Analogy Causes Distorted Memory by Blending Memory Episodes

Margarita Pavlova (margarita.velinova@gmail.com)
Boicho Kokinov

Department of Cognitive Science and Psychology,
New Bulgarian University, 21 Montevideo Street
Sofia 1618, Bulgaria

Abstract

The present study compares two cases of blending between episodes: blending of episodes that share a number of elements (superficially similar episodes) and blending of episodes that share the same structure of relations but do not share the same elements. According to classic theories and models of blending, superficially similar episodes are more likely to be blended because there is a larger overlap of the feature vectors representing them. In contrast, according to the AMBR model of analogy-making and memory, analogous episodes are more likely to be blended. The results obtained in the present study support the prediction of the AMBR model: people blend structurally similar episodes much more often than superficially similar ones. These results are consistent with previous experiments on the influence of analogy-making on constructive memory.

Keywords: analogy; memory; memory distortions; blending of episodes; psychological experimentation.

Constructive Memory

Two popular metaphors for memory are known to cognitive psychologists. The classic one suggests that it is a physical place where our memories for events, concepts, and objects are stored and later on retrieved. The more recent metaphor for memory views it as a dynamic and constructive process (Moscovitch, 1995; Loftus, 1997; Neisser & Harsch, 1992; Roediger & McDermott, 1995; Schacter, 1999). This relatively modern concept of memory suggests that we reconstruct episodes by taking a small piece of information about the episode and then with the help of general knowledge about the category to which it belongs, we reconstruct it altogether (Kokinov & Petrov, 2001). According to this constructivist point of view on memory, recollections can not only be partial or lost, but they can also be distorted. There are two known mechanisms of memory distortion – episode blending and schematization (use of general schematic knowledge).

There is much evidence now that people do distort real episodes. Sir Frederick Bartlett (1932) first demonstrated a case of memory distortions as a result of intrusions from general schematic knowledge in the reconstruction of the target event. Loftus and Palmer (1974) enriched these findings and demonstrated that depending on the schema activated, the reconstructed episodes varied. Furthermore, various other experiments by Loftus (1977; 1997; 2003) have indicated various instances of blending of episodes – a slideshow and a piece of consecutive information concerning the target object; a real event and an imagined one; a personal experience and an advertisement; an actual autobiographical recollection and an implanted one. All these findings suggest that misinformation alters one's recollections about an event regardless of it being actual or not. One important conclusion is drawn from these studies: people pick elements from one event and implant them into another, thus mixing up the two events and blending the recollections of both. Simarly, the case study of John Dean's memory (Neisser, 1981) provided an analysis of his recollections and revealed a lot of inaccuracies. Discrepancies and fault memories are common even for highly emotional events. Neisser & Harsch (1992) focused on the so called flashbulb memories and explored the participants' immediate and delayed recollections of the *Challenger* incident, showing that the participants wrongly recalled the event and reported various details most probably taken from different events, hence they strongly believed that their memories were accurate and vivid. Nystrom and McClelland (1992) also obtained similar effects: after studying a number of sentences, their participants blended them. Roediger and McDermott (1995) demonstrated that a word not present in a list could be wrongfully recalled if it was associated with some of the words presented in the list.

All of the above mentioned data have been extended and supported in a number of psychological experiments, as well as in cognitive neuroscience, brain imaging, and brain lesions studies (Moscovitch, 1995; Schacter, 1999; Kokinov & Hirst, 2003).

Despite the extensive experimental work demonstrating memory distortion, the mechanisms of memory construction are still a topical issue. Various researchers suggest different points of view on the mechanisms and explanation of memory construction. This lack of theory ground in the field makes the research move in various directions with no clear predictions and explanations.

Among the few existing models that do explain and reproduce episode blending are Murdock's TODAM model (1993; 1995), McClelland's Trace Synthesis Model (1995), and Metcalfe's CHARM model (1990). Although they are quite different in a number of aspects, these models share a common concept: they are based on distributed representations of features of objects and episodes which means that the overlap of these features causes memory distortion. Therefore, these models explain the cases when two similar episodes are blended (i.e. when most of the features in the feature vector are the same).

