parsed correctly (as indicated by a correct response to the comprehension question) were examined, the crucial interaction in response times still obtained [$F_1(1,74) = 4.02$, $MSE = 20825.29$, $p < .05$; $F_2(1,15) = 3.78$, $MSE = 4164.55$, $p = .07$]. After unambiguous sentences, response times were faster to inference probe words ($M = 609$, $SEM = 15$) than to control probe words

($M = 679$, $SEM = 22$) [$F_1(1,74) = 11.93$, $MSE = 15302.19$, $p = .005$; $F_2(1,15) = 6.59$, $MSE = 11638.10$, $p = .02$]. In contrast, after ambiguous sentences, response times did not significantly differ for inference probe words ($M = 656$, $SEM = 24$) and control probe words ($M = 659$, $SEM = 22$), $F\text{s} < 1.09$.[3] Response times to the inference probe words were faster in the unambiguous versus ambiguous condition [$F_1(1,74) = 4.12$, $MSE = 19871.30$, $p = .046$; $F_2(1,15) = 3.26$, $MSE = 3897.01$, $p = .09$]. Response times to the control probe words in the two conditions did not significantly differ ($F\text{s} < 1$).

Overall, these findings suggest that the interference of syntactic parsing with inferencing was not due to an output dependence between the two component processes. However, this conclusion rests on post hoc analyses. Experiments 2a–2c were conducted to test the output dependence account more directly, and thus this issue will be revisited after presentation of Experiments 1b–1c.

3. Experiment 1b

Experiment 1a showed that response times were faster to inference probe words than to control probe words in the unambiguous condition but not in the ambiguous condition. The preferred interpretation of this pattern is that readers formed inferences in the unambiguous condition, whereas inferencing was constrained in the ambiguous condition due to increased resource demands of syntactic processing. However, the interaction could be explained by a word-based priming account if one assumes that facilitation for the inference probe relative to the control probe was due to lexical-semantic priming from words in the critical sentence, along with the assumption that syntactic parsing can interfere with this low-level priming. Experiment 1b was conducted to assess the potential contribution of word-based priming to the response time advantage of inference over control probe words in the unambiguous condition.

3.1. Method

A set of 60 sentences were drawn from the experimental materials used in Experiment 1a, including the 16 target sentences and 44 sentences selected from the filler texts. The order of the words within each sentence was scrambled (as in Long et al., 1992). The sentences were then presented one at a time to 24 undergraduates who participated to partially satisfy course requirements in Introductory Psychology. Participants were told to read each string of words at their normal reading rate. The offset of a sentence was followed by a 750-ms interval and then a probe word for lexical decision. For the scrambled target sentences, the probe word was either the inference word or the control word (counterbalanced across participants).

[3] A qualitatively similar pattern obtains for those items that were not parsed correctly (as indicated by an incorrect response to the comprehension question). After unambiguous sentences, response times were faster to inference probe words ($M = 645$, $SEM = 36$) than to control probe words ($M = 700$, $SEM = 26$), $t(25) = 3.79$, $p < .01$. (Most items had too few incorrect responses to allow for meaningful item analyses.) After ambiguous sentences, response times did not significantly differ for inference probe words ($M = 650$, $SEM = 40$) and control probe words ($M = 683$, $SEM = 30$), $t(44) = 0.64$. Overall, these results suggest that the additional reanalysis of ambiguous sentences interfered with inferencing whether the reanalysis successfully arrived at the correct reinterpretation or not.

3.2. Results and discussion

Response times did not significantly differ for inference and control probe words [$M = 573$, $SEM = 17$, and $M = 589$, $SEM = 16$, respectively; $t(23) = 1.49$, $p = .15$]. This finding suggests that any facilitation in response time to inference probe words in the unambiguous condition in Experiment 1a due to semantic relationships between the inference probe word and words in the critical sentence was minimal.

4. Experiment 1c

Experiment 1a provided initial evidence for the shared resource assumption, by showing that causal inferencing was constrained after the more difficult ambiguous sentences, relative to their syntactically unambiguous counterparts. Somewhat unexpectedly, the effect in the unambiguous condition appeared to involve both a decrease in response times to inference probes and an increase in response times to control probes. A plausible explanation for the latter finding is that response times to the control probe words in the unambiguous condition were elevated due to the spillover of the inference processes beyond the sentence boundary. Nonetheless, the fact that a difference in response times to control probes contributed to the overall pattern raises the possibility that the results reflected some uncontrolled difference between the inference and control probe words when they were presented in the context of a reading task.[4]

Experiment 1c was conducted to provide converging evidence for differences in the extent to which readers form causal inferences in the ambiguous and unambiguous conditions, using modified materials that did not involve different probe words in the inference and control conditions. In this experiment, the control condition involved an explicit statement of the intended inference, thus obviating the need for causal inferencing (cf. Cook, Limber, & O'Brien, 2001; Gernsbacher, Hallada, & Robertson, 1998; Noordman, Vonk, & Kempff, 1992; Potts et al., 1988; Singer, Harkness, & Stewart, 1997). More specifically, a version of the first of the two critical sentences in each text was written in which the target inference was explicitly stated. For example, whereas the original *inference version* of one critical sentence pair read as follows

> Today, ominous clouds rolled in over the mountains.
>
> The climbers [who were] expected to descend on Monday were delayed.

the *control version* of the first sentence explicitly stated the intended inference connecting the two sentences:

> Today, ominous clouds rolled in over the mountains and a violent storm began raging.
>
> The climbers [who were] expected to descend on Monday were delayed.

The target sentences were the same as in Experiment 1a (with either ambiguous or unambiguous syntax). In all conditions, the inference probe word was presented for lexical decision.

[4] Thanks to Debra Long for suggesting this possibility and for recommendations that motivated the method used in Experiment 1c.

If the increased resource demands of the ambiguous target sentences interfere with inferencing, response times to the probe words will be slower after the inference version of the first critical sentence than after the control version. In contrast, if readers are able to form the inferences in the unambiguous condition, response times will not differ after the inference versus control versions of the first critical sentence, because the inference concept will have been activated in either case.

4.1. Method

The procedure and materials were the same as in Experiment 1a, except for the modifications to the materials described above. Sixty-four undergraduates participated to partially satisfy course requirements in Introductory Psychology. The two within-subject variables were defined by the version of the first critical sentence (inference or control) and the syntax of the target sentence (ambiguous or unambiguous, as in Experiment 1a).

4.2. Results and discussion

As a manipulation check, reading times for target sentences were examined. Reading times (in ms) were longer for ambiguous sentences ($M = 5067$, $SEM = 256$) than for unambiguous sentences ($M = 4288$, $SEM = 201$), $F(1,63) = 16.01$, $MSE = 1213802.43$, $p < .001$, suggesting that syntactic processing was more demanding for sentences with reduced relative clauses.

