Original Article

QJEP

Quarterly Journal of Experimental Psychology
2021, Vol. 74(6) 1117–1127
© Experimental Psychology Society 2021
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/1747021820982602
qjep.sagepub.com
SAGE

Encoding and referent event influence on retrospective memory

Andrea E O'Rear[1,2] and Gabriel A Radvansky[1]

Abstract

Previous work from our lab has shown that event structure can influence memory performance. Our work in prospective memory has shown that, consistent with an event model view, performance is better when multiple encoding events refer to a common retrieval event. The aim of this study was to assess the generality of this influence of event model structure on memory by using two retrospective memory tasks. This was done using lists of sentences (Experiment 1) and narrative texts (Experiment 2). The results of these retrospective memory tasks replicated that of the prospective memory task and are most consistent with an event cognition account. These results also suggest that encoding and referent event structures may affect some levels of representation (e.g., the surface form) more than others (e.g., the textbase and event model). Overall, we demonstrate that event structure has principled influences on memory apart from the nature of the materials or the task. Moreover, we discuss how these findings are inconsistent with more traditional theories of memory processing, such as associative interference and spreading activation accounts.

Keywords

Event cognition; recognition; narrative; retrospective memory

Received: 9 August 2019; revised: 8 November 2020; accepted: 1 December 2020

Event cognition (Radvansky & Zacks, 2014) is a guiding framework for understanding how people structure and process complex sets of information. Previous work by O'Rear and Radvansky (2019), in the first direct test of location-based prospective memory, revealed an effect of the number of encoding and referent events on performance. Specifically, when people needed to remember to do two future tasks, performance differed based on the number of events in which the two instructions were encoded and the number of future events to which those two instructions referred. Memory was best when tasks were learned in two locations and were to be done in one common location. The aim of this study was to assess whether this principle of event cognition is a generalisable one about how cognition processes and remembers information, or whether these principles are actually constrained to a narrow range of circumstances, such as those involved in prospective memory.

Event cognition

People create mental representations, or *event models*, of various situations that they encounter (Radvansky & Zacks, 2014). Following the Event Horizon Model, event model structure can influence memory and cognition in a number of ways. Of particular concern here are two principles: (a) unrelated sets of information are segregated into separate event models, serving as a form of chunking, and this can facilitate memory (Kurby & Zacks, 2008; Pettijohn et al., 2016; see also Radvansky, 2012); and (b) information from separate events that contain related elements can interfere with one another.

Of central interest here is a study by O'Rear and Radvansky (2019, Experiment 2) on prospective memory that assessed event structure and memory performance. For this study, people navigated a virtual mall doing an ongoing task, and when they arrived in target locations, they were to recall prospective memory tasks. Going beyond prior research that focused on only a single type of event structure on memory, O'Rear and Radvansky assessed two types, namely encoding events and referent

---

[1]Department of Psychology, University of Notre Dame, Notre Dame, IN, USA
[2]Department of Psychological Sciences, Saint Mary's College, Notre Dame, IN, USA

Corresponding author:
Andrea E O'Rear, Department of Psychological Sciences, Saint Mary's College, Notre Dame, IN 46556, USA.
Email: aorear@saintmarys.edu

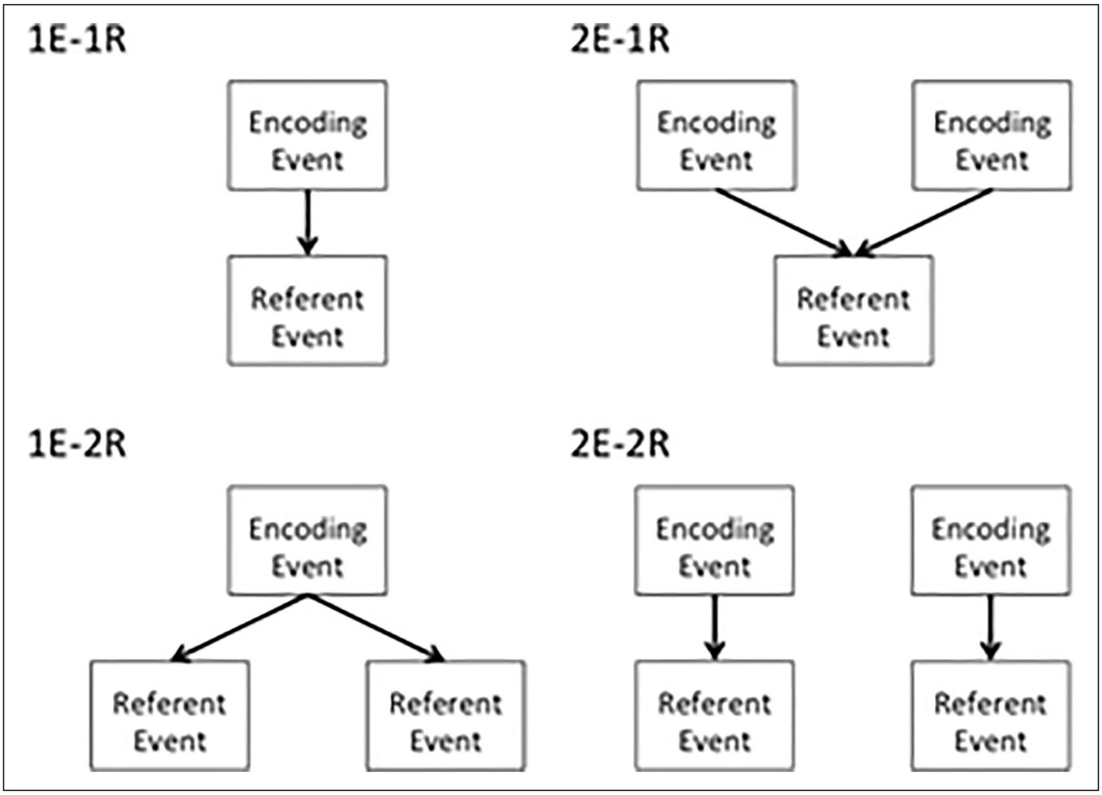


Figure 1. Basic design used in O'Rear and Radvansky (2019, Exp. 2) and in the present study.

events. On each trial, there were two prospective memory tasks. Importantly, we varied (a) the number of encoding events (locations) in which the two tasks were learned and (b) the number of referent events (locations), in which the tasks were to be done. The design is shown in Figure 1. For the encoding events, the two tasks could either be learned at one location (the information desk) or two (the information desk and the mall manager's office). For the referent events, the two tasks were either to be done in one location (e.g., both in American Beagle Outfitters) or two different locations (e.g., task 1 in American Beagle Outfitters, and task 2 in Radio Shock).

