Assessing Two-Mode Semantic Network Story Representations Using a False Memory Paradigm*

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Abstract

This paper describes a novel method of representing semantic networks of stories (and other text) as a two-mode graph. This method has some advantages over traditional one-mode semantic networks, but has the potential drawback (shared with n-gram text networks) that it contains paths that are not present in the text. An empirical study was devised using a false memory paradigm to determine whether these induced paths are remembered as being true of a set of stories. Results indicate that participants report false memories consistent with the induced paths. Implications for further research and two-mode semantic representations are discussed.

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1 Introduction

In recent years interest has grown in the use of networks to represent relationships revealed in text, including the text of stories. The classic work in this vein is by Schank and Abelson who sought to "emulate the human conceptual mechanisms that deal with language" [20, p. 1] by specifying story scripts that people use to organize knowledge about the world. These works provide the basis for plans that can deal with novel situations (i.e., ones not covered by existing scripts). The scripts take the form of a network of connected acts and states. Classical work in artificial intelligence also sought to represent knowledge in natural language systems as directed networks of relations (e.g., class inclusion, actions) between objects (see [17, 23]).

Recently the idea of semantic networks has broadened to include any representation of connections between words in texts. Some researchers derive these networks using simple n-grams of proximate words [8, 9, 3, 21], on the assumption that semantic meaning flows between adjacent words. Some introduce elements of syntactic analysis to such networks to reduce noise they can otherwise contain [4].

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Recently we have sought to represent the text of stories as a network of relations between entities and actions using semantic role labeling [5]. We initially considered using one-mode networks of entities connected with directed edges labeled with actions, in the manner of classical semantic networks. While this method avoids a problem to be discussed below, it does so at the cost of excluding possibly important information from the representation of the story. To illustrate this, consider the following simple story:

> John had an appointment with Bill. Bill went shopping then waited for John at Starbucks. John drove to Starbucks, but he had an accident on the freeway. He panicked. He could miss Bill. He waited for the police, then he walked to Starbucks and he just caught Bill.

Some simple subject-verb-object relationships exist in this story that can be straightforwardly represented as labeled directed edges.

bill $\xrightarrow{go}$ shopping

john $\xrightarrow{have}$ accident

john $\xrightarrow{catch}$ bill

For indirect objects that modify verbs, it is possible to combine the verb and preposition into an edge label, as is conventionally done in semantic networks.

bill $\xrightarrow{wait\_for}$ john

john $\xrightarrow{wait\_for}$ police

But it is unclear what to do with the phrase *on the freeway*, since it modifies the noun *accident*, rather than the verb *have*. One sentence *he [John] panicked* cannot be represented at all because it has no object. Another disadvantage is that since all the verb edges in the one mode representation are distinct, there is no way to represent that *have* occurs more frequently in this story (as one might be able to do with a weighted edge, for example).

A solution to these shortcomings is to represent the story as a two-mode graph [5], where mode 1 represents nouns, and mode 2 represents verbs. Directed edges in this graph are labeled S (subject_of), O (has_object), or [preposition]. The complete two-mode representation of the above story is shown in Figure 1.