4.2.1. Response times

Mean lexical decision times for inference probe words in each condition are reported in Table 3. Trials with incorrect responses or response times more than 2 *SD*s above the condition mean were excluded from analyses (6%). A repeated measures ANOVA yielded a main effect of first sentence version [$F_1(1,63) = 15.56$, $MSE = 3265.30$, $p < .001$; $F_2(1,15) = 6.04$, $MSE = 1999.97$, $p = .03$]. The effect of target sentence was not significant [$F_1(1,63) = 2.04$, $MSE = 3297.02$, $p = .16$; $F_2(1,15) = 1.08$]. Although the interaction term did not reach significance [$F_1(1,63) = 3.98$, $MSE = 3184.26$, $p = .05$; $F_2(1,15) < 1$], paired comparisons showed a significant difference in response times in the ambiguous condition [$F_1(1,63) = 16.73$, $MSE = 3414.61$, $p < .001$; $F_2(1,15) = 5.67$, $MSE = 1835.56$, $p = .03$], but not in the unambiguous condition [$F_1(1,63) = 2.10$, $MSE = 3034.95$, $p = .15$; $F_2(1,15) = 1.80$, $MSE = 1587.45$, $p = .20$]. Response times to the inference probe words were faster in the unambiguous versus ambiguous condition [$F_1(1,63) = 11.93$, $MSE = 3525.09$, $p = .02$; $F_2(1,15) = 1.91$, $MSE = 1274.66$, $p = .19$], whereas response times to the control probe words in the two conditions did not significantly differ (*F*s < 1).

Table 3
Mean lexical decision times for inference probe words (correct responses only) for Experiment 1c

	Inference	Control	Difference
Unambiguous clause	578 (12)	564 (12)	14
Ambiguous clause	602 (12)	560 (11)	42

Note. Response times are reported in milliseconds. Standard errors are reported in parentheses. "Control" refers to the condition in which the inference was stated in the first critical sentence, whereas "Inference" refers to the condition in which it was not.

Overall, this pattern supports the conclusion that the increased resource demands in the ambiguous condition interfered with inferencing, whereas readers were able to form the inferences in the unambiguous condition. Thus, the results converge with those from Experiment 1a to provide evidence for the shared resource assumption.

4.2.2. Comprehension performance

Comprehension scores were collapsed across first critical sentence condition. Performance did not significantly differ for unambiguous sentences ($M = 86\%$, $SEM = 2$) and ambiguous sentences ($M = 82\%$, $SEM = 2$), $F_1(1,63) = 2.20$, $MSE = 179.73$, $p = .14$; $F_2(1,15) = 1.41$, $MSE = 77.28$, $p = .25$. Thus, the comprehension difference in the ambiguous and unambiguous conditions found in Experiment 1a did not replicate, which provides tentative evidence against an output dependence account of the differences in response times found here. Experiments 2a–2c were conducted to further evaluate this account.

5. Experiment 2a

According to the output dependence account, inferencing may have been constrained in the ambiguous sentence condition in Experiment 1a because readers often did not arrive at the correct interpretation of the information in the relative clause. The concern here is that a correct interpretation of the information in the relative clause may have been necessary to establish the inference. However, inspection of the materials revealed that in most cases, the information needed to make the target inference was primarily contained in the main clause of the sentence. Nonetheless, in Experiment 1a, the difficulty of reanalyzing the relative clause in the ambiguous target sentence may have interfered with arriving at the correct interpretation of the main clause. If so, then inferencing in the ambiguous sentence condition may have been compromised because the information needed from the main clause was unavailable (i.e., output dependence). Thus, it is important to establish the extent to which the main clause of the target sentence was parsed correctly in the ambiguous condition, relative to the unambiguous condition.

To do so, a different set of comprehension questions were used in Experiment 2a. Specifically, questions were written that tested whether the *main clause* of the target sentence had been parsed correctly (in contrast to the questions used in Experiment 1a, which primarily tapped comprehension of the relative clause). Lower comprehension performance in the ambiguous condition than in the unambiguous condition would suggest that the difficulty of reanalyzing the relative clause in ambiguous sentences interfered with interpretation of the main clause, and thus that output dependence may have contributed to the constrained inferencing in the ambiguous condition. Alternatively, equivalent comprehension performance in the ambiguous and unambiguous conditions would suggest that the limited inferencing in the ambiguous condition was not because readers were less likely to correctly interpret the main clause that supported the inference.

5.1. Method

Fifty-six undergraduates participated to partially satisfy course requirements in Introductory Psychology. The design, materials and procedure were identical to those used in Experiment 1a, except that comprehension questions specifically testing whether the main clause had been parsed correctly were used. A minor change was also made to the lexical decision probe words presented during a subset of the filler texts. This alteration is not relevant to evaluation of the output dependence account but is relevant to an issue addressed by Experiment 3, and thus it will be described further in the context of that discussion.

5.2. Results and discussion

Reading times (in ms) were longer for ambiguous sentences ($M = 5058$, $SEM = 227$) than for unambiguous sentences ($M = 3966$, $SEM = 148$) [$F_1(1,55) = 41.37$, $MSE = 807493.49$, $p < .001$; $F_2(1,15) = 22.37$, $MSE = 414847.61$, $p < .001$], suggesting that syntactic processing was more demanding for ambiguous sentences.

5.2.1. Response times

Mean times for correct responses to lexical decision probe words (96% of trials) are reported in Table 2. A repeated measures ANOVA yielded no main effect of target sentence (Fs < 1) and a significant main effect of probe word [$F_1(1,55) = 21.30$, $MSE = 7424.18$, $p < .001$; $F_2(1,15) = 6.84$, $MSE = 8186.47$, $p < .02$]. The critical interaction obtained [$F_1(1,55) = 4.07$, $MSE = 6023.59$, $p < .05$; $F_2(1,15) = 3.85$, $MSE = 2041.76$, $p < .07$], replicating the key finding from Experiment 1. Thus, inferencing was constrained in the ambiguous sentence condition relative to the unambiguous condition. Although response times were faster to inference probe words than to control probe words after both unambiguous and ambiguous sentences [unambiguous: $F_1(1,55) = 17.89$, $MSE = 8584.58$, $p < .001$, $F_2(1,15) = 10.89$, $MSE = 4850.10$, $p = .005$; ambiguous: $F_1(1,55) = 5.98$, $MSE = 4863.18$, $p < .02$, $F_2(1,15) = 2.05$, $MSE = 5379.57$, $p = .17$], the effect was clearly weaker after ambiguous sentences than after unambiguous sentences. There was a trend for faster response times to the inference probe words in the unambiguous versus ambiguous condition [$F_1(1,55) = 3.93$, $MSE = 5454.75$, $p = .053$; $F_2(1,15) = 1.91$, $MSE = 1274.66$, $p = .19$]. Response times to the control probe words in the two conditions did not significantly differ (Fs < 1).

5.2.2. Comprehension performance

As performance on the comprehension questions following the critical texts did not vary with probe word condition, results were collapsed across this variable. Performance was uniformly high and did not significantly differ for unambiguous sentences ($M = 88\%$, $SEM = 1$) and for ambiguous sentences ($M = 86\%$, $SEM = 2$), Fs < 1. Thus, participants were as successful at extracting information from the main clause in the ambiguous condition as they were in the unambiguous condition, suggesting that any contribution of inferior main clause output to constrained inferencing in the ambiguous condition was minimal.

