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Two Predictions of a Compound Cue Model of Priming

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Abstract

This paper examines two predictions of the compound cue model of priming (Ratcliff and McKoon, 1988). While this model has been used to provide an account of a wide range of priming effects, it may not actually predict priming in these or other circumstances. In order to predict priming effects, the compound cue model relies on an assumption that all items have the same number of associates. This assumption may be true in only a restricted number of cases. This paper demonstrates that when this assumption does not hold, the model does not easily predict priming. Second, the model fails on its own grounds in that it makes explicit predictions with respect to repetition priming effects, which do not match previously observed properties of repetition priming.

In traditional spreading activation models of priming (Collins and Loftus, 1975), priming is described as the spread of activation from a prime through a network of interconnected words in long term memory (LTM). Activation levels of words connected to the prime (“associates”) are thereby increased, speeding subsequent response times to them (“associative priming”). In contrast, compound cue models (Ratcliff and McKoon, 1988; Doshier and Rosedale, 1989) offer an alternative in which priming effects result from the combination of a prime and target in short term memory (STM). The goal of this paper is to demonstrate that the compound cue model (Ratcliff and McKoon, 1988) depends on an assumption that does not generally hold. When this assumption is not met, the model does not generally predict priming effects. Additionally, despite the fact that the model makes clear predictions with respect to repetition priming (speeded responses to the second or subsequent repetition of a prime), these predictions are not consistent with previously observed effects. Therefore, the model fails on two counts: it only predicts associative priming in a restricted set of conditions, and it makes discrepant predictions concerning repetition priming effects.

In the compound-cue model (Ratcliff and McKoon, 1988), items in STM combine to form a joint retrieval cue (compound cue) that is compared against all items in LTM. As a result of this cue formation, semantically associated prime-target pairs will be more easily retrieved from LTM than non-associated prime-target pairs. Ease of retrieval is modeled by assuming connections between the items in the cue in STM and all items stored in LTM. Non-associated connections are assigned a residual (i.e. small) connection strength, while self-self connections (i.e. connections between an item in STM and its own representation in LTM) and connections to (semantic) associates are assigned larger values. These connection strengths are summed and combined into a familiarity value for the joint cue. When a cue’s familiarity value is relatively large, response time (e.g., in a lexical decision task) is predicted to be relatively fast, and when the familiarity value is relatively small, response time is predicted to be relatively slow. The relation between familiarity value and response time has been modeled by a diffusion (random walk) process (Ratcliff and McKoon, 1988; Ratcliff, 1978), and by a linear approximation to experimentally obtained data (Ratcliff and McKoon, 1995).

Within the SAM (Search of Associated Memory) model of memory (Gillund and Shiffrin, 1984), the familiarity value of a compound-cue can be calculated as in (1), from Ratcliff and McKoon (1988:388):

$$F(i, j) = \sum_{k=1}^K S_{ck} S_{ik} W_p S_{jk}^{(1-W_p)} \quad (1)$$

In this equation, S is the connection strength between each item in STM and its representation in LTM, k represents the total number of concepts in LTM, c is the value of the context (set to 1 to avoid complications), i is the prime item, j is the target item, and W_p gives the weighting on the prime. The value of W_p is constrained to be less than 0.5 so that the more recently presented item ($1 - W_p$) is weighted more heavily than the less recently presented item (W_p) (Ratcliff and McKoon, 1988).

Associative priming

Associative priming is a phenomenon in which a word will be recognized more quickly in a related than unrelated context. For example, bug will be recognized more quickly following fly than cot, across a variety of experimental paradigms and conditions (Neely, 1991). In order to predict this type of priming the compound-cue model depends on an assumption that all items in a cue in STM have roughly the same number of non-residual connections to items in LTM (McNamara, 1992: 1180fn2). The examples below demonstrate the consequences of violating this assumption. Note that these examples examine the case for which the prime is constant, and the target changes, while other approaches examine the effects of changing the prime before a constant target. Both approaches are equally valid, and moreover both produce the same results within the compound cue model.