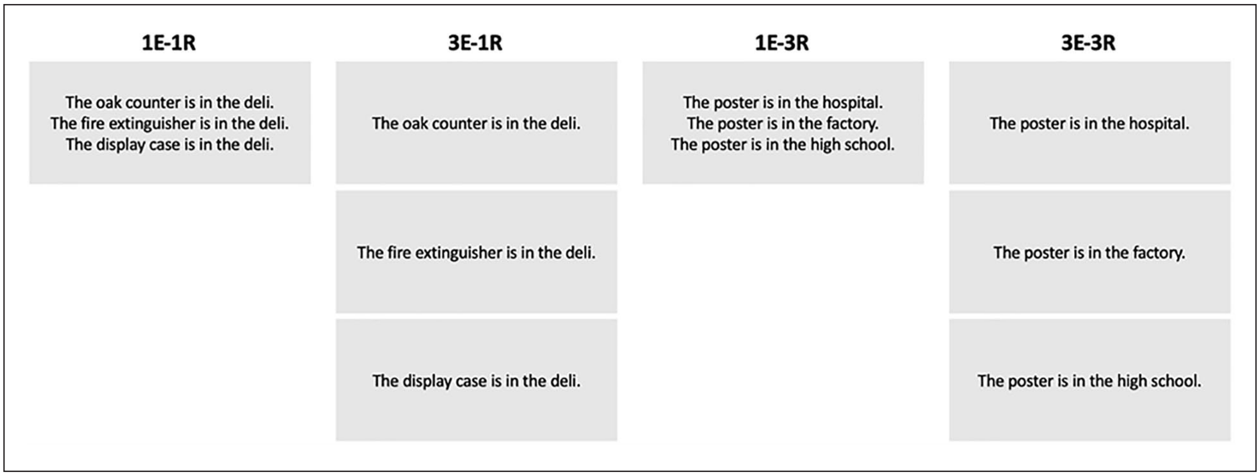
The results revealed that performance was better in the 2E-1R condition compared with the other three. The event cognition explanation was that in this condition, the same referent event was processed twice, once at each encoding location, thereby increasing memory for what was to be done in that place. In the 1E-1R and 1E-2R conditions, there was only a single encoding of either a single referent event or two referent events, and in the 2E-2R condition, there were two encoding events, but they each referred to a single referent event, resulting in each to be processed only once.

The aim of the current work was to explore whether the influence of the number of encoding and referent events reflects general influence of event structures in event cognition. This was done by assessing whether this pattern of data would be observed in two different retrospective memory paradigms. To do this, people either learned lists of sentences (Experiment 1) or read narrative texts (Experiment 2). In both cases there were single or multiple encoding events, and single or multiple referent events.

Experiment 1

For Experiment 1, people memorised sets of sentences about objects in locations in which there was a common concept across the three sentences (either a common object or a common location). The encoding events were whether the sentences in a set of three were presented together in a common computer window (1E) or one at a time in different computer windows (3E). The referent events were whether the sentences in a set of three all referred to a common event of multiple objects in one location (1R) or referred to three separate events of a common object in each of three locations (3R). According to an event cognition view, performance should be best in the 3E-1R condition.

More specifically, people learned a list of sentences about objects in locations, such as "The potted palm is in the museum." For each object and location, there were either one or three associations, with the stipulation that one concept would have three and the other would have one. Following prior research of the differential fan effect



1E-1R

The oak counter is in the deli.
The fire extinguisher is in the deli.
The display case is in the deli.

3E-1R

The oak counter is in the deli.

The fire extinguisher is in the deli.

The display case is in the deli.

1E-3R

The poster is in the hospital.
The poster is in the factory.
The poster is in the high school.

3E-3R

The poster is in the hospital.

The poster is in the factory.

The poster is in the high school.

Figure 2. Example materials for the conditions in Experiment 1. Each box represents one window on a computer screen. Only one window was shown at a time.

(e.g., Radvansky et al., 2017; Radvansky & Zacks, 1991), these materials were divided into two conditions. The first was the *Single Location* condition in which a set of sentences were about multiple objects in a single location, such as:

> The oak counter is in the deli.
>
> The fire extinguisher is in the deli.
>
> The display case is in the deli.

In cases such as this, people can easily integrate this information into a common event model. The second was the *Multiple Location* condition in which a set of sentences were about a single object in multiple locations, such as:

> The poster is in the hospital.
>
> The poster is in the factory.
>
> The poster is in the high school.

Here, people are likely to treat these as referring to three different events, and so each of these is represented by a separate event model. A consequence of this is that on a later recognition test, people respond faster to memory probes from the Single Location condition than those in the Multiple Location condition. Thus, this satisfies our requirement for materials that refer to single or multiple events.

For the encoding events, we manipulated the grouping of the sentences during learning. All of the sentences about a common object or location were either presented together, as part of a single learning event, or separately in a randomly ordered study list (as is typically done in differential fan effect studies), as part of multiple learning events. For the learning (encoding) and referent events, the conditions were 1E-1R, 1E-3R, 3E-1R, and 3E-3R. Figure 2 shows an example of what a participant could see for each of these four conditions.

For the Event Cognition view (O'Rear & Radvansky, 2019), memory will be better when multiple learning events refer to a common event as compared with other conditions. That is, relative to the other combinations of learning and referent events, memory will be better when there are multiple learning events (study sentences presented singly) that refer to a common event (Single Location condition). That is, 3E-1R > 1E-1R, 1E-3R, and 3E-3R.

Method

Participants. We tested 50 participants (38 female, ages 18–22, $M = 19.6$) who were drawn from the University of Notre Dame, Department of Psychology participant pool. These people were compensated with partial class credit. To determine the sample size, given that there had never been any prior studies of this sort, we simply decided that once we had begun testing with 3 weeks left in the semester, to continue testing until the semester completed. An additional three participants were replaced for failing to comply with instructions. The university's Institutional Review Board approved all procedures.

Materials. Participants studied 24 sentences in the form of "The *object* is in the *location*," such as "The welcome mat is in the hospital." Each object was paired with one or three locations, and each location was paired with one or three objects, such that one of the concepts had three associations, and the other had one. The assignment of the objects and locations to the study list design was randomly assigned for each person to produce a unique set of study sentences.

For the recognition test, the studied probes were the 24 study sentences and 24 nonstudied probes that were recombinations of objects and locations from within the same cell of the design. For instance, if the two 1E-3R study sentences were "The oak counter is in the hotel" and "The pay phone is in the high school," then the corresponding nonstudied probes would be "The oak counter is in the high school" and "The pay phone is in the hotel." Creating the nonstudied probes this way avoids the possibility that people will use plausibility judgements (Reder & Anderson, 1980) to make the recognition decisions. Because the nonstudied probes had the same number of associations with the object and location concepts, they could be assigned to the various conditions, as appropriate.

Procedure. The experimenter read brief instructions to participants, who were then taken to individual testing rooms. They read and electronically signed an informed consent form, followed by a demographics form and more detailed instructions. When the experiment began, the object-location sentences were presented on screen for 7 s per sentence. For half of the sentences in a set, each sentence was presented alone in the computer window for 7 s. However, for trials where the three sentences were shown together in a common window, they remained on screen for 21 s. The entire list of sentences was presented twice across two blocks in which a different random order was used for each block, with each participant receiving unique random orders.

After this study period, participants completed a recognition test. A practice round of 18 trials came first to accustom participants to the button presses. The left mouse button indicated a "yes" response, and the right mouse button indicated a "no" response. Participants were encouraged to respond as fast and as accurately as possible. During the practice round participants were to say "yes" when the screen showed "STUDIED," and "no" when it showed "NOT STUDIED." During the recognition test, one sentence would be shown at a time in the centre of the screen. Half of the sentences were those originally studied, and the other half were recombinations of the objects and locations. Each studied and nonstudied probe sentence was presented only once. A debriefing was provided at the end of the experiment.

Results and discussion

For this study, we analysed the response time and accuracy data. Like other work of this sort (e.g., Radvansky & Zacks, 1991), the primary dependent measure is response time.

Response times. The response time data, averaged across the Studied and Nonstudied trials, are shown in Figure 3. Note that the response time data only includes those trials in which a correct response was made. These data were submitted to a 2 (Studied vs Nonstudied) × 4 (Condition) repeated-measures analysis of variance (ANOVA).[1] After this, planned comparisons were made among the various conditions following O'Rear and Radvansky (2019). For the main ANOVA, there was a main effect of Studied-Nonstudied, $F(1,\ 49)=38.05$, $MSE=171{,}628$, $p<.001$, $\eta_p^2=.44$, with people responding faster to Studied probes ($M=1{,}627$ ms; $SE=34$) than to nonstudied probes ($M=1{,}882$ ms; $SE=40$). There was also a significant main effect of Condition, $F(3,\ 147)=14.64$, $MSE=143{,}997$, $p<.001$, $\eta_p^2=.23$. The interaction was not significant, $F(3,\ 147)=1.17$, $MSE=174{,}001$, $p=.33$, $\eta_p^2=.02$.

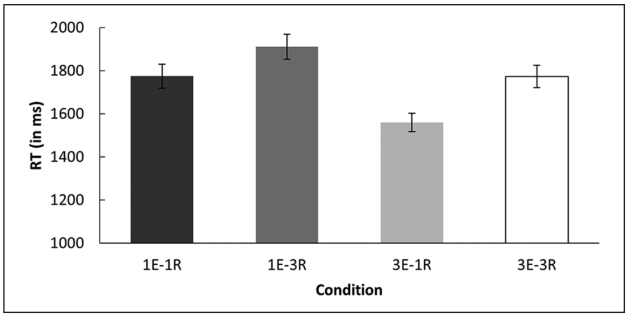


Figure 3. Response times, with standard error bars, in each structure condition when indicating whether a given sentence was previously learned. These data are averaged across the Studied and Nonstudied conditions.

Comparisons across the four conditions revealed that, consistent with the O'Rear and Radvansky (2019) prospective memory data, response times to the 3E-1R condition were faster than those in the 1E-1R, 1E-3R, and 3E-3R conditions, $F(1,\ 49)=15.98$, $MSE=143{,}850$, $p<.001$, $\eta_p^2=.25$, $F(1,\ 49)=57.02$, $MSE=108{,}327$, $p<.001$, $\eta_p^2=.54$, and $F(1,\ 49)=21.20$, $MSE=107{,}127$, $p<.001$, $\eta_p^2=.30$, respectively. Thus, memory was best when information about a single event was encountered across multiple events, consistent with an Event Structure view. Note also that the difference between the 3E-1R and 3E-3R conditions corresponds to the difference between the fan level 3 for the Single Location and Multiple Location conditions in traditional differential fan effect studies (e.g., Radvansky & Zacks, 1991).

In addition, there was a significant difference between the 1E-1R and 1E-3R conditions, $F(1,\ 49)=5.43$, $MSE=172{,}931$, $p=.02$, $\eta_p^2=.10$, and the 3E-3R and 1E-3R conditions, $F(1,\ 49)=5.29$, $MSE=180{,}944$, $p=.03$, $\eta_p^2=.10$, with the difference between the 1E-1R and 3E-3R conditions not being significant, $F<1$. It is unclear what the reason is for the very slow performance in the 1E-3R condition, although we tentatively suggest that this smaller effect likely reflects two factors. The first is that there is an overall cost because this condition did not receive the benefit of the 3E-1R conditions, and the second

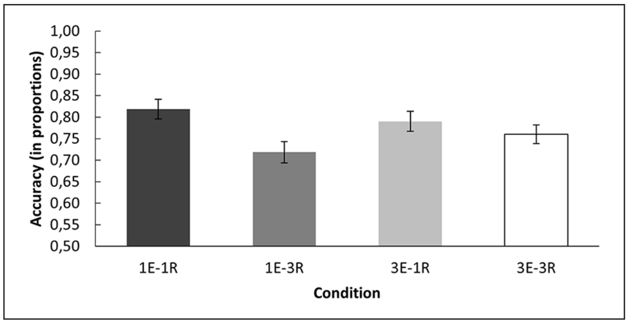


Figure 4. Accuracy level, with standard error bars, in each structure condition when indicating whether a given sentence was previously learned. These data are averaged across the Studied and Nonstudied conditions.

is that the difference between the 1E-1R and 1E-3R conditions also parallels the difference between the Single Location and Multiple Location conditions in traditional differential fan effect studies (e.g., Radvansky & Zacks, 1991), except that here the three facts are presented together during study rather than separately.

