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Exploring Causal Connections and their Role in Reunion Effects

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Abstract

Past research on anaphor resolution has investigated the availability of discourse information related to characters that part and reunite. Upon reunion, distant concepts that have been associated with the characters before they separated become more accessible than they were just before the reunion. This phenomenon has been referred to as the *reunion effect* and has been replicated across several studies. In an effort to explain the causes of this effect, we argue that causal relations between sentences determine the availability of discourse information, and test this explanation by performing a causal analysis of materials and five simulations of the data from two sets of published studies. We then present the results of two new experiments that manipulate the causal connection between the reunion sentence and prior discourse concepts. Results show that predictions based on causal relations provide a better fit for observed patterns of data than predictions based in semantic and lexical associations. The results are consistent with a model of text comprehension where causal connections to earlier information are instantiated into an ongoing representation of the discourse, and the accessibility of a concept is a function of its status in this causal model at a given point in time.

What Happens at Reunions?

Exploring Causal Connections and their Role in Reunion Effects

Past research has investigated waxing and waning in the availability of discourse information related to characters that part and reunite (Gerrig & McKoon, 1998; 2001; Gerrig & O'Brien, 2005; Greene, Gerrig, McKoon, & Ratcliff, 1994; Lea, Mason, Albrecht, Birch, & Myers, 1998; Lea, Kayser, Mulligan & Myers, 2002; Long & Lea, 2005; McKoon, Gerrig & Greene, 1996). It has been shown that concepts that were associated with both characters in a story become less accessible after a separation of the characters, and then regain accessibility after a reunion. This phenomenon has been referred to as the *reunion effect*. In an effort to explain the causes of this effect, the central questions of this paper are: How do we access information in a memory representation of a text and what accounts for observed changes in information accessibility?

The approach used in the present research is based on a theory of dynamic causality-based comprehension (Langston, Trabasso & Magliano, 1999; Trabasso & Bartolone, 2003; Trabasso & Wiley, 2005). This theory describes narrative comprehension as the process of tracking characters in space and time, monitoring their concerns, states, and actions, and establishing causal connections between text constituents. The mental text representation resulting from these comprehension processes can be depicted as a causal network where units of information from a text are connected by their causal relationships. During reading, the online accessibility of previously read information is proposed to be a direct function of the degree of causal relation (or causal distance) between that information and the text currently being processed. Thus, the accessibility of concepts mentioned early in a text may be determined by the causal connections available between the early sentence and later sentences.

In this paper, we investigate whether this theory of narrative comprehension can provide a plausible account of reunion effects. We attempt to address this question by simulating the original empirical results of Greene et al. (1994), and Lea, et al. (1998) using causal networks derived from the texts they used in their studies. The results of the simulations are consistent with the theory that reunion effects occur because reunion sentences are causally connected to the early episodes of these texts, which reactivates the concepts in those sentences. However, these results are also consistent with the resonance approach that has been previously used to explain them, which suggests that lexical, semantic

and referential overlap between the reunion sentences and early episodes causes the reactivation of earlier concepts (McKoon, Gerrig, & Greene, 1996; Myers & O'Brien, 1998). Thus, to further investigate the role of causal connections on the reunion effect, two new experiments are reported where we attempt to disentangle the effects of overlap and the presence of direct causal relations between early episodes and reunions.

Previous Accounts of the Reunion Effect

Greene et al. (1994) first established the *reunion effect* with stories in which characters part and reunite. An example story, called "Cousin", published by Greene et al. (1994), is shown in Figure 1. Greene et al. created two versions of each story. Both versions had the same Introduction and Conclusion but varied in their Continuation (the middle component). The Introduction of each version introduces two characters and ends with the departure of one character. The Conclusion of each version begins with the return of that character which brings about the reunion of both characters. During the middle portion of the story, the Continuation focuses on one character or the other. In the Concept Absent condition, the continuation focuses on Gloria, and the target concept COUSIN is not part of the continuation (hence the concept is absent). In the Concept Present condition, also presented in Figure 1, the character Jane is the agent of the action, and the episode involves the cousin. The assumption by Greene et al. (1994) was that the target concept's accessibility would be maintained in the Continuation segment when the agent (Jane) was associated with the concept (cousin) but not when the continuation focused the unassociated agent (Gloria).

-- INSERT FIGURE 1 HERE --

In order to measure the access of the target concepts during reading, word recognition probes were presented after the reading of a sentence at one of three locations (1) Before the Reunion (after sentence 11), (2) After the Reunion (after sentence 12), or (3) After the Pronoun (after sentence 13). In the case of this example story, the recognition probe was COUSIN. The dependent variable was the response time (in milliseconds) taken to recognize the word probe as having occurred or not in the story.

The results showed faster recognition of the probe in the Concept Present condition than in the Concept Absent condition before the reunion. However, there were no differences in recognition times between versions either after the reunion, or after the pronoun sentences. After the reunion sentence,

the recognition times for the Concept Absent version decreased and did not differ from those for the Concept Present version. Greene et al. (1994) concluded that the reunion of the two characters increased the availability of the target concept from the introduction. Thus, the referent for the pronoun was already available following the reunion sentence, and the mention of the unheralded pronoun “she” did not alter accessibility any further. The change in accessibility from before to after the reunion sentence is the *reunion effect*.

To explain their data, Greene et al. (1994) adopted Clark and Marshall's (1981) idea of a reference diary. According to the concept of a reference diary, in conversational discourse participants maintain memory structures of shared experiences to help them interpret referential and ambiguous expressions. As participants enter or exit discourse situations, the memory structures associated with the participants become more or less accessible. Greene et al. (1994) suggested readers might act as third party or “side participants” in a discourse. Thus, when two characters reunite, their shared knowledge becomes more accessible to the reader than it was before the reunion. In the above example story, the conversation between Gloria and Jane in the story's introduction sets up mutual knowledge about the cousin. According to this reference diary account, the reader searches their memory for shared knowledge between the participants, and this knowledge is reinstated in the reader's focus of attention upon their reunion.

In a second set of experiments on the *reunion effect*, Lea et al. (1998) raised the question whether mutual character knowledge was necessary for the effect and offered an alternative explanation using an associative memory-based model of text processing. The key assumption for the associative memory-based model is that word-level and conceptual overlap between reunion sentences and the introduction produces reactivation of information through a *resonance* process (McKoon, Gerrig, & Greene, 1996; Myers & O'Brien, 1998; Myers, O'Brien, Albrecht, & Mason, 1994).

In the Greene et al. (1994) study, it was presumed that common ground was necessary for the reunion effect. Common ground was not manipulated in the Greene et al. study even though it was suggested to operate in both story versions upon the reunion, and was discussed as a condition that was necessary for the reunion effect. Thus, Lea et al. (1998) made an important contribution to understanding this effect by varying common ground experimentally across story versions. They operationally defined

common ground by making the target concept either privileged knowledge of one character (no common ground) or shared knowledge by both characters (common ground). In the Cousin story, for example, Jane complains out loud to Gloria about her cousin's cooking, establishing the cousin concept in common ground. In the no-common-ground version, after leaving Gloria, Jane complains to herself about her cousin, so that concept is not part of information shared with Gloria. Lea et al. (1998) reasoned that if common ground were necessary for the reactivation of earlier concept, then they should find a reunion effect only when the target concept was part of common ground. They replicated the findings of Greene et al. (1994) in Experiment 1 (which shows that their slightly revised passages could produce the effect) but found a reunion effect independent of common ground in Experiment 2. Both common ground and no-common-ground conditions showed that the target concept became more accessible after the reunion sentence.

In place of the reference diary account, Lea et al. (1998) offered a memory-based explanation for the reunion effect. They proposed that access of distant concepts is produced by overlap between currently activated concepts and earlier concepts through a resonance process. In the resonance model of Myers and O'Brien (1998) (and in the memory-based model of McKoon et al, 1996), concepts and propositions derived from the text are placed in working memory as they are read. These new concepts make contact with ideas in memory as related concepts and propositions (those that share lexical, semantic or referential overlap) resonate to the new information. The resonating elements further cause other related elements in the representation to also resonate. The resonance process continues until it stabilizes and some subset of earlier information enters working memory. That information becomes available for possible integration with what is currently being read, while the activation for other concepts that are not selected or integrated into the ongoing discourse representation quickly decays. Thus, in relation to the present finding, the resonance model assumes that the concept of Jane is associated with the concept of cousin through their co-occurrence in the introductory sentences. The reintroduction of Jane in the Reunion Sentence, along with the presence of Gloria, is sufficient in overlap to reactivate concepts such as cousin from the introduction where both characters were mentioned (Keysar, 1997, makes a similar point). Consistent with this reasoning, McKoon et al.'s (1996) study showed that reunion sentences served to activate any concept associated with the characters in the introduction prior to

leaving and reuniting. Subsequent studies on the reunion effect also provide further support for memory-based models (Gerrig & McKoon, 1998, 2001). Both the Myers and O'Brien resonance model (1998) and the McKoon et al. memory-based model (1996) are associative memory-based models of comprehension, in that both rely upon word-level associations to reactivate and access concepts in memory. Both explain the reunion effect as the result of passive and "dumb" recognition processes that use cues available in the reunion sentence that reactivate prior text information.

While it is clear that some quality of the reunion sentence is responsible for reactivating concepts from the introduction, it is less clear what the exact characteristics of the reunion sentence might be that are responsible for these effects. Both Lea and Gerrig describe the importance of the character re-entering the story as causing reactivation of earlier concepts associated with them. This would suggest that character names may serve as important memory cues. However, in the reunion sentence, the other character (who has been present throughout), is also mentioned. Is the mention of both characters critical for overlap with the introduction which also contains both characters? For example, in another set of studies the compound cue "leather couch" was suggested to provide sufficient overlap to cue earlier information (Myers, O'Brien, Albrecht & Mason, 1994), so perhaps the compound cue of both characters is also at work here. Or is the mention of a single character sufficient? But, if so, how does the dumb recognition process know to focus on the newly introduced character? What is it in the reunion sentence that specifically acts to cue memory for earlier concepts? This has not been operationally defined in quantifiable terms in previous studies. The passages were designed based on intuitions that reunion sentences would "resonate" with earlier text segments. However, the passages may also be taking advantage of some other elements of discourse that may actually be responsible for re-activating the introductory segments. Studies on the reunion effect have shown that the reunion segments do indeed "cue" the earlier segments of the texts, and this effect has been obtained reliably across many studies. The question that we pose here is what feature or features of these texts are responsible for this. Is it lexical or semantic overlap between reunion sentences and introductory sentences? Or is it something else that directs activation to previously mentioned concepts?

