Retrieval Competition in Memory for Analogies

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Abstract*

An important question for cognitive models of human memory is the question of how analogical similarity affects memory retrieval. While the importance of surface lexical and semantic similarities between reminding cues and memory targets has been well-documented, clear empirical evidence that human memory retrieval is influenced by analogy has proven difficult to demonstrate. We report two experiments in which subjects used a series of single sentences as reminding cues for previously-seen mini-texts. Some cue sentences contained nouns and verbs that were hyponyms (i.e., words subordinate to the same category) of those in corresponding target sentences presented in one or two earlier passages. The role of analogical similarity in reminding was examined by varying the correspondence of noun case-role assignments of cue/target homonyms. Results indicate that retrieval competition and analogical similarity influence reminding. Recall of semantically-related passages was significantly greater for structurally consistent (i.e., analogical) cues. Retrieval access was impaired when two semantically related passages were present in memory. Access to the passage with analogical resemblance to the cue was decreased by retrieval competition to an extent consistent with a ratio rule.

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One of the most intriguing qualities of human memory is its capacity to allow novel experiences to activate relevant prior knowledge, even though the objects and events in the new situation have never been directly associated with those involved in the remembered ones. A person who sees the movie *West Side Story* for the first time is likely to be reminded of the play *Romeo and Juliet*, notwithstanding the displacement of the characters over centuries and continents. Although such remindings are surely related to general principles of memory retrieval, they differ significantly from standard retrieval tasks studied by psychologists. Unlike standard retrieval tasks, such as free or cued recall, there is no clear "right answer" as to what one should be reminded of in response to a given cue. Further, reminding may be unintentional (although as Schank, 1982, observed, one may also seek to be reminded).

The above example illustrates *analogical* reminding, in which the relations embodied in the cue and in the stored situation correspond in systematic ways, despite notable differences between their constituent elements. In other words, two episodes are structurally consistent (analogous) when the overall conceptual relationships between their actors, actions, plans, goals, and themes are similar. In spite of the centrality of structural consistency in proposed definitions of the "soundness" or "goodness" of analogies (Falkenhainer, Forbus, & Gentner, 1989; Holyoak & Thagard, 1989), it has proved surprisingly difficult to provide empirical evidence that human memory retrieval is influenced by analogy. The importance of surface lexical and semantic similarities has been well-documented, but clear evidence demonstrating the effect of structural consistency on reminding (such as the overall plot similarity between *Romeo and Juliet* and *West Side Story*) has been difficult to achieve. The answer to the question of whether structural consistency influences reminding would have important implications for psychological and artificial-intelligence models of analogical, episodic, and case-based retrieval. Do the individual elements of a story simply serve as independent retrieval cues, or do the relations among those elements also have an impact on what is recalled? Is the effect of structural consistency influenced by whether or not the target situation is semantically related to more than one episode in long-term memory?

Previous Studies

The evidence concerning the role of structural consistency in analogical reminding is mixed. Indeed, the most robust finding in the analogy literature is that people often fail to retrieve relevant, but superficially-dissimilar, source analogs (Gick & Holyoak, 1980; Gentner & Landers, 1985; Ratterman & Gentner, 1987; Seifert, McKoon, Abelson, & Ratcliff, 1986). Such negative findings suggest that the process by which analogs are retrieved may not be sensitive to their configural properties, even though such properties are crucial in ensuring that the retrieved information is actually useful.

However, there is evidence that if the source and target share similar features, then degree of isomorphism has an impact on retrieval (e.g., Holyoak & Koh, 1987; Ross, 1989). Subjects in Ratterman and Gentner (1987) were given a set of stories and were asked to write down any stories that they were reminded of from a previous session,

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one week earlier. Two types of cue/target similarity were manipulated: direct similarity of objects and actions (i.e., similar vs. dissimilar concrete nouns and verbs), and configural similarity of causal structure (i.e., similar vs. dissimilar causal connections among the objects and actions). Direct similarity of objects and actions was the dominant determinant of reminding; however, consistent, though nonsignificant, trends suggested that cue/target analogical similarity may also influence remindings (see also Gentner & Landers, 1985; Johnson & Seifert, 1990; Read & Cesa, 1991).

