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Influence of Event Segmentation on Associative Recognition: Memory for Sentences Rearranged within and across Narrative Event Boundaries

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Abstract

Association and the subjective experience of time comprise two fundamental aspects to the understanding of episodic memory. The ability to recognize previously paired items from memory and reject novel pairings, termed associative recognition, is integral to everyday life; however, the mechanisms that underlie this ability remain largely debated. Recent studies of event segmentation, however, which propose that we tend to "chunk" segments of our temporal experience into distinct events in memory, may hold part of the answer. Though the field of cognitive psychology is rife with literature regarding these phenomena separately, previous research has not addressed the potential effect of this tendency to segment events in memory on recognition for associations. The present study signifies a first step toward understanding and characterizing this influence. Participants read a number of stories segmented into discrete events, followed by a test phase, during which they were presented with sentences that were *intact*, *recombined within*, or *recombined between* events. Though the results varied by story, participants false alarmed significantly more to test sentences *recombined within* versus *recombined between* events in the story most likely to accurately represent people's memory for associations within and between events. This suggests that rearranged associations within these event segments are more easily accepted as correct than are those rearranged across event boundaries.

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Whenever a person manages to remember that she left her keys in her jacket pocket, as opposed to the kitchen counter or the hook by the door, she has successfully utilized associative memory. This ability to recognize previously paired items or occurrences and to discard pairings that did not occur together is a process that has been studied extensively. Many researchers have found evidence to suggest that associative recognition is a dual-process, involving a rapid familiarity judgment and a slower, more accurate, recall-based process (Rotello & Heit, 2000; Quamme, Yonelinas, & Norman, 2007), and that these processes might be utilized according to their relative efficiency for the task at hand (Malmberg & Xu, 2007). This evidence suggests that—in order to reject an association of two items previously encountered, but not associated—one must recollect details in order to overcome the familiarity of the individual items.

One factor that has been shown to affect people's recollection of details is event segmentation. Studies of event segmentation have found evidence that—rather than encoding memory as a continuous stream of experiences—people remember events in discrete "chunks," or segments (Ezzyat & Davachi, 2011). The evidence suggests that boundaries between these memory segments in laboratory-based reading and film tasks are driven by perceived shifts in context due to changes in location, characters, goals of a character, or objects in the environment, which decrease the predictability of new information (Kurby & Zacks, 2007; Zacks, Speer, & Reynolds, 2009).

While much research has been undertaken to model associative recognition memory and event segmentation individually, the relationship between the two has yet to be explored. Since event segmentation affects detail recollection—a process involved in the rejection of previously

non-associated pairs—we anticipated that event segmentation might also affect associative recognition. In other words, if events are organized into discrete segments in memory, then a person's ability to reject recombined elements that were each individually encountered, but not previously associated, should be moderated by whether or not those elements occurred within the same or different event segments. Therefore, this study investigated the effect of event segmentation on associative recognition memory in the context of written narratives.

We hypothesized that higher levels of false memory for rearranged associations from across an event boundary might indicate that event segmentation enhances recollection of details within an event, since people utilize those details to reject recombined pairs. Conversely, higher levels of false memory for rearranged associations from within a single event might suggest that event segmentation causes details within an event to be more confusable, perhaps by making within-event associations more familiar.

Method

Participants

Participants were recruited from the online Grand Valley State University introductory psychology pool. Ten participants engaged in a pilot study, and 87 took part in the primary experiment. Participation in this study resulted in course credit toward students' introductory psychology course.