Activation Based on Causal Relations

The alternative explanation for reunion effects that we propose is similar in spirit to these resonance models, but specifies a particular kind of associations that drive the accessibility of earlier information. The theory of dynamic causality-based comprehension assumes that readers track characters' actions, motivations, events and locations in order to form a causal model of the discourse (Trabasso, van den Broek, & Suh, 1989; Trabasso & Wiley, 2005). As a result, the accessibility of concepts from prior text is determined by the *causal connections* that can be made to recent clauses. This approach offers the causal structure of the text as a mechanism for determining the accessibility of concepts. This approach has been used successfully across a number of studies on text comprehension which have shown that causal connections can predict offline measures such as coherence judgments (e.g., Trabasso, Secco & van den Broek, 1984), recall (e.g. O'Brien & Myers, 1987; Trabasso, Suh, Payton & Jain, 1994), and importance ratings (e.g. Trabasso & Sperry, 1985; van den Broek, 1988); *but also online measures* such as reading times (e.g., Langston & Trabasso, 1998; Myers, Shinjo, & Duffy, 1987), picture recognition times (Sundemeier, van den Broek, & Zwann, 2003) and probe verification results (e.g. Rizella & O'Brien, 1996; Suh & Trabasso, 1993; Trabasso & Wiley, 2005).

According to this causality-based theory of comprehension (Langston, Trabasso, & Magliano, 1999; Trabasso & Bartolone, 2003; Trabasso & Wiley, 2005), a reader understands a story dynamically by adding information from each new clause or sentence of text as it is encountered into a long-term memory representation. The basis of comprehension is the integration of new information in long-term memory via causal connections between new and old text constituents. The integration of new information into the causal network updates the accessibility of all concepts in long-term memory by spreading activation and changing connection strengths between propositions. Prior conditions that are connected to the new conditions increase their relative accessibility over those conditions that are not connected, or are connected more distantly. In the context of the present studies, we suggest that it is causal connections between the reunion sentences and earlier sentences that alter the accessibility of target concepts from earlier sentences.

In the experiments of Greene et al. (1994) and Lea et al. (1998), a recognition probe is presented after the reading of a reunion sentence to test for the accessibility of a target concept from the introduction. According to the causality-based theory of comprehension, if the reunion sentence has

direct causal connections to the sentence that contains the target concept, then the recognition probe will be recognized quickly. If the reunion sentence is only indirectly causally connected to the sentence that contains the target concept, then the probe should be recognized more slowly. The central assumptions for the causality-based explanation are that (1) the comprehension of each sentence will update and change the accessibility of constituent information according to its causal relations and (2) response times to recognition probes will depend upon the accessibility of text constituents that contain the probe words as a function of the causal distance of that concept from the sentence immediately preceding the probe. This second assumption is the main hypothesis to be tested across simulations and experiments (i.e. that causal distance predicts the observed response time measures of target concept accessibility).

Simulation of Greene et al. (1994) Experiments

In this first simulation, we test whether causal distance provides a good fit for the observed response times in the three experiments by Greene et al. (1994). To test the theory of dynamic causality-based comprehension, the causal relationships between all propositions in the experimental stories are identified *a priori* by a discourse analysis (following Trabasso, van den Broek, & Suh, 1989). This analysis results in a causal network for each story that can be used to generate quantitative measures of accessibility of target concepts by calculating the shortest causal distance between the last sentence read before each probe location, and the prior sentence that contains the recognition word. To simulate the results of Greene et al, all stories for each experiment were analyzed, including both the Concept Absent and Concept Present conditions. The contrast between the two versions and probe locations enables a test of whether the causal distance to the target concept varies with changes in reaction times.

In sum, the simulation consists of: (1) a discourse analysis of the causal relations for each narrative and derivation of causal network mental representations of the texts, (2) the quantification of causal distance as the shortest distance in intervening nodes between the probe location and the target concept, and (3) the use of this measure to predict the observed response times. The goodness-of-fit for our predictions is found by regression and how much variance in the observed data is accounted for by the theoretical measures.

Discourse Analysis

The causal discourse analysis of Trabasso et al. (1989) was applied to each of the stories used by Greene et al. (1994) in three experiments. We illustrate the discourse analysis on the “Cousin” story. This story was introduced by Greene et al. (1994) as representative of all of their stories. The story is analyzed at the sentence level. Figure 1 shows the causal networks for the two versions of the Cousin story used by Greene et al. The numbers or nodes stand for sentences, and causal relationships are indicated by arrows between the nodes. The causal relationships were identified using causal analysis procedures introduced by Trabasso et al. (1989).

These procedures involved first categorizing the episodic function of each sentence (e.g., setting, event, goal, internal response, attempt, or outcome, based on Stein & Glenn, 1979), and then assigning the causal relations between each new sentence and each previous sentence in accordance to the functional relations between these conditions. This is a syntactic approach that establishes motivational, psychological, physical, or enabling causal relationships between conditions. A second procedure by which causal relations were established involved testing sentence pairs using counterfactual expressions in the context of the story, and by asking why and how questions. These approaches are illustrated in the context of the first story below.

Discourse Analysis of the Introduction. In Figure 1, the circled numbers 1 and 3 correspond to those sentences that contained the target concept and probe recognition word, COUSIN. The recognition probe word, COUSIN, was presented after the participant read sentences 11, 12, or 13. Sentence 11 is the before-reunion sentence. Sentence 12 is the reunion sentence. Sentence 13 is the pronoun sentence where the target concept is referred to as an unheralded pronoun. The probes were named, consequently Before Reunion, After Reunion, and After Pronoun.

The first six sentences constitute the Introduction of the story. The Introduction of the Concept Absent and Present versions were identical and thereby yielded identical causal networks. The Absent versus Present variation begins with sentence 7. The causal network of the Introduction is a linear chain from sentence 1 to sentence 6 with the addition of causal relationships between sentence 1 and sentence 3 or sentence 6. The kinds of categories and relationships are illustrated here for sentences 1-6: Jane’s dread of her dinner with her cousin, an internal response (emotion) in sentence 1 psychologically causes her to complain to her roommate in sentence 2 (an attempt). The setting information that she gets sick at

her cousin's whenever she eats there (sentence 3) psychologically causes Jane to dread going there to eat (sentence 1). Her attempt at complaining (sentence 2) enables her to tell her roommate about a setting, namely, that she gets sick every time she eats at her cousin's house (sentence 3). Her complaint (sentence 3) psychologically causes Gloria to ask her why she agreed to go (sentence 4). Her roommate's question (sentence 4) psychologically causes her to answer the question by stating that she is too wimpy to say no (sentence 5). Her inability to say no (sentence 5) psychologically causes a goal to have dinner with her cousin (sentence 1) and that motivates her attempt to leave to have dinner (sentence 6).

A second way test for possible causal relationships between sentences is to employ a counterfactual test between a candidate pair of sentences. This test is one of necessity in the circumstances of the story, based on Mackie (1980). The counterfactual involves the negation of each of the related sentences so that if there is a necessity dependency between A and B, the negation of A negates B, in the circumstances of the story. In the context of this story, the logic is that if Jane did not dread her forthcoming dinner with her cousin, she would not have, in the circumstances of the story, complained to her roommate. If she had not complained to her roommate, she would not have said that she got sick whenever she ate dinner at her cousin's. If she did not get sick every time she ate at her cousin's, she would not have dreaded having dinner with her cousin. If she did not utter this complaint, then Gloria would not have, in the circumstances of the story, asked her why she agreed to go. If Gloria had not asked her the question, Jane would not have replied that she was too wimpy to say no. If she had not finished her conversation with her roommate and if she did not have a dinner date with her cousin, she would not have gone to have dinner with her cousin.

Discourse Analysis of the Continuations. In the Concept Absent condition, presented in Figure 1, sentence 2 establishes the existence of Gloria as a roommate. This enables Gloria to decide to cook dinner in sentence 7. There is a linear, temporal-causal chain from sentence 6 to 8 to 7 to 9 to 10 to 11. Jane's leaving (sentence 6) physically causes Gloria to be home alone and psychologically causes her goal to eat well (sentence 8). Her decision to eat well (sentence 8) motivates her to make something nice for dinner (sentence 7) and to find ingredients (sentence 9). Her search for ingredients (sentence 9) is an attempt that physically causes an outcome, namely, having enough eggs for a quiche (sentence 10).

Sentence 10 enables her to eat dinner, an inferred action that enables her to complete the dinner and wash the dishes (sentence 11). In the circumstances of this story, Jane would not have arrived home with Gloria still up (sentence 12) if Gloria had not been at home and had not cleaned up after her meal (sentence 11). It was the act of cleaning up that enabled Gloria to still be awake when Jane arrived home.

In the Concept Present condition, there is also a linear, temporal-causal chain from 6 to 8 to 10 to 11. Jane's leaving, an attempt, (sentence 6) enables her arrival, an outcome (sentence 7). Her goal to have dinner at her cousin's (sentence 6) motivates her cousin to tell her what she is cooking (sentence 8). The latter is also enabled by Jane's arrival (sentence 7). Jane's reaction (sentence 9), an internal response, is a dead end consequence of what her cousin said (sentence 8). The cousin's cooking (sentence 8) enables them to sit down for dinner (sentence 10). Sitting down for dinner (sentence 10) enables them to finish and Jane to leave (sentence 11). Jane's leaving (sentence 11) enables the reunion (sentence 12). Sitting down for dinner (sentence 10), satisfied the goal to have dinner (sentence 1).

The causal distance in the network from the processing of sentence 11 to sentences 1 or 3 that contain "cousin" as a word is defined as the shortest number of intervening nodes (sentences) between node 11 and 1 or 3 in the network. In the Absent version, the shortest causal distance between sentences 11 and 1 or 3 is 4 nodes (sentences 10, 9, 7, and 2 intervene between sentences 11 and 1 or 3). In contrast, the shortest causal distance between sentences 11 and 1 for the Present version is 1 node (sentence 10 is the only intervening sentence) so that the Before Reunion sentence is psychologically much closer in the text representation (1 node versus 4 nodes) to the sentence containing the probe word cousin in the Present than the Absent version. This difference in causal distance predicts that cousin should be more accessible in the Present than in the Absent version at the time of the pre-reunion probe.

Discourse Analysis of the Conclusion. In the Absent condition, Jane's leaving (sentence 6) is an attempt that enables her return in sentence 12. Her motivation to return is also inferred from the information that she lives with Gloria and that she is returning home (sentence 2). In the Present condition, Jane's return (sentence 12) is enabled by her attempt to leave her cousin's house (sentence

11) and by a motivational inference (sentence 2). The causal distance between the Reunion (sentence 12) and the sentences that contain cousin is the same, namely 1 intervening node away (sentence 2 or 6 for Absent; sentence 2 for Present). There should be no difference in accessibility of Cousin after reading the Reunion sentence, and at the time of the Reunion sentence probe, and, hence, no difference in recognition response times.

In both networks, Jane's going to her cousin's house (sentence 6) enables her roommate to ask about whether the cousin played her old disco records (sentence 13). Thus, there is again one intervening node between the pronoun sentence and a sentence containing the target concept, cousin (sentence 3). Since the causal distance is 1 in both conditions, this predicts no difference in recognition response times between versions after the pronoun sentence has been read.