For these examples, x is a prime with 30 non-residual connections to items in LTM, and y is an unrelated item with 20 non-residual connections to items in LTM, none of which overlap with those of x (i.e. x and y share no associates). The related item z also has 20 non-residual connections to items in LTM, five of which overlap with those of the prime x (i.e., x and z are semantic associates). An estimate of a typical adult's vocabulary size of roughly 50,000 words (Aitchinson, 1987), is used to approximate the total number of concepts in LTM (k) contributing to the familiarity value of the cue. Ratcliff and McKoon (1988) set residual connection strengths to 0.2, and self-self and associate connection strengths to 1.0. These values will be used here for ease of exposition, though others can be used to produce the same results (e.g., Ratcliff and McKoon (1995) determined the best fit parameter setting for a three item cue to be 1.72 for self-self and associate connection strengths, and 0.22 for residual connection strengths). The value of W_p is set to 0.1, as in Ratcliff and McKoon (1988). Given these values for the number of associates for the prime and each target, priming is predicted: the cue $x-y$ produces a lower familiarity value than the cue $x-z$.¹

¹Rather than showing the summation over all 50,000 items, four partial sums are shown, which represent the four possible connection strength combinations with two different values for connection strengths. The integer coefficients of these partial sums add to 50,000 – the total number of items in the sum. Term (A) represents non-residual prime connections combined with residual target connections. Term (B) represents shared (i.e. both non-residual) connections between the prime and target. Term (C) represents the non-residual target connections combined with residual prime connections. Term (D) represents the connections that are residual for both the prime and the target. This presentation is somewhat different than that of Ratcliff and McKoon (1988), in order to more clearly demonstrate the respective contributions of prime and target to familiarity value.

Familiarity value of $\underline{x - y}$			
(A)	(B)	(C)	(D)
$F(x, y) = 30(1.0)^{0.1}(0.2)^{0.9} +$	$0 +$	$20(0.2)^{0.1}(1.0)^{0.9} +$	$49950(0.2)^{0.1}(0.2)^{0.9}$
$= 30(1)(0.235) +$	$0 +$	$20(0.851)(1) +$	$49950(0.2)$
$= 7.05 +$	$0 +$	$17.02 +$	9990
$= 10,014.07$			

(2)

Familiarity value of $\underline{x - z}$			
(A)	(B)	(C)	(D)
$F(x, z) = 25(1.0)^{0.1}(0.2)^{0.9} +$	$5(1.0)^{0.1}(0.2)^{0.9} +$	$15(0.2)^{0.1}(1.0)^{0.9} +$	$49955(0.2)^{0.1}(0.2)^{0.9}$
$= 25(1)(0.235) +$	$5(1)(1) +$	$15(0.851)(1) +$	$49955(0.2)$
$= 5.875 +$	$5 +$	$12.765 +$	9991
$= 10,014.64$			

(3)

The result is that the cue containing semantic associates (3) produces a higher familiarity value than the cue which does not contain semantic associates (2). The higher familiarity value will result in a faster response time, yielding a priming effect for the semantic associate $\underline{z}$ compared to the non-associate $\underline{y}$.

However, if the targets do not have the same number of associates, priming will no longer be predicted. For example, if the number of associates of $\underline{y'}$ is 22, the cue $\underline{x - y'}$ will produce a higher familiarity value (and consequently a faster response time) than $\underline{x - z}$, as shown in (4):

Familiarity value of $\underline{x - y'}$			
(A)	(B)	(C)	(D)
$F(x, y') = 30(1.0)^{0.1}(0.2)^{0.9} +$	$0 +$	$22(0.2)^{0.1}(1.0)^{0.9} +$	$49948(0.2)^{0.1}(0.2)^{0.9}$
$= 30(1)(0.235) +$	$0 +$	$22(0.851)(1) +$	$49948(0.2)$
$= 7.05 +$	$0 +$	$18.72 +$	9989.6
$= 10,015.37$			