Research Design

The present study incorporated two within-subjects independent variables—test condition (*intact*, *recombined within*, *recombined between*) and story (Suzy, Timothy, Declan)—which were manipulated as within-subjects variables such that each participant read all three stories and encountered 12 trials of each test sentence type per story. Two between-subjects variables were

also used to counterbalance the stories. One, story order, varied the order in which participants read the stories using the Latin square method. The other, event order, manipulated the reading order of adjacent event pairs such that all events were either read in the order in which they were written (original order) or (swapped order). For example, if the original event order for Suzy began with (1) morning routine (2) at work (3) bookstore (4) dentist, then half of the participants read the events in that order, and half read them as (1) at work (2) morning routine (3) dentist (4) bookstore. In this way, stories and event pairs within stories were counterbalanced to control for carryover effects. Likewise, the number of sentences between the two from which a recombined test sentence is assembled was held constant: There was always be five sentences between them. For example, if, "**She browses the New Release section** *while smiling at a passerby*," was the recombined test sentence, there were exactly five sentences between, "**She browses the New Release section** while she picks at a bit of fuzz on her sleeve," and, "She flips her empty coffee cup into the trash *while smiling at a passerby*."

The experiment comprised two dependent variables. The main measure of interest was response, or reported memory for test sentences, which participants indicated as a "yes" or "no" after reading each test sentence. For the purposes of analysis, we averaged within participants to find the mean number of "yes" responses (out of 12 trials) for each condition. For the sake of clarity, "yes" responses will be referred to as "hits" for *intact* test sentences and "false alarms" for *recombined* test sentences. Reaction time data was also collected. Since test sentences varied in length, reaction time was defined as the time in milliseconds it took for a participant to respond to a test sentence *minus* the expected reading time. Expected reading time (calculated as 500ms + 200ms per word + 100ms per interval between words) resulted in negative means,

indicating that participants generally took less time than expected to read and answer each trial; therefore, the more negative the value, the shorter the reaction time.

Measure

Participants read three narrative story sets on a computer, each following a different character engaging in everyday activities. Each story was composed of six events, with event boundaries denoted by both passage of time (e.g. "*Several days later*…") and changes in setting. A test phase followed each story, during which participants were presented with sentences that (1) they had read before (*intact* condition), (2) were comprised of two sentence halves from within a single event rearranged to form a new sentence (*recombined within* condition), or (3) were comprised of half of a sentence from one event, and half from a different event (*recombined between* condition). For example, the main character of a story might go to the bookstore and browse the New Release section while picking at a bit of fuzz on her sleeve, and later flip her coffee cup into the trash while smiling at a passerby. In the following event, she might go to the dentist, where she scribbles her signature on the sign-in sheet while peeking up at the clock on the wall. An *intact* test question would present a sentence that has been read before, such as, "She browses the New Release section while picking at a bit of fuzz on her sleeve." A *recombined within* test question, however, would present a sentence such as this: "She browses the New Release section while smiling at a passerby." Contrastingly, a *recombined between* test question would present a sentence recombined across event boundaries, such as: "She flips her coffee cup into the trash while peeking up at the clock on the wall."

Procedure

Prior to the study, participants read and completed consent forms to ensure informed consent and confirm their eligibility to take part in psychological experiments. Once the

experiment was ready to begin, participants were informed that this was a study of memory for associations within sentences, and given instructions for the reading and recognition procedures of the study. They then took a practice test, which involved reading a short story with the layout and procedures of the experiment. After a brief pause for questions, participants were prompted to continue on to the first phase of the experiment. Each story appeared on the computer screen on a sentence-by-sentence basis. A test sequence followed each story, in which a sentence appeared on the screen and participants were prompted either to indicate that, yes, they had read that sentence before, or no, they had not read that sentence before. Each test phase included 12 each of *intact*, *recombined within*, and *recombined between* test sentences. After the experiment ended, participants received debriefing forms with information clarifying the purpose and hypothesis of the experiment, and the researcher answered any further questions. The entire process required approximately 40 minutes to complete.

Results

To assess participants' memory for story sentences, we performed a two-way analysis of variance (ANOVA) using story (Suzy, Timothy, Declan) and test condition (*intact*, *recombined within*, *recombined between*) as independent variables and response (mean "yes" responses) as the dependent variable. No counterbalance variables reached significance in this analysis, so they were removed from the model. The analysis yielded two significant main effects and an interaction. First, there was a significant main effect for test condition, $F(2, 639) = 6.73$, $p < 0.01$. Orthogonal contrasts revealed that participants accepted *intact* test sentences ($M = 5.12$) more often, on average, than *recombined* test sentences ($M = 4.54$), $F(1, 639) = 12.51$, $p < 0.001$; however, there was no significant difference in participants' mean false alarm rates between test sentences *recombined within* ($M = 4.45$) versus *recombined between* ($M = 4.63$) events, F(1,

639) = 0.95, $p = 0.33$. This indicates that participants were able to discriminate between sentences they had seen before and those that were recombined, but provides no evidence to suggest that they false alarmed more often to one or the other recombined test conditions.