Accuracy. The accuracy data, averaged across Studied and Nonstudied trials, are shown in Figure 4. These data were also submitted to a 2 (Studied vs Nonstudied) × 4 (Condition) repeated-measures ANOVA. After this, planned comparisons were made among the various conditions. For the main ANOVA, there was a main effect of Studied-Nonstudied, $F(1, 49) = 11.19$, $MSE = 0.05$, $p = .002$, $\eta_p^2 = .19$, with people responding more accurately to Studied probes ($M = 0.81$; $SE = 0.01$) than to nonstudied probes ($M = 0.73$; $SE = 0.02$). There was also a significant main effect of Condition, $F(3, 147) = 4.56$, $MSE = 0.04$, $p = .004$, $\eta_p^2 = .09$. The interaction was not significant, $F < 1$.

Comparisons across the four conditions revealed few significant differences, none of which strongly supported any of the three theories outlined earlier. This is likely because in these sorts of paradigms, the response time data is more informative. The significant differences were between the 1E-1R and 1E-3R conditions, the 1E-1R and 3E-3R conditions, and the 1E-3R and 3E-1R conditions, $F(1, 49) = 12.33$, $MSE = 0.04$, $p = .001$, $\eta_p^2 = .20$, $F(1, 49) = 4.67$, $MSE = 0.04$, $p = .003$, $\eta_p^2 = .09$, and $F(1, 49) = 6.29$, $MSE = 0.049$, $p = .02$, $\eta_p^2 = .11$, respectively. Thus, while there is some evidence that having a single referent event can lead to greater accuracy, this pattern is not universally observed.

Typical results of differential fan effect studies (e.g., Radvansky & Zacks, 1991) fit in nicely with the results of Experiment 1. The relationship between the 3E-1R and 3E-3R conditions here replicates what is seen when comparing three objects in the Single Location condition versus three objects in Multiple Locations condition. This is because the "3E" occurs when the sentences are shown separately, which is how traditional fan effect studies present them. The current experiment further shows that the same fan effect is found when the sentences are presented at the same time, as in the 1E-1R and 1E-3R conditions. What is interesting is that, while having one referent event does lead to faster response times than having multiple referent events, it is the combination of encoding and referent events that matters. The 3E-1R condition had faster responses than all other conditions, supporting the Event Cognition principle that having multiple opportunities to encode a referent event strengthens memory for that event. Thus, these data provide us a more in-depth look into event model organisations and their effects on memory.

Experiment 2

For Experiment 2, people read narrative texts in which information about one or two topics was conveyed by one or two story characters. The encoding events were whether the topic(s) were conveyed by a single character (1E) or by one character followed by another (2E). The referent events were either a single topic discussed (1R) or two separate topics (2R). Again, for an event cognition view, performance should be best in the 2E-1R condition.

One advantage of assessing memory for narrative texts is that it allows for recognition tests to measure three different levels of representation (Schmalhofer & Glavanov, 1986). The first level is the *surface form*, which represents verbatim memory and is usually the shortest lasting representation. The second is the *textbase*, which contains the propositions or ideas of a text, but not necessarily the wording. The third is the *event model*, which captures the referential meaning of a text and incorporates inferences from general knowledge. This level is the deepest and longest lasting (Fisher & Radvansky, 2018; Kintsch et al., 1990).

As with Experiment 1, the Event Cognition prediction is that performance will be better when multiple events (different narrators) refer to a common event (common topic). Thus, 2E-1R > 1E-1R = 1E-2R = 2E-2R. What is unknown is the degree to which different levels of representation are affected. These factors may influence all levels, or they may be restricted to one or two. How memory for text is influenced by the structure of the encoding and referent events provides insight into how memory is being influenced by these factors.

Method

Participants. Participants who were 18 years or older and fluent in English were recruited through Amazon's Mechanical Turk website (www.mturk.com; see Mason & Suri, 2012) and evenly divided into four between-participants groups, which were divided in half to control for topic presentation order. Two hundred fifty-six people completed the study originally. Participants were considered to be not doing the task properly if (a) they had reading times under 1 s or over 10 s for 50% or more sentences, and/or (b) they had response times under 1.5 s or over 60 s for 25% or more of the recognition test probes. Six participants were excluded for meeting just the reading time exclusion criterion, 22 were excluded for meeting the just test response time exclusion criterion, and 21 were excluded for meeting both criteria. In addition, one participant was excluded for responding "No" to all test probes, and six were excluded for responding "Yes" to over 50% of the Wrong probes. This resulted in 56 excluded participants, leaving a total of 200 (50 per group). Participants were compensated with US$4.00. The University of Notre Dame's institutional review board approved all procedures.

Materials. Each participant read three narratives—two filler stories and one experimental story. The filler stories (one before and one after the experimental story) were included to reduce primacy and recency effects. They were similar in length (filler stories: 55 and 48 sentences; experimental story: 46 sentences).

For the experimental text, four versions of a narrative discussing one or two topics (ice wine and the invention of sliced bread[2]) were created.[3] For each version, there were four presentation structures, with one or two characters presenting one long topic (32 sentences) or two short topics (16 sentences each). More specifically, the four structures were as follows: (a) one character discusses one long topic; (b) one character discusses two short topics; (c) two characters, identified by different names, each discuss half of one long topic; and (d) two characters each discuss one short topic. These conditions were labelled as 1E-1R, 1E-2R, 2E-1R, and 2E-2R, respectively. An example narrative is provided in the online Supplementary Material.

After reading the narratives, there was a distractor task. Participants rated a series of 50 words on pleasantness, using a scale from 1 (very unpleasant) to 7 (very pleasant).

Finally, there was a sentence recognition test. Four types of recognition probes were created for the critical topic sentences in the experimental texts. There were four sets of probe sentences from each short topic and eight from each long topic. Half of the probes for the long topics were the same as those used for the short topics. Each participant was tested on the 32 probes relevant to their version of the narrative. *Verbatim* probes were exact sentences that were read earlier. *Paraphrase* probes differed in wording from the original sentences, but conveyed the same underlying ideas. *Inference* probes reflected inferences that people likely made during reading. Finally, *Wrong* probes were incorrect but thematically consistent with the narrative topic. Comparisons among these types of probes provided measures of the surface form, textbase, and event model levels of memory (Schmalhofer & Glavanov, 1986).