However, it would be difficult to explain blending of superficially dissimilar episodes using these models as a theoretical ground. Moreover, these models represent episodes as a list of features with no internal structure or relations between their elements. This may not seem a problem if structure does not play a role in the memory construction process. But, is this really the case?

The Role of Analogy in Memory Construction

Analogy is a mechanism that can potentially change the representation of knowledge. Blanchette and Dunbar (2002) demonstrated that structural similarity could alter the representation of the target stimulus. Their data suggested that integration of analogical inferences into the target resulted in false recognition of information on a subsequent recognition test. Perrott, Gentner & Bodenhausen (2005) extended these findings and showed that this phenomenon was true even for inferences that were incongruent with the participants' own attitudes. It can be implied from both studies that structure is important to other cognitive processes, including memory construction.

The classic models successfully predict and explain blending of superficially similar episodes; however, there are experimental data that show that even dissimilar episodes can be blended.

Evidence from experiments conducted by Kokinov and his colleagues suggests that structural similarity may have a greater impact on the process of memory construction. Accordingly, Kokinov and Zareva (2001) and Zareva and Kokinov (2003) demonstrated that two dissimilar episodes could be blended if they were connected to one another by a double analogy with a third one. These experimental studies can (only) be explained with the AMBR model of analogy-making and memory.

AMBR was introduced by Kokinov (1988) and then further developed (Kokinov, 1994b; Kokinov & Petrov, 2001). It is based on the general hybrid (symbolic and connectionist) cognitive architecture DUAL (Kokinov, 1994a) which is based on decentralized representations and emergent computations produced by a vast amount of micro-agents that act in parallel and tend to be co-activated.

The model views recall as a reconstruction by analogy, which means that a new episode is constructed analogous to an old one. During this recognition process there is a competition among various elements from various episodes to be transfered into the target. Two sets of hypotheses are made in order to find the best match to the target. Now, if two episodes share the same structure of relations, then the hypotheses start to support each other, making the elements of both episodes stronger. Therefore, the existance of analogous episodes in memory results in greater possibility of blending. Moreover, once there has been an analogy established between two episodes, their elements get connected by permanent links, which makes the blending between them even more probable. The model predicts that with all chances being equal it will be more probable that two structurally similar episodes be blended than two superficially similar ones (Kokinov, 1994b; 1998).

Several experiments (Kokinov & Zareva, 2001; Zareva & Kokinov, 2003; Kokinov, Petkov, & Petrova, 2007; Kokinov, Feldman, & Petkov, 2009), as well as computer simulations (Grinberg & Kokinov, 2003) have been conducted to test this and other predictions of the model concerning the influence of structure on memory construction. In the most recent one (Feldman and Kokinov 2009) the authors designed an experiment which tested the two possible mechanisms of memory construction simmultaneously. They used short stories which were either superficially or structurally similar to one another. The results were in favor of the AMBR model: the participants blended structurally similar episodes more often than superficially similar ones.

The current paper presents an experimental study that supports and further extends the findings in the Feldman and Kokinov (2009) work.

Experiments

Two very similar experiments were conducted with the goal to explore the various mechanisms of construction of memory episodes and to continue the line of experimental work on the influence of analogy-making on constructive memory.

Experiment 1

The main idea of Experiment 1 was to further develop and improve the experiment conducted by Feldman and Kokinov (2009) with a new procedure and new, simpler, and better controlled stimuli. The problem with the previous experiment was that it used short stories as stimuli, which makes it very difficult (if not impossible) to control the number of shared elements, interpretations, and associations they may trigger in the participants. To address this issue simpler non-verbal graphic stimuli were designed which have limited and better controlled semantics, and thus make it possible to accurately count the shared elements.

Hypothesis The hypothesis of the experiment is that analogical episodes are more probable sources of intrusions than superficially similar or dissimilar episodes.