Method

Causal networks were analyzed for each story in Experiments 1-3 of Greene et al. (1994) in order to quantify the causal distance between probe locations and target concepts. In their Experiment 1, Greene et al. (1994) presented probe words in only two locations, Before Reunion and After Pronoun sentences. In Experiments 2 and 3, three locations were probed: Before Reunion, After Reunion, and After Pronoun. The main change between Experiment 1 and Experiments 2 or 3 was the addition of the After Reunion Probe. The Introduction and Continuation sections of the stories were not changed from experiment to experiment. In Experiment 3, the Pronoun sentence was changed to minimize associations between this sentence and the content in the Introduction other than the pronoun. For example, the question in Experiment 1 was "Did she poison you again?" This sentence might have facilitated associations of poison with getting sick, bad food, and the cousin. In Experiment 3, the question was changed to that in the above example, "Did she play you old disco records?" so that the pronoun, "she", is the only word that could enable the activation of the cousin concept. The experimental designs were a 2 (Probe Location) x 2 (Continuation) factorial for Experiment 1, and a 3 (Probe Location) x 2 (Continuation) factorial for Experiments 2 and 3. The dependent measure was the response time in milliseconds to the recognition probe.

There were 40 stories in Experiment 1, with two versions of each. Experiment 2 used the same materials plus 2 new stories. Experiment 3 only slightly revised these 42 stories by modifying the

pronoun sentence. Although this sentence was after the main probe points of interest, we reanalyzed these new endings. The stories were originally created using a formula that made for similar causal structures across each example. Stories would typically begin with persons A and B who have some kind of long-standing relationship that entails common goals and obligations (roommates, married couple, girlfriend-boyfriend, friends, or working such as boss-employee) and who are engaged in a shared activity (taking care of the baby, dating, browsing, hanging posters, shopping for records, etc.). Person A leaves person B in order to pursue a personal subordinate goal. Person A returns to Person B after that goal is attempted and completed by success or failure. The leaving is motivated by Person A's subordinate goal whereas returning is motivated by success or failure at the subordinate goal, the relationship and ongoing joint activity or, occasionally, by explicit goals to meet. The leaving itself can be seen as an enabling condition for the reunion. Further, Person B's location is often explicitly mentioned and can also be seen as enabling the reunion. Thus, there were typically causal, enabling relationships between the separation and reunion sentences that provided important causal connections between the sentences in the Conclusion and earlier ones in the Introduction.

The two authors independently performed a causal analysis of the stories. The second author was a blind coder and was not aware of the purpose of the coding, including the target concepts, location of probe words, or results for different conditions at the time of coding. The second author performed coding of these stories in order to learn the causal analysis approach for another set of studies on hindsight bias. For the full set of 42 stories, there were 1133 possible connections. The overall Kappa was 0.73, indicating good agreement between the scorers. Using Tom Trabasso's scoring as the signal, Jennifer Wiley's respective probabilities of a hit, miss, or false alarm were .934, .04, and .026, showing high reliability of detecting a connection. Differences between the authors were resolved by discussion and determined by reference to similar instances in other passages in an attempt to keep coding as consistent as possible. Only causal connections that were agreed upon by both coders were included in these analyses.

The shortest causal distance between each sentence preceding the recognition probe and the target concepts was found for each causal network of each story in each of the three experiments. The

causal distance was defined by the shortest pathway between the nodes for the probes and target concepts and quantified by counting the number of intervening nodes between them.

Results

The predicted response times are plotted as a function of the published observed response times for each condition of each experiment of Greene et al. (1994) in Figure 2. Table 1 summarizes the evaluation of the predictions in terms of regression of causal distance on the response times.

-- INSERT FIGURE 2 HERE --

-- INSERT TABLE 1 HERE --

In Table 1, it can be seen that variation in causal distance accounted for 93, 82, and 82 percent of the variation in mean response times for the Greene et al. (1994) Experiments 1-3, respectively. Although the number of data points per prediction is small, all three sets of predictions account for substantial degrees of variance and all correlations reached statistical significance. In Figure 2, across experiments, it can be seen that the success in the prediction lies primarily in simulation of the one slow response time in each experiment. This is the data point for the probe Before the Reunion in the Absent Concept Continuation condition. The other three or five data points per experiment show much less variation and were found to be statistically non-significant in the response times by Greene et al. (1994).

In order to show a correspondence statistically between the causal distances and response times for Greene et al's Experiment 1, we performed a 2 (Continuation) x 2 (Probe Location) analysis of variance on the causal distances for the 40 texts in each condition. We found, as did Greene et al. (1994), significant main effects of Continuation and Probe Location ($F(1, 39) = 40.44$, $MSE = .768$, $p < .01$) and ($F(1, 39) = 51.15$, $p < .01$). Of importance is the replication of their significant interaction between these two factors for causal distances ($F(1, 39) = 43.38$, $p < .01$). The largest mean causal distance, 2.75 (SE .23), was that for the Continuation Absent version at the Before Reunion probe. In individual comparisons, this mean was found to be significantly different from the other three causal distance means and the latter were not different statistically from one another. The respective mean causal distances were .78 (SE .13), .53 (SE .10), and .73 (SE .15) for the Absent-After Pronoun, Present-After Pronoun, and Present-Before Reunion conditions.

Analyses of Variance in a 2 (Continuation) x 3 (Probe Location) design on the causal distances for Greene et al.'s Experiments 2 and 3 were also carried out and yielded similar main effect and interaction findings to those reported by Greene et al. (1994) on response times. The changes to the pronoun sentences in Greene et al.'s Experiment 3 did not affect the causal relations in the texts, so the analyses for both experiments are identical. The ANOVA on causal distances for all 42 texts used in Experiments 2 and 3 revealed effects for Probe Location, $F(2, 82)=39.37$, $MSE=.699$, $p<.01$; for Continuation, $F(1, 41)=31.97$, $p<.01$; and for the Probe Location x Continuation Interaction, $F(2, 82)=32.16$, $p<.01$. The highest mean causal distance in both experiments was found for the Continuation Absent/Before Reunion condition ($M = 2.79 (.22)$). The remaining means ranged between .62 and 1.05 (.11 to .15). Follow-up comparisons on causal distance means indicated that only the Concept Absent/Before Reunion mean was statistically significant from the other means. This correspondence between causal distance and response time accounts for the relative inaccessibility of Concept Absent/Before Reunion word probes and also explains why the simulation accounted for large proportions of variance for all three of their experiments.

Summary of Greene et al. Simulations

This analysis indicates that the causal distance measures predicted response times and accessibility of information in long-term memory during reading of a story. These results show that a causality-based memory account of the reunion effect provides a good fit for the data. Before the reunion occurs, accessibility of constituents favors the Concept Present version. When the reunion occurs, new connections to the reunion sentence reduce the causal distance between the current sentence and sentences in the introduction, and thereby increase the accessibility of the sentence that contains the probed concept.

Simulation of Lea et al. (1998) Experiments

Lea et al. (1998) successfully replicated the findings of Greene et al. (1994). In our simulation of the Lea et al.'s (1998) Experiment 1, the discourse analysis and analyses of variance are identical to those carried out for the Greene et al. (1994) Experiment 3, with the exception that Lea et al. (1998) used slightly different terminology for the conditions. They refer to the person who was the target as the "Outsider" rather than the "Concept". Hence the two conditions are referred to as Outsider Absent

(Concept Absent) and Outsider Present (Concept Present). The amount of variance accounted for by the causal distance analysis in Lea et al.'s recognition data was 83 percent, replicating the findings from our simulation of Greene et al.'s Experiment 3.

In their Experiment 2, Lea et al. (1998) revised the stories so that the variable of interest was what they called Common Ground. Common Ground was defined operationally by manipulating the text. In the *Common Ground* condition, Person A tells Person B about the target concept. In the *No Common Ground* condition, the Person A thinks about the target concept without the awareness of Person B. In Experiment 2, Lea et al. (1998) used the same recognition probes for the shared or unshared concept at the same three sentence locations of Greene et al.'s (1998) Experiment 3.

In rewriting the stories of their Experiment 1, Lea et al. (1998) altered the Concept (Outsider) Absent versions to create *No Common Ground* stories. The Common Ground stories were based on the original Concept (Outsider) Absent versions. Lea et al.'s (1998) *No Common Ground* version of the Cousin story appears in Figure 3. To achieve No Common Ground in this story, Jane departs in Sentence 3 without explanation. Sentences 5-8 contain information relevant to the target concept, cousin. Instead of being communicated to Gloria, as in the Common Ground version, the target concept is expressed in the form of thoughts as self-communication.

Method

Discourse analysis of the 42 pairs of stories of Lea et al.'s (1998) Experiment 2 was carried out in the same manner as was done for the Greene simulations. Figure 3 shows the causal network for the No Common Ground Cousin story. The circled nodes for sentences 1 and 3 are those that contain the concept word, cousin. The recognition probes were presented after sentences 14, 15 and 16, which correspond to Before Reunion, Reunion, and Pronoun sentence.

-- INSERT FIGURE 3 HERE --

Note that in Figure 3, sentence 15, the Reunion sentence, is caused by sentences 3, 4, and 14. In the circumstances of this story, Jane would not have arrived home with Gloria still up if Gloria had not been at home and had not cleaned up after her meal. Jane also would not have arrived home, if Jane had not left to have dinner with her cousin, and if she had not promised to see Gloria later that night. Sentence 4 is also directly connected to 16, because Gloria would not have asked Jane the question

unless she presumed that Jane had seen her cousin. These respective relationships are enabling or motivational.

The connections between the Reunion sentence and prior sentences were independently coded by the two authors in the interest of establishing reliability. Again, the second author was blind to the purpose of the causal analysis at the time of coding. There were 1043 possible connections. The overall Kappa was 0.73, indicating good agreement between the scorers. Using Tom Trabasso's scoring as the signal, Jennifer Wiley's respective probabilities of a hit, miss, or false alarm were .928, .041, and .031, showing high reliability of detecting a connection. Differences between the authors were resolved by discussion and reference to similar examples. Only causal connections that were agreed upon by both coders were included in these analyses.

Results

The causal distance measures accounted for 95 percent of the variance in the published response times for each condition, as shown in Table 1.

The mean causal distances for the Common Ground and No Common Ground versions were 3.31 and 3.60 for the Before Reunion probe; 1.29 and 1.24 for the After Reunion Probe; and .83 and 1.0 for the After Pronoun probe. An analysis of variance examining the effects of Probe Location and Story version on the causal distance measure showed that only the effect for Probe Location factor was statistically significant, $F(2,82)=56.57$, $MSE=.64$, $p<.0001$. Pairwise comparisons of the three probe locations showed that the causal distances from Before Reunion probes to the target concepts were longer than the distances from the After Reunion and After Pronoun probes ($p<.01$), while causal distances from the latter two probe points to the target concepts did not differ.

Regardless of whether a concept is mentioned in common ground, the reunion sentence increased the accessibility of earlier sentences that contained the probed concept. As in the first set of simulations, causal distances fit the pattern of the observed data. As shown in Table 1, the causal distances accounted for 95% of variance in observed response times from this experiment. The fit of the predictions of the causal distance measures, against the standardized observed results for all 5 published experiments, is shown in Figure 4.

-INSERT FIGURE 4 HERE-

The results of the simulations suggest that a causality-based theory of comprehension provides one possible account of reunion effects. However, the previously offered explanation for these effects based in resonance and overlap of discourse information also provides an intuitively compelling account for how distant concepts may be reactivated. Further, the potential contributions of these two mechanisms may be difficult to isolate. Establishing causal relations in many ways depends on an initial memory-based process, as the overlap of agents, events, objects, and locations enables the recognition of causal dependencies between sentences. And in normal discourse, sentences that are related causally may also share a great deal of lexical and semantic overlap, as these attributes of discourse naturally co-occur (Magliano, Zwann & Graesser, 1999; Zwann, Magliano, & Graesser, 1995). Thus, the goal of the two new experiments presented here was to attempt to disentangle the effects of overlap and causal relations on reunion effects. We do this in two ways – first by attempting to manipulate and examine the role of direct causal connections on the accessibility of distal concepts, and second, by attempting to fit priming data as a function of changes in lexical overlap, semantic association and causal distance that occur due to the reading of the reunion sentences.

Experiment 1

Across all simulations, the causal distance between the last read sentence and the probed concept provided an excellent fit for recognition time measures, consistent with the predictions of a causality-based theory of comprehension. However, the mention of the two characters in the reunion sentence, or the mention of one character returning to a specific location in the reunion sentence, may have acted as a compound cue. This cue could have served to reactivate the target concept through a memory-based priming mechanism since the target concepts were either associated with both characters, or with one character and a specific location, in the introductory sentences of each text. In this experiment, we attempted reduce the overlap between the reunion sentence and the target concept sentence by selecting words from the introduction that were not mentioned in the same sentence as either both characters or a character and a specific location. The associations between target concepts and reunion sentences could not be eliminated entirely, but by reducing the possible associations that were available, we hoped to test more cleanly for effects of direct causal connections.

Further, the causal distance to the target concept was also manipulated while controlling for content, by locating the probed concept either late in the second episode (far from the separation sentence, but closer to the reunion) or early in the first episode (near or in the separation sentence). To create the two versions of each passage, a target word was identified near or in the separation sentence of the Concept Absent passages from Greene et al. Experiment 3 and the Lea et al. experiments. Use of a target word in or near the separation sentence was intended to result in a direct causal relation, but a distant surface relation to the reunion sentence. This word was exchanged with a word or phrase that appeared a sentence or two before the reunion (which would result in a less direct causal relation, but closer surface relation).

Example Cousin Text For Experiment 1

1. Jane was dreading her dinner with her cousin, Marilyn.
 2. She complained loudly to her roommate Gloria.
 3. "Every time I go to dinner at my cousin's I get sick."
 4. Gloria asked, "Why did you agree to go?"
 5. Jane said, "Because I'm too wimpy to say no."
 6. Jane went off to have dinner (quiche).
 7. Gloria decided to cook something nice for herself for dinner.
 8. "As long as I'm home alone," she thought, "I'll eat well."
 9. Gloria searched her refrigerator for ingredients.
 10. She found enough eggs to make a quiche (dinner).
 11. After dinner, she put the dishes in the dishwasher.
 12. Gloria was still up at when Jane arrived home about midnight.
 13. Gloria asked Jane, "Do you ever play your old disco records?"
 14. Jane chuckled and said, "I can't get Disco Inferno out of my mind."
- PROBE WORD: QUICHE

One half of participants saw the target concept late in the text (the underlined words), the other half saw the target word early in the text (the words in parentheses). Half saw the probe before the reunion sentence (12), and half saw it after. According to the causal analysis of this text (see Figure 1, Concept Absent version), sentence 6 is directly connected to the reunion sentence (i.e. causal distance of 0) whereas it is much more distantly related to the pre-reunion sentence (i.e. causal distance of 4). Thus, when the target concept appears in Sentence 6 (the early mention condition), a causality-based explanation of reunion effects predicts that the concept QUICHE should become more accessible from before to after the reunion. On the other hand, the causal distance between the late-mentioned concept and the pre-reunion and reunion sentences varies in the opposite direction. Sentence 10 is only 1 node away from the pre-reunion sentence, whereas the reunion is 2 nodes away. Therefore, a causality-based explanation predicts that QUICHE should become less accessible after the reunion sentence in this case.

Performing a causal discourse analysis on all passages yielded average causal distances in the early-mention versions of 2.95 (SE .30) from the pre-reunion sentence and .70 (SE .15) after the reunion sentence. For the late-mention versions, the average causal distances were .60 (SE .20) from the pre-reunion sentence, and 2.15 (SE .18) after the reunion sentence. Thus, a causality-based theory of comprehension would predict that the reunion sentence should make the early-mentioned concept more accessible since it is directly causally related to the reunion sentence, whereas the opposite pattern is predicted for the late-mention condition.

The predictions of memory-based approaches are harder to ascertain. Because the compound cue has been removed, and the target concept is now associated with only one character, one hypothesis would be that the reunion sentence might no longer provide enough overlap with the sentence containing the target concept to reactivate that concept. Further, because the mention of the target concept is more recent in the late-mention passages, and because target concept is also associated with a single character, perhaps more activation will be seen in response to the late-mention probe than the more distant and equally associated early-mention probe.

On the other hand, if greater activation is found for the early target concept, then it is possible that memory-based approaches could claim that associations with a single concept or character may be enough to reactivate distant concepts from text. It should be noted, however, that any such explanation would require additional assumptions to be added to memory-based accounts. In particular, they would have to add an assumption that introducing information not currently in working memory somehow receives focus or causes more activation to its associates which reduces the parsimony of the memory-based position. Because the actual features of the reunion sentence that serve as effective memory cues are not operationally defined in previous studies, it is hard to make a prediction of the conditions under which a reader will activate earlier concepts according to memory-based approaches (c.f. Long & Lea, 2005).

Another tack is to examine whether resonance, operationalized using measures of lexical and semantic overlap, predicts activation patterns to a greater or lesser degree than causal distances. Following other researchers, we quantify predictions for lexical overlap using the repetition of words or roots across propositions, and semantic overlap using LSA cosines for pairs of sentences (van den

Broek, Rapp, & Kendeou, 2005; Wolfe, Magliano & Larsen, 2005). This approach is utilized in the analysis of the new experiments to attempt to understand the roles of overlap and causal connections in determining the activation of distant concepts in text. Further, we perform fit analyses at the passage level where predictions of the causal measures and the association measures are more likely to diverge.

Method

Participants. Forty undergraduates at the University of Illinois at Chicago participated in return for course credit. The data of eight additional participants were discarded because they made more than 30% errors or had missing data in one condition.

Materials. For the experimental items, we adapted 20 Concept Absent texts from Greene et al. Experiment 3 (1994) (similar to the Lea et al. (1998) Outsider Absent versions). The passages ranged in length from 13-16 sentences. The first section of each story introduced two main characters often at a particular location. In the second section, the two characters separate and the text describes the actions of one character left alone. This section was followed by a “Reunion” Sentence in which the two main characters are reunited at a location. A probe word was presented either before or after this sentence. For each text, a concept mentioned either early or late in the passage, and mentioned in a sentence that associated it with only one other character, served as a probe word.

We created two versions of each experimental passage. In one version the target concept was mentioned near or in the separation sentence. In the second version, the target concept was switched with a word or phrase that appeared near the reunion sentence. A second example is included in the Appendix.

Filler items were also adapted from Greene et al. experimental materials (There were 24 filler items total, with 20 from the Greene et al. materials plus four additional passages of similar form to complete the design). The filler passages were 13–16 sentences in length. They were similar in style to the experimental items in that they described two or more characters. However, in these passages the characters either did not separate, or did not reunite. Probes words were presented either early (in the first 4 sentences) or late (around sentence 10). The probe words for the filler passages were common nouns, with 18 of the test words requiring “no” responses and 9 of these negative test words referring to social roles. Specifically, 12 probes were presented late and required a “no” response. Six probes

appeared early and required a “no” response, and 6 probes appeared early and required a “yes” response.

Design. There were two variables in the experimental texts: story version (Early Concept, Late Concept) and probe position (Before Reunion, After Reunion); this created four conditions. Four counterbalanced lists were created with 5 passages in each condition. Participants were randomly assigned a list. As a result, each participant saw five passages in each condition, and across participants, each passage occurred in each condition an equal number of times. The order of the passages was the same for all participants.

Procedure. The procedure of this experiment followed that of Greene et al. and Lea et al. Each participant completed a session that lasted approximately one hour. All materials were presented on a computer monitor controlled by a Pentium PC. Participants were instructed to place their right middle finger on a line-advance key, their right index finger on a “yes” key, and their left index finger on a “no” key. Each experimental session began with 50 lexical decision test items to give the participants practice with the response keys and to emphasize quick responding. During this practice task, participants were shown feedback on their accuracy and response times, and instructed to try to respond in less than 1 second.

After the lexical decision practice, the participant was given instructions for the experiment. Each passage was preceded by a message that read “press advance key to continue.” When the participant pressed the key, the first line of the passage was presented. Each press of the line-advance key erased the current line of text and presented the next line. Participants were instructed to read so that they understood each passage. At various points in the story, a press of the advance key resulted in a recognition probe word being displayed instead of the next line of the story. The probe word appeared in the center of the screen in all capital letters. The probe word remained on the screen until the “yes” or the “no” response key was pressed. Participants were instructed to respond “yes” if the probe word had been presented earlier in the passage, and “no” if they thought the word had not appeared in the passage. Participants were instructed to respond as quickly and accurately as possible. Participants were presented with 4 filler stories as practice before the first experimental passage was presented.

Causal distances were derived from the previous network analyses performed for the simulations. Latent Semantic Analysis cosines between the reunion sentence and sentence containing the target concept were computed using the “Sentence Comparison” tool at <http://lsa.colorado.edu/> and selecting ‘General Reading up to First Year College’ as an LSA space to generate a measure of “semantic association”. Co-occurrences of content words (including words that shared roots such as he/his) in the reunion sentence and the sentence containing the target concept were also computed to generate a measure of “lexical overlap”. When target concepts appeared in more than one early sentence, the sentence that yielded the highest LSA measure or overlap measure was used. These metrics were used to predict response times to recognition probes for the target concepts.

Results

F_1 refers to tests against an error term based on subject variability and F_2 refers to tests against an error term based on item variability. Only recognition times for correct trials were analyzed. Average accuracy was 77% and did not vary across conditions ($F < 1$). Following Greene et al, response times longer than 2000ms were discarded, resulting in a loss of less than .05 of the data. Mean recognition times (with standard errors) based on subject means for Experiment 1 are presented in Table 2.

-- INSERT TABLE 2 HERE --

In order to examine the effect of the early versus late mention on reunion effects, we performed a repeated measures 2x2 ANOVA. Neither main effect reached significance either by subjects or items ($F_s < 1.7$). However, a significant interaction was observed between early vs. late mention and probing before vs. after reunion, $F_1(1, 39)=17.2$, $MSE=32,899$, $p < .01$, $F_2(1, 19)=4.45$, $MSE= 45,806$, $p < .05$. This interaction was found because the patterns in the early mention condition replicated findings of the reunion effect, such that the distant concept was more accessible after the reunion sentence than before it ($t(39)=1.99$, $p < .05$). On the other hand, the late mention condition showed the opposite pattern, with the recently mentioned concept becoming less accessible from before to after the reunion ($t(39)=3.85$, $p < .01$). Further, the early-mentioned concept was more accessible after reunion than the late-mentioned concept ($t(39)=2.12$, $p < .04$).

Because the early mentioned concept was closely connected to the separation sentence, which in turn formed an enabling connection to the reunion sentence, we interpret the reactivation of this distant

concept as occurring due to the establishment of causal connections in an ongoing representation of the discourse. When the concept was mentioned later in the discourse, although it was more recent and still associated with one of the characters from the reunion sentence, it was also not directly causally linked to the reunion sentence. Hence, activation for the more recent concept was not facilitated by the reunion. Importantly, after the reunion sentence the early mention of the target concept was more accessible than the more recent mention.

These results fit well with predictions based on causal analyses of the texts. When analyzed on a condition level as in the previous simulations, causal distances between the probe location and the target concept accounted for 71% of the variance in average response times for each condition. Table 2 also shows the condition averages for the causal distance, LSA and word overlap measures. Interestingly, the average amount of semantic overlap and word overlap in each condition also followed a similar pattern as causal distance measures, such that the two conditions with the slowest recognition times also had the lowest LSA cosines and the least word overlap. As a result, LSA cosines accounted for 80% of variance, while word overlap accounted for 33% of average response times when fits were analyzed at a condition level.

Because causal distance measures and LSA measures are so highly correlated at the condition level ($r = -.99$), we cannot examine their comparative fit. However, at the passage level, the two measures are less correlated ($r = -.43$), and thus make divergent predictions for recognition times. This allows the independent predictions of each measure to be better assessed. An additional advantage to the passage-level fit analysis is the larger number of observations that contribute to the regressions. As shown in Figure 5, when fit was analyzed at the level of each text in each condition, decreases in causal distance to the target concept from before to after the reunion sentence significantly predicted the decreases in response time that were observed. Changes in causal distance accounted for 40% of the variance for changes in response times ($R = .63$, $F(1,38) = 25.01$, $p < .01$) from before to after the reunion sentence. While increases in LSA or word overlap scores from before to after the reunion sentence also tended to lead to decreases in response times, neither predictor reached significance and each only accounted for 7% of the variance in reunion effects. These results show that changes in causal connections are determining the re-activation of the target concept, more so than semantic or lexical associations. The

strong fit for LSA at the condition level seems to be an artifact of its similarity to the causal distance measure.

--INSERT FIGURE 5 HERE --

Discussion

In addition to replicating the reunion effect in the distant concept condition, this experiment also demonstrated that recently mentioned concepts can become less accessible when the topic of a discourse shifts, which has been demonstrated in other anaphor studies. Introducing a new episode (the reunion) caused earlier text concepts to become less accessible (e.g. Anderson, Garrod, & Sanford, 1983; Clark & Sengul, 1979; Gerrig & McKoon, 2001). At the same time, some distant concepts became more accessible than concepts that occurred in middle of the story (e.g. O'Brien & Myers, 1987; Myers, O'Brien, Albrecht & Mason, 1994) due to the reunion sentence. Although the reunion sentence shared associations with both the early mention sentence and the later mention sentence, and the later mention was more recent, clearly there was something in the reunion sentence that cued readers to more strongly activate concepts from the introductory segment of the text. Our results suggest that the causal relations that could be made between the reunion sentence and earlier sentences determined the activation of earlier text information. The decrease in causal distance to the target concept that occurred due to the reunion sentence provided a good index for changes the accessibility of the target concept, both on a condition level (which is the level that has been tested in previous experiments through manipulations) as well as on an item level. Lexical and semantic overlap measures did not predict the patterns of activation for the target concepts found at the item level.

Experiment 2

Although Experiment 1 demonstrated that causal distance could predict the accessibility of distant concepts in a reunion effect paradigm, this was achieved by manipulating whether the target concept was mentioned early or late in the text, while keeping the causal relation to the introduction constant. The purpose of Experiment 2 was to manipulate the causal connections between reunion sentences and the introduction by keeping the target concept in the introduction, but varying the causal connections to the introductory sentences. This allowed for more divergence between the predictions of causal distance and semantic association measures. In our causal analysis of the original texts, the reunion sentences were

directly connected to separation sentences since separation of the characters was an enabling condition for their reunion. In order to manipulate these causal connections in this study, in one version of each passage we eliminated the enabling relations by either bringing the second character back immediately after the separation or by having the characters talk about an episode in the past in the opening segment.

An example of how the causal relation between the target concept and the reunion sentence can be removed is presented in Figure 6. In the no-causal-connection version of the COUSIN passage, the dinner with the cousin is in the past and Jane no longer leaves. Therefore, when Jane and Gloria are again mentioned in the same sentence, it is no longer directly *causally* related to sentence referring to the cousin. A causal analysis of this revised text indicates that the distance between the reunion/co-mention sentence and the closest sentence containing the target concept COUSIN is 4 nodes. The causal distance between the pre-reunion/co-mention sentence and the target concept COUSIN in this particular passage is 5 nodes.

--INSERT FIGURE 6 HERE --

Two raters (JW and a trained research assistant) completed a causal discourse analysis on the two versions of the 20 passages. Each rater computed the shortest number of intervening nodes to the target concept from two probe points: the pre-reunion/co-mention sentence and the reunion/co-mention sentence, based on their own causal analysis. The overall interrater reliability, computed using Pearson correlation since the scores were continuous measures, was 0.88, indicating good agreement between the scorers on the length of the causal chain between the probe point and the target concept at each location in each condition. Only causal connections that were agreed upon by both coders were included in the causal distance measures for these analyses.

The analysis on the Causal-Connection versions (which were based on the original Concept Absent versions) yielded an average causal distance to the target concept of 3.75 (SE .21) nodes from the pre-reunion/co-mention sentence, and .95 (SE .20) nodes from the reunion/co-mention sentence. Analysis on the No-Causal-Connection versions created for all passages yielded an average causal distance to the target concept of 3.85 (SE .18) nodes from the pre-reunion/co-mention sentence, and 3.40 (SE .26) nodes from the reunion/co-mention sentence. Thus, the causality-based approach predicts that

COUSIN will only be more accessible after the reunion/co-mention sentence specifically for the causal connection versions of these passages.

On the other hand, we attempted to keep the word-level associations between reunion/co-mention sentences and introductory sentences constant in both the Causal-Connection and No-Causal - Connection conditions. As shown in Table 3, both LSA cosines and Word Overlap scores are similar across conditions. Resonance and associative memory approaches would predict reactivation of COUSIN under these circumstances since the same memory cues between the two sentences were still present. COUSIN is still associated with Jane and Gloria. When Jane is mentioned in sentence 13, the concept of COUSIN should be reactivated through its association with Jane and Gloria earlier in the passage. Therefore, according to these approaches COUSIN should be more accessible after the late mention of Jane in both conditions.

Method

Participants. Sixty undergraduates at the University of Illinois at Chicago participated in Experiment 2 in return for course credit. All participants were native English speakers. The data of eight additional participants were discarded because they made more than 30% errors, had missing data in one condition, or failed to complete the experiment.

Materials. For the experimental items, we again adapted 20 narrative texts from Greene et al. (1994) Concept Absent versions (similar to the Lea et al. (1998) Outsider Absent versions). The first section of each Concept Absent story introduced two main characters, referring to each of them with a proper name and ending with a separation. In the second section, the text described the actions of one character. This section was followed by a sentence in which the two main characters are again both mentioned, and a reunion occurs. For the present study, we will refer to this as the “Co-mention Sentence.” A probe word was presented either before or after this sentence. For each text, the name of a social role (e.g., cousin) served as a probe word.

We created a second version of each experimental passage that eliminated the causal relation between the “co-mention” sentence and the early sentence in which the target character was mentioned (the target sentence), by bringing the second character back immediately after the separation (N=11), or by having the characters talk about an episode in the past in the opening segment (N=9, as in the

example above). Instead of a operating as a reunion sentence *per se*, the co-mention sentence was the first time that both characters were explicitly mentioned again after the continuation segment. A passage that illustrates bringing the second character back immediately after the separation and before the continuation is included in the Appendix. Filler items were the same as in Experiment 1.

Design. There were two variables in the experimental texts: story version (Causal Connection, No Causal Connection) and probe position (before the Co-mention Sentence, after the Co-mention Sentence); this created four conditions. Four counterbalanced lists were created with 5 passages in each condition. Participants were randomly assigned a list. As a result, each participant saw five passages in each condition, and across participants, each passage occurred in each condition an equal number of times. The order of the passages was the same for all participants.

Procedure. The procedure was identical to Experiment 1.

Results

F_1 refers to tests against an error term based on subject variability and F_2 refers to tests against an error term based on item variability. Only accurate probe recognition response times are included. Average accuracy was 81% and did not vary by condition, $F < 1$. Following Greene et al, response times longer than 2000ms were discarded, resulting in an additional loss of less than .05 of the data. Mean recognition times (with standard errors) based on subject means for Experiment 2 are presented in Table 3.

-- INSERT TABLE 3 HERE --

In order to examine the effect of a causal connection between the Co-mention Sentence and the Target sentence upon response times, we performed a repeated measures 2x2 ANOVA. A main effect for Probe Position was reliable by subjects, $F_1(1, 59)=7.47$, $MSE=17,083$, $p < .01$; but this effect was not reliable by items, $F_2 < 1$. Probes tended to receive faster responses after the Co-mention sentence than before it. No main effect was found for the Causal Connection manipulation, $F_s < 1$.

However, most importantly, a significant interaction was observed between Causal Connection condition and Probe Position in both subjects and items analyses, $F_1(1, 59)=10.85$, $MSE=17,083$, $p < .01$, $F_2(1, 19)=4.93$, $MSE=6,312$, $p < .04$. Follow-up tests revealed that the interaction was due to faster responses from before to after the Co-mention Sentence in the Causal Connection condition ($t(59)=4.19$,

$p < .01$). The patterns in the Causal Connection condition replicated previous findings of the reunion effect, such that the third character was more accessible after the Co-mention sentence than before it. However, no differences were seen in response times for the No-Causal-Connection condition from before to after the Co-mention sentence ($t < 1.2$).