6. Experiment 2b

Experiment 2a established that the difficulty of reanalyzing the relative clause in the ambiguous target sentence did not interfere with arriving at the correct interpretation of the main clause. Informal inspection of the materials suggested that in most cases, the main clause contained the relevant information for making the target inference. Experiment 2b was conducted to provide empirical support for this assumption. In Experiment 2b, the relative clause was removed from each target sentence (e.g., "The animal [that was] curled up in the corner jumped forward suddenly" was changed to "The animal jumped forward suddenly"), leaving only the information in the main clause. If the information contained in the main clause of the sentence is sufficient to form the inference, response times will be faster to inference probe words than to control probe words, despite the absence of the relative clause. Alternatively, if the information in the relative clause is necessary to establish the inference, readers will not be able to form the target inferences. The latter finding would be consistent with the output dependence account of the pattern of response times in Experiment 1a, according to which inferencing may have been constrained in the ambiguous sentence condition because readers often did not arrive at the correct interpretation of the information in the relative clause.

6.1. Method

Twenty-four undergraduates participated to partially satisfy course requirements in Introductory Psychology. The within-subject variable was probe word (inference or control). The materials and procedure were identical to those used in Experiment 1a, except that the relative clause was removed from the target sentence in each text, and comprehension questions were revised accordingly (to tap understanding of content other than the now absent relative clauses).

6.2. Results and discussion

Response times were analyzed for correct responses to lexical decision probe words (96.4% of trials). Response times were faster for inference probe words ($M = 632$, $SEM = 23$) than for control probe words ($M = 686$, $SEM = 24$), $F_1(1,23) = 8.15$, $MSE = 4326.06$, $p < .01$; $F_2(1,15) = 7.445$, $MSE = 5664.14$, $p < .02$. This finding indicates that the information contained in the relative clauses in Experiment 1a was not necessary to establish the inferences. These results also demonstrate that the information contained in the main clause of the target sentences was sufficient to establish the inferences.

7. Experiment 2c

Experiments 2a and 2b provide evidence that weighs against the output dependence account for the interference of syntactic processing with causal inferencing. Specifically, readers did not require a correct interpretation of the relative clause to make the inference, and they were able to correctly interpret the main clause that was sufficient for the inference. However, one final source of output dependence is still possible: although readers did not require a correct interpretation of the relative clause to draw the inference, an *incorrect* interpretation may have yielded information inconsistent with the intended inference. Consider again the ambiguous version of the target sentence from above, "The animal curled up in the corner jumped forward suddenly." As explained previously, most readers will initially assume that "curled" is the main verb of the sentence and will need to reanalyze downstream when they encounter the actual main verb of the sentence ("jumped"). However, readers may fail to correctly reanalyze the relative clause. Even if they ultimately arrive at the correct interpretation, the representation of the initial incorrect interpretation may linger (Christianson et al., 2001). In the example above, "curled" would still be marked as a main verb, and the reader's interpretation would consist of "The animal curled up in the corner and jumped forward suddenly." On one hand, this incorrect interpretation does not seem grossly inconsistent with the intended inference (i.e., that Mary scared the animal). On the other hand, the misinterpretation may result in subtle semantic differences that would make the inference less likely—for example, perhaps an animal that first curled up after Mary tapped on the cage would seem more playful than scared.

To investigate the extent to which an incorrect interpretation of the relative clause might interfere with inferencing, the ambiguous version of each target sentence was revised in Experiment 2c. Specifically, each target sentence was written so that the ambiguous verb was in fact a main verb in the sentence—that is, each ambiguous sentence now included what would have been the "incorrect" interpretation of the relative clause in the previous experiments. If interpreting the ambiguous verb as a main verb yields a meaning that is less consistent with the intended inference, then inferencing will be constrained in the ambiguous condition (relative to the unambiguous condition). This finding would be consistent with an output dependence account. In contrast, the shared resource account predicts that inferencing will not be constrained in the ambiguous condition when the ambiguous verb resolves as a main verb. The logic is thus: If readers initially assume that the ambiguous verb is a main verb, when it is in fact a main verb there will be no need for reanalysis. If reanalysis is not required, the resource demands of parsing ambiguous versus unambiguous sentences will not differ, and thus inferencing in the two conditions should not differ.

7.1. Method

Forty-seven undergraduates participated to partially satisfy course requirements in Introductory Psychology. The design, materials and procedure were identical to those used in Experiment 1a, with two exceptions. First, the ambiguous versions of the target sentences were revised so that the ambiguous verb resolved as the main verb, as described above. In each case, this involved the addition of one function word (either "and" or "but"). For example, the target sentence "The family doctor begged to come at once would be there soon" was changed to "The family doctor begged to come at once and would be there soon." Second, any comprehension question testing comprehension of the relative clause were revised to tap understanding of content other than the now altered relative clause.

7.2. Results and discussion

Reading times (in ms) did not differ for ambiguous sentences ($M = 4853$, $SEM = 207$) and unambiguous sentences ($M = 4967$, $SEM = 195$), Fs < 1, which suggests that the resource demands of parsing ambiguous versus unambiguous sentences did not differ.

7.2.1. Response times

Mean times for correct responses to lexical decision probe words (97% of trials) are reported in Table 2. A repeated measures ANOVA yielded no main effect of target sentence (Fs < 1) and a main effect of probe word [$F_1(1,46) = 21.27$, $MSE = 15868.32$, $p < .001$; $F_2(1,15) = 3.68$, $MSE = 14851.09$, $p = .074$]. The interaction was not significant, Fs < 1. Thus, as predicted by the shared resource assumption, inferencing here was not constrained in the ambiguous condition relative to the unambiguous condition. Response times were faster to inference probe words than to control probe words both after unambiguous sentences [$F_1(1,46) = 9.09$, $MSE = 19188.09$, $p = .004$; $F_2(1,15) = 3.08$, $MSE = 10142.61$, $p < .10$] and after ambiguous sentences [$F_1(1,46) = 11.41$, $MSE = 14301.98$, $p = .001$; $F_2(1,15) = 3.04$, $MSE = 7796.81$, $p = .10$]. Response times to the inference probe words in the unambiguous versus ambiguous condition did not significantly differ (Fs < 1.22), nor did response times to the control probe words in the two conditions (Fs < 1).

7.2.2. Comprehension performance

As performance on the comprehension questions following the critical texts did not vary with probe word condition, results were collapsed across this variable. Performance was uniformly high and did not significantly differ for unambiguous sentences ($M = 88\%$, $SEM = 2$) and for ambiguous sentences ($M = 85\%$, $SEM = 2$), Fs < 1.53.

8. Experiment 3

The results thus far are most consistent with the shared resource assumption, according to which the increased resource demands associated with reanalyzing ambiguous syntax limited the resources available for inferencing. However, the specific nature of the resource dependence that constrained inferencing is unclear at this point. Several theories assume that the cognitive resources available to the text processing system must be used for both processing and maintenance of intermediate and final products (e.g., Just & Carpenter, 1992). Accordingly, one possibility is that the available resources were insufficient to support the *processing* of the inference (e.g., integration of the various pieces of information involved in the inference). Another non-exclusive possibility is that available resources were insufficient to support *maintenance* of information needed for the inference (cf. Carpenter & Just, 1989). The increased demands of processing the ambiguous second sentence may have limited the resources available for maintaining the critical information from the first sentence while the second one was being processed. Thus, failure to establish the inference would result because the various pieces of information that supported the inference were not concurrently active.