Analogical Reminding Within a Constraint-Based Retrieval System

The present experiments were designed to test a recent artificial-intelligence model of analogical reminding, ARCS (Thagard, Holyoak, Nelson, & Gochfeld, 1990). Thagard et al. assert that semantic similarity and isomorphism (i.e., structural consistency and one-to-one mapping) influence reminding. Semantic similarity concerns taxonomic relations between individual concepts, such as superordination (e.g., dog - animal) and hyponymy (e.g., dog - cat). The similarity constraint favors mappings between concepts with close taxonomic relationships. The isomorphism constraint depends crucially on case-role relations (i.e., mapped elements should fill corresponding case roles across propositions in which they appear). Analogs are represented in ARCS as symbolic structures within a semantic network; during the retrieval process, a "mapping network" is formed to enforce the constraints, and a connectionist settling process then guides retrieval of the stored structure(s) that best satisfy the constraints.

Retrieval in ARCS is fundamentally competitive in that evidence favoring access to one stored structure serves to reduce (via inhibitory links) the likelihood of retrieving other stored structures. A central prediction, then, is that reminding will be competitive, so that if a cue has strong semantic links to multiple stored structures, reminding of each will be impaired relative to the case in which it is the sole semantically-related candidate. In addition, ARCS predicts that the effect of structural consistency will interact with competition. A disanalogous passage (relative to a given cue) might have a high probability of retrieval if it were the only semantically-related structure in memory. However, it would have a greatly decreased retrieval probability if a semantically-related analogous structure was also in memory.

The basic qualitative predictions of ARCS are mimicked by a simple mathematical model, the Bradley-Terry-Luce choice model (Bradley & Terry, 1953; Luce, 1959; Wickens, 1989a). The choice model states that the probability of making a given choice or response is a function of the "strength" (e.g., preference) of that choice divided by the strength of all choices or responses. As applied to memory retrieval, the choice model, like ARCS, predicts that the probability of retrieving a given item is determined by how strongly that item is associated to a given cue relative to the strength of all other items associated to that cue (see Raajimakers & Shiffrin, 1981). According to the choice model, the probability that a subject makes response type i to cue type j is:

$$p_{ij} = S_i \Big/ \sum_{k=1}^{n} S_k$$

S_i is the strength of response type i, and the summation is over the strengths of all the response types available to the subject from cue j. The choice model captures two aspects of the competitive responding inherent in ARCS. First, choices are made in comparison to available alternatives so that relative weighting should apply. Second, the dependence of these weights on the chosen alternatives implies that a consistent set of estimates should be obtained over all conditions. Accordingly, we used the choice model to derive quantitative predictions for reminding performance in our experiments.

Experiments 1 and 2

We performed two experiments to investigate the influence of structural consistency and competition on analogical reminding. The general design was to have subjects encode a series of very simple (2-3 sentence) passages, in the context of various incidental tasks designed to ensure semantic processing. After a brief delay, subjects were given a series of single-sentence cues in the forms *The subject verb the object* (SVO) or *The object was verb by the subject*, and asked to recall as much as they could from any and all passages of which they were reminded by each cue sentence. Some of the cue sentences contained nouns and verbs that were hyponyms of those in corresponding target sentences in one or two of the earlier passages; other cue sentences were unrelated to any of the prior passages.

