Mediated Priming does not Rely on Weak Semantic Relatedness or Local Co-occurrence

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Abstract

A series of experiments are presented that replicate the mediated priming effect (e.g., *lion-stripes*) using a naming latency task, and demonstrates that mediated priming does not rely on weak, but direct, semantic relationships or lexical co-occurrence as suggested by McKoon and Ratcliff (1992). The magnitude of mediated priming is not negatively correlated with either semantic relatedness or lexical co-occurrence as McKoon and Ratcliff would predict. Furthermore, we show that differences in the contextual nature of the prime - target pairs affects whether or not mediated priming occurs. These findings are discussed in the context of the HAL memory model suggesting a view of "mediated" priming that is more consistent with a distributed representational view.

Semantic priming refers to the advantage in responding to a target when preceded by a related prime compared to a target preceded by an unrelated prime (e.g., *cat-dog* vs *cell-dog*). Presumably, this occurs due to the direct relationship between the prime and target. However, semantic priming can also occur for items that have been argued to be not directly related; this is referred to as multi-step or mediated priming. Balota and Lorch (1986) provide one of the clearest demonstrations of mediated priming. They found priming with items such as *lion* and *stripes* and argued that this effect was due to the relationship the prime and target have with the conceptually mediating item, *tiger*. Most investigators account for mediated priming within a spreading activation framework, where activation spreads from the prime item through the mediating item to the target (Balota & Lorch, 1986; McNamara, 1992). An alternative explanation has been proposed by McKoon and Ratcliff (1992).

McKoon and Ratcliff (1992) argue that mediated priming occurs because of a weak, but direct, relationship between the prime and the target. This priming relationship is guided by two factors, lexical co-occurrence and semantic relatedness. According to McKoon and Ratcliff these factors are the driving force behind the prime-target relationship and should be able to predict amount of priming for both directly related and mediated prime-target pairs.

Livesay and Burgess (1997) tested these hypotheses proposed by McKoon and Ratcliff (1992). In a series of experiments, Livesay and Burgess found that neither lexical co-occurrence nor semantic relatedness correlated with magnitude of mediated priming. In addition, Livesay and Burgess found differences among stimuli that could explain the fragility of the mediated priming effect. They separated the stimuli into two categories, contextually consistent (CC) and contextually inconsistent (CI) pairs. CC pairs were mediated prime-target pairs that share a common context (e.g., *bat bounce*, common context is ball), CI pairs are less likely to share a common context (e.g., *day-dark*, common context is night). When they separated the stimuli into these categories and re-analyzed the priming data, the CC items showed robust mediated priming and the CI items showed no mediated priming. These results are somewhat problