Research Report

MEMORY PROCESSES AND EXPERIENTIAL CONTINUITY

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Abstract—*What are the memory processes that produce coherent representations of temporally discontinuous experiences? In this article, we describe the memory process of* resonance, *a process that provides renewed access to long-term memory information that is relevant to cues in working memory. Our experiments demonstrate parallel waxing and waning of information as a function of relevance to a current episode, a pattern of accessibility of information that contributes to the achievement of continuity across experiences.*

In Goodman's short story "The Closet" (1997), a social worker, Rosleva, has come to help with a problem: Evelyn's sister Lily has moved into a closet. After a brief conversation with Evelyn and her husband, Stan, on the topic of Lily's living arrangements, Rosleva announces, "Well, I'll go and try to talk to her." Stan and Evelyn are dubious that Rosleva will achieve success, but half an hour passes, and Evelyn gets caught up in a reverie:

> Evelyn stood by the front window and watched the light rain drift in a mist down the street. Birds splashed in pools of water between the roots of macadamia-nut trees. In the winter she and Lily used to go mudsliding near Paradise Park, up at Jackass Ginger. They took torn cardboard boxes and hiked up, ankle deep in mud. . . . (p. 75)

When Rosleva reappears, Evelyn and the reader are abruptly drawn out of this reverie. Stan asks, "She came out?" and Rosleva replies, "She came out."

This brief excerpt provides an example of circumstances that are pervasive in complex texts: Readers must achieve continuity across temporally discontinuous episodes. In this case, readers understand "She came out?" with apparently little difficulty despite the interlude of Evelyn's reverie. The need to disentangle temporally discontinuous episodes is also pervasive in day-to-day experiences. Consider a series of conversations between colleagues about the likely outcome of an electoral campaign. The colleagues have the phenomenological impression of being ready, at each reunion, to pick the conversation up where they left off the last time. In this article, we argue that a particular memory process, *resonance*, plays an important role in ensuring experiential continuity across temporally discontinuous episodes (Albrecht & Myers, 1995; Gerrig & McKoon, 1998; Lea, Mason, Albrecht, Birch, & Myers, 1998; McKoon, Gerrig, & Greene, 1996; KcKoon & Ratcliff, 1992; Myers & O'Brien, 1998; O'Brien, Rizzella, Albrecht, & Halleran, 1998).

Resonance is a fast, passive, and easy process by which cues in working memory interact in parallel with, and allow access to, any of the information in long-term memory (Gillund & Shiffrin, 1984; Hintzman, 1988; Murdock, 1983; Myers & O'Brien, 1998; Ratcliff, 1978; Ratcliff & McKoon, 1988; Tulving, 1974). Different information in long-term memory is evoked to different degrees depending on the strength of the association with the cues in working memory. The accessibility of information changes continuously over time as successive cues enter and then leave working memory. These changes are not, however, goal-directed: The accessibility of discourse representations is influenced by cues within the text rather than by higher-order principles of what readers might or must do.

Consider again the reunions of the politically inclined colleagues. We suggest that the cues at each reunion resonate through the colleagues' memory to increase immediately the accessibility of the long-term memory information necessary to continue dialogue on the topic. And, as this information takes over working memory, there are no longer cues to keep accessible whatever was in mind just before the reunion, with the consequence that information from before the reunion fades in accessibility. By ensuring reaccess of prior relevant information, resonance allows temporally discontinuous but related episodes to be bound together in memory; by allowing intervening, nontopical information to fade, resonance keeps unrelated episodes separate.

Our research was intended to test resonance-based predictions about the relative accessibility of discourse entities at different points throughout stories with episodic structures. In particular, we wished to demonstrate that some entities fade from accessibility at the same time that other entities increase in accessibility. As a consequence, only appropriate connections are made across episode boundaries. Past research has documented increases in accessibility (Greene, Gerrig, McKoon, & Ratcliff, 1994; McKoon et al., 1996), but not the complementary and simultaneous fading of accessibility. In six experiments, we used a memory probe procedure to observe the concepts in stories waxing and waning in accessibility as they were bound together or separated from each other across story episodes.

To demonstrate the binding together of temporally discontinuous experiences, we created brief texts with appropriate episodic structures. Consider the story in Table 1, which is analogous in structure to our other experimental stories. The story introduces two characters who discuss a third, *outsider* character—in this case, the cousin. The story has three versions that differ in the middle part; the critical version is the one labeled *competitor*. In this version, the outsider disappears from the scene and a new character, the mother, whom we call the *competitor*, is introduced. The important predictions, based on expectations about how resonance functions, are that cues in the reunion portion of the story will function to renew the outsider's accessibility: Jane's return home should cue access to the story's introductory material (cf. Lea et al., 1998). Each of the experimental stories had material in the reunion portion that provided cue overlap with the introductory portion. By contrast, the absence of competitor-relevant cues in the reunion portion will allow the competitor's accessibility to fade.

Note that the pronoun sentence in the reunion portion uses an *unheralded pronoun* (in this case, *she*), a pronoun for which no referent is present in the immediate discourse context (Gerrig, 1986; Greene et al., 1994). ("She" in "She came out?" from "The Closet" is a textual example of such a pronoun.) We hypothesize that resonance, in making the outsider readily available, allows the pronoun to be

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Table 1. *Example story*

	INTRODUCTION	
	Jane was dreading her dinner with her cousin, Marilyn. She complained loudly to her roommate Gloria. "Every time I go to dinner at my cousin's I get sick." Gloria asked, "Why did you agree to go?" Jane said, "Because I'm too wimpy to say no." Jane went off to have dinner.	
	MIDDLE	
Competitor	Outsider Present	Outsider Absent
As long as she was staying home alone, Gloria thought she'd eat well. She called up her mother to get the recipe for chili. Her mother cautioned her to use very fresh onions. Gloria made sure to follow that advice. (1) After dinner, she cleaned up the kitchen. (2)	When she arrived, Marilyn was just finishing the cooking. "You're in luck," she said, "we're having fried squid." Jane knew she was in for a wonderful evening. The two of them sat down to dinner. After dinner, they talked for a while, and then Jane left. (2)	Gloria decided to cook something nice for herself for dinner. "As long as I'm alone," she thought, "I'll eat well." Gloria searched her refrigerator for ingredients. She found enough eggs to make a quiche. After dinner, she put the dishes in the dishwasher. (2)
	REUNION	
	Reunion sentence: Gloria was still up when Jane arrived home about midnight. (3) *Pronoun sentence:* Gloria asked Jane, "Did she make the evening unbearable?" (4) *Final sentence:* Jane chuckled and said, "I just want to get some sleep." (5)	

Note. The numbers in parentheses indicate the test points for the probe words.

correctly bound to the outsider. The competitor, the mother, provides an alternative referent for the pronoun. If readers' text representations were not properly disentangled, we would expect the mother to be considered as a referent of "she." But by the resonance account, the reunion cues will make "cousin" accessible while "mother" becomes relatively inaccessible. That is, the resonance account predicts that the competitor will not, in fact, provide any competition: "Cousin" will wax in accessibility as "mother" wanes.

The other two versions of the middle of each story, the *outsider-present* and *outsider-absent* versions, provided necessary control conditions. In the outsider-present version, the outsider should be accessible in the discourse representation at all times. In the outsider-absent and competitor versions, the outsider should decrease in accessibility in the middle portions, but, by the resonance account, the reunion cues should bring the outsider back to accessibility again, matching the accessibility of the outsider in the outsider-present version. The reunion cues should bring back the outsider equally well for the competitor version as for the outsider-absent version because the existence of the competitor should not have a negative impact on the ability of the reunion cues to provide renewed accessibility to the outsider.

GENERAL METHOD

Each of our six experiments sampled from the same set of stories and used the same probe recognition procedure. What differed among the experiments were the probe words and the probe positions.

Participants

Across the six experiments, the number of participants varied from 15 to 30. All participants were undergraduates at Northwestern University.

Materials

As already noted, Table 1 provides an example of the structure of the experimental stories. Each text began by introducing two main characters and an outsider. The texts differed only with respect to the middle portion. Each middle portion either included the outsider (i.e., outsider-present version), excluded the outsider (i.e., outsider-absent version), or introduced a competitor (competitor version). Each story ended with a reunion portion, in which the two original characters

Table 2. *Results of experiments: Response times (in milliseconds) and error rates (in parentheses)*

		Probe point				
Story	Probe word	1 One sentence before reunion sentence	2 Immediately before reunion sentence	3 Immediately after reunion sentence	4 Immediately after pronoun sentence	5 Immediately after final sentence
Experiment 1						
Outsider present	Outsider		845 (10%)		845 (9%)	
Competitor	Outsider		923 (11%)		862 (10%)	
Experiment 2						
Outsider absent	Outsider		939 (13%)		876 (16%)	
Competitor	Outsider		939 (15%)		863 (8%)	
Experiment 3						
Outsider absent	Outsider		905 (12%)	846 (8%)		
Competitor	Outsider		921 (13%)	853 (12%)		
Experiment 4						
Competitor	Outsider		915 (13%)	882 (10%)		
Competitor	Competitor		815 (6%)	851 (7%)		
Experiment 5						
Competitor	Competitor	829 (3%)	846 (3%)	880 (6%)		
Experiment 6						
Competitor	Competitor		825 (10%)			924 (16%)

were brought back together. Each story was intended to have a normal narrative structure. For example, in the example given in Table 1, one character goes off to dinner and then returns home. In other stories, a mother goes off to her son's room to attempt a rational discussion with him and then returns to her husband in the living room, and a student goes in to a professor's office to discuss her exam grade and then returns to her fellow students waiting in the hallway.

Across the experiments, the number of experimental stories read by each participant varied from 26 to 40. The experimental stories were mixed with filler stories (2 or 3 fillers for every 4 experimental stories). The test words for the filler stories were probed at locations other than the five used for the experimental stories. In addition, some of the filler test words had not appeared in their stories. Each probe word was the role name of the outsider or competitor (e.g., "cousin," "mother"; "son," "uncle"; "professor," "secretary").

Design and Procedure

Across the six experiments, the outsider and the competitor probe words were tested at five different points, indicated by the numbers in parentheses in Table 1. The story versions, probes, and probe locations used in each experiment are indicated in Table 2.

Participants read stories one sentence at a time from a computer screen. They advanced to each next sentence in a story by pressing the space bar on the keyboard. At one or more points in each story, they were interrupted and asked to indicate as quickly and accurately as possible whether a probe word (e.g., "cousin," "mother") had appeared in the story. When a test word was displayed, it appeared alone on the screen in all capital letters. It remained on the screen until a response key was pressed, "/" for "yes, the word had appeared in the story" or "z" for "no, the word had not appeared in the story." An incorrect response was followed by an error message, the word "ERROR" presented for 1,500 ms. Participants were encouraged to respond quickly and accurately to the test words; responses slower than 1,200 ms were followed by the message "TOO SLOW." In an effort to ensure that participants read stories carefully, we presented true/false comprehension sentences after each block of four stories. Incorrect true/false responses were followed by the error message, "ERROR," presented for 1,500 ms. Responses to the probe words provide precise estimates of the relative availability of discourse referents. Responses were highly accurate, so the dependent measure of interest is response time—the more available a discourse concept, the faster the response time.

RESULTS

The results are summarized in Table 2. For each experiment, we tested response times and error rates with analyses of variance with participants (F_1) and items (F_2) as the random variables ($p < .05$ throughout this article). Only correct responses were used in calculating the means for the response times.

The first three studies examined the accessibility of the outsider character in the presence of the competitor (see Table 2). In Experiment 1, when the outsider was present throughout the story, response times for the outsider were consistently fast. However, with the competitor version of the middle part of the story, slower response times show the outsider had become less accessible by the end of the middle (test point 2), only to increase in accessibility after the reunion (test point 4), $F_1(1, 27) = 11.41$, $F_2(1, 36) = 4.94$, $SEM = 29.89$ ms. Similarly, Experiment 2 demonstrated increases in accessibility of the outsider after the reunion irrespective of whether the outsider had been absent in the middle part of the story or a competitor had been added, $F_1(1, 15) = 10.19$, $F_2(1, 36) = 4.69$, $SEM = 51.86$ ms. For Experiment 3, we used test point 3 to demonstrate that the outsider character's accessibility had increased dramatically by the end of the first sentence of the reunion, $F_1(1, 23) = 4.98$, $F_2(1, 36) = 4.16$,

SEM = 27.46 ms. Experiment 3 is particularly important because it shows that, as predicted, the cues in the reunion sentence alone are sufficient to bring the outsider back into discourse focus.

Each of these experiments demonstrates that cues in the reunion and pronoun sentences bring the outsider character back to discourse focus. Furthermore, the competitor does not seem to have provided much competition—response times for the outsider were virtually unaffected by the presence of the competitor. Jointly, these data provide strong evidence of a bond between the temporally discontinuous introductory and reunion portions of the stories.

In Experiments 4, 5, and 6, we tested the complementary prediction that the competitor ought to fade in accessibility over the same period of time in which the outsider grows more accessible. In these experiments, participants always read the competitor version of the middle of the story. The data of Experiment 4 show the predicted interaction: The competitor decreased in accessibility from before to immediately after the reunion (from test point 2 to test point 3), but the outsider increased in accessibility, $F_1(1, 23) = 16.1$, $F_2(1, 36) = 7.1$, *SEM* = 9.55 ms. Experiments 5 and 6 traced out the competitor's accessibility, high before the reunion (test points 1 and 2), and decreasing after the reunion (test points 3 and 5). In Experiment 5, the three means were reliably different, $F_1(2, 58) = 7.5$, $F_2(2, 58) = 10.4$, *SEM* = 9.2 ms, but more important, post hoc analyses confirmed that the first two means (i.e., 829 ms vs. 846 ms) are not reliably different, both $F_1(1, 30)$ and $F_2(1, 30) = 1.3$, whereas the gap between 846 ms and 880 ms is, $F_1(1, 30) = 7.2$, $F_2(1, 30) = 7.3$. In Experiment 6, the contrast between test points 2 and 5 was reliable, $F_1(1, 14) = 21.7$, $F_2(1, 25) = 29.6$, *SEM* = 12.9 ms.

DISCUSSION

The two sets of experiments complement each other in showing the swift and simultaneous waxing and waning of accessibility of discourse referents as a function of working memory cues resonating with long-term memory. This pattern is demonstrated clearly in Figure 1, which documents reciprocity in the accessibility of the outsider and competitor entities. Response times for the outsider speed up at the reunion (between test points 2 and 3) as response times for the competitor slow. Moreover, the decreased response times for the outsider at the reunion suggest that this character has become accessible once again as a referent in advance of the pronoun in the next sentence (McKoon et al., 1996).

Our results bolster an approach to text-processing research known as *memory-based text processing* (McKoon et al., 1996; O'Brien, Lorch, & Myers, 1998). The memory-based approach has had an important impact on theories of text processing by demonstrating that significant aspects of comprehension do not require readers to engage in special, goal-directed behaviors. For much of comprehension, readers do not have to purposefully activate or suppress information, as has been suggested in other approaches to text processing (e.g., Gernsbacher, 1990; Graesser, Singer, & Trabasso, 1994). The memory-based approach suggests that much of the ebb and flow of information in discourse representations can be explained without recourse to goal-directed processes. We believe that ordinary memory processes such as resonance provide the automatic foundation for important literary effects such as inferences about common ground and characters' perspectives (Gerrig & McKoon, 1998). In the current experiments, resonance made the referent of a pronoun available just by virtue of the reunion cues—without readers engaging in a special process of "pronoun resolution."

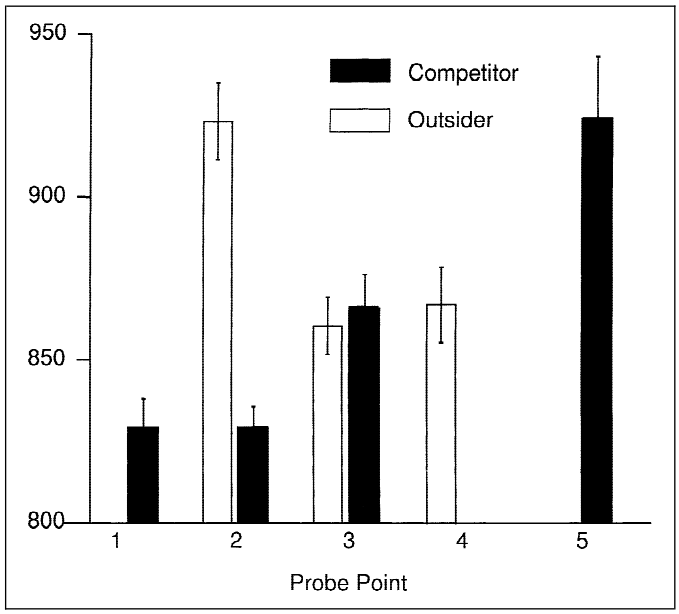

Fig. 1. Mean response times for the outsider and competitor probes at five points, from Experiments 1 through 6.

We argue, furthermore, that the memory-based approach has implications beyond the bounds of text comprehension. Our experiments show resonance at work in a situation analogous to the kinds of situations people face as an important aspect of everyday life. Interactions with other people and topics unfold in time, in temporally discontinuous episodes. We suggest that the process of resonance helps to bind those episodes together by making prior related experiences more accessible in memory even as the current episode is evolving. We emphasize the fluidity of this process moment by moment; as interactions with people and topics provide new cues, new information from memory is made ready to interact with and help in interpreting each new facet of experience. In this way, the resonance process is among the most important memory processes that give continuity to people's experiences outside of conscious awareness.

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