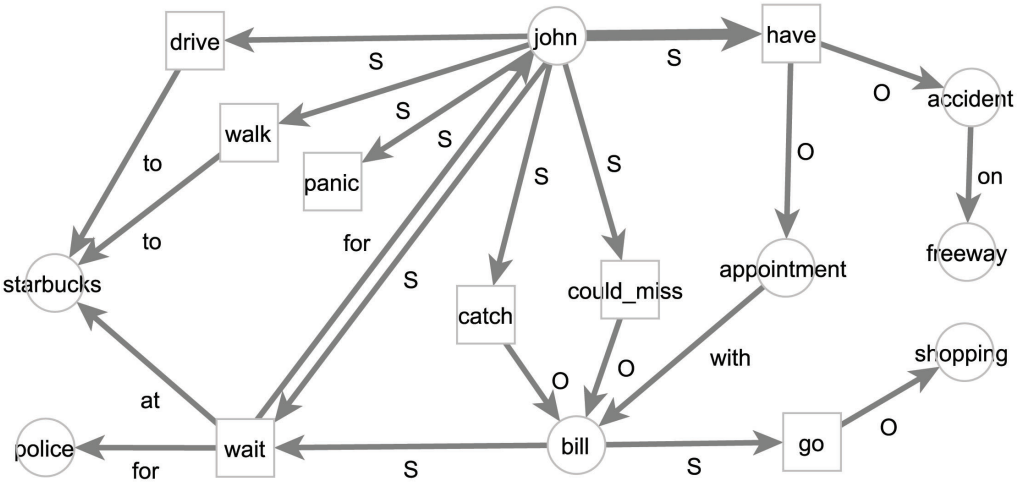

Figure 1 A two-mode representation of the example story.

In addition to better representing some of the grammatical constructions, the two-mode scheme also allows for extraction of the individual modes, showing verbs that are related because of their connections to nouns, and nouns that are related because of their connections to verbs, as shown in Figure 2.

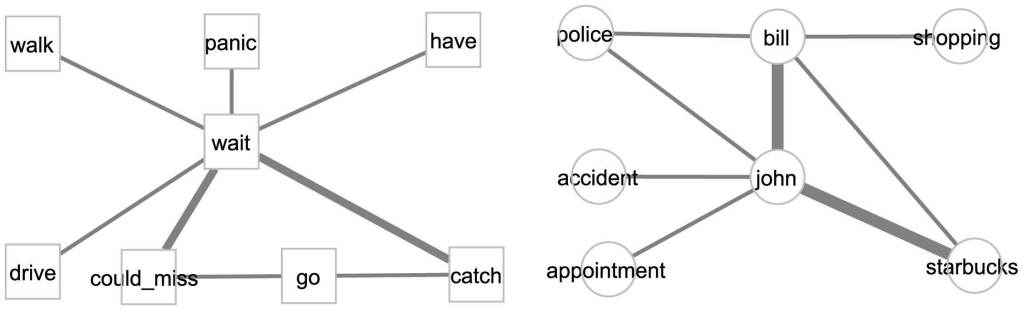

Figure 2 Extracted modes of the graph in Figure 1.

1.1 Induced Connections

However the two mode scheme has a potential problem. Where nouns are connected through a common verb, as is the case with *wait* in the example above, an ambiguity is created. Was it John or Bill who waited for the police? Which one waited at Starbucks? Both possibilities are readable from the two-mode graph, and this is reflected in the noun-mode graph as well, where both John and Bill are connected to police even though Bill never came in contact with them in the story.[1]

Our question is: Is this a "fatal flaw" of the two-mode representations provided their proposed relation to human cognition? Or could these induced paths generate semantic activation in the minds of subjects when they are remembering elements of stories? Some existing research suggests the latter outcome as a possibility. Research in human memory has examined the role of semantic activation in prompting false memories for events (for an excellent review see [10]). Generally, this class of theories proposes that false memories emerge from infelicitous semantic activation occurring when a recognition probe mismatches information stored in memory. This spurious activation is misinterpreted by individuals leading them to claim that they remember the probe. If two-mode networks structurally resemble the semantic network of participants' memories for stories then induced paths from these networks should provide fertile grounds for falsely remembering story elements that never occurred in a story. To address the possibility we examined whether these "induced paths" from two-mode networks derived from stories would reflect sources of semantic activation that lead to false memories.

1.2 False Memories

Examination of the factors involved in the creation of false memories provides a fruitful method of investigating the underlying mechanisms involved in the organization of human

[1] This problem is even worse for n-gram representations, which do not restrict connections to grammatical relations. A 3-gram graph of the story (with stop-words eliminated) has connections between *john* and *shopping*, *police* and *walk*, *accident* and *starbucks*, etc., none of which reflect events in the story.

memory. Memory errors have been studied using a variety of methods and have been found to occur when new words or sentences are similar in meaning to studied items (e.g., [1]), for new items that are visually or phonologically similar to old items (e.g., [14]), during free recall tests [22], and during eyewitness testimony [16]. A method that has been widely used to investigate false memories is the Deese-Roediger-McDermott (DRM) paradigm wherein after studying a list of related words such as *bed*, *rest*, *tired*, and *dream*, people often erroneously claim that a non-presented critical lure (*sleep*) was originally included in the list [6, 19]. Thus, the critical lure serves as an overarching theme of the related study list but the theme itself is never actually studied.