As an example, one of the sentences from the ice wine text was, "In some countries, some winemakers use mechanical freezing to simulate the effect of a natural frost." The verbatim probe was the same sentence. The paraphrase probe was, "The effect of naturally occurring frost is simulated with mechanical freezing by winemakers in some countries." The inference probe was "Some winemakers like to make the sweet, concentrated wine even though they don't live in the right climate." Finally, the wrong probe was, "In all winemaking countries, mechanical freezing is used to increase production of ice wine."

Procedure. Separate links for each version of the experimental narrative were posted on MTurk along with a short description of the study. Interested workers clicked the link to see details. If they chose to participate, they clicked another link, which took them to the informed consent. Following agreement, reading instructions appeared, and then each participant read one version of the experimental narrative, in between the two filler stories. Participants read the stories at their own pace, one sentence at a time, by clicking a "Next" button. A title was presented at the beginning of each narrative. Reading times were recorded.

After reading, a distractor task was given. Participants saw 50 words, one at a time in a random order, and were asked to rate the pleasantness of each one on a 7-point Likert-type scale.

Next, participants completed the recognition test. They saw all 32 probe sentences, one at a time. The probes for the first topic were presented first, and the probes for the second topic were presented second (when applicable), but the order was randomised within these halves. The task was to click a "Yes" button if the sentence was read earlier in the text, and a "No" button otherwise. After the recognition test, participants were provided with a debriefing page.

Results and discussion

Recognition was scored by calculating the A′ indices for the surface form, textbase, and event model levels of memory, following Schmalhofer and Glavanov (1986). Surface form was calculated using "Yes" responses to *verbatim* probes as Hits and "Yes" responses to *paraphrase* probes as False Alarms. Textbase memory was calculated using "Yes" responses to *paraphrase* probes as Hits and "Yes" responses to *inference* probes as False Alarms. Finally, event model memory was calculated using "Yes" responses to *inference* probes as Hits and "Yes" responses to *wrong* probes as False Alarms.

Three 2 (Encoding Events: 1 or 2) × 2 (Referent Events: 1 or 2) ANOVAs were done to compare performance in the four structure conditions at each of the different memory levels. Data are shown in Figure 5.

Surface form. At the surface form level, a 2 × 2 ANOVA revealed a main effect of Referent Events, $F(1, 196) = 6.28$,

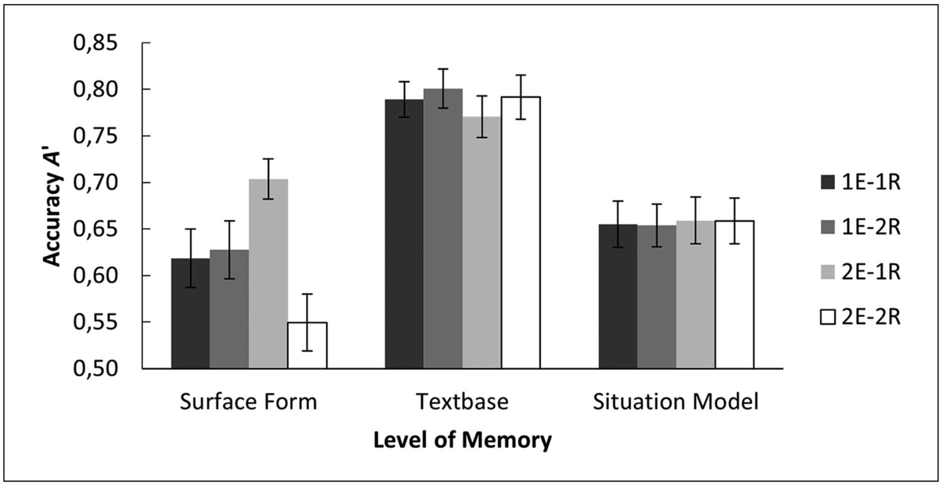


Figure 5. Accuracy, with standard error bars, at three levels of memory for each of the structure conditions.

$MSE=0.04$, $p=.01$, $\eta_p^2=.03$, with higher performance for those having one referent event. This was qualified by a significant interaction, $F(1,\ 196)=7.92$, $MSE=0.04$, $p=.005$, $\eta_p^2=.04$. Planned comparisons revealed that people in the 2E-1R condition had better performance than those in the 1E-1R and 2E-2R conditions, $p=.04$, $d=.45$ and $p<.001$, $d=.83$, respectively, and marginally better performance than those in the 1E-2R condition, $p=.07$, $d=.40$. Those in the 2E-2R condition also had marginally lower performance than those in the 1E-1R and 1E-2R conditions, $p=.09$, $d=.32$ and $p=.06$, $d=.36$, respectively. The 1E-1R and 1E-2R conditions did not differ, $p=.83$, $d=.04$. Overall, the pattern of performance is consistent with the Event Cognition prediction and replicates O'Rear and Radvansky (2019), as well as Experiment 1.

Textbase. At the textbase level, there were no significant main effects or interactions, all $F\text{s}<1$.

Situation model. At the situation model level, there were no significant main effects or interactions, all $F\text{s}<1$.

These findings also provide greater insight into event cognition. First, there was no evidence that the encoding event structure influenced performance at the textbase and event model levels. That is, whether there were one or two story characters conveying information about the topic(s) did not affect memory at those levels. At first this may seem contradictory to other research that has shown that event structure can improve memory (e.g., Kurby & Zacks, 2008; Pettijohn et al., 2016). However, it should be noted that these are actually different types of event structure.

In the prior work, when there were event boundaries, they referred to the structure of a greater larger action. In comparison, a shift in topic in the current texts is close to a shift to entirely different narrative. Other work (Thompson & Radvansky, 2016) has shown that shifts outside of a narrative do not affect processing within it. Thus, at the textbase and event models levels, a shift in topic appears to be handled by cognition in a similar manner.