Table 1 presents an example of a set of two passages and a related cue sentence. The target sentence in each passage is identified by italics. We will refer to the non-target portion of each passage as the "surround". One passage contains an analogous target, *The pastor calmed the businessman*, in which the nouns fill case roles parallel to those of their respective hyponyms in the target-cue sentence, *The rabbi reassured the chairman*. The other passage contains a disanalogous target, *The executive soothed the priest*, in which the case roles of the noun hyponyms are reversed between the target sentence and cue. Of the cues which shared noun and verb homonyms with target sentences, half were matched to a single previously-studied analogous or disanalogous target sentence (singleton condition) and half were matched to two previously-studied analogous and disanalogous target sentences (competitor condition).

We predicted (a) passages in the competitor condition would be recalled less often than in the singleton condition, (b) passages cued with analogous sentences would be retrieved more frequently than passages cued with disanalogous ones, and (c) there would be an interaction of analogy with retrieval competition such that the effect of cueing with analogous sentences would be greater in the

Table 1. Example of Paired Passages with Consistent Versus Inconsistent Targets in Relation to Cue Sentence

Consistent Target
Having just been fired from a high level job, he decided to go to his church for counseling. *The pastor calmed the businessman.*
Inconsistent Target
The church was having trouble approaching local corporations for contributions to the shelter. *The executive soothed the priest.*
Target-Cue Sentence
The rabbi reassured the chairman.

competitor than in the singleton condition.

Several points about the general nature of the materials deserve emphasis. First, structural consistency was simply manipulated by a single cross-mapping between a pair of SVO sentences. Second, semantic overlap was equated as structural consistency was varied. Third, the cue and target sentences had no direct lexical overlap, but were nonetheless semantically related by virtue of shared superordinates linking corresponding hyponyms. Fourth, because the cue sentences were directly related only to fragments of the passages (i.e., to the target sentences but not the surrounds), any reminding would have to be based on only partial overlap between cues and passages (cf. Johnson & Seifert, 1990).

Method

Materials

There were 24 sets of materials similar to the example in Table 1, each consisting of two target passages and one cue sentence. All sets of materials appeared in all conditions. Each of the two passages within a set contained a target sentence that was related to the set's cue sentence. The matched target and cue sentences all shared two sets of associated nouns (e.g., *pastor*, *priest*, *rabbi*; *businessman*, *executive*, *chairman*) and a single set of associated verbs (e.g., *calm*, *soothe*, *reassure*). The nouns and verbs within a set were chosen so that the nouns would jointly make sense in either the object or subject position. Within each passage pair, verbs were randomly assigned to pairs of target nouns, after which each target sentence was randomly assigned to one of the two passages. In order to avoid confounding cue/target consistency with surface order of the noun hyponyms, an equal number of active and passive cue sentences and target sentences were constructed in each condition. Random assignment was used to decide whether cue and target sentences would be active or passive and which target passage would be analogously cued.

Materials ratings: In order to determine whether people are sensitive to our structural consistency manipulation when retrieval is *not* required, 96 undergraduates attending the University of California, Los Angeles (UCLA) were asked to assess the perceived similarity of the cue sentences and the passages. Subjects were told to rate, "How similar are the scenes being described in the story and the sentence?" for consistent, inconsistent, and unrelated (i.e., cues for a different passage) cues and targets. Responses were recorded on a 6-point Likert scale (1 = completely dissimilar, 6 = completely identical). There was a significant difference between subject ratings for analogous (M = 3.98) and disanalogous (M = 2.75) cue/passage pairs, $min\ F'$ (1, 100) = 28.04, as well as disanalogous and unrelated cue/passage pairs (M= 1.59), $min\ F'$ (1, 75) = 36.10, both $p < .0001$. (In order to be able to generalize our findings beyond the specific materials we created, the conservative $min\ F'$ formulation of analysis of variance was calculated for all tests of mean differences; Clark, 1973.)