(4)

This is because terms (A) and (C) contribute more to the familiarity value of the cue $\underline{x - y}$ (and $\underline{x - y'}$) than of the cue $\underline{x - z}$, and the increased contributions of terms (B) and (D) for the latter cue cannot make up the difference. The increase in familiarity value primarily results from the much larger contribution from term (C) for the cue $\underline{x - y'}$, reflecting the large number of non-residual, non-shared associates to $\underline{y'}$. The increase in term (C) in the cue $\underline{x - y'}$ is larger than the larger contributions of terms (B) and (D) in the cue $\underline{x - z}$, and therefore associative priming is no longer predicted.

The above example demonstrates that the priming effect predicted by the model is not completely determined by semantic associations between words, but also by the overall amount of non-residual connectivity between items in STM and LTM. In order to balance the contribution to the cue from this non-residual connectivity, and ensure that any prediction of priming does derive from semantic association, the number of connections must either be explicitly matched across items or assumed to be equal. While the consequences of violating this assumption of equality have not been clearly addressed in the literature, the examples above demonstrate that even a small difference in the number of associations (22 vs. 20) can be enough to prevent a prediction of priming.

Moreover, if the distribution of the number of associates contains sufficient variability under any measure, then it may not be possible to avoid violating this assumption. In fact, Nelson,

McEvoy, Schreiber (1998) found that the number of associates produced for a word in a free association measure follows a normal distribution, from which two samples would not be guaranteed equal. As the examples above demonstrate, the presence of even a small amount of variability could cause related and unrelated targets to differ in this crucial respect. Therefore, despite acknowledging the greater number of semantic associates to a related target, the model may not predict a priming effect. Whether or not this actually causes the predictions of the model to fail for a particular set of materials depends on a number of unexplored factors, including the values of the connection strengths and the weighting constant W_p , the total number of items in LTM, the difference in the number of non-residual connections between items, and the number of shared connections. As a result, there may be quite a large number of conditions under which the compound cue model actually does not predict associative priming.

Intriguingly, this very property of the model enables a novel prediction exactly the opposite of that made within spreading activation based fact retrieval paradigms (Anderson, 1983). Within spreading activation models, a fixed amount of activation spreads over all links to a given concept. For a concept that has a large number of facts associated with it, activation of any one fact will be relatively weak, resulting in a relatively slow retrieval time. Within the compound cue model, a cue containing a target with a large number of associates will produce a higher familiarity value than a cue containing a target with a small number of associates, even if neither target shares any associates with the prime. For example, the value of the cue $\underline{x-y}$ (above) is 10,014.07, which increases to 10,015.37 when the number of non-residual connections is increased to 22 (the cue $\underline{x-y'}$ above), predicting a faster response time, despite neither target sharing connections with $\underline{x}$. Therefore, in contrast to the spreading activation based model, the compound cue model predicts that targets with fewer associated concepts will be harder (as shown by longer response times) than targets with more associated concepts.

Repetition Priming

Repetition priming is an effect where recognition times for a word are speeded when a word is preceded by itself, as compared to either a different (unrelated) word (Forster, 1998) or to a prior presentation of the same word (Ostergaard, 1998; Logan, 1990). That is, responses will be faster to the third repetition of an item than to the second, and faster still to the fourth, etc., following a power function (Logan, 1988). Such measures use the first presentation of the item as a baseline, and measure increases in reaction time to subsequent presentations relative to the first presentation (Logan, 1990: 6). While it has been previously argued that comparing cues containing different numbers of items (Ratcliff and McKoon, 1988: 393; McNamara, 1992: 1184; Ratcliff and McKoon, 1994: 181; Ratcliff and McKoon, 1995: 1381; see also McNamara, 1994a, 1994b) does not provide a proper baseline, this restriction is essentially arbitrary, as the function relating familiarity value to response time is not at all sensitive to the size of the cue. As discussed in more detail below, it is entirely likely that cues of different sizes can produce comparable or even identical reaction times. Moreover, the model's inability to account for repetition priming is apparent even when cues containing the same number of items are used as baselines.