One theory that has been proposed to explain the DRM illusion is the activation/monitoring theory. This theory posits that activation of critical lures occurs during processing of list items via spreading activation of conceptual representations within a semantic network [11]. During encoding, a summation of multiple implicit associative responses produced by the studied associates may internally activate the conceptual representation of the critical lure thus making it available in memory [13]. During retrieval, test probes may serve to reactivate the associative network that subsequently makes the critical lure susceptible to false remembering due to a high degree of overlap between the lure and its activated representation within the associative network [15]. Thus, the relationships formed between items or sentences may allow extraction of the overall theme of the associated list or cause the critical lure to become activated and available in memory, depending on the subjective organization imposed by the participant during encoding [10].

To date, only a handful of DRM studies have placed associates in the context of sentences or stories during encoding. Placing related items in the context of sentences or text (e.g., "after work she was very tired", "after dinner she laid down in bed") influences false memories [7, 18], and new sentences that are related to a previously heard story are often falsely identified as having been previously studied [2]. These findings suggest that people make inferences and associations that are consistent with the overall meaning of a passage or text. For example, Dewhurst, Pursglove, and Lewis [7] found that 5-year-olds were more likely to falsely recognize critical lures after reading stories with DRM associates placed within the sentences of the text as compared to the standard list encoding (although there were no differences for 8- and 11-year-olds). They argued that the story context made it easier for younger children to identify its overall theme, whereas older children may have a greater ability to identify thematic associations during list processing and therefore had equally high false alarms in both encoding conditions.

In this experiment we employed a similar false memory paradigm in which participants read two stories at encoding and later made recognition decisions for sentences that either occurred (i.e., targets) or did not occur (i.e., lures) in stories that we developed. More specifically, we chose the two lure types that differed based on their occurrence in the two-mode network generated from the stories. For example, one lure type occurred in the two-mode network but did not occur in either story (i.e., an *induced path*; "Bill waits for the police" from the story above). Another lure type chosen from the stories reflects a path that neither occurred in the stories nor in the two-mode network but is composed of nouns and verbs in the graph (i.e., *synthesized path*; "Bill drove to Starbucks"). If induced paths in two-mode networks represent underlying semantic structure of human memories for stories then participants should incorrectly claim that induced path statements occurred in the stories more than synthesized path statements. Therefore, we hypothesized that statements from induced paths would falsely remembered more often on average than statements from synthesized paths.

2 Methods

2.1 Participants

A total of 34 undergraduate students from the Arizona State University were recruited from the psychology subject pool. Each participant was tested individual or in groups of two to eight in sessions that lasted approximately 20 minutes.

2.2 Materials

We created two stories of about 500 words each as stimuli for the experiment (see Appendix). Both were set in the context of the current Syrian civil war in order to maximize possibilities for finding induced paths in the resulting two-mode semantic networks. One was a "Fighters" story in which a group of men cross the border from Turkey into Syria in hopes of joining the fight against government forces. The other was a "Refugees" story about a family living in a Syrian refugee camp who cross the border from Syria into Turkey in order to escape the fighting.

Both stories were represented as two-mode, directed semantic graphs of the kind described above, and these were joined to produce an aggregate graph representing both stories. A researcher then examined the paths in comparison to the original stories to produce three kinds of stimulus sentences. *Old sentences* were simple sentences in the stories corresponding to paths present in the graph. Two types of new sentences were composed from elements in the graphs. *Induced sentences* were based on paths present in the graph but not present in the stories. *Synthesized sentences* were plausible sentences composed from nodes in the graph but were no represented by paths in the graph.