Subjects and Design

All subjects were UCLA undergraduates, with 36 subjects in Experiment 1 and 72 in Experiment 2. Two within-subject factors were manipulated: (1) whether cues were analogous or disanalogous with respect to a corresponding target sentence in a passage, and (2) whether one (singleton condition) or two (competitor condition) passages related to a given cue had been studied. For example, if both the passages in Table 1 were presented to a subject, the two passages would represent the competitor condition; whereas if only one of the paired passages had been presented, it would represent the singleton condition. Cue sentences thus might be semantically related to (a) both an analogous passage and a disanalogous passage, (b) a single analogous passage, or (c) a single disanalogous passage. This manipulation enabled us to test the prediction that competition would decrease reminding, especially for disanalogous passages. In Experiment 1, subjects first read a set of target materials that contained 4 unrelated and 8 related target passages. After completion of a distractor task, subjects were given booklets containing 4 unrelated and 6 related cue sentences (2 competitor, 2 analogous, and 2 disanalogous).

In Experiment 2, subjects initially read 4 unrelated, and 4 related target passages along with 3 other target passages for an additional factor that will not be discussed in the present paper. After completion of a distractor task, subjects were given 4 unrelated and 3 related cue sentences (1 competitor, 1 analogous, and 1 disanalogous) and 2 cues for the additional factor.

Procedure

Subjects were told that they would be asked to read and rate a series of passages for plausibility, meaningfulness, and imagibility. Subjects rated one attribute on each of three passes through a booklet. For the first pass, subjects were given 30 s to read and rate each passage; for the second and third passes they were given 20 s for each. After completion of the third pass through the booklets, subjects were given a 4 min distractor task.

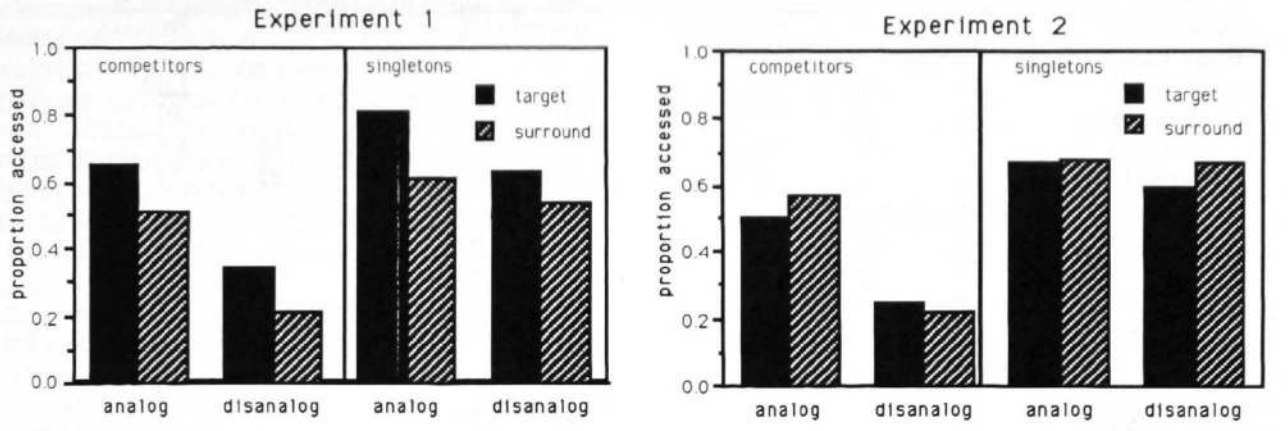

Figure 1. Proportion of Passages Accessed as a Function of Competition and Analogy.