Importantly, there was an influence of event structure on surface form memory, even if there was no apparent impact on a deeper conceptual understanding. This suggests that the pattern of data in Experiment 1 may also have been due to processing at the surface form level. Similarly, in the O'Rear and Radvansky (2019) study, participants in that virtual mall were likely emphasising a more superficial memory of the tasks to be done, rather than one based on meaningful connections. This is reasonable given that people never actually did the prospective memory tasks, nor were they semantically tied to the locations in which they were to be done. Instead, people selected items from a list, which can be done using surface form knowledge.

Overall, this work emphasises that people are processing events at many different levels, such as the events in a narrative sequence, the different events within a larger text, the different events of different narratives, and the extra-narrative events. Moreover, the influence of event structure may affect one level of representation rather than another, depending on the level of the event of concern in an analysis.

General discussion

The aim of this study was to determine whether the event cognition principles revealed by O'Rear and Radvansky (2019) in a study of prospective memory are generalisable. Here it was found that they extend to two new retrospective memory tasks. The results of both experiments were consistent with Event Cognition theory in that memory performance was better when there were multiple encoding events and a single referent event. In Experiment 1, memory performance was better when three sentences were learned in different events, but referred to a common event (3E-1R), and in Experiment 2, people had better performance at the surface form level when a narrative had multiple characters talking about a common topic (2E-1R). Moreover, the results of Experiment 2 suggest that these event structures did not affect all types of knowledge acquired during the study.

Relationship to other event cognition work

The results of this study touch on several aspects of event cognition. First, prior research on event cognition and memory retrieval has revealed a differential fan effect, in which it has been shown that when information sharing a common concept is stored across multiple event models, there is retrieval interference. However, when that information is integrated into a common event model, then such interference effects can be avoided (Gerard et al., 1991; Radvansky, 1999, 2005; Radvansky et al., 1996, 1997, 1998, 2005; Radvansky & Zacks, 1991). The consequences of having multiple event models may also be observed when an event shift occurs (e.g., a person exits her car and enters a restaurant) (Glenberg et al., 1987; Morrow et al., 1987, 1989). For example, with the phenomenon of walking through doorways causes forgetting (Pettijohn & Radvansky, 2015, 2016; Radvansky & Copeland, 2006c; Radvansky et al., 2010, 2011, 2015), common sets of information are represented in multiple event models, thereby impairing retrieval.

As noted earlier, the pattern of results of Experiment 1, in terms of sets of sentences that were consistent with either multiple events or a single event, is consistent with this, apart from whether there was a single or multiple encoding event. This suggests that the structure of the encoding events themselves are not incorporated into the structure of the resulting event models, but that the structure of these events can influence the strength with which they are stored in memory.

Beyond this, both of the present experiments contribute an expanded understanding of the findings reported by Pettijohn et al. (2016). That study found that dividing information into multiple event models can improve memory. Unlike the differential fan effect, which shows that grouping information in one referent model improves memory, that study focused on the number of encoding events. For example, learning a list of words all in one room is one encoding event, while learning each half of the list in different rooms is two encoding events. This study puts these findings together and demonstrates that there is an interactive effect of these events, wherein multiple encoding events and one referent event results in the strongest memory trace.

As information is encountered, event structure can help people to manage it more effectively, making it easier to remember (Kurby & Zacks, 2008; Pettijohn et al., 2016; see also Radvansky, 2012). While this previous work has shown that dividing a set of information into multiple event-based chunks can improve memory, the current studies show that memory can also be improved by separating out references of a common event into multiple encoding events. For example, Pettijohn et al. (2016) tested this across three tasks. In two experiments, people learned a list of words in either one room or computer window, or half in each of two rooms or computer windows. In two other experiments, people read narratives with zero, one, or two event boundaries. Overall, the addition of event boundaries improved memory. Thus, larger sets of information can be encoded more effectively when broken into multiple event models. Thus, the structure of the encoding events can help to improve memory.

Overall, the results of this study are consistent with and expand on prior research on event cognition and memory. Specifically, we were able to show that the structure of both encoding and retrieval events meaningfully influence later memory.

Relationship to traditional theories of memory

One of the important ideas for event cognition theory is that traditional theories that do not take into account the complexity and structure of events and event models may provide a misunderstanding of the broader operations of cognition in more real-world settings. Along these lines, the current work has some implications for more traditional theories of memory. Of particular concern here, given that these studies involve multiple associations with information elements, are theories of associative interference and spreading activation. What these traditional approaches would predict for the current experiments, and why they fall short, are considered next.

Associative interference. According to traditional theories of memory retrieval, the more associations that are learned with a concept, the more difficult memory retrieval for any one of those items will be. This is because the other related items serve as sources of interference for any given one item. This can manifest itself in many ways. For recall tests, this could be manifested as a cue overload effect in which larger numbers of items in a memory set associated with a cue result in associative interference and poorer memory (e.g., Öztekin & McElree, 2007; Roediger & Guynn, 1996; Watkins & Watkins, 1975, 1976). Alternatively, for recognition tests this could be manifested as a fan effect in which larger numbers of items in memory associated with a concept in a memory probe result in greater retrieval time and/or error rates.

For the current experiments, the prediction of an associative interference view is that the more information that is associated with a memory cue or concept in a memory probe, the worse performance should be. That is, multiple associations with both the encoding and referent events would result in poorest memory, whereas only a single association with each would result in the best memory. However, this did not happen.

The reason that this traditional account fails, in its typical form, is because it treats all information features as equivalent. However, the way that information is structured into event models can alter the pattern of results. While there is not much event cognition research on cue overload, per se, there are dozens of experiments showing that integrating information into event models can reduce associative interference in a fan effect paradigm (Radvansky, 1998, 1999a, 1999b, 2005, 2009; Radvansky & Copeland, 2006a, 2006b; Radvansky et al., 1993, 1996, 1997, 1998, 2005, 2017; Radvansky & Zacks, 1991). The current experiments go beyond this to show that when one considered the structure of events, and how they related to memory processing, characteristics of the information at lower levels, such as the number of associations between information features, lose their ability to predict future memory performance.

Spreading activation. Another traditional memory theory is that of spreading activation (e.g., Collins & Loftus, 1975). Specifically, the idea is that as one item or piece of information in memory is activated, those other memories that are associated with it become more activated and accessible, resulting in memory improvements, such as priming effects (e.g., Meyer & Schvaneveldt, 1971; Tulving & Schacter, 1990).