There was also a main effect for story, $F(1, 782) = 404.04$, $p < 0.0001$, such that participants accepted test sentences from Suzy's story (*M* = 7.82) more often than from Timothy's story (*M* = 3.40), and accepted test sentences from Declan's story (*M* = 2.98) the least often, on average. All of these differences reached significance at an overall $\alpha = 0.05$, calculated with a least squares means posthoc procedure.

The analysis also returned a significant interaction between story and test condition, $F(4, 782) = 4.59$, $p < 0.01$. A least squares means posthoc procedure revealed that, while the Suzy story led participants to false alarm significantly more often to test sentences *recombined within* (*M* = 8.05) than *recombined between* (*M* = 7.31) events, the Timothy story resulted in the opposite: participants false alarmed more frequently, on average, to test sentences *recombined between* (*M* = 3.61) than *recombined within* (*M* = 2.54) events. The difference between the false alarm rates in the Declan story did not reach significance. Table 1 gives the means and standard deviations from this analysis, and Figure 1 displays the interaction in graphical form.

In order to better understand these findings, we carried out a two-way ANOVA with test condition, story, story order, and event order as independent variables and reaction time as the dependent variable, which resulted in four significant main effects and no interactions. Within the main effect for test condition, $F(2, 639) = 3.9$, $p = 0.02$, orthogonal contrasts showed that participants responded to *intact* test sentences (*M* = -1013) more quickly than *recombined* test sentences (*M* = -907), $F(1, 639) = 5.02$, $p = 0.025$; however, there was only a marginally

significant difference between participants' reaction times to test sentences *recombined within* (*M* = -862) versus *recombined between* (*M* = -953) events, $F(1, 639) = 2.78$, $p = 0.0957$.

A main effect for story was also found, $F(2, 782) = 83.61$, $p < 0.001$, such that participants responded the quickest to test sentences from the Declan story (*M* = -1323), significantly slower to those from the Timothy story (*M* = -881), and the slowest to those from the Suzy story (*M* = -624). A least squares means posthoc procedure showed that all of these differences reached significance at an overall $\alpha = 0.05$. Average reaction times by story and test condition are shown visually in Figure 2.

Two counterbalance variables reached significance in this analysis, as well. There was a main effect for story order, $F(2, 782) = 32.6$, $p < 0.001$, and a least squares means posthoc procedure revealed that when participants read the stories in Timothy-Declan-Suzy order (*M* = -687), they took significantly more time to respond than when they read the stories in either the Declan-Suzy-Timothy (*M* = -1066) or Suzy-Timothy-Declan (*M* = -1074) orders. Figure 3 presents this data, within each story, in graphic form. The main effect for event order also reached significance, $F(2, 782) = 44.24$, $p < 0.001$, such that participants who read event pairs in the order in which they were originally written (*M* = -794) responded significantly slower than did participants who read them in the swapped order (*M* = -1091). Figure 4 displays a visual representation of the effect of event order on reaction time.

A final ANOVA examined the responses from a different perspective, with accuracy—mean "yes" responses to intact test sentences and "no" responses to recombined test sentences—as the dependent variable and story and test condition as the independent variables. Once again, the counterbalance variables did not reach significance. This analysis uncovered a main effect for both test condition, $F(2, 639) = 20.75$, $p < 0.0001$, and story, $F(2, 782) = 8.19$, $p < 0.001$.