Design The experiment had a within-subjects design. The manipulated variable was the type of distracter and it had three levels:

- **Analogous** – distracters designed by combining two bases that share the same structure, but do not share the same elements.
- **Superficially similar** – distracters designed by combining two bases that share the same elements and thus are superficially similar, but do not share the same structure, i.e. the relations between the elements in the two bases are different.
- **Dissimilar** – distracters designed by combining two bases that share neither the same structure, nor the same elements.

Procedure The experiment consisted of three sessions immediately following one after another.

The participants were first presented with the four bases for each set simultaneously. They had to observe the bases and when they were finished, they were presented with the next four bases of the next set and so on, until all the sets have been presented. The sets were randomized.

Next, the participants were given a filler task. They read an excerpt from "*Dandelion Wine*" by Ray Bradbury translated into Bulgarian and answered some general questions about the text. This session served as a retention interval and its purpose was to guarantee that the participants did not think of nor retain the bases from session one in their working memory and had to extract them from their long-term memory in the recognition task later. The duration of this session was 15 to 20 minutes, depending on the reading speed of each participant.

Last, the participants were given a recognition task. They were once again presented with the eight sets of configurations of geometric figures. This time, however, they saw not only the bases, but also the distracters for each set. Each set was presented separately, i.e. the participants first saw all configurations for the first set, then for the second, and so on. The order of the sets was the same as in session one. The participants had to carefully observe each configuration and then to point the four configurations they believed they saw in session one, i.e. they had to recognize which four of the configurations were the bases from the first session. Their answers were registered in a protocol.

Stimuli Eight sets of 16 configurations of geometric figures were used for sessions one and three. In each set 4 configurations were the bases and the other 12 were the distracters. Five independent experts assessed the superficial and the structural similarity of the bases.

The bases were specifically designed so they composed three pairs as follows: two pairs were structurally analogous to one another (F1~F2 and F3~F4), two pairs were superficially similar to one another, but did not share the same structure (F1≈F3 and F2≈F4), and finally the last two pairs were dissimilar and shared neither the same structure, nor the same superficial elements (F1≠F4 and F2≠F3). See Figure 1 for an example.

The distracters were designed in such a way that each represented a specific combination of two bases. There were three types of distracters – analogous, superficially similar, and dissimilar.

The analogous distracters were designed by mixing the elements of two analogous bases. We took one or more elements from one base and placed them into the other, keeping the original structure of both bases. We created 4 distracters of this type for all the sets (for each pair of bases there were two corresponding distracters, see Figure 2). This method was also applied to the superficially similar distracters (in this case, we mixed two superficially similar bases), and for the dissimilar distracters (in this case, we mixed two dissimilar bases). Figure 2 illustrates all the distracters designed for the bases in Figure 1.

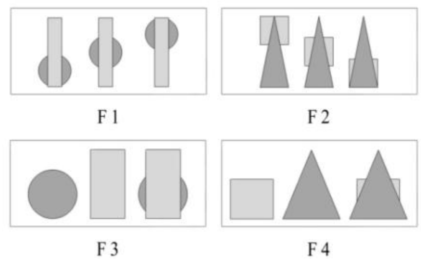

Figure 1: An example of the bases. The bases compose the following pairs: analogous configurations (F1~F2 and F3~F4), superficially similar configurations (F1≈F3 and F2≈F4), dissimilar configurations (F1≠F4 and F2≠F3).