For the current experiments, according to a spreading activation account, performance would be a function of the amount of overlap of different memory sets. Specifically, when memory traces share a common element, the activation of one of those memories as a result of its retrieval should facilitate the retrieval of the others that are associated with it. That is, the more associations with encoding and referent concepts, the better memory should be, whereas only a single association with each would result in the poorest memory. However, this did not happen. The reason that this standard form of this traditional account fails is for the same reason as the associative interference account: it does not take into account how information is structured into events models, and how this structure influences memory processing.

Overall, while the results of the current experiments were inconsistent with the associative interference and spreading activation theories as they are traditionally applied, we do not think that our results negate the value of either of them. However, they do place clear limits. Specifically, large associative interference and spreading activation effects are typically observed in list processing studies. When we scale up to larger, more complex memory traces, just how and when they apply requires more careful consideration.

That said, there are certainly limitations to this study as well to be explored in future work. For one, the event structures were all manipulations that were part of the tasks. It is not clear whether the same pattern of results would be observed if event structures outside of the task itself were to be manipulated. Also, all the materials used here were verbal and were used in tasks in which a memory test was expected. It is not clear the extent to which this pattern would extend to nonverbal information, and when a memory test is not expected. This is important because many of the events we encounter have salient nonverbal elements to them, and people do not typically expect their memory to be tested.

Conclusion

We demonstrated a pattern of influence on memory is a general consequence of event structure. The same basic pattern was observed with sentence lists as well as narrative texts. This underscores the importance of event cognition to the processes and mechanisms of human thought. By understanding how event information is structured and how this structure interacts with the architecture of cognition, the better we will be able to predict and understand complex levels of thought.

Authors' note

This work was done, in part, as fulfilment of the doctoral dissertation of Andrea E. O'Rear.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This project was partially supported by a University of Notre Dame Graduate Student Research Award, awarded to A.E.O. This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under Grant DGE-1313583, awarded to A.E.O. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

ORCID iD

Andrea E O'Rear https://orcid.org/0000-0003-3936-7451

Data accessibility statement

The materials and data for the experiments reported here are available at: https://osf.io/j6b3y/?view_only=66f6d032cc2c480f8d8b0e7f3979200f

Supplementary material

The supplementary material is available at qjep.sagepub.com.

Notes

1. The analysis of both Studied and Nonstudied trials is a common practice in experiments of this sort.
2. These topics were chosen to be interesting but not well known by participants. Each topic used information from various sources (Bowen, 2010; Latson, 2015; Lawlor, 2010; Nix, 2015; Wikipedia Contributors, 2017, 2018).
3. While there were four primary versions, the topics were also counterbalanced within those versions. Thus, there are effectively eight narratives, but only four have the experimental manipulations.

References

Bowen, A. J. (2010). Managing the quality of ice wines. In A. Reynolds (Ed.), *Managing wine quality, Vol. 2: Oenology and wine quality* (pp. 523–552). Woodhead Publishing Limited.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, *82*(6), 407–428. https://doi.org/10.1037/0033-295X.82.6.407

Fisher, J. S., & Radvansky, G. A. (2018). Patterns of forgetting. *Journal of Memory and Language*, *102*, 130–141. https://doi.org/10.1016/j.jml.2018.05.008

Gerard, L., Zacks, R. T., Hasher, L., & Radvansky, G. A. (1991). Age deficits in retrieval: The fan effect. *Journal of Gerontology*, *46*(4), 131–136. https://doi.org/10.1093/geronj/46.4.P131

Glenberg, A. M., Meyer, M., & Lindem, K. (1987). Mental models contribute to foregrounding during text comprehension. *Journal of Memory and Language*, *26*(1), 69–83. https://doi.org/10.1016/0749-596X(87)90063-5

Kintsch, W., Welsch, D., Schmalhofer, F., & Zimny, S. (1990). Sentence memory: A theoretical analysis. *Journal of Memory and Language*, *29*(2), 133–159. https://doi.org/10.1016/0749-596X(90)90069-C

Kurby, C. A., & Zacks, J. M. (2008). Segmentation in the perception and memory of events. *Trends in Cognitive Sciences*, *12*(2), 72–79. https://doi.org/10.1016/j.tics.2007.11.004

Latson, J. (2015, July 7). *How sliced bread became the "greatest thing*." http://time.com/3946461/sliced-bread-history/

Lawlor, J. (2010, February 25). *Frozen vines (and fingers) yield a sweet reward*. https://www.nytimes.com/2010/02/26/travel/escapes/26icewine.html

Mason, W., & Suri, S. (2012). Conducting behavioral research on Amazon's Mechanical Turk. *Behavior Research Methods*, *44*(1), 1–23. https://doi.org/10.3758/s13428-011-0124-6

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, *90*(2), 227–234. https://doi.org/10.1037/h0031564

Morrow, D. G., Bower, G. H., & Greenspan, S. L. (1989). Updating situation models during narrative comprehension. *Journal of Memory and Language*, *28*(3), 292–312. https://doi.org/10.1016/0749-596X(89)90035-1

Morrow, D. G., Greenspan, S. L., & Bower, G. H. (1987). Accessibility and situation models in narrative comprehension. *Journal of Memory and Language*, *26*(2), 165–187. https://doi.org/10.1016/0749-596X(87)90122-7

Nix, E. (2015, January 16). *Who invented sliced bread?* https://www.history.com/news/hungry-history/who-invented-sliced-bread

O'Rear, A. E., & Radvansky, G. A. (2019). Location-based prospective memory. *Quarterly Journal of Experimental Psychology*, *72*(3), 491–507. https://doi.org/10.1177/1747021818758608

Öztekin, I., & McElree, B. (2007). Retrieval dynamics of proactive interference: PI slows retrieval by eliminating fast assessments of familiarity. *Journal of Memory and Language*, *57*(1), 126–149. https://doi.org/10.1016/j.jml.2006.08.011

Pettijohn, K. A., & Radvansky, G. A. (2015). Walking through doorways causes forgetting: Environmental effects. *Journal of Cognitive Psychology*, *28*(3), 329–340. https://doi.org/10.1080/20445911.2015.1123712

Pettijohn, K. A., & Radvansky, G. A. (2016). Walking through doorways causes forgetting: Event structure or updating disruption? *The Quarterly Journal of Experimental Psychology*, *69*(11), 2119–2129. https://doi.org/10.1080/17470218.2015.1101478