Importantly, participants were significantly more accurate when responding to test sentences from the Timothy (*M* = .74) story than from the Suzy (*M* = .69) or Declan (*M* = .69) stories. As displayed in Figure 5, there was also a significant interaction between test condition and story, $F(4, 782) = 3.86$, $p = 0.004$, such that participants were significantly more accurate in identifying recombined test sentences when they were *recombined* between versus *within* events for the Suzy (*M* = 8.79, 7.95) and Declan (*M* = 9.02, 8.39) stories, but there was no significant difference for the Timothy story (*M* = 9.25, 9.46).

Discussion

Though there was no significant difference between participants' overall false alarm rates for test sentences recombined *between* versus *within* events, the results do suggest that there may be a difference in people's ability to reject pairings of information recombined within events versus across event boundaries: Given the great amount of variation by story in test sentence responses, the stories were likely not uniformly successful in engendering event boundaries. In fact, the two stories that resulted in significant false alarm differences had effects in opposite directions: The average number of false alarms for test sentences from the Suzy story was higher for *recombined within* versus *between* events by an average of 0.75 "yes" responses (out of 12); in the Timothy story, however, the number of false alarms was higher for test sentences *recombined between* versus *within* events by an average of 1.07 "yes" responses. This result would seem contradictory, if not for the systematic variation in participants' reaction times, as demonstrated in the consistent pattern of reaction time differences by story shown in Figures 2 through 4.

Participants took significantly longer to respond to test sentences from the Suzy story than from the other two, and the later on in the story order that Suzy's story appeared, the longer

participants took to respond overall. Longer reaction times could signify a number of different situations; however, it is likely that slower response times indicate greater engagement in the task for several reasons. First, responses to the Declan story—the story to which participants responded the quickest—lacked any indication of memory discrimination: there was no significant difference between the mean of affirmative (“yes”) responses given for any of the test conditions within the Declan story. In contrast, responses to the Suzy story—the story to which participants responded the slowest—did indicate significant memory discrimination in responses. Second, participants, on average, took less time to read and respond to test trials than the amount of time they were anticipated to take just to read the item – as evinced by the negative reaction time means. While this may indicate a misjudgment in the amount of time participants would take to read the sentences, it more likely implies that the shorter a participant’s reaction time to a trial, the lower his or her level of engagement in the task, especially given the sheer amount of material participants were requested to read. Therefore, it might be that the event boundaries in the Suzy story were more concrete, or conducive to event segmentation, than were those in the Timothy and Declan stories; or, alternatively, the Suzy story might have engaged participants in the task to a greater extent, leading to more thoughtful responses.

Either way, if this interpretation is correct, then the higher false alarm rates for test sentences *recombined within* versus *between* events from the Suzy story indicate that people segment events in memory, and that associations within these events are more easily accepted when rearranged than are associations across event boundaries. This could be due to more similar content within distinct spatial/temporal contexts, leading the two halves of a recombined prompt to cue the recollection of context between them more easily within than between event boundaries, which mutually reinforces the association. Likewise, there is evidence that people

perceive context to shift more rapidly at event boundaries than within events (Polyn, Norman, & Kahana, 2008), further supporting the idea that the reduced similarity in context at event boundaries makes recombined associations across such boundaries to stimulate less overlapping activation, and therefore be less mutually reinforcing.

These findings have consequence for any context in which correctly remembering associated information is necessary. For example, if a lecturer wishes to introduce the names and key dates associated with several historical figures within a single chapter, her students might be more likely to remember the correct associations if they are introduced in different lecture periods or with significant breaks in between. Similarly, a student might be more likely to retrieve correct name-date associations on an exam if he studied the associations in discrete chunks.

Of course, this interpretation—that the results from the Suzy story most correctly represents people's memory for associations within and between events—does require some follow-up in order to determine its accuracy. Given the great variability in results for each story, future studies should more rigorously standardize the content, sentence length, word length, and so forth between stories. Likewise, if lack of participant engagement accounted for some of the variation, then shorter testing sessions might help to maintain that engagement and yield more precise results. Future studies should also attempt to measure reading time directly, in order to more exactly establish participants' reaction times on test trials. Shortening the gap between recombined elements in the stories might also serve to decrease some of the variance found in the present study. Despite its limitations, as a preliminary study, the present experiment was useful as a means of discerning what differences within a story might matter in terms of variance in results, and what best to address in order to refine them for the most accurate results.