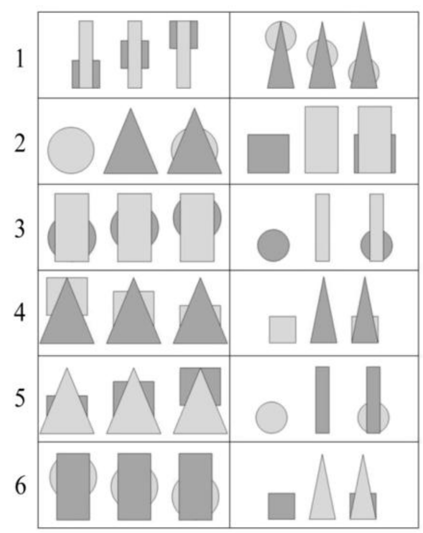

Figure 2: An example of the distracters designed for the bases in Figure 1. Each line illustrates the variations of the distracters for each pair of bases: Blending between: 1). F1 and F2 – analogous distracters. 2). F3 and F4 – analogous distracters. 3). F1 and F3 – superficially similar distracters. 4). F2 and F4 – superficially similar distracters. 5). F1 and F4 – dissimilar distracters. 6). F2 and F3 – dissimilar distracters.

Participants The sample consisted of 32 participants (17 female and 15 male). The age of the participants ranged from 19 to 53 (M = 25.13, SD = 7.01). They were university students and participated voluntarily.

Results and Discussion The data are presented in Figure 3. The data show that in 43% of the cases the participants blended the bases. The amount of blending in this experiment is considerably higher than the amount Feldman and Kokinov (2009) observed; they registered 22.5% intrusions. The higher percentage obtained in the current experiment can be attributed to the new stimuli. The configurations have more restricted semantics and are not subjected to schemas or general knowledge and thus are more difficult to be retrieved.

Figure 3 illustrates the distribution of both the correct responses and the falsely recognized configurations in the recognition task. A repeated measures ANOVA showed that the main effect of type of distracter was significant [$F(2,62) = 12.561$, partial $\eta^2 = 0.29$, $p = 0.001$]. One-sample T-test showed that there was a significant difference between the analogous and the superficially similar distracters [$t(1,31) = 2.837$, $p = 0.008$], and between the analogous and the dissimilar distracters [$t(1,31) = 5.454$, $p < 0.001$]. Although there was no significant difference between the superficially similar and the dissimilar distracters, there was a tendency for a significance ($p = 0.085$).

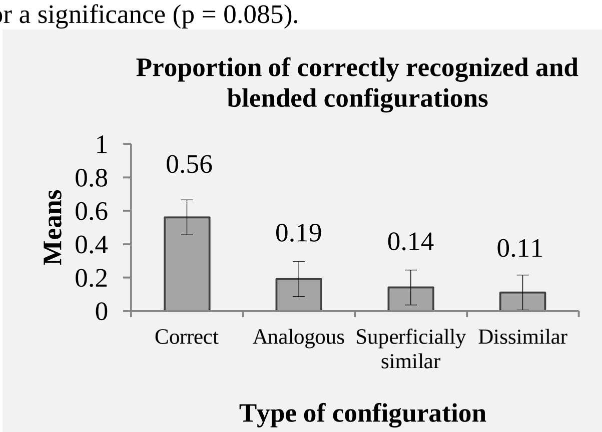

Figure 3: Amount of correctly recognized bases and blending in the recognition task in session three.

The obtained results are exactly as expected and predicted by the AMBR model: the greatest amount of blending was between the analogous bases. Nevertheless, the experiment needed some improvement. It was speculated that the participants did not make the analogical inference in the first session alone, but made such inferences (again) in the third session when they were once again presented with the full set of distracters and bases. To refute this possibility, a new experiment was conducted.

Experiment 2

The goal of Experiment 2 was to replicate Experiment 1 with a new procedure: presentation of the stimuli in session three one by one, not simultaneously.

Procedure The procedure of Experiment 2 was identical to that of Experiment 1 with a modification of session three and different filler tasks in session two. The experiment was run on the E-prime software and the stimuli were presented centered on the screen. The three sessions followed immediately one after another.

Session one was exactly the same as in Experiment 1. However, this time the participants observed the bases for a maximum of 1 minute per set. This was done in order to control the amount of time each participant spent studying the bases.

In session two the participants were given filler tasks. The duration of this session was 15 minutes. Its purpose was again to serve as retention interval.

In session three the participants received a recognition task. They were given all the configurations (bases and distracters) presented one by one and fully randomized. Their task was to decide for each configuration whether they saw it in the first session by pressing the corresponding key (Yes or No) on a B-box.