Experiment 3 was designed to evaluate the hypothesis that the resource demands of reanalyzing syntactically ambiguous sentences interfered with the maintenance of information needed to establish inferences. Instead of using probe words corresponding to the inference concept, a key *content* word from the first of the two critical sentences (i.e., the sentence preceding the target sentence) was presented after the target sentence (e.g., for the sentence pair "Mary tapped on the front of a cage. The animal that was curled up in the corner jumped forward suddenly," TAPPED was used as a probe word). Response times to content probe words were compared to response times for matched control words (e.g., FANNED).

Results from Experiment 1a suggested that inferences were established when the syntax of the target sentence was unambiguous, implying that readers maintained the important content from the first critical sentence through processing of the subsequent target sentence. Accordingly, after unambiguous target sentences, response times were predicted to be faster to content probe words than to control probe words. The more interesting prediction concerns the pattern of response times in the ambiguous sentence condition. If the resource demands of reanalyzing ambiguous syntax interferes with maintenance, an interaction is predicted to obtain such that the difference in response times to content and control probes will be smaller after ambiguous sentences than after unambiguous sentences. Alternatively, to the extent that the increased demands of parsing ambiguous sentences interferes with the processing of the information needed for the inference rather than with the maintenance of this information, only a main effect of probe word is predicted.

8.1. Method

8.1.1. Participants and design

Twenty-four undergraduates participated to partially satisfy course requirements in Introductory Psychology. The two within-subject variables were target sentence (ambiguous or unambiguous) and probe word (content or control).

8.1.2. Materials and procedure

The materials and procedure were identical to those used in Experiment 1a (including the comprehension questions), except for the probe words used in the lexical decision task. Instead of inference probe words, one of the key content words from the first critical sentence was selected. For each content probe word, a control word was selected that had the same number of letters and syllables, was the same part of speech, and had a similar word frequency (mean occurrences per 1,000,000 words was 56 with $SD = 48$ for both content and control words, based on the norms from Kucera & Francis, 1967).

To provide evidence that the content and control words were suitably matched, whichever of the two probe words was not presented in the critical text on a given trial was instead presented after a sentence in a filler text that was not semantically related to either the content or the control probe word. For correct responses to probe words when presented in filler contexts, mean response time was 684 ms ($SEM = 30$) for content probes and 654 ms ($SEM = 27$) for control probes, $t(23) = 1.08$.

8.2. Results and discussion

Reading times (in ms) were longer for ambiguous sentences ($M = 5658$, $SEM = 685$) than for unambiguous sentences ($M = 4040$, $SEM = 346$), $F_1(1,23) = 9.50$, $MSE = 3306043.13$, $p = .005$; $F_2(1,15) = 7.33$, $MSE = 2858963.89$, $p = .016$.

8.2.1. Response times

Mean times for correct responses to lexical decision probe words (97.3% of trials) are reported in Table 4. A repeated measures ANOVA yielded only a significant main effect of probe word [$F_1(1,23) = 11.14$, $MSE = 16361.62$, $p = .003$; $F_2(1,15) = 5.91$, $MSE = 18590.16$, $p < .03$]. Neither the main effect of target sentence nor the interaction was significant, Fs < 1.

Table 4
Mean response times to lexical decision probe words (correct responses only) for Experiment 3

	Content probes	Control probes	Difference
Unambiguous clause	621 (31)	714 (27)	93
Ambiguous clause	646 (25)	728 (33)	82

Note. Response times are reported in milliseconds. Standard errors are reported in parentheses.

Thus, response times were faster to content probe words than to control probe words both after unambiguous sentences [$F_1(1,23) = 5.28$, $MSE = 19470.87$, $p = .031$; $F_2(1,15) = 4.44$, $MSE = 11529.40$, $p = .05$] and after ambiguous sentences [$F_1(1,23) = 9.89$, $MSE = 8117.64$, $p = .005$; $F_2(1,15) = 3.99$, $MSE = 14705.05$, $p = .06$]. Response times to the content probe words did not significantly differ in the unambiguous versus ambiguous condition (Fs < 1), nor did response times to the control probe words in the two conditions (Fs < 1).

Overall, these findings suggest that the increased resource demands of reanalyzing ambiguous sentences did not interfere with the maintenance of information that supported the inference. In contrast, the results are consistent with the hypothesis that the increased parsing demands limited the resources available for the processing of the inferences.

One could argue that faster response times to content probe words than to control probe words was due to repetition priming. That is, the response time advantage for content probe words may have been due to relatively low-level priming due to recent encounter of the specific words and not to the maintained activation of important conceptual information for integration with subsequent content. To estimate the potential contribution repetition priming could have made to the observed effects, 16 filler texts in Experiment 2a served as a repetition priming condition. Specifically, a content word from one sentence in each filler text was selected for use as a *repetition* probe word. Across the 16 texts, the characteristics of the repetition probe words used were matched to those of the content probe words used in Experiment 3: mean word frequency was 55 and 56, respectively; mean number of letters was 6.3 in both word sets; mean number of syllables was 1.7 and 1.6, respectively; each word set included 12 nouns, 3 verbs, and 1 adjective. Each repetition probe word was presented after the sentence following the one in which it appeared (as was the case for the content probe words in Experiment 3), with the mean number of intervening words matched with the mean for Experiment 3 (15.8 and 15.1, respectively). In contrast to the criterion used to select content probe words for Experiment 3, an effort was made to select words that did not express the important conceptual information most likely to be carried over for integration with subsequent content (e.g., In the sentence, “She also prepared a wide *range* of special biscuits,” RANGE was used as a repetition probe word but the conceptual information important in the context is “She prepared biscuits”). In the control condition, the word in the text was replaced with a contextually appropriate substitute (e.g., “She also prepared a wide *assortment* of special biscuits,”). Thus, the same word (e.g., RANGE) was used as a probe in both conditions but was only repeated (i.e., had only appeared in the text) in the repetition condition.

Although there was a trend for faster response times when the probe word had appeared in the text ($M = 630$, $SEM = 27$) than when it had not ($M = 660$, $SEM = 24$), this difference did not reach significance $F(1,54) = 2.75$, $MSE = 8849.47$, $p = .10$. Furthermore, the effect is relatively weak compared to the overall advantage for content probe words over control probe words observed in Experiment 3 (a 30 ms difference versus 88 ms, respectively). Thus, repetition priming cannot completely account for the advantage of content probe words over control probes observed in Experiment 3. The idea that the potential contribution of repetition priming was relatively minimal is also consistent with previous research on repetition priming for words embedded in text. Relative to the robust repetition priming effects for isolated words in lists, repetition priming for words previously appearing in text is typically weak for very low frequency words and non-existent for higher frequency words like many of those used in the present experiment (e.g., see discussion and results reported in Speelman, Simpson, & Kirsner, 2002).