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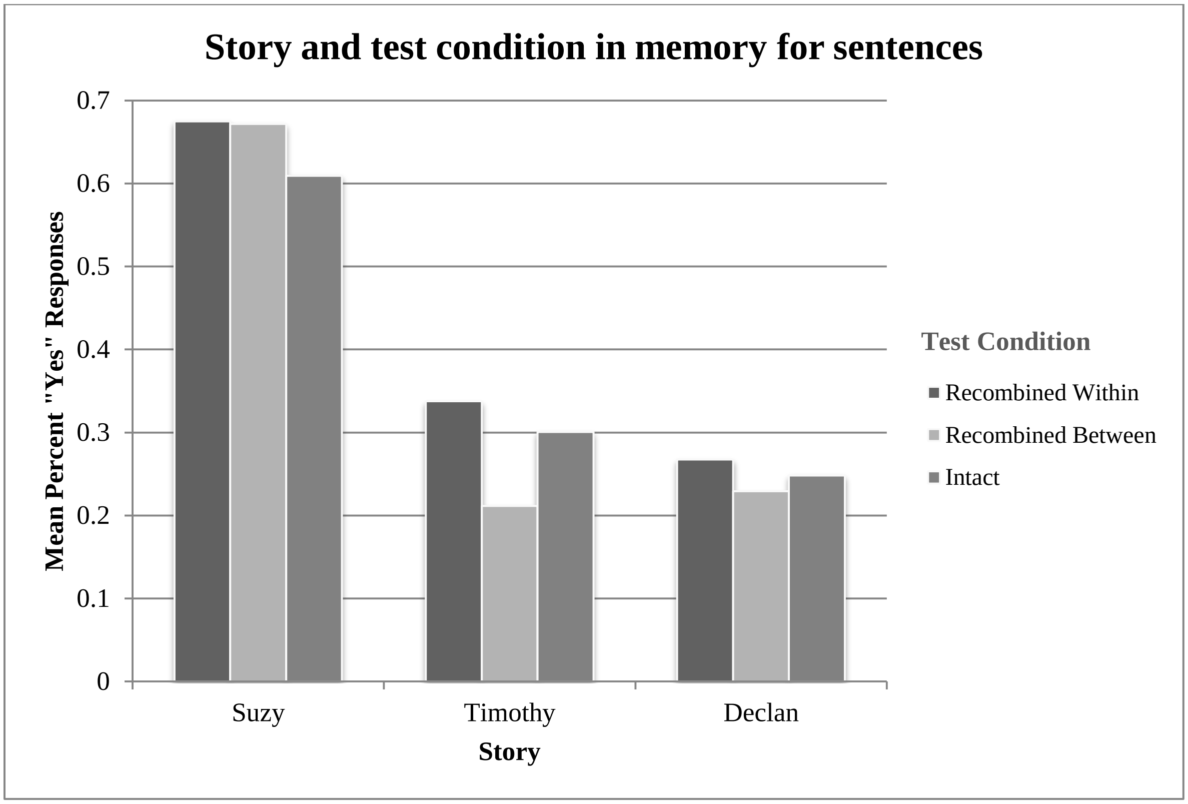
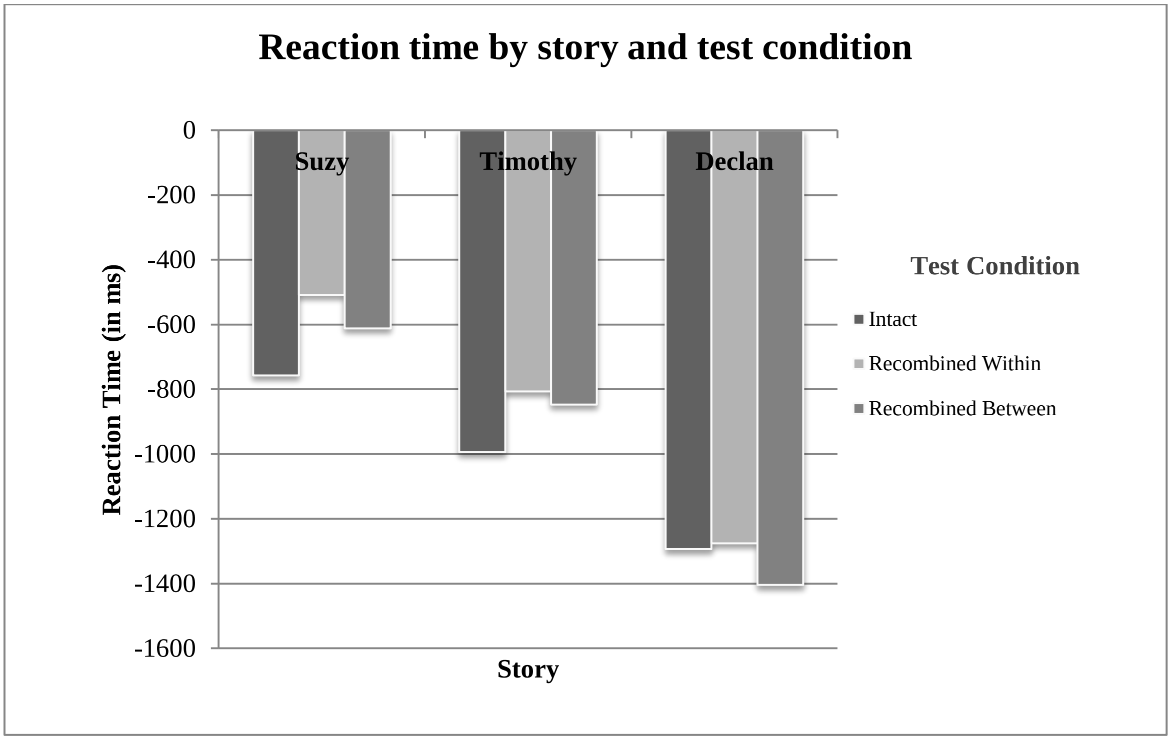
Appendix A: Table 1. Mean percent test sentence acceptance (and standard deviation) for each story by test condition.