2.3 Design and Procedure

Participants were informed that they were going to read a set of stories and that their memory would later be tested on the content of the stories. The two stories used were counterbalanced such that the "Fighters" story was read first by half the participants, whereas the "Refugees" story was read first by the other half of the participants. Encoding was self-guided, such that when participants finished with a sentence or paragraph they pressed the spacebar to continue to the next screen. At the end of the first story, participants were informed that they had finished the first story and could begin reading the second story when ready. Separate stories were demarcated simply with the heading "Story 1" and "Story 2". Upon conclusion of the study phase, a 5-minute distractor phase consisting of solving Sudoku puzzles was administered. Following this, instructions for the recognition test were given. Participants were told they were going to be shown a series of sentences. Upon presentation, they were to think back to the stories earlier and if they remembered seeing the presented sentence in one of the stories they were to press the "old" key. If the sentence was new, they were to press the key labeled "new" to indicate that they did not read the sentence in the previous stories. The test phase consisted of 20 old sentences and 40 new sentences. Of the old items, 10 were taken from each of the two stories. The new items consisted of 20 synthesized sentences and 20 induced sentences. Upon conclusion of the test phase participants were debriefed and thanked for their participation.

3 Results

The proportion of sentences correctly recognized as old ($M = .60$) was greater than the proportion of new sentences incorrectly called old ($M = .20$), $t(33) = 13.97, p < .001, d = 2.69$. Critically, however, there was a significant difference in the proportion of new sentences incorrectly called old across the different classes of new items. The proportion of false alarms to synthesized sentences ($M = .23$) was greater than false alarms to induced sentences ($M = .18$), $t(33) = 2.43, p < .05, d = .239$.

4 Discussion

Overall, we found that our participants" abilities to discriminate target from lure statements drawn from the stories was fairly accurate. However, participants also made quite a few false alarms, which is reasonable considering that all of the lures consisted of nouns, verbs, and objects that occurred in the stories. Contrary to our hypothesis, participants made more false alarms, on average, to synthesized than induced lures. These results were unexpected in the sense that they were not predicted by our motivating hypothesis that induced paths in two-mode networks represent semantic structure that leads to ambiguous activation at test. These results have experimentally and theoretically interesting implications regarding false memories for textual passages. In the current study we have developed a novel extension of the basic false memory paradigm for investigating false memories from narrative. The combination of this paradigm with semantic network modeling suggests new and interesting methodological innovations for studies of false remembering linked to nodes in semantic networks.

Theoretically, these results indicate that semantic network modeling can provide useful information about the underlying semantic structure in which inappropriate activation occurs. However, it is important to note that additional methodological and theoretical work is needed to clarify the link between semantic space derived in these models and semantic space in the human mind. For example, longer delays between the reading the stories and taking a recognition memory task may lead to a reversal of the false alarm effects. Based on this line of reasoning, induced paths may reflect stronger thematic connections in semantic memory that are invariant to forgetting. In the current study we focused on only semantic origins of false memories. In future work additional structural and discourse related overlap could be manipulated across stories to promote false memories.

Implications of these results for the two-mode semantic networks are also interesting. The fact that we observed false-alarms in both the induced and synthesized paths suggest that when people read stories they do indeed form memories about connections between entities and events that are not present in the story itself. This means that if the objective of a representation of the text is to reflect the way it is remembered by readers (as opposed to providing a "factual" representation of the text per se), then the induced paths in the two-mode networks are not necessarily a fatal flaw in the approach. Further research is needed on the reasons behind the higher false alarm rate for synthesized vs. induced paths; our intuition is that introducing a delay between reading and remembering may reverse this effect. If so, then it strengthens the case for a two-mode over a one-mode semantic graph representation, as this would provide evidence that memories are structured in a way similar to the two-mode graphs.

The findings are also interesting outside the domain of computerized representations of stories. If false memories induce connections between story elements where no explicit links exist, then this provides fertile ground for interpretations that connect different stories into a

system—what we [12] call a narrative—even when the particulars of those stories may not strictly support this integration. This could explain why stories tend to change from their original forms over time as their accounts circulate in discourse and are passed from person to person. If these changes can be considered random, they may even hint at a mechanism for narrative evolution.