8.2.2. Comprehension performance

Comprehension scores were collapsed across probe word condition. Performance did not significantly differ for unambiguous sentences ($M = 74\%$, $SEM = 3$) and ambiguous sentences ($M = 70\%$, $SEM = 5$), $F\text{s} < 1$.

9. Experiment 4

Experiment 3 examined the specific nature of the resource dependence between syntactic processing and causal inferencing, and the results were most consistent with the hypothesis that the increased resource demands of syntactic processing limited the resources available for the processing of inferences (rather than for the maintenance of the information needed to form the inferences). Experiment 4 was designed to examine more closely how the resource demands of one component may interfere with the processing of another. According to the *cancellation hypothesis*, if insufficient resources are available to complete a process in a timely manner, then that process is cancelled. The cancellation may arise either because the process is never initiated, or because it is initiated but then terminated (e.g., a process may be terminated if it fails to complete before the end of the input is reached). According to this account, inferencing was constrained in the ambiguous condition because the inference process was cancelled when insufficient resources were available. In contrast, the *slowing hypothesis* states that when limited resources are available, a process that is allocated fewer resources as a result can still run to completion but will take longer to do so (for relevant discussion see Just & Carpenter, 1992). According to this account, inferencing was constrained in the ambiguous condition because the inference process had been allocated fewer resources and thus had not yet completed when the probe word was presented.

To evaluate these two hypotheses, a simple change was made to the procedure used so far. In the previous experiments, probe words were presented 750 ms after the preceding sentence. In Experiment 4, this interval was increased, with probe words presented 1500 ms after the preceding sentence. If the increased resource demands of syntactic processing result in the cancellation of the inference process, then allowing additional time for completion should not matter—that is, the cancellation hypothesis predicts that inferencing will still be constrained in the ambiguous condition, relative to the unambiguous condition. However, if the increased resource demands of syntactic parsing result in the slowing of the inference process, the inference process may be completed if allowed additional time to compensate for the reduced allocation of resources—that is, the slowing hypothesis predicts that inferencing will no longer be constrained in the ambiguous condition, relative to the unambiguous condition.

An additional advantage of the design of Experiment 4 is that it allows further evaluation of two alternative accounts introduced earlier. First, consider again the idea that inferencing was constrained in the ambiguous condition because insufficient resources were available for the maintenance of the information needed to form the inference (see Experiment 3). If the necessary information has not been maintained through 750 ms, it is unlikely to be available after 1500 ms. Thus, this account predicts that inferencing will still be constrained after 1500 ms.

Second, the output dependence account states that inferencing was constrained in the ambiguous condition because the inference process received inferior output from syntactic parsing. If the output of syntactic parsing is inferior 750 ms after the sentence, the most straightforward assumption is that the output of syntactic parsing will still be inferior after 1500 ms. Any further syntactic reanalysis is unlikely to take place during the additional 750 ms after the sentence boundary and the first 750 ms interval, given previous research showing that reanalysis is typically completed at the point of disambiguation (e.g., Clifton, Speer, & Abney, 1991; Ferreira & Henderson, 1990; Hoeks, Vonk, & Schriefers, 2002; Pickering, Traxler, & Crocker, 2000, Experiments 1–2; Rayner et al., 1992; Trueswell, 1996). Some research has shown increased reading times in the spillover region, which is the sentence region immediately following disambiguation (e.g., Pearlmutter & MacDonald, 1995; Pickering et al., 2000, Sturt, Pickering, Scheepers, & Crocker, 3; Sturt et al., 2001; cf. Mak, Vonk, & Schriefers, 2002 Traxler, Morris, & Seely, 2002, for unambiguous sentences of varying difficulty). Unfortunately, not all research reports reading times for regions beyond the spillover region. However, when reading times for subsequent regions have been reported, reading times have typically been shown to return to baseline by the end of the sentence (e.g., Pearlmutter & MacDonald, 1995; Schneider & Phillips, 2001; Sturt et al., 2001, Experiment 1; but see Sturt et al., 2001, Sturt, Scheepers, & Pickering, 23 & Sturt et al., 2002). Thus, the most straightforward prediction of the output dependence account is that inferencing will still be constrained after 1500 ms.

9.1. Method

Forty-two undergraduates participated to partially satisfy course requirements in Introductory Psychology. The design, materials and procedure were identical to those used in Experiment 1, except that probe words were presented 1500 ms after the preceding sentence, rather than 750 ms as in Experiment 1a.

9.2. Results and discussion

Reading times (in ms) were longer for ambiguous sentences ($M = 4731$, $SEM = 236$) than for unambiguous sentences ($M = 4183$, $SEM = 204$), $F_1(1,41) = 7.59$, $MSE = 832774.04$, $p = .009$; $F_2(1,15) = 5.91$, $MSE = 449128.50$, $p = .028$.

9.2.1. Response times

Mean times for correct responses to lexical decision probe words (98% of trials) are reported in Table 2. A repeated measures ANOVA yielded no main effect of target sentence [$F_1(1,41) = 2.29$, $MSE = 8729.37$, $p = .14$; $F_2 < 1$], a significant main effect of probe word [$F_1(1,41) = 30.45$, $MSE = 5118.10$, $p < .001$; $F_2(1,15) = 7.06$, $MSE = 6495.34$, $p = .018$], and a significant interaction [$F_1(1,40) = 4.82$, $MSE = 5315.64$, $p < .05$; $F_2(1,15) = 3.30$, $MSE = 4361.36$, $p = .089$]. Somewhat surprisingly, the evidence for inferencing was actually stronger in the ambiguous condition than in the unambiguous condition, although response times were faster for inference probe words than for control probe words in both conditions [unambiguous: $F_1(1,41) = 6.68$, $MSE = 4368.62$, $p = .013$, $F_2 < 1.12$; ambiguous: $F_1(1,41) = 25.12$, $MSE = 6128.80$, $p < .001$, $F_2(1,15) = 8.13$, $MSE = 6862.73$, $p = .012$]. Response times to the inference probe words did not significantly differ in the unambiguous versus ambiguous condition (Fs < 1). Response times to the control probe words were faster in the unambiguous condition than in the ambiguous condition [$F_1(1,41) = 6.52$, $MSE = 6965.95$, $p = .015$; $F_2(1,15) = 2.77$, $MSE = 4560.04$, $p = .12$].

Although the decline in inferencing in the unambiguous condition was not predicted, a straightforward explanation is that because the inference was completed earlier in the unambiguous condition, activation for the inference concept began to decline with the longer delay. Although outside the scope of the current study, future research could be directed at further exploring the time course of the maintenance of inferential concepts after inferences are formed (previous research has focused primarily on how long various inferences take to develop, e.g., Calvo, 2001; Kintsch, 1998; Myers, O'Brien, Albrecht, & Mason, 1994).