Table 2. Min F' Analysis of Sentence-Access Main Effects and Interactions

	Competition		Structural Consistency		Interaction	
	min F'	*df*	*min F'*	*df*	*min F'*	*df*
Experiment 1						
target sentence	10.95**	*34*	9.27**	*42*	< 1	
surround sentences	10.22**	*42*	6.56*	*38*	2.54	*39*
Experiment 2						
target sentence	20.15***	*68*	3.56[a]	*54*	1.19	*39*
surround sentences	19.99***	*53*	4.33*	*48*	4.87*	*47*

[a] $p < .05$ for both subject and item ANOVAs but not for *min F'*, * $p < .05$, ** $p < .01$, *** $p < .001$

After completion of the distractor task, subjects were told that they would now read a group of sentences, some of which were similar to one or more passages that they had read in the first part of the experiment. They were instructed to rate each sentence for plausibility, meaningfulness, and imagibility and write down the passage or passages they were reminded of while they made these ratings. No time limit was imposed, but subjects were told that after they turned the page of the booklet, they should not turn back to that page even if they were later reminded of something. The entire experimental session lasted approximately 30 min.

Results

The written reminding protocols were scored with respect to which of the studied passages was accessed in response to a given sentence cue. Access to the target sentence and the surround of each passage was scored separately. For each separate attempt at recalling a passage (i.e., each attempt to report what the subject considered a single passage), credit for access was given to whichever studied passage had content words recalled; if content words from two passages were included, credit was given to the passage that contributed the greater number of content words. If subjects wrote down content words from two passages in *separate* retrieval attempts in response to a single cue, access credit was given for each. Because synonym substitutions could be confused with interchanges of hyponyms across paired passages, a criterion of literal recall was used in scoring content words. An important feature of this access measure is that it is not itself sensitive to the structure of the accessed passage, thus providing a strong test of the hypothesis that structural consistency actually facilitates access to passages, regardless of whether the relational structure of the accessed passage can be reported correctly.

Summaries of the main effects and interactions in the retrieval probabilities are as follows:

Competition: As can be seen in Figure 1 and Table 2, for a given cue sentence the probability of retrieving a target passage greatly decreased when there was more than one lexically-related target passage in memory.

Structural Consistency: Analogously-cued target passages were recalled more often than disanalogously-cued target passages. In Experiment 2, there was a reliable competition by analogy interaction for surround sentences. In the competition condition, analogously-cued surround sentences were recalled significantly more often than disanalogously-cued passages, *min F'* $(1, 43) = 6.60$, $p < .05$.

Choice Model

Each panel of Table 3 presents a 4 x 4 matrix of access proportions for each response type (e.g, consistent, inconsistent, unrelated, and no recall) that can occur in each experimental condition (e.g., competition, consistent, inconsistent, and unrelated). Only 12 of the combinations are possible. For example, an inconsistent passage cannot be recalled in response to a consistent cue in the singleton condition, because no such inconsistent passage was presented to the subject. To fit the choice model, it is assumed

Table 3. Observed and Predicted Proportions of Recalled Sentences by Experimental Condition

Response type	Competition		Consistent		Inconsistent		Unrelated		Strength
Experiment 1 target sentences									
Consistent	.55	*.56*	.78	*.78*	–	–	–	–	1.00
Inconsistent	.30	*.28*	–	–	.60	*.63*	–	–	.49
Unrelated	.01	*.03*	.03	*.04*	.07	*.06*	.17	*.16*	.05
No recall	.13	*.14*	.19	*.19*	.33	*.31*	.83	*.84*	.24
Experiment 1 surround sentences									
Consistent	.48	*.46*	.59	*.61*	–	—	–	–	1.00
Inconsistent	.18	*.26**	–	–	.55	*.47*	–	–	.56
Unrelated	.01	*.04**	.04	*.05*	.07	*.07*	.16	*.14*	.09
No recall	.32	*.25*	.37	*.33*	.38	*.46*	.84	*.86*	.54
Experiment 2 target sentences									
Consistent	.47	*.48*	.67	*.66*	–	–	–	–	1.00
Inconsistent	.22	*.28*	–	–	.60	*.54*	–	–	.59
Unrelated	.00	*.05**	.01	*.06**	.07	*.08*	.21	*.18*	.09
No recall	.30	*.20**	.32	*.28*	.33	*.38*	.79	*.82*	.41
Experiment 2 surround sentences									
Consistent	.54	*.50*	.66	*.71*	–	–	–	–	1.00
Inconsistent	.21	*.29**	–	–	.66	*.58*	–	–	.58
Unrelated	.00	*.04**	.01	*.06**	.07	*.08*	.23	*.20*	.08
No recall	.25	*.17**	.32	*.23**	.26	*.33**	.77	*.80*	.33