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A Appendix: Stories Used in the Study

A.1 Fighters Story

Three young men drive along a dirt road in a small silver car. The road winds along the Turkey side of the Turkey/Syrian border. The car stops on the side of the road. One of the men exits the car. His name is Asan. Asan grabs a pair of binoculars and looks at the valley. The other men exit the car too.

"That is the border between Turkey and Syria there," Asan points.

Army troops swarm the area.

The other young men, Raji and Abdullah, make frustrated noises. They hoped this part of the border would be clear. Raji and Abdullah are part of a larger group of young men. These men want to sneak into Syria to join the Free Syrian forces.

"We need to cross soon," says Raji. "I want to fight."

"We have one more chance," replies Asan. "I know someone who might still be able to help us make the crossing."

The three men return to the car. Asan drives in a different direction. Soon the car arrives in a small village. Asan parks in front of a small house. The three men exit the car. An old man sits at a home-made table in front of the house. The old man smiles at Asad. He offers tea to the young men. The cups are mismatched.

They drink the tea. Asan asks if the old man still knows the secret way into Syria. The old man says yes. He tells them about a narrow, winding path through the hills. It will take the fighters around the border patrols. The Army forces have not found it.

"It is dangerous," the old man warns the men. "You must walk and go at night or they might see you."

Asan wants to wait for one more night but Raji is impatient. Raji, Asan and Abdullah drive back to their apartment and collect the rest of the group. Asan tells them to pack food and water in backpacks that they can carry. Once they cross the border they will be met by members of the Free Syrian forces.

The group crams into three cars and they drive back to the beginning of the trail. Night falls as the men get out of the cars. The drivers will stay behind and wait for the next group who wants to cross into Syria. Asan wishes luck to Raji and Abdullah. Raji has the only flashlight for the group. He takes the lead and finds the small trail. The men walk in single file. No one talks. They walk for hours. They are not caught.

Morning comes. The group arrives in Syria. They are met by Free Syrian Forces. They have crossed the border.

A.2 Refugees Story

Ahmed stands on a dusty road. The Syrian/Turkey border lies in front of him. A city of tents and shacks sprawls behind him. Refugees live in the city. Ahmed was a teacher in Aleppo. His students have all left. Assad's Army turned the city into a war zone. They shelled houses indiscriminately. The Free Syrian forces destroyed the rest of the city trying to fight back. Ahmed and his family now try to escape the conflict. Ahmed hopes to take his family to Turkey where they will be safe. There are people who will smuggle refugees across the border. The cost is expensive.

Ahmed and his wife sold the last of their possessions several days ago. They live in the refugee camp now.

"This country was my home," Ahmed says. He points in the direction of Aleppo. "I lived in Aleppo my entire life. I met my wife there. My daughter and son were born there. Now the city is destroyed. I must leave. I must keep my family safe."

Ahmed walks back through the refugee camp. People look sad and scared. Ahmed talks to no one.

He steps inside a shelter made from a blue tarp. A pretty woman dishes beans into four small, chipped bowls. There is no table. Two children sit on the floor. They eat quickly. Ahmed thanks his wife. Another man walks up to the tent.

Ahmed greets Niam. Ahmed invites the younger man inside. Niam declines. "I have checked the road. It is clear. We leave tonight. Be ready at sundown. Make sure you bring plenty of water," Niam says.

Ahmed nods. He looks at Fatima, his wife. She looks scared. It will be a long walk into Turkey. The children are young. They will get tired. "We will be ready," Ahmed says.

At sundown Niam returns. Ahmed and Fatima carry food and water in their backpacks. Fatima puts two blankets in each backpack for the children. The children carry nothing. Niam leads them out of the refugee camp. Night falls. Niam turns on a flashlight. He hands another flashlight to Fatima. Fatima shines it in front of the children.

The group walks for hours. Ahmed and Niam talk softly. Fatima tells the children stories. The moon rises in the sky. The children grow tired. Ahmed and Fatima pick them up and carry them.

The moon begins to set. Ahmed and Fatima grow weary. Suddenly Niam points his flashlight.

"There," Niam says. They see a lake. The moonlight shines on the water. "You are safe. Welcome to Turkey," says Niam.