Most important for present purposes, inferencing in the ambiguous condition clearly was not constrained relative to the unambiguous condition. This finding is inconsistent with the cancellation hypothesis and also provides further evidence against the output dependence account and the hypothesis that limited resources were available for the maintenance of information. Each of these accounts predicted that inferencing would still be constrained after 1500 ms. In contrast, the results are consistent with the slowing hypothesis. Although speculative, the slowing account also provides a possible explanation for the elevated response times to control probes in the ambiguous condition, relative to the unambiguous condition. If the trends for slower response times to control probe words in the unambiguous condition in previous experiments were due to some spillover of wrap-up processing, the slowing hypothesis would expect that completion of wrap-up processing would be evidenced at a later point in the ambiguous condition.

9.2.2. Comprehension performance

As performance on the comprehension questions following the critical texts did not vary with probe word condition, results were collapsed across this variable. Performance was greater for unambiguous sentences ($M = 79\%$, $SEM = 2$) than for ambiguous sentences ($M = 69\%$, $SEM = 2$), $F_1(1,41) = 10.03$, $MSE = 214.32$, $p = .003$; $F_2(1,15) = 4.76$, $MSE = 174.83$, $p < .05$.

10. General discussion

The present research evaluated the shared resource assumption, which is central to several prominent theoretical accounts of text processing. Consistent with the assumption, Experiments 1a, 1c, and 2a showed that the increased resource demands of one text processing component (syntactic reanalysis) can interfere with the successful operation of another component process (causal inferencing).[5] The pattern of results across Experiments 2a-4 suggested that output dependence between the two components contributed minimally to this interference. Although output dependence contributed minimally to interference between components in the current situation, it is clearly a plausible and theoretically important form of interaction between the various components involved in text processing. As such, it may be responsible for interference in other situations. One factor

[5] One possibility is that the reduced relative structure results not only in more difficult syntactic processing, but also in more difficult semantic parsing. Thus, the resource demands of these processes may contribute to the interference with inferencing. Importantly, any contribution of semantic parsing to the disruption of inferencing is consistent with the primary goal of the paper—to evaluate the shared resource assumption—which states that text processing components share resources. Interference between syntactic parsing and causal inferencing supports the assumption, but so too would any interference of semantic parsing with inferencing.

that may influence the extent to which output dependence contributes to interference between components is text difficulty. For example, the overall quality of processing output is likely to be better for simple narratives on familiar themes (as in the present research) than for more difficult expository texts on unfamiliar topics. Thus, output dependence would likely play a more prominent role in the processing of expository texts than of narrative texts.

Given that Experiments 2a-4 showed a minimal contribution of output dependence to constrained inferencing, the patterns of response times found in Experiments 1a, 1c, and 2a are better understood as resulting from some form of resource dependence. The fact that evidence for processing resource competition obtained even with simple narratives suggests that interference between components due to processing resource demands is likely to be a relatively general phenomenon in text processing.

Experiments 3–4 further clarified the nature of this resource dependence. Results suggested that syntactic processing interfered with inferencing by limiting the resources available for processing, rather than by limiting the resources available for maintenance of process inputs. Experiment 3 showed that processing the ambiguous sentences did not interfere with maintenance of key concepts from preceding sentences. The results of Experiment 1c provide converging evidence for this conclusion. If reanalyzing ambiguous syntax interfered with maintenance of previous text information, the explicitly stated inference concept in the control condition of Experiment 1c should have been less activated after ambiguous target sentences than after unambiguous target sentences. If so, one would have expected slower response times after ambiguous target sentences than after unambiguous sentences in the control condition. However, this was clearly not the case (with a slight numerical advantage in the opposite direction). Overall, Experiments 1c, 3, and 4 support the conclusion that increased demands of syntactic processing did not interfere with maintenance of key concepts.

This conclusion may seem somewhat surprising, given the earlier research by Carpenter and Just in which the syntactic processing demands of complex sentences were shown to interfere with maintenance of an extrinsic memory load. One possibility is that intentional maintenance of a short list of unrelated words across unrelated sentences differs from the kind of information maintained during the processing of connected discourse and in the way that information is maintained. Given the present finding that increased processing demands of syntactic processing interfered minimally with maintenance of previous content, further research is needed before conclusions from research using isolated sentences and extrinsic memory loads can be confidently generalized to situations involving the processing of text material and the maintenance of information intrinsic to the text processing task itself.

Just as the present results are not consistent with particular versions of the shared resource assumption, they are also not necessarily inconsistent with all theories assuming separate resources. For example, the finding that syntactic processing demands did not interfere with maintenance of information from a preceding sentence is not inconsistent with the account forwarded by Martin and Romani (1994). To revisit, based on neuropsychological data, they proposed that the maintenance of phonological, syntactic, and semantic information is supported by separate resources. If one further assumes that resources available for maintenance are also separate from those used for processing, then the processing demands of syntactic parsing would not be expected to interfere with the maintenance of semantic information.

The present findings are less easily reconciled with SSIR theory, which assumes that separate resources are available for sentence interpretation processes and post-interpretive processes. If the present pattern of interference is due to the interference of syntactic reanalysis processes with causal inferencing, reconciliation of these findings with SSIR would require either (a) inclusion of causal inferencing in sentence interpretation processes or (b) exclusion of syntactic reanalysis processes from sentence interpretation processes. Concerning the former, the target inferences in the present materials required the integration of semantic information across two sentences, which violates the definition of interpretive processing as "assigning syntactic structure and using it to determine the meaning of a sentence" (Caplan & Waters, 1999, p. 79). Thus, this route to reconciliation would require the expansion of the definition of sentence interpretation within SSIR theory. By contrast, syntactic reanalysis is clearly involved in deriving the syntactic structure of a sentence and thus it would seem difficult to exclude these processes from interpretive processing on definitional grounds. In either case, reconciliation of the present findings with SSIR theory would require further specification of the processes thought to be serviced by interpretive versus post-interpretive resources.

On a related note, Caplan and Waters (1999) briefly introduced a more generalized account in their closing discussion, the separate language interpretation resource (SLIR) hypothesis, which does explicitly exclude syntactic reanalysis from interpretive processes. However, the basis for distinguishing between interpretive and post-interpretive processes in SLIR is somewhat different than in SSIR, with interpretive processes "thought to be obligatorily activated when their inputs are attended to. They generally operate unconsciously, and they usually operate quickly and remarkably accurately" (p. 93). They distinguish the resources available to these "obligatory, unconscious, and fast" processes from those available to processes that require "conscious, slow, controlled processing" (p. 93). To the extent that syntactic reanalysis and causal inferencing are both conscious, slow, controlled processes, the present results would not be inconsistent with SLIR because the interference would involve two post-interpretive processes. However, syntactic reanalysis is not always slow nor does it always involve conscious, controlled processing (for relevant discussion, see Ferreira, 1999). Likewise, causal inferencing can often be performed relatively quickly, without controlled processing, and outside of conscious awareness (Singer, Graesser, & Trabasso, 1994). More generally, conceptual difficulties arise from using continuous variables to define dichotomous categories (Rawson, 2004). Caplan and Waters (1999) acknowledged "that some reanalysis is part of the interpretation process…We recognize that there is no full theory of the set of processes that constitute interpretive and post-interpretive processing and of their boundary. The distinction is admittedly vague enough to allow researchers to use it to escape from unwelcome results" (p. 116). Thus, further theoretical specification may be necessary to clearly determine how the present results bear on the SLIR hypothesis.