Memory for test sentences by story and test condition						
			Story			
			Suzy	**Timothy**	**Declan**	***Mean***
Test Condition	**Intact**	*M*	0.68	0.34	0.27	0.430
		SD	2.17	2.09	2.27	
	Recombined Within	*M*	0.67	0.21	0.23	0.370
		SD	2.14	1.88	2.20	
	Recombined Between	*M*	0.61	0.30	0.25	0.387
		SD	2.44	2.1	2.1	
Mean			0.653	0.283	0.250	0.400

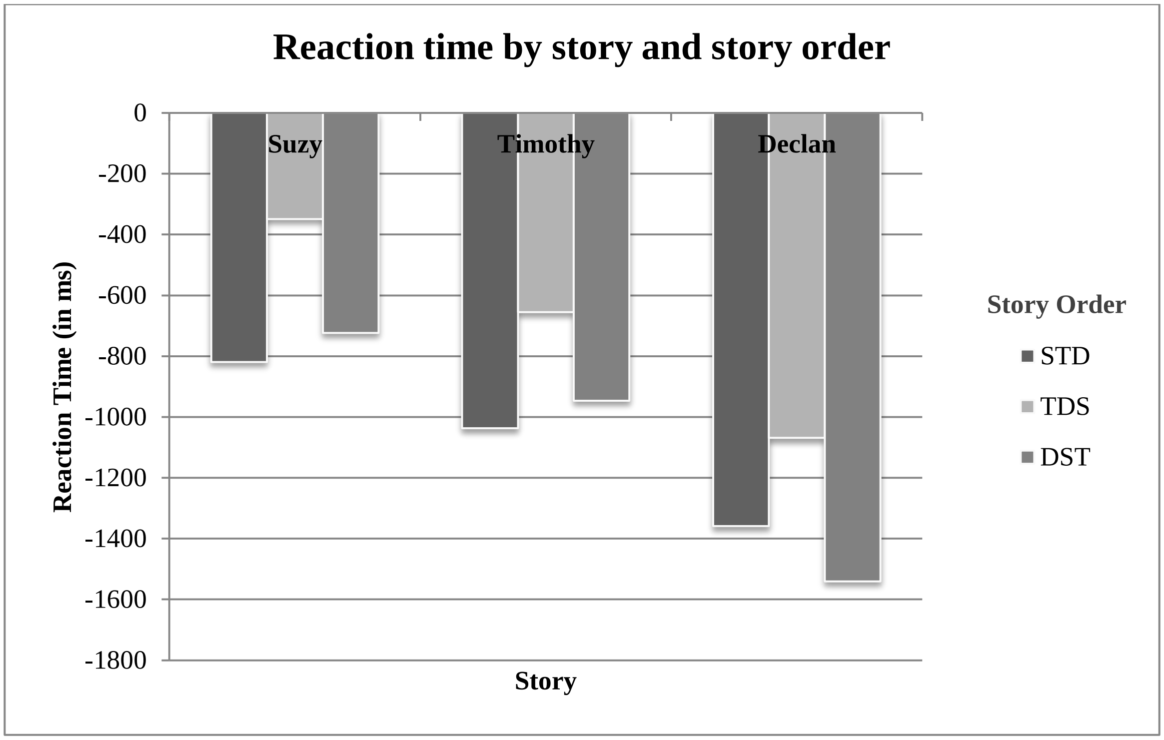
Appendix B: Figure 1. Interaction effect between story and test condition for affirmative ("yes") responses.



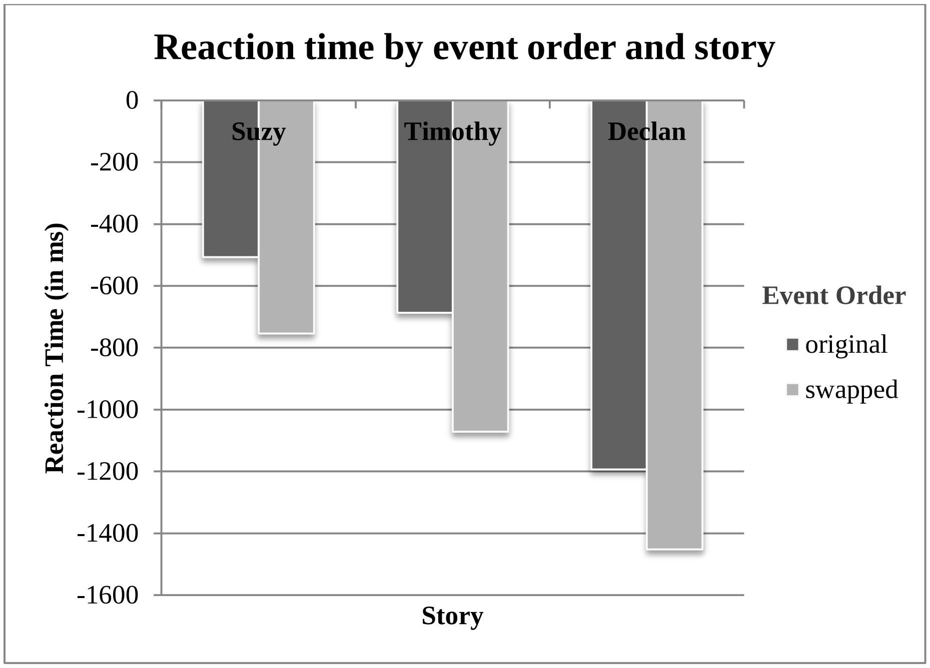
Appendix B: Figure 2. Calculated reaction time (actual response time – expected reading time) by test condition and story. Lower values indicate faster reaction times.



Appendix B: Figure 3. Calculated reaction time (actual response time – expected reading time) by story order and story. Lower values indicate faster reaction times.



Appendix B: Figure 3. Calculated reaction time (actual response time – expected reading time) by event order and story. Lower values indicate faster reaction times.



Appendix B: Figure 5. Interaction effect between story and test condition for response accuracy.