Stimuli The stimuli for sessions one and three were the same as in Experiment 1. Twenty water-jars problems were used in session two. The stimuli for this session were changed due to concerns about the possible associations and mood the story by Bradbury may have triggered in the participants. Previous data suggest that mood is a factor for noticing relations between objects (Hristova, 2009). Thus, to elliminate the possible influence of mood on analogy-making (and subsequently, memory construction) we decided to use a neutral and simpler filler task.

Participants The sample consisted of 35 participants (18 female and 17 male). The age of the participants ranged from 20 to 40 years (M = 27.11, SD = 5.68). They were university students and participated voluntarily.

Results and Discussion The data are presented in Figure 4. The data show that in 68% of the cases the participants blended the bases. This percentage can be explained with the different procedures used in Experiments 1 and 2. In contrast with Experiment 1 where the participants gave an explicit answer for only 32 configurations, this time they gave an explicit answer for all 128 of them, which increases the likelihood of error. One-sample T-test of the correctly recognized bases showed a performance that was significantly above the chance level [$t(34) = 2.758$, $p = 0.009$].

Figure 4 illustrates the distribution of both the correct responses and the falsely recognized configurations (when the participants gave a Yes answer to distracters and not to bases, indicating they have recognized them as familiar) in the recognition task. Note that the participants did not have the opportunity to examine each set separately and could not make any inferences based on comparisons among the configurations. Hence, the analogical inferences took place in the first session alone. A repeated-measures ANOVA showed that the main effect of type of distracter was significant [F (2,68) = 5.15, p = 0.008]. The pair-wise comparison showed that there was a significant difference between the analogous and the superficially similar distracters [F (1,34) = 1.371, p = 0.033], and between the analogous and the dissimilar distracters [F (1,34) = 1.771, p = 0.002]. There was no significant difference between the superficially similar and the dissimilar distracters. The results showed that the participants much more often blended the bases which were analogous to one another.

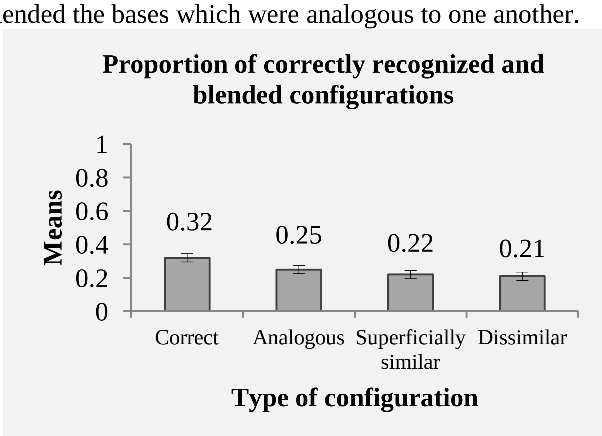

Figure 4: Amount of correctly recognized bases and blending in the recognition task in session three.

Again, the obtained data confirmed the predictions of the AMBR model, restating the results from Experiment 1, and from previous research (Feldman and Kokinov, 2009).

General discussion

The study presented in this paper contrasts two different types of explanations of the mechanisms of blending between episodes. According to the classic models and experiments (Loftus, 1977; McClelland, 1995; Metcalfe, 1990) episodes are blended because they share a lot of elements. The events in classic models are represented by feature vectors and when there is a case of two events whose features are the same, the vectors get mixed and a new blended event appears in the output. The AMBR model predicts that events that share the same structure of relations i.e. are analogous, are more probable sources of blending.

The presented experiments test this prediction and try to distinguish between the two contrasting points of view on the process of memory construction. Eight sets of four configurations of geometric figures (bases) were designed specifically so that they are relevant to both views. In each pair the two bases are either analogous, or superficially similar, or dissimilar to one another. This means that within each base there is a superficial similarity to another base (e.g. the same objects, the same pattern, the same frame or contour in both configurations), and a structural similarity to yet another one (e.g. the same system of relations between objects that are distant on the surface level in both configurations). In addition, to have even better knowledge of the sources of intrusion, specific distracters were also designed. They provided the opportunity to correctly examine and accurately assign the observed intrusions to the corresponding type. By engaging the participants into a recognition task and not a free recall task, we eliminated the possibility of guessing the origin of each element while analysing the data.