Note. Italicized values are expected proportions, non-italicized values are observed proportions.
* Difference between observed and expected cell frequency is ≥ 1 standardized cell deviation

that each of the 4 possible response types has a certain "strength" and that all 12 response outcomes can be predicted by these strengths as a function of the choice rule.

The italicized values in Table 3 are the predicted access proportions derived by fitting the choice model, and the rightmost column in the table reports the strength parameters for the four response types. (The statistics reported here were obtained from TWOWAY: Wickens, 1989b; see pp. 109-116, Wickens, 1989a). As can be seen , the choice model accurately describes our data; 92-99% of variance is accounted for relative to a model in which all response types have equal strength. Corroborating ARCS, the estimated strength parameters for inconsistently-cued passages are almost half of those for consistently-cued passages.

General Discussion

We have shown that reminding can be described as a competitive selection among alternatives as represented by the choice model. Further, the present findings clarify a number of basic constraints on the mechanisms of analogical reminding and support several predictions from ARCS (Thagard et al., 1990). We found that varying the structural consistency of single sentence cues influenced access to semantically-related passages stored in memory. This effect on access was not only observed for the target sentence that was semantically linked to the cue, but it also extended to the indirectly-related surround portion of the passage. These results were obtained under conditions in which similarity of individual concepts was equated (because the same words were used in both the consistent and inconsistent cues), and surface correspondences at the level of word order were controlled (by random assignment of active versus passive voice to cues and target sentences). Our measure of access to passages did not depend on successful completion of post-access processes such as problem solving or explanation, thus localizing the impact of consistency at the initial access stage itself. Finally, the observed effect of configural overlap manifested itself in an access measure based on recovery of content words from the passage, rather than recovery of relational structure (although subjects did accurately recall the case-role structure). Our results therefore support the conclusion that structural relations between a cue and stored memory representations constitute one of the basic constraints on initial access.

The present study also provided clear evidence that memory access is fundamentally competitive, as the ARCS model postulates. We found that the presence in memory of two representations containing a target sentence semantically-related to the cue impaired access to either of the competitors. Access suffered even though instructions to subjects stressed that they should report all passages of which they were reminded.

As predicted by the ARCS model, the effect of structural consistency on memory access is greater when competing representations are activated by the cue. The fact that previous studies of analogical reminding only examined the equivalent of our singleton conditions, for which the influence of structural consistency tended to be weaker than in our competitor conditions (see Table 3), may have contributed to some of the failures to find robust effects of configural overlap on reminding (e.g., Seifert et al., 1986; Ratterman & Gentner, 1987). As analogical reminding in everyday life presumably takes place in the context of competition among multiple partially-activated memory

representations, it would seem that laboratory studies of reminding have probably tended to understate the influence of analogical similarity on memory retrieval. Also, the insignificant difference (M = .02) between recall of analogous and disanalogous singleton surround sentences has important implications for artificial intelligence models of reminding— simple recall schemes that rank-order indexed targets by their degree of similarity and select the "best" one will likely not make accurate models of human reminding.

Future work needs to address the role of comprehension and inference processes in reminding. ARCS, which uses only taxonomic relations between individual concepts as retrieval paths, lacks any capacity to infer, for example, that the overall theme of a passage is "retaliation". As a result, the model is unable to use such implicit abstractions to guide retrieval by indexing episodes with similar abstract themes. We have attempted to address this problem with SAARCS (Lange, Melz, Wharton, & Holyoak, 1990), a hybrid connectionist model that integrates text inferencing and analogical reminding.