Pettijohn, K. A., Thompson, A. N., Tamplin, A. K., Krawietz, S. A., & Radvansky, G. A. (2016). Event boundaries and memory improvement. *Cognition*, *148*, 136–144. https://doi.org/10.1016/j.cognition.2015.12.013

Radvansky, G. A. (1998). The organization of information retrieved from situation models. *Psychonomic Bulletin & Review*, *5*(2), 283–289. https://doi.org/10.3758/BF03212952

Radvansky, G. A. (1999a). Memory retrieval and suppression: The inhibition of situation models. *Journal of Experimental Psychology: General*, *128*(4), 563–579. https://doi.org/10.1037/0096-3445.128.4.563

Radvansky, G. A. (1999b). The fan effect: A tale of two theories. *Journal of Experimental Psychology: General*, *128*(2), 198–206. https://doi.org/10.1037/0096-3445.128.2.198

Radvansky, G. A. (2005). Situation models, propositions, and the fan effect. *Psychonomic Bulletin & Review*, *12*(3), 478–483. https://doi.org/10.3758/BF03193791

Radvansky, G. A. (2009). Spatial directions and situation model organization. *Memory & Cognition*, *37*(6), 796–806. https://doi.org/10.3758/MC.37.6.796

Radvansky, G. A. (2012). Across the event horizon. *Current Directions in Psychological Science*, *21*(4), 269–272. https://doi.org/10.1177/0963721412451274

Radvansky, G. A., O'Rear, A. E., & Fisher, J. S. (2017). Event models and the fan effect. *Memory & Cognition*, *45*(6), 1028–1044. https://doi.org/10.3758/s13421-017-0713-4

Radvansky, G. A., & Copeland, D. E. (2006a). Memory retrieval and interference: Working memory issues. *Journal of Memory and Language*, *55*(1), 33–46. https://doi.org/10.1016/j.jml.2006.02.001

Radvansky, G. A., & Copeland, D. E. (2006b). Situation models and retrieval interference: Pictures and words. *Memory*, *14*(5), 614–623. https://doi.org/10.1080/09658210600647714

Radvansky, G. A., & Copeland, D. E. (2006c). Walking through doorways causes forgetting: Situation models and experienced space. *Memory & Cognition*, *34*(5), 1150–1156. https://doi.org/10.3758/BF03193261

Radvansky, G. A., Krawietz, S. A., & Tamplin, A. K. (2011). Walking through doorways causes forgetting: Further explorations. *Quarterly Journal of Experimental Psychology*, *64*(8), 1632–1645. https://doi.org/10.1080/17470218.2011.571267

Radvansky, G. A., Pettijohn, K. A., & Kim, J. (2015). Walking through doorways causes forgetting: Younger and older adults. *Psychology and Aging*, *30*(2), 259–265. https://doi.org/10.1037/a0039259

Radvansky, G. A., Spieler, D. H., & Zacks, R. T. (1993). Mental model organization. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(1), 95–114. https://doi.org/10.1037/0278-7393.19.1.95

Radvansky, G. A., Tamplin, A. K., & Krawietz, S. A. (2010). Walking through doorways causes forgetting: Environmental integration. *Psychonomic Bulletin & Review*, *17*(6), 900–904. https://doi.org/10.3758/PBR.17.6.900

Radvansky, G. A., Wyer, R. S., Jr., Curiel, J. M., & Lutz, M. F. (1997). Situation models and abstract ownership relations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(5), 1233–1246. https://doi.org/10.1037/0278-7393.23.5.1233

Radvansky, G. A., & Zacks, J. M. (2014). *Event cognition*. Oxford University Press.

Radvansky, G. A., & Zacks, R. T. (1991). Mental models and the fan effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*(5), 940–953.

Radvansky, G. A., Zacks, R. T., & Hasher, L. (1996). Fact retrieval in younger and older adults: The role of mental models. *Psychology and Aging*, *11*(2), 258–271. https://doi.org/10.1037/0882-7974.11.2.258

Radvansky, G. A., Zacks, R. T., & Hasher, L. (2005). Age and inhibition: The retrieval of situation models. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *60*(5), P276–P278. https://doi.org/10.1093/geronb/60.5.P276

Radvansky, G. A., Zwaan, R. A., Federico, T., & Franklin, N. (1998). Retrieval from temporally organized situation models. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*(5), 1224–1237. https://doi.org/10.1037/0278-7393.24.5.1224

Reder, L. M., & Anderson, J. R. (1980). A partial resolution of the paradox of interference: The role of integrating knowledge. *Cognitive Psychology*, *12*(4), 447–472. https://doi.org/10.1016/0010-0285(80)90016-X

Roediger, H. L. I. I., & Guynn, M. J. (1996). Retrieval processes. In E. L. Bjork & R. A. Bjork (Eds.), *Memory* (pp. 197–236). Academic Press.

Schmalhofer, F., & Glavanov, D. (1986). Three components of understanding a programmer's manual: Verbatim, propositional, and situational representations. *Journal of Memory and Language*, *25*(3), 279–294. https://doi.org/10.1016/0749-596X(86)90002-1

Thompson, A. N., & Radvansky, G. A. (2016). Event boundaries and anaphoric reference. *Psychonomic Bulletin & Review*, *23*(3), 849–856. https://doi.org/10.3758/s13423-015-0961-x

Tulving, E., & Schacter, D. L. (1990). Priming and human memory systems. *Science*, *247*(4940), 301–306. https://doi.org/10.1126/science.2296719

Watkins, M. J., & Watkins, O. C. (1976). Cue-overload theory and the method of interpolated attributes. *Bulletin of the Psychonomic Society*, *7*(3), 289–291. https://doi.org/10.3758/BF03337192

Watkins, O. C., & Watkins, M. J. (1975). Buildup of proactive inhibition as a cue-overload effect. *Journal of Experimental Psychology: Human Learning and Memory*, *1*(4), 442–452. https://doi.org/10.1037/0278-7393.1.4.442

Wikipedia Contributors. (2017, September 3). Ice wine. In *Wikipedia, The Free Encyclopedia*. https://en.wikipedia.org/w/index.php?title=Ice_wine&oldid=798702285

Wikipedia Contributors. (2018, March 6). Sliced bread. In *Wikipedia, The Free Encyclopedia*. https://en.wikipedia.org/w/index.php?title=Sliced_bread&oldid=829023931