A follow-up analysis indicated that no differences in reunion effects were seen due to the way that the causal relation was eliminated (speaking about a concept in the past or separating but returning immediately, $F < 1$). Both kinds of passages showed the same reunion effect in the Causal-Connection condition and no effect in the No-Causal-Connection condition.

As shown in Table 3, these results fit well with predictions based on causal analyses of the texts. When fit was analyzed at the condition level, causal distances between the probe location and the target concept accounted for 79% of the in average response times for each condition. As opposed to Experiment 1, the correlation between causal distance and LSA was only $r = -.68$. As a result, LSA measures accounted for only 4% of the variance in average response times for each condition. Overlap measures accounted for only 25% of average response times at a condition level.

As shown in Figure 7, when fit was analyzed at the level of each text in each condition, decreases in causal distance to the target concept from before to after the reunion sentence significantly predicted the decreases in response time that were observed. Changes in causal distance accounted for 20% of the variance for changes in response times ($R = .44$, $F(1,38) = 9.31$, $p < .01$) from before to after the reunion sentence. Increases in LSA cosines from before to after the reunion sentence also tended to lead to decreases in response times, and this measure of semantic association accounted for 4% of the variance in reunion effects ($R = .19$, $F(1,38) = 1.36$, $p < .25$). Word overlap measures accounted for less than 1% of the variance in reunion effects.

The lower fit of the causality-based predictions in this experiment was due to half of the passages having no direct causal connections between co-mention sentences and the introductory sentences. For the narratives in the Causal Connection condition, the results were similar as in the previous experiment. Changes in causal distance significantly predicted reunion effects ($R = .49$, $F = 5.63$, $p < .03$), while changes in LSA cosines did not ($R = -.05$, $F < 1$). However, for the narratives in the no-causal-connection condition, LSA cosines were a marginal predictor of the reunion effects ($R = -.42$, $F = 3.81$, $p < .07$), whereas the

causality-based measures were not ($R=.31$, $F=5.63$, $p<.03$). There are a couple of reasons why causal distances might not have been predictive in this condition. One possibility is that the lack of a causal connection to the reunion sentence meant that there was less of a difference in causal distance between the co-mention sentence and the sentence that preceded it. This led to less variability in that measure which lowered the ability to find a correlation with it. An alternative possibility is that the effects of semantic association may have emerged because these passages were largely missing an underlying causal structure. This suggests that semantic association is a mechanism that may help to reactivate distal concepts under conditions when a causality-based mechanism may not be effective.

-INSERT FIGURE 7 HERE-

Discussion

As a whole, the results of this experiment are most consistent with a causality-based account of reunion effects. Only causal distance measures provided a good fit for the patterns of activation at the condition level. Memory-based approaches would predict reactivation of COUSIN in both conditions. The target concept COUSIN is associated with Jane and Gloria in both conditions, and should be cued when both characters are mentioned again in the “co-mention” sentence. However, the reactivation was only observed when there was a fairly direct causal relation between the co-mention sentence and the earlier text segment. Further, activation of the target concept was seen to vary as a function of changes in causal distance in the text-level analysis. The results of the present experiment support the interpretation that the causal distance between a probe location and a prior concept plays a role in determining the accessibility of that concept. They also suggest a role for semantic associations in reactivating prior concepts, but that mechanism appears secondary to a causality-based mechanism when causal connections are available.

General Discussion

What happens at reunions? Like most people could tell you, at reunions we are reminded of our reasons for leaving. A reunion reminds us of the fact that we left, or that a character left, as well as the reasons for the separation from the previous context or another character. In terms of a model of text processing, what this means is that there is nothing special about reunions other than that they act as bridges to earlier segments of discourse through their causal connections to previously read text. Our

explanation is an attempt to further specify a memory-based account for the reunion effect, where the memory representation is based on a causal model of entities and their relations within context of the story. The results across several simulations and two new experiments are consistent with a model of text comprehension where causal connections to earlier information are instantiated into an ongoing representation of the discourse, and the accessibility of a concept is a function of its status in this causal model at a given point in time.

This approach shares many assumptions with other memory-based accounts of comprehension. We view the comprehension process as occurring via the integration of new information with old information in memory, which in turn renders some earlier text information more accessible (Gerrig & McKoon, 2001; Lea, et al, 1998; McKoon et al, 1996; Myers & O'Brien, 1998). Our approach is more specified than the previously proposed memory-based models, positing that it is causal connections in particular that cue readers to activate and integrate distant concepts into an ongoing discourse representation. The overlap between predictions of association-based memory models and our causality-based memory model may be substantial. For example, in order for causality to be detected, agents and objects must overlap in space and time. Therefore, any pair of sentences that has a causal relation will most likely share word-level and conceptual relations as well. However, the opposite is not the case. Not all pairs of sentences that share word or concept overlap will be related causally (See Trabasso, et al, 1989 for empirical evidence of this). These results suggest that causal status may be an important basis by which the subset of information that is to remain in working memory is selected.

The advantages of our causality approach are that the mechanisms for reactivating and integrating earlier concepts are defined *a priori* and are testable. In these simulations and experiments we show that the causal structure of a text can be identified reliably. The passage level analysis, and manipulations that make causal distance and semantic association less correlated, allow us to test for independent effects of causal status and semantic association. One general caveat is that in order to manipulate the effects of causality and lexical/semantic associations on comprehension we created passages that may have been unnatural and somewhat awkward for readers. This is a problem whenever one seeks to disentangle features of text that naturally co-occur. Given this issue, it is of course possible that the effects obtained with these materials may not generalize to other texts.

However, at least for this set of stimuli, causal distance proved to be a much better predictor of activation patterns for distant concepts than were measures of semantic or lexical overlap.

The historical roots of interest in the reunion effect sprang from a general concern with how people resolve ambiguous or “unheralded” anaphoric expressions in discourse, and more generally how antecedents to referential expressions are identified, accessed or otherwise connected to the current topic. Catherine Emmott (1997), a linguist, has suggested that readers understand narratives by constructing dynamic, mental representations of possible worlds based upon information from the text. The reader’s mental representations store and accumulate information about characters and their actions. Characters and objects are tracked, as are their locations and movements. Characters act and interact with each other in time and space. They behave in ways that correspond to a reader’s real life experiences and thus have verisimilitude. The reader pays special attention to changes in time, location and characters as these are the critical components of events that form the backbone (or frame boundaries) of narrative. This view can be seen at once to be consistent with “reference diary” accounts discussed by Gerrig and colleagues, as well as with the situation model and scenario-based approaches to comprehension that are perhaps the most accepted current frameworks for understanding how readers construct meaning from text (Kintsch, 1998). More recent embodiment accounts have demonstrated that readers do monitor, index, and sometimes even mentally simulate the actions of characters (Glenberg & Kaschak, 2003; Zwann, 2004). Moreover, we would argue that attending to these elements of a narrative allows the reader to encode important cues to causality and that the representation of the narrative is built around this causal structure.

A question that often arises is about the nature of this causal representation process. Can a causality-based representation be constructed by passive and automatic processes, or must it be thought of as effortful or strategic? In order to generate the coding we used here to quantify the causal status of propositions, we engaged in very effortful and strategic process of episodic categorization and explicit hypothetical reasoning. However, we do not believe that this is the way that causal status is assessed by readers as they read. We performed these rule-based procedures as experimenters attempting to demonstrate reliability of our intuitions. We would argue that as readers we all perform a rudimentary causal analysis of events in an implicit, spontaneous fashion. Causality is implicit in our language and

essential to human experience. Inferences about causality are central to understanding other people, their dispositions, and intentions. They are fundamental to our understanding of events, and therefore central to how we understand narratives. Developing causal models of human events need not be seen as an effortful process. People automatically process the causal status of verbs and their implications. We suggest the building of causal discourse structures, and the updating and integration of new information into a causal network, can be done with equal facility. Clearly, more work needs to be done to directly test the nature of this representation process as the present studies do not address this issue. But, building a causal representation of a discourse would seem to be a very effective way to process information, and the data are consistent with it being the basis of text representation and a prime determinant of the availability of discourse information in memory.

An alternative to a causality-based account would be a resonance model that established reference through some combination of word and concept-level priming without attending to higher-order relations such as the causal structure of the text. The idea of passive activation of prior text information via compound cues is one that has received considerable study within cognitive psychology. Although the exact nature of the cues that would be used in a resonance model have not been specified, it is possible that some version of a bottom-up memory-based approach could also account for patterns of activation, especially given the overlap in agents and objects that usually occurs between causally related sentences. However, the simple models of overlap used here did not predict the patterns of activation that were seen, which suggests that additional assumptions would need to be articulated and added to any resonance approach. The conclusion of this set of studies, as has been true of other results consistent with a resonance model (e.g. O'Brien & Myers, 1987), is that causal analysis provides a good fit for predictions of accessibility of prior discourse information. The data suggest that the waxing and waning in the availability of prior discourse information is a function of its status in a causal model of the discourse.

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Author Note

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Appendix: Example of "Boss" Texts used in Experiments

Base Text

1. Karen and Susan were in desperate need of some money.
2. They decided that they would ask Karen's boss, Hank.
3. They jumped in the car and Karen drove to his apartment.
4. When they got there Karen said, "I'd better talk to my boss alone."
5. Karen walked resolutely into the apartment.
6. Susan turned on the car's radio to pass the time.
7. She was lucky because one of her favorite songs came on.
8. She rarely heard songs she liked on the radio these days.
9. Susan turned up the volume and sang along loudly.
10. Some neighborhood kids started to stare at her.
11. Fifteen minutes later Karen returned to the car and Susan.
12. Susan asked, "Where are we going next?"
13. Karen replied, "To the bank."

PROBE WORD: BOSS

Experiment 3 Texts with Early vs. Late Mention of Target Concepts

1. Karen and Susan were in desperate need of some money.
2. They decided that they would ask Karen's boss, Hank.
3. They jumped in the car and Karen drove to his apartment.
4. When they got there Karen said, "I'd better talk to my boss alone."
5. Karen walked resolutely into the apartment (away from the car).
6. Susan turned on the radio to pass the time.
7. She was lucky because one of her favorite songs came on.
8. She rarely heard songs she liked on the radio these days.
9. Susan turned up the volume on the car radio (and sang along loudly).
10. Some neighborhood kids started to stare at her.
11. Fifteen minutes later Karen returned to Susan.
12. Susan asked, "Where are we going next?"
13. Karen replied, "To the bank."