The results support the predictions of the AMBR model and accord with the data from prior research (Feldman & Kokinov, 2009). Even though it might be argued that the results could be assigned to a different strategy (for example, picking distracters that are more similar to the studied items), the data suggest that the most consistent strategy used by the participants was choosing analogous distracters. In other words, the participants blended analogous configurations more often than superficially similar ones. In addition, the results show that even when there is no internal structure based on semantics and general knowledge, but only on analogy, the analogy is sufficient to establish blending between the episodes. Moreover, the data obtained in the current paper further extend the findings of Blanchette and Dunbar (2002), and Perrott et al. (2005) studies showing that even when there is both structural and superficial similarity between episodes, people tend to blend episodes based on their structural, and not their superficial similarity.

Certainly, future experiments and computer simulations on the role of analogy-making in memory will shed more light on the mechanisms of memory construction.

Acknowledgements

We would like to express our gratitude towards Penka Hristova and Georgi Petkov for the constructive feedback they shared concerning the initially designed stimuli. We would also like to thank Viara Kuneva, Violeta Andreeva, Kristina Gotseva, Victoria Kuzeva, and Dimitar Lazov for their expert assessment of the stimuli. Last but not least, we wish to thank Armine Janyan for her help in conducting the second experiment.

References

Bartlett, F. (1932). *Remembering.* Cambridge: Cambridge University Press.

Blanchette, I., & Dunbar, K. (2002). Representational Change and Analogy: How Analogical Inferences Alter Target Representations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(4), 672-685.

Feldman, V., & Kokinov, B. (2009). Analogical Episodes are More Likely to be Blended than Superficially Similar Ones. *Proceedings of the 31st Annual Conference on Cognitive Science*. Hillsdale, NJ: Lawrence Erlbaum.

Grinberg, M., & Kokinov, B. (2003). Analogy-Based Episode Blending in AMBR. In B. Kokinov, & W. Hirst (Eds.), *Constructive Memory.* Sofia: NBU Press.

Hristova, P. (2009). People in Negative Mood May See Relations Where People in Positive Mood May Not. In B. Kokinov, K. Holyoak, & D. Gentner (Eds.), *New Frontiers in Analogy Research*. Sofia: NBU Series in Cognitive Science.

Kokinov, B. (1988). Associative Memory-Based Reasoning: How to Represent and Retrieve Cases. In T. O'Shea, & V. Sgurev (Eds.), *Artificial Intelligence III: Methodology, Systems, Applications*. Amsterdam: Elsevier Science Publishers.

Kokinov, B. (1994a). The DUAL Cognitive Architectre: A Hybrid Multi-Agent Approach. In A. Cohn (Ed.), *Proceedings of the 11th European Conference on Artificial Intelligence.* London: John Wiley & Sons.

Kokinov, B. (1994b). A Hybrid Model of Reasoning by Analogy. In K. Holoyak, & J. Barnden (Eds.), *Advances in Connectionist and Neural Computation Theory* (Vol. 2 Analogical Connections). Norwood, NJ: Ablex.

Kokinov, B. (1998). Analogy is Like Cognition: Dynamic, Emergent, and Context-Sensitive. In K. Holyoak, D. Gentner, & B. Kokinov (Eds.), *Advances in Analogy Research: Integration of Theory and Data from the Cognitive, Computational, and Neural Sciences*. Sofia: NBU Press.

Kokinov, B., & Hirst, W. (Eds.). (2003). *Constructive Memory.* Sofia: New Bulgarian University Press.