Studies on the role of comprehension and inference processes in reminding should also help determine exactly *why* structural consistency is a factor in recall. It is possible that the main benefit of structural consistency between a cue and a target is that similar cue/target structures guide the inferences made and thereby result in more matching of abstract concepts. For example, the inferences needed to fully comprehend the sentences *The priest calmed the chairman* and *The chairman calmed the priest* could be very different (e.g., religious vs. financial counseling). While the present study has demonstrated that the structural differences between cues such as the priest/chairman do indeed affect reminding, it has not determined whether that effect is due to the structural differences *per se*, the different inferences the structural differences engender, or a combination of the two.

References

Bradley, R. A., & Terry, M. E. (1953). Rank analysis of incomplete block designs. I. The method of paired comparisons. *Biometrika, 39,* 324-345.

Clark, H. H. (1973). The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior, 12,* 335-359.

Falkenhainer, B., Forbus, K. D., & Gentner, D. (1989). The structure-mapping engine: Algorithm and examples. *Artificial Intelligence, 41,* 1-63.

Gentner, D., & Landers, R. (1985). Analogical reminding: A good match is hard to find. *Proceedings of the International Conference on Systems, Man and Cybernetics* (pp. 607-613). Tucson, AZ.

Gick, M. L., & Holyoak, K. J. (1980). Analogical problem solving. *Cognitive Psychology, 12,* 306-355.

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. *Cognitive Psychology, 15,* 1-38.

Holyoak, K. J., & Koh, K. (1987). Surface and structural similarity in analogical transfer. *Memory & Cognition, 15,* 332-340.

Holyoak, K. J., & Thagard, P. (1989). Analogical mapping by constraint satisfaction. *Cognitive Science, 13,* 295-355.

Johnson, H. M., & Seifert, C. M. (1990). Predictive utility in case-based memory retrieval. In *Proceedings of the 12th Annual Meeting of the Cognitive Science Society* pp. 757-763). Hillsdale, NJ: Erlbaum.

Lange, T., Melz, E., Wharton, C., & Holyoak, K. J. (1990). Analogical retrieval within a hybrid spreading-activation network. In D. S. Touretzky, J. L. Elman, T. J. Sejnowski, & G. E. Hinton (Eds.), *Proceedings of the 1990 Connectionist Models Summer School.* San Mateo, CA: Morgan Kaufmann.

Luce, R. D. (1959). *Individual choice behavior: A theoretical analysis.* New York: Wiley.

Raajimakers, J. G. W., & Shiffrin, R. M. (1981). Search of associative memory. *Psychological Review, 88,* 93-134.

Ratterman, M. J., & Gentner, D. (1987). Analogy and similarity: Determinants of accessibility and inferential soundness. *Proceedings of the Ninth Annual Meeting of the Cognitive Science Society* (pp. 22 -34). Hillsdale, NJ: Erlbaum.

Read, S. J., & Cesa, I. L. (1991). This reminds me of the time when...: Expectation failures in reminding and explanation. *Journal of Experimental Social Psychology, 27,* 1-25.

Ross, B. H. (1989). Distinguishing types of superficial similarities: Different effects on the access and use of earlier problems. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 456-468.

Seifert, C. M., McKoon, G., Abelson, R. P., & Ratcliff, R. (1986). Memory connections between thematically similar episodes. *Journal of Experimental Psychology: Human Learning and Memory, 12,* 220-231.

Schank, R. C. (1982). *Dynamic memory.* New York: Cambridge University Press.

Thagard, P., Holyoak, K. J., Nelson, G., & Gochfeld, D. (1990). Analog retrieval by constraint satisfaction. *Artificial Intelligence, 46,* 259-310.

Wickens, T. D. (1989a). *Multiway contingency tables analysis for the social sciences.* Hillsdale, NJ: Lawrence Erlbaum.

Wickens, T. D. (1989b). *Twoway* [computer program]. University of California, Los Angeles.