PROBE WORD: CAR

Experiment 4 Text with No Direct Causal Connection between Co-mention and Target due to immediate return

1. Karen and Susan were in desperate need of some money.
2. They decided that they would ask Karen's boss, Hank.
3. They jumped in the car and Karen drove to his apartment.
4. When they got there Karen said, "I'd better talk to my boss alone."
5. Karen walked back to the car with the money.
6. Susan turned on the car's radio to pass the time.
7. She was lucky because one of her favorite songs came on.
8. She rarely heard songs she liked on the radio these days.
9. Susan turned up the volume and sang along loudly.
10. Some neighborhood kids started to stare at her.
11. Fifteen minutes later Karen asked Susan to turn the radio down.
12. Susan asked, "Where are we going next?"
13. Karen replied, "To the bank."

PROBE WORD: BOSS

Table 1. Summary of Regression Results: Prediction of Condition-Level Response Times by Average Causal Distance between Probe Location and Sentence containing Target Concept.

Greene et al (1994)	<i>R</i>	<i>R</i> ²	<i>F</i>	<i>df</i>	<i>p</i>
Experiment 1	0.96	0.93	24.89	1,3	< .05
Experiment 2	0.91	0.82	18.40	1,5	< .02
Experiment 3	0.91	0.82	18.35	1,5	< .02
Lea et al (1996)					
Experiment 1	0.91	0.83	19.75	1,5	<.02
Experiment 2	0.97	0.95	80.56	1,5	<.01

Table 2: Average Causal Distance, LSA, Word Overlap and Probe Recognition Times by Condition in Experiment 1

	Causal	LSA	Word	Recognition
Probe Condition	Distance	Cosine	Overlap	Times (in ms)
Early Mention/Before Reunion	2.95	.12	0.15	1255.56 (56.0)
Early Mention/After Reunion	0.7	.28	1.1	1175.13 (44.1)
Late Mention/ Before Reunion	0.6	.30	0.65	1122.48 (51.8)
Late Mention/After Reunion	2.15	.15	0.30	1279.97 (57.7)

Table 3: Average Causal Distance, LSA, Word Overlap and Probe Recognition Times by Condition in Experiment 2

Probe Condition	Causal Distance	LSA Cosine	Word Overlap	Recognition Time
Causal/Before Co-mention	3.75	.17	0.45	1215.86 (21.5)
Causal /After Co-mention	0.95	.21	1.05	1123.43 (23.9)
No Causal/Before Co-mention	3.85	.17	0.45	1175.15 (23.4)
No Causal/After Co-mention	3.40	.21	1.10	1193.89 (21.9)

Figure Captions

Figure 1: Causal Discourse Analyses and Examples of Cousin Stories for Greene et al Simulation

Figure 2: Observed Reaction Times (standardized) for each probe condition with Causal Distance

Predictions represented by line graphs. Greene et al (1994) Experiment 1 is the left panel, Experiment 2 is the colored bars in the right panel, and Experiment 3, the open bars.

Figure 3: Causal Discourse Analysis and Example Story for Lea, et al. (1998) Experiment 2

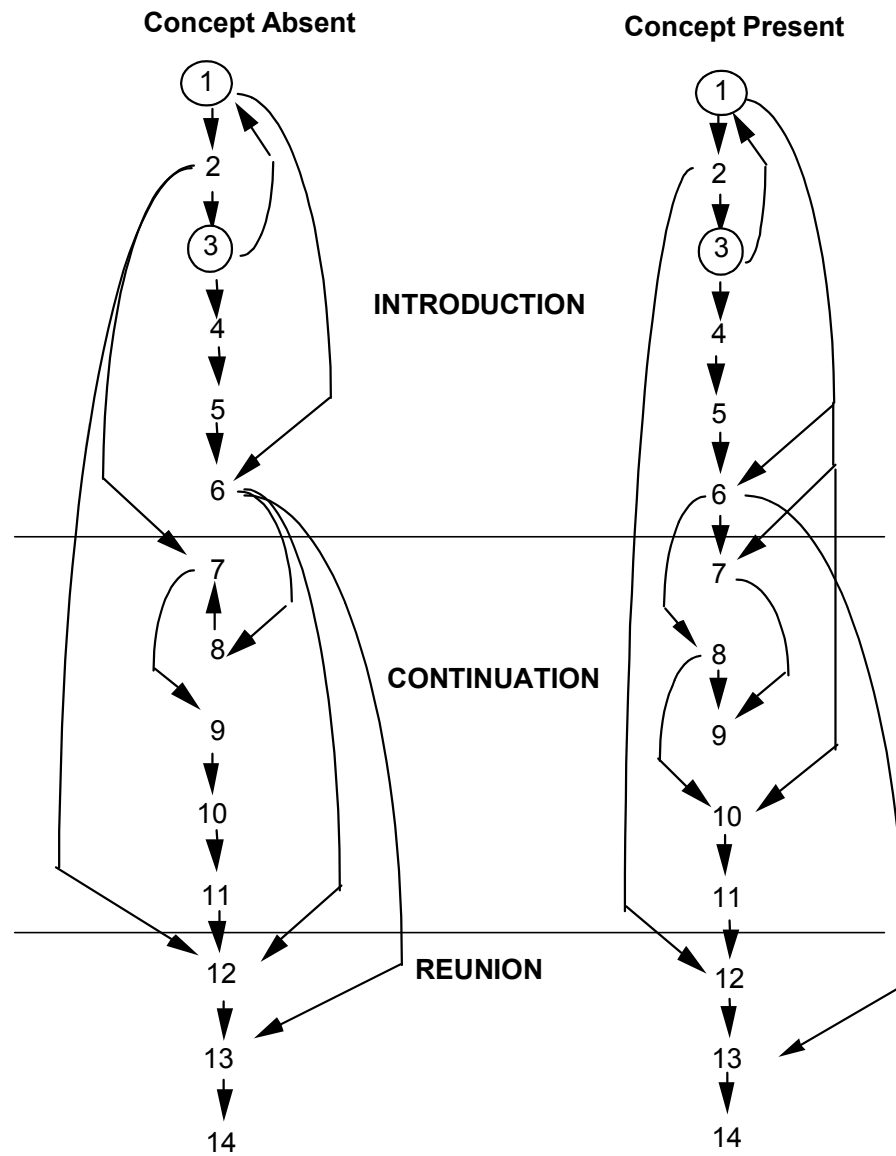
Figure 4: Observed (RTs) and Predicted (Causal Distances) Accessibility for all conditions in all experiments of Greene et al (1994) and Lea et al. (1998)

Figure 5: Observed Reunion Effects and Predicted Accessibility for all Texts in Experiment 1

Figure 6: Causal Discourse Analyses and Example Stories for Experiment 2

Figure 7: Observed Reunion Effects and Predicted Accessibility for all Texts in Experiment 2

Figure



Cousin Example Texts (Greene et al. 1994, Exp 3)

Introduction

1. Jane was dreading her dinner with her cousin, Marilyn.
2. She complained loudly to her roommate, Gloria.
3. "Every time I go to dinner at my cousin's, I get sick."
4. Gloria asked, "Why did you agree to go?"
5. Jane said, "Because I'm too wimpy to say no."
6. Jane went off to have dinner.

Continuation (Concept Absent Condition)

7. Gloria decided to cook something nice for herself for dinner.
8. "As long as I'm home alone," she thought, "I'll eat well".
9. Gloria searched her refrigerator for ingredients.
10. She found enough eggs to make a quiche.
11. After dinner, she put the dishes in the dishwasher.

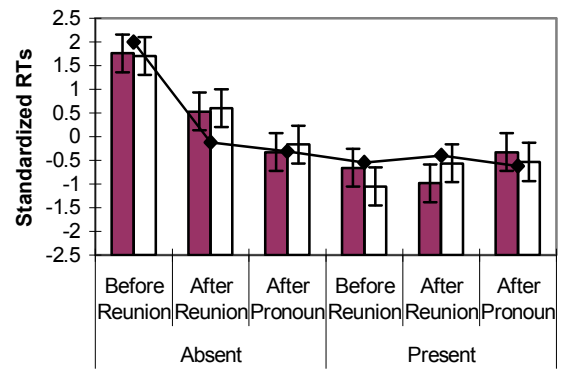
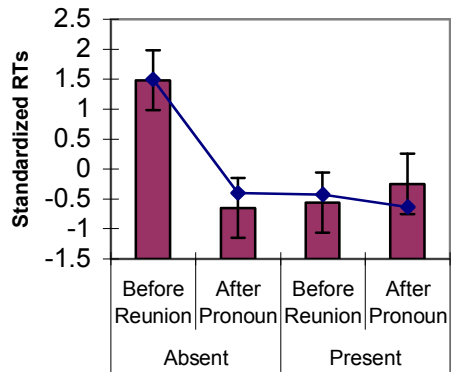
Continuation (Concept Present Condition)

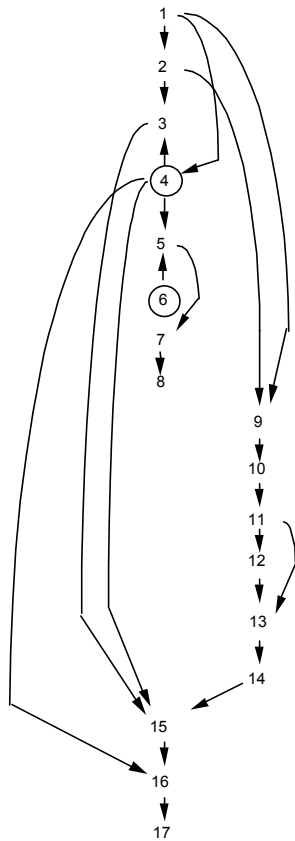
7. When she arrived, Marilyn was just finishing the cooking.
8. "You're in luck," she said, "we're having fried squid."
9. Jane knew she was in for a wonderful evening.
10. The two of them sat down to dinner.
11. After dinner, they talked for a while and then Jane left.

Conclusion

12. Gloria was still up when Jane arrived home about midnight.
13. Gloria asked Jane, "Did she play you old disco records?"
14. Jane chuckled and said, "I can't get Disco Inferno out of my mind."