The prediction for repetition priming relies on the fact that the model measures association in terms of overlap in connectivity (Ratcliff and McKoon, 1988: 388). Such measures are maximized at identity. For example, using the values from the examples above, a repeated item cue $\underline{x-x}$ has a familiarity value of 10,024. The cue $\underline{x-x}$ has a larger familiarity value than the cue $\underline{x-z}$, above, which contains a number of semantic associates (familiarity values of 10,024 vs. 10,014.64, respectively). Increasing the number of shared connections (i.e. associates) between the first and second item in the cue increases terms (B) and (D) at the expense of terms (A) and (C), and maximizes the familiarity value of the cue as (A) and (C) approach zero. The

value of 10,024 therefore represents the maximum familiarity value for a cue containing two items each with 30 connections. For a cue in which both items have 30 connections but no shared associates (i.e. term (B) is 0), the cue has its minimum value of 10,020.58. For any such cue in which some connections are shared the familiarity value of the cue will range between these two extremes.

Additionally, it has been observed that cue size and familiarity are inversely related, such that as the number of items in the cue increases, the familiarity value of the cue decreases (McNamara, 1992: 1186; Gillund and Shiffrin, 1984). While this is generally the case, it is more accurate to say that the range of familiarity values increases with increasing cue size, while the upper limit remains constant, and therefore only the lower end of the range of values of an N-item cue is necessarily smaller than the minimum value for a cue containing N-1 items. Cues containing items which are not semantically associated (e.g., baseline cues) tend towards the minimum familiarity value.

For example, the familiarity value of a three item cue containing no overlap in semantic associates between items in the cue is 10,015.79 (using the values above, and 30 associates per item, with weights set to 0.7 for the first item, 0.2 for the prime, and 0.1 for the target; roughly following Ratcliff and McKoon, 1995: 1387)². This is smaller than the minimum value of 10,020.58 obtained for a two item cue, in which both items have 30 non-residual connections. However, the maximum value of such a three item cue is 10,024, when all three items share every connection (i.e. the three items are identical), the same maximum value as for the two item cue.

These two properties of the model explains why it does not provide an accurate account of repetition priming effects, whether cues of different sizes are compared or whether successive repeated item cues are compared to baseline cues containing the same number of items. Taking first the case where repeated item cues of different sizes are compared, every cue will produce the same familiarity value, no matter how many items are added. Therefore, no facilitation in response time is predicted for successive repetitions, when compared to the first presentation of an item. When compared to a baseline cue containing the same number of items, the familiarity value of the baseline cue will steadily decrease as items are added to the cue, predicting a steady rise in reaction time. However, as before, familiarity values to the repeated item cue will not change. While this correctly predicts that the priming effect (difference in response time between baseline and repeated item cue) will grow larger as items are added to the cue with successive repetitions, the response times to the baseline cues would be increasing, with no change to the repeated item cues. The expected pattern is exactly the opposite, in which response times to the repeated item cues would become successively faster.

Conclusions

The compound cue model described in this paper was tested with respect to its ability to predict associative priming and effects of repetition priming. The prediction of associative priming relies almost entirely on an assumption that all items have roughly the same number of non-residual connections to items in LTM. It was demonstrated that this assumption will be violated in a potentially very large number of cases, and that the robustness of the model's ability to predict priming is at the mercy of on a number of largely unexplored factors, including the actual number of items in LTM, the actual number of non-residual associates, and the potential for differences in association strength. Moreover, the model fares even less well with repetition

²The values of the weights have been reversed here, to account for effects of raising values smaller than 1 to fractional exponents, but still giving the most weight to the target. In Ratcliff and McKoon, they weighted the target at 0.7, but allowed connection strengths to have values greater than 1.

priming, where it failed to predict any advantage in reaction time for items preceded by themselves one or more times, contrary to previous experimental results (Logan, 1988, 1990; Ostergaard, 1998).

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