The present findings do inform the important issue concerning the relative contributions of the various component processes to differences in reading comprehension ability. Previous researchers have proposed that lower-level processes such as syntactic parsing are primarily responsible for comprehension differences between high-skill and less-skilled readers (e.g., Perfetti, 1988). However, Long, Oppy, and Seely (1997) reported evidence that high-skill and less-skilled readers generate low-level representations of equivalent quality, and they concluded that differences in skill are attributable to deficiencies of higher-level processes. The present account suggests a possible reconciliation of these views: High- and less-skilled readers may achieve similar levels of success at lower levels of processing (as demonstrated by Long et al., 1997), but less-skilled readers may require more resources to do so. This greater demand would leave fewer resources available for higher-level processes, which would explain the evidence that less-skilled readers are less likely to make inferences during reading. However, the failure to make inferences would not be due to deficient inference processes per se, but rather to insufficient resources available for inference processes to operate due to the demands of lower-level processes. Although speculative, this discussion illustrates the promise of the basic approach of this research for addressing important theoretical questions within the field.

The current method also provides an important tool for answering other key questions concerning the shared resource assumption. For instance, the basic approach can be used to establish the generality of the present conclusion that the processing demands of one component can limit the resources available for the processing of another. Future studies will be directed at further exploring the resource dependence between syntactic parsing and inferencing (e.g., by extending to other syntactic constructions and other kinds of inference) and to exploring interactions between these and other component processes (including those mentioned in the Introduction, e.g., semantic parsing and lexical analysis). Thus, the present research represents important foundational work by providing initial evidence for processing resource interference between components and also by introducing experimental methods that may be fruitfully employed in future research.

Appendix A. Critical sentence pairs, inference and control probe words for lexical decision, and comprehension questions

Note: For the target sentence in each pair, the words in brackets were included in the unambiguous condition and were not included in the ambiguous condition. The capitalized words below each pair are the corresponding inference and control probe words, respectively. The first comprehension question for each pair was used in Experiment 1a, and the second comprehension question for each pair was used in Experiment 2a.

Susan felt her baby's forehead with her palm.
The family doctor [that she] begged to come at once would be there soon.
FEVER DAIRY
Did the doctor beg Susan?
Was the doctor going to be there soon?

Lisa had to drive to her office an hour each way.
The paper [that was] opened to the apartment listing caught her eye.
CLOSER NARROW
Was the paper opened to apartments?
Did the paper catch Lisa's eye?

The drawing for the contest was going to be made soon.
The woman [who was] mailed the information was pleasantly surprised.
WON SIT
Did the woman mail the information?
Was the woman surprised?

Ellen was not able to eat breakfast before work.
The restaurant [that she] visited for an early lunch was excellent.
HUNGRY STUPID
Was the restaurant excellent?
Was the restaurant not very good?

Mary tapped on the front of a cage.
The animal [that was] curled up in the corner jumped forward suddenly.
SCARED CARVED
Did the animal curl up suddenly?
Did the caged animal move slowly backward?

Tim and his friends decided to see who could throw rocks the farthest.
The neighbor [who was] rushed to the hospital had to get fourteen stitches.
HIT SUN
Did someone take the neighbor to the hospital?
Did the neighbor have to get stitches?

Jerry was proofreading the copy of his manuscript.
The secretary [that he] yelled at the next day quit.
ERRORS BAKERS
Did the secretary yell at someone?
Did the secretary quit?

Steve was organizing a group to make signs and to contact the press.
The workers [who were] presented the last offer from management had been insulted.
STRIKE SCREEN
Did the workers present the offer?
Did the workers insult someone?

Detective Benson had received a call early this afternoon.
The gallery [that was] sold the famous paintings reported it immediately.
STOLEN HUMBLE
Did the gallery sell the paintings?
Did the gallery contact the police?

Judith's parents realized what happened while they were gone.
The wine [that was] spilled on the rug was difficult for Judith to conceal.
PARTY LEVEL
Was the wine difficult to conceal?
Was the wine easy to conceal?

Today, ominous clouds rolled in over the mountains.
The climbers [who were] expected to descend on Monday were delayed.
STORM TREAT
Did the climbers descend on Monday?
Did the climbers descend on time?

A servant discovered that the refrigerator's motor was broken.
The chef [who was] asked to prepare the steaks immediately had to throw them out.
SPOILED CLOAKED
Did the chef ask to prepare the steaks?
Did the chef keep the steaks?

Cleo brushed against a table with a vase on it.
The water [that] spilled wet the expensive carpet.
KNOCKED BOOSTED
Did the water spill on the carpet?
Did the water get the carpet wet?

Congress announced that the budget for the next fiscal year had been decided.
Military officials [who were] delivered the reports were unhappy with the changes.
CUT RED
Were the military officials unhappy?
Were the military officials pleased?

George booked a flight that was going out tomorrow afternoon.
The old friend [that he] remembered fondly had unexpectedly passed away.
FUNERAL HARMONY
Did George remember his old friend?
Had George expected his friend to die?

Scott waited impatiently with the other children.
The boy [who was] sat on the pony was coming back around.
RIDE PAIR
Did someone sit the boy on the pony?
Was the boy coming back around?

References

Binder, K. S., Duffy, S. A., & Rayner, K. (2001). The effects of thematic fit and discourse context on syntactic ambiguity resolution. *Journal of Memory and Language, 44*, 297–324.

Britt, M. A., Perfetti, C. A., Garrod, S., & Rayner, K. (1992). Parsing in discourse: Context effects and their limits. *Journal of Memory and Language, 31*, 293–314.

Calvo, M. G. (2001). Working memory and inferences: evidence from eye fixations during reading. *Memory, 9*, 365–381.

Caplan, D., & Waters, G. S. (1999). Verbal working memory and sentence comprehension. *Behavioral and Brain Sciences, 22*, 77–126.

Carpenter, P. A., & Just, M. A. (1989). The role of working memory in language comprehension. In H. A. Simon, D. Klahr, & K. Kotovsky (Eds.), *Human information processing* (pp. 31–68). Hillsdale, NJ: Lawrence Erlbaum.

Christianson, K., Hollingworth, A., Halliwell, J. F., & Ferreira, F. (2001). Thematic roles assigned along the garden path linger. *Cognitive Psychology, 42*, 368–407.

Clifton, C., Jr., Speer, S., & Abney, S. P. (1991). Parsing arguments: phrase structure and argument structure as determinants of initial parsing decisions. *Journal of Memory and Language, 30*, 251–271.

Cook, A. E., Limber, J. E., & O'Brien, E. J. (2001). Situation-based context and the availability of predictive inferences. *Journal of Memory and Language, 44*, 220–234.

Duffy, S. A., Morris, R. K., & Rayner, K. (1988). Lexical ambiguity and fixation times in reading. *Journal of Memory and Language, 27*, 429–446.

Ferreira, F. (1999). Distinguishing interpretive and post-interpretive processes. *Behavioral and Brain Sciences, 22*, 98–99.