Kokinov, B., & Petrov, A. (2001). Integration of Memory and Reasoning in Analogy-Making: The AMBR Model. In D. Gentner, K. Holyoak, & B. Kokinov (Eds.), *The Analogical Mind: Perspectives from Cognitive Science.* Cambrigde, MA: MIT Press.

Kokinov, B., & Zareva, N. (2001). Episode Blending as Result of Analogical Problem Solving. *Proceedings of the 23rd Annual Conference of the Cognitive Science Society.* Erlbaum, Hillsdale, NJ.

Kokinov, B., Feldman, V., & Petkov, G. (2009). Analogy-Making Automatically Produces False Memories for Both Mapped Situations. In B. Kokinov, K. Holyoak, & D. Gentner (Eds.), *New Frontiers in Analogy Research.* Sofia: NBU Press.

Kokinov, B., Petkov, G., & Petrova, N. (2007). Context-Sensitivity of Human Memory: Episode Connectivity and Its Influence on Memory Reconstruction. In B. Kokinov, D. Richardson, T. Roth-Berghofer, & L. Vieu (Eds.), *CONTEXT 2007*. Heidelberg: Springer-Varlag Berlin.

Loftus, E. F. (1977). Shifting Human Color Memory. *Memory & Cognition, 5*(6), 696-699.

Loftus, E. F. (1997). Creating False Memories. *Scientific American*(277), 70-75.

Loftus, E. F. (2003). Our Changeable Memories: Legal and Practical Implications. *Nature Reviews: Neoruscience, 4,* 231-234.

Loftus, E. F., & Palmer, J. C. (1974). Reconstruction of Automobile Destruction: An Example of the Interaction Between Language and Memory. *Journal of Verbal Learning and Verbal Behavior, 13*, 585-589.

McClelland, J. (1995). Constructive Memory and Memory Distortions: A Parallel-Distributed Processing Approach. In D. Schacter (Ed.), *Memory Distortions: How Minds, Brains, and Societies Reconstruct the Past*. Cambridge, MA: Harvard University Press.

Metcalfe, J. (1990). Composite Holographic Associative Recall Model (CHARM) and Blended Memories in Eyewitness Testimony. *Journal of Experimental Psychology: General, 119*(2), 145-160.

Moscovitch, M. (1995). Confabulation. In D. Schacter (Ed.), *Memory distortions: How minds, brains, and societies reconstruct the past*. Cambridge, MA: Harvard University Press.

Murdock, B. B. (1993). TODAM2: A Model for the Storage and Retrieval of Item, Associative, and Serial-Order Information. *Psychological Review, 100*(2), 183-203.

Murdock, B. B. (1995). Developing TODAM: Three Models for Serial-Order Information. *Memory & Cognition, 23*(5), 631 - 645.

Neisser, U. (1981). John Dean's Memory: A Case Study. *Cognition, 9*, 1-22.

Neisser, U., & Harsch, N. (1992). Phantom Flashbulbs: False Recollections of Hearing the News about Challenger. In E. Winograd, & U. Neisser (Eds.), *Affect and Accuracy in Recall: Studies of "Flashbulb Memories"*. Cambridge: Cambridge University Press.

Nystrom, L., & McClelland, J. (1992). Trace Synthesis in Cued Recall. *Journal of Memory and Language, 31*, 591-64.

Perrott, D. A., Gentner, D., & Bodenhausen, G. V. (2005). Resistance is Futile: The unwitting Insertion of Anlogical Inferences in Memory. *Psychonomic Bulletin & Review, 12*(4), 696-702.

Roediger, H. L., & McDermott, K. B. (1995). Creating False Memoeries: Remembering Words Not Presented in Lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(4), 803-814.

Schacter, D. L. (1999). The seven sins of memory: insights from psychology and cognitive neuroscience. *American Psychologist, 54*, 182-203.

Zareva, N., & Kokinov, B. (2003). Blending of Non-Similar Episodes as a Result of Analogical Mapping With a Third One. *Proceedings of the 25th Annual Conference of the Cognitive Science Society.* Erlbaum, Hillsdale, NJ.