Figure

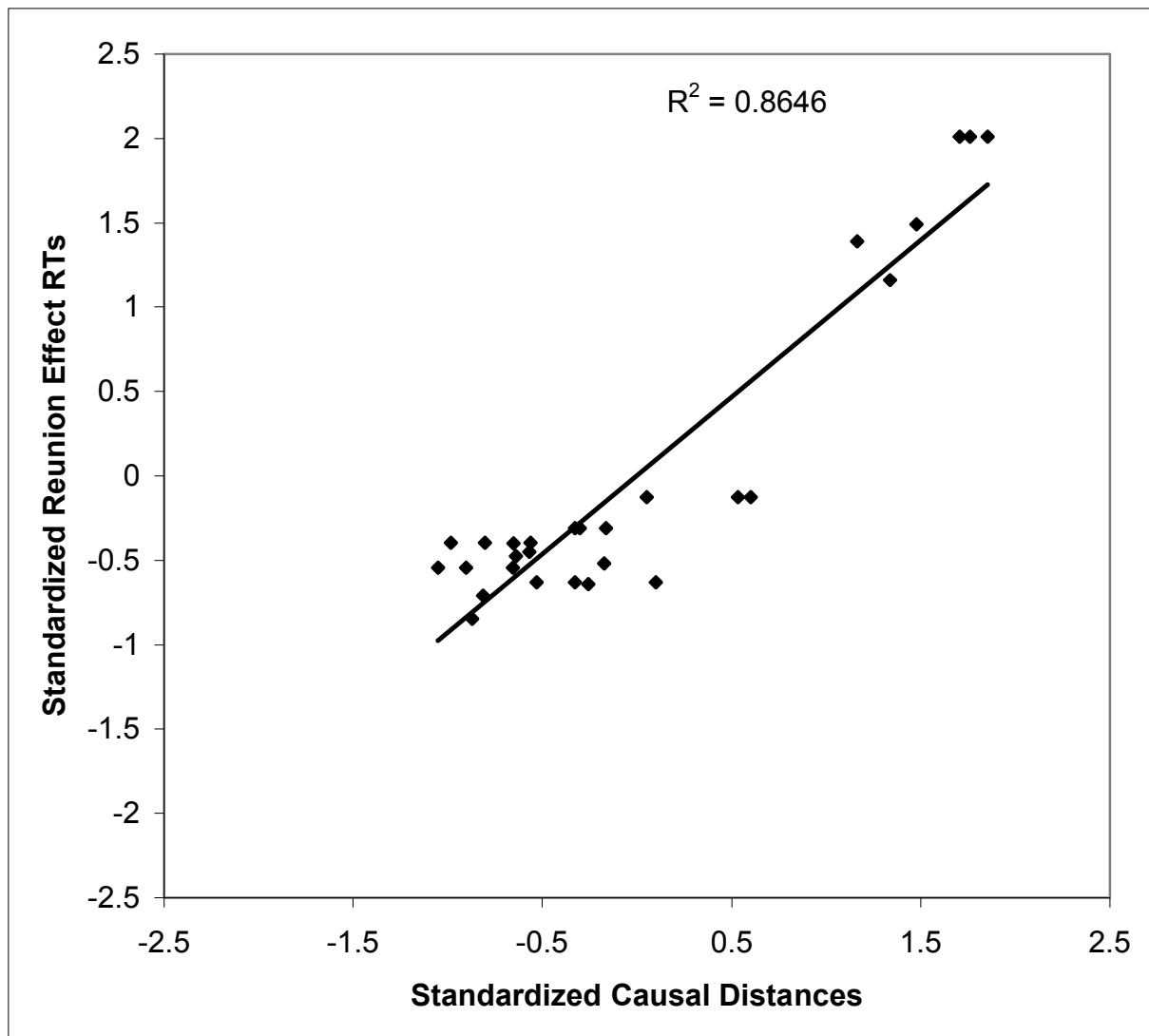




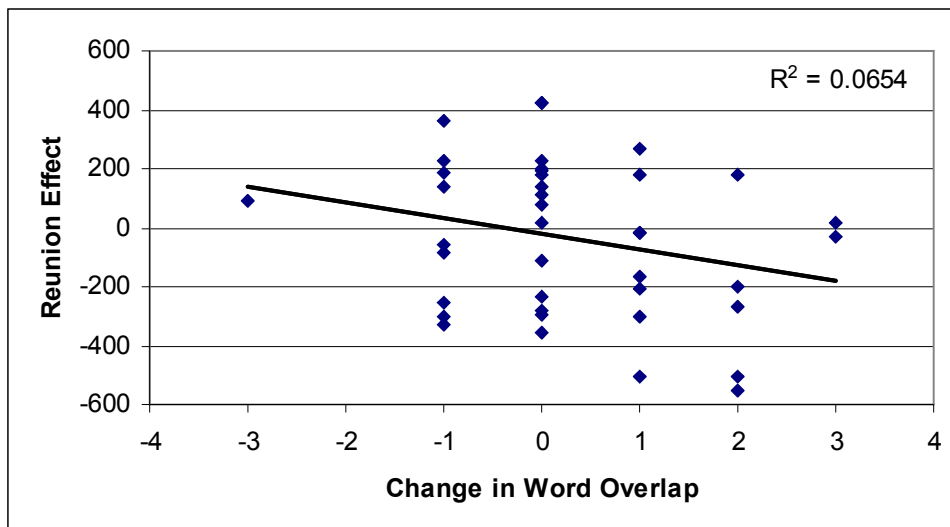
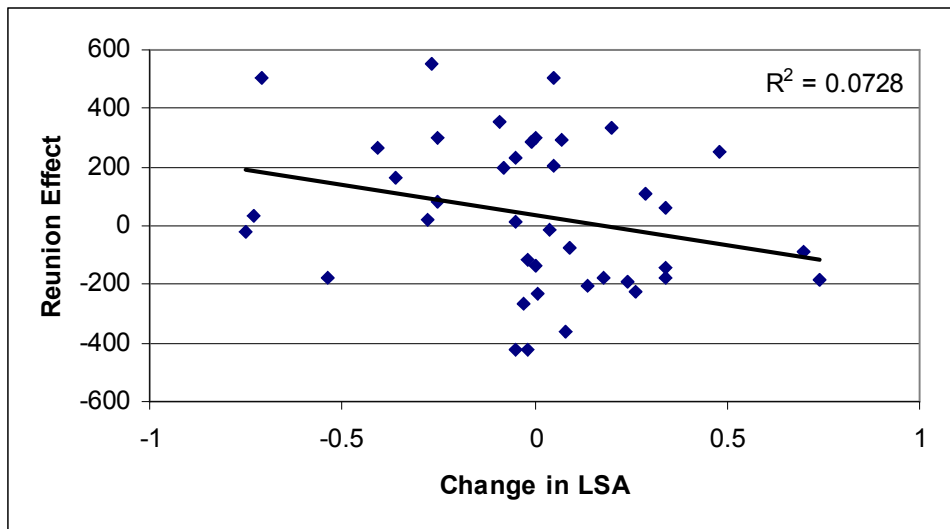
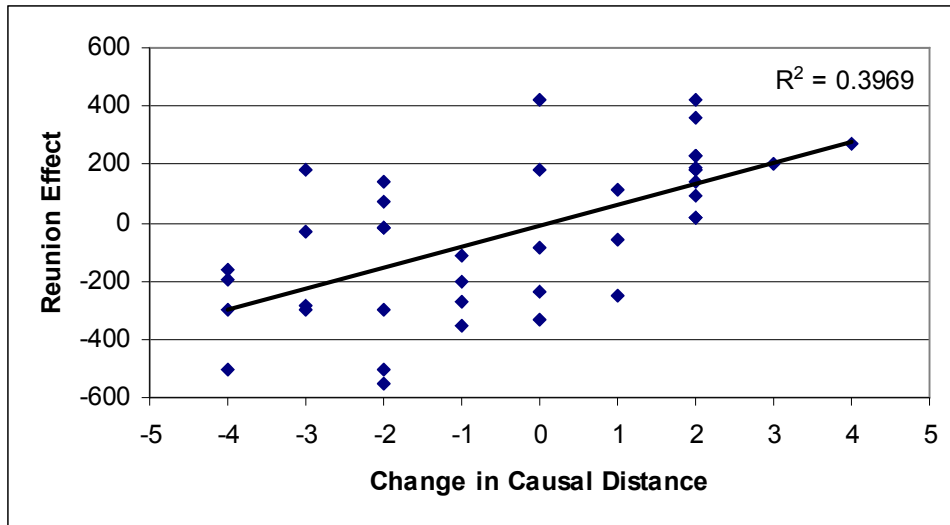
Cousin Story – No Common Ground

1. Jane and her roommate Gloria were leaving work.
2. "Are you headed home?" asked Gloria.
3. "No, but I'll see you later tonight," replied Jane.
4. Jane drove off to have dinner with her cousin, Marilyn.
5. As she drove, she started to have regrets.
6. She usually got sick when she ate at her cousin's.
7. Jane wondered why she had agreed to go.
8. She decided she was just too wimpy to say no.
9. Meanwhile, Gloria went home and
10. decided to cook something nice for herself.
11. "As long as I'm home alone," she thought, "I'll eat well."
12. Gloria searched her refrigerator for ingredients.
13. She found enough eggs to make a quiche.
14. After dinner, she put the dishes in the dishwasher.
15. Gloria was still up when Jane arrived home about midnight.
16. Gloria asked Jane, "Did she play you old disco records?"
17. Jane chuckled and said, "I can't get Disco Inferno out of my mind."

Figure



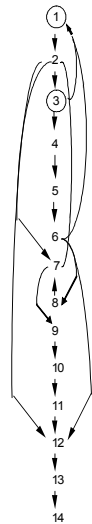
Figure





Example passage with NO causal relation between target concept and co-mention sentence

- 01 Jane remembered her dinner last night with her cousin, Marilyn.
 - 02 She complained loudly to her roommate Gloria.
 - 03 'Every time I go to dinner at my cousin's I get sick.'
 - 04 Gloria asked, 'Why did you agree to go?'
 - 05 Jane said, 'Because I'm too wimpy to say no.'
 - 06 Jane relaxed by reading the local paper.
 - 07 Gloria decided to cook something nice for dinner.
 - 08 'As long as we're at home,' she thought, 'We'll eat well.'
 - 09 Gloria searched her refrigerator for ingredients.
 - 10 She found enough eggs to make a quiche.
 - 11 After dinner, she put the dishes in the dishwasher.
 - 12 Gloria and Jane were still up when the clock turned midnight.
 - 13 Gloria asked Jane, 'Do you ever play your old disco records?'
 - 14 Jane chuckled and said, 'I can't get Disco Inferno out of my mind.'
- PROBE WORD: COUSIN



Example passage with causal relation between target concept and co-mention sentence

- 01 Jane remembered her dinner with her cousin, Marilyn.
 - 02 She complained loudly to her roommate Gloria.
 - 03 'Every time I go to dinner at my cousin's I get sick.'
 - 04 Gloria asked, 'Why did you agree to go?'
 - 05 Jane said, 'Because I'm too wimpy to say no.'
 - 06 Jane went off to have dinner.
 - 07 Gloria decided to cook something nice for dinner.
 - 08 'As long as I'm home alone,' she thought, 'I'll eat well.'
 - 09 Gloria searched her refrigerator for ingredients.
 - 10 She found enough eggs to make a quiche.
 - 11 After dinner, she put the dishes in the dishwasher.
 - 12 Gloria was still up at when Jane arrived home about midnight.
 - 13 Gloria asked Jane, 'Do you ever play your old disco records?'
 - 14 Jane chuckled and said, 'I can't get Disco Inferno out of my mind.'
- PROBE WORD: COUSIN

Figure