Ferreira, F., & Clifton, C., Jr. (1986). The independence of syntactic processing. *Journal of Memory and Language, 25*, 348–368.

Ferreira, F., & Henderson, J. M. (1990). Use of verb information in syntactic parsing: evidence from eye movements and word-by-word self-paced reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 555–568.

Frazier, L. (1987). Sentence processing: a tutorial review. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 601–681). Hillsdale, NJ: Lawrence Erlbaum.

Gernsbacher, M. A., Hallada, B. M., & Robertson, R. R. W. (1998). How automatically do readers infer fictional characters' emotional states? *Scientific Studies of Reading, 2*, 271–300.

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review, 101*, 371–395.

Hoeks, J. C. J., Vonk, W., & Schriefers, H. (2002). Processing coordinated structures in context: the effect of topic-structure on ambiguity resolution. *Journal of Memory and Language, 46*, 99–119.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: individual differences in working memory. *Psychological Review, 99*, 122–149.

Keller, T. A., Carpenter, P. A., & Just, M. A. (2001). The neural bases of sentence comprehension: a fMRI examination of syntactic and lexical processing. *Cerebral Cortex, 11*, 223–237.

King, J., & Just, M. A. (1991). Individual differences in syntactic processing: the role of working memory. *Journal of Memory and Language, 30*, 580–602.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: a construction-integration model. *Psychological Review, 95*, 163–182.

Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. Cambridge, UK: Cambridge University Press.

Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.

Long, D. L., Golding, J. M., & Graesser, A. C. (1992). A test of the on-line status of goal-related inferences. *Journal of Memory and Language, 31*, 634–647.

Long, D. L., Oppy, B. J., & Seely, M. R. (1997). Individual differences in readers' sentence- and text-level representations. *Journal of Memory and Language, 36*, 129–145.

Lucas, M. M., Tanenhaus, M. K., & Carlson, G. N. (1990). Levels of representation in the interpretation of anaphoric reference and instrument inference. *Memory & Cognition, 18*, 611–631.

Mak, W. M., Vonk, W., & Schriefers, H. (2002). The influence of animacy on relative clause processing. *Journal of Memory and Language, 47*, 50–68.

Martin, R. C., & Romani, C. (1994). Verbal working memory and sentence comprehension: a multiple-components view. *Neuropsychology, 8*, 506–523.

McKoon, G., & Ratcliff, R. (1989). Assessing the occurrence of elaborative inference with recognition: Compatibility checking vs compound cue theory. *Journal of Memory and Language, 28*, 547–563.

McKoon, G., & Ratcliff, R. (1992). Inference during reading. *Psychological Review, 99*, 440–466.

Millis, K. K., & Graesser, A. C. (1994). The time-course of constructing knowledge-based inferences for scientific texts. *Journal of Memory and Language, 33*, 583–599.

Millis, K. K., Morgan, D., & Graesser, A. C. (1990). The influence of knowledge-based inferences on the reading time of expository text. In A. C. Graesser & G. H. Bower (Eds.), *The psychology of learning and motivation: Inferences and text comprehension* (Vol. 25, pp. 197–212). San Diego, CA: Academic Press.

Millis, K. K., & Simon, S. (1994). Rereading scientific texts: changes in resource allocation. In H. van Oostendorp & R. Zwaan (Eds.), *Naturalistic text comprehension* (pp. 113–133). Norwood, NJ: Ablex Publishing..

Myers, J. L., O'Brien, E. J., Albrecht, J. E., & Mason, R. A. (1994). Maintaining global coherence during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*, 876–886.

Noordman, L. G. M., Vonk, W., & Kempff, H. J. (1992). Causal inferences during the reading of expository texts. *Journal of Memory and Language, 31*, 573–590.

Pearlmutter, N. J., & MacDonald, M. C. (1995). Individual differences and probabilistic constraints in syntactic ambiguity resolution. *Journal of Memory and Language, 34*, 521–542.

Perea, M., Rosa, E., & Gómez, C. (2002). Is the go/no-go lexical decision task an alternative to the yes/no lexical decision task? *Memory & Cognition, 30*, 34–45.

Perfetti, C. A. (1988). Verbal efficiency in reading ability. In M. Daneman, G. E. MacKinnon, & T. G. Waller (Eds.), *Reading research: Advances in theory and practice* (Vol. 6, pp. 109–143). San Diego, CA: Academic Press.

Pickering, M. J., Traxler, M. J., & Crocker, M. W. (2000). Ambiguity resolution in sentence processing: evidence against frequency-based accounts. *Journal of Memory and Language, 43*, 447–475.

Potts, G. R., Keenan, J. M., & Golding, J. M. (1988). Assessing the occurrence of elaborative inferences: lexical decision versus naming. *Journal of Memory and Language, 27*, 399–415.

Raaijmakers, J. G. W., Schrijnemakers, J. M. C., & Gremmen, F. (1999). How to deal with "the language-as-fixed-effect-fallacy": common misconceptions and alternative solutions. *Journal of Memory and Language, 41*, 416–426.

Rawson, K. A. (2004). Exploring automaticity in text processing: syntactic ambiguity as a test case. *Cognitive Psychology, 49*, 333–369.

Rayner, K., Carlson, M., & Frazier, L. (1983). The interaction of syntax and semantics during sentence processing: eye movements in the analysis of semantically biased sentences. *Journal of Verbal Learning and Verbal Behavior, 22*, 358–374.

Rayner, K., & Frazier, L. (1989). Selection mechanisms in reading lexically ambiguous words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 779–790.

Rayner, K., Garrod, S., & Perfetti, C. A. (1992). Discourse influences during parsing are delayed. *Cognition, 45*, 109–139.

Schneider, D., & Phillips, C. (2001). Grammatical search and reanalysis. *Journal of Memory and Language, 45*, 308–336.

Singer, M., Graesser, A. C., & Trabasso, T. (1994). Minimal or global inference during reading. *Journal of Memory and Language, 33*, 421–441.

Singer, M., Harkness, D., & Stewart, S. T. (1997). Constructing inferences in expository text comprehension. *Discourse Processes, 24*, 199–228.

Speelman, C. P., Simpson, T. A., & Kirsner, K. (2002). The unbearable lightness of priming. *Acta Psychologica, 111*, 191–204.

Sturt, P., Pickering, M. J., Scheepers, C., & Crocker, M. W. (2001). The preservation of structure in language comprehension: Is reanalysis the last resort? *Journal of Memory and Language, 45*, 283–307.

Sturt, P., Scheepers, C., & Pickering, M. (2002). Syntactic ambiguity resolution after initial misanalysis: the role of recency. *Journal of Memory and Language, 46*, 371–390.

Traxler, M. J., Morris, R. K., & Seely, R. E. (2002). Processing subject and object relative clauses: evidence from eye movements. *Journal of Memory and Language, 47*, 69–90.

Trueswell, J. C. (1996). The role of lexical frequency in syntactic ambiguity resolution. *Journal of Memory and Language, 35*, 566–585.

Whitney, P., Ritchie, B. G., & Crane, R. S. (1992). The effect of foregrounding on readers' use of predictive inferences. *Memory & Cognition, 20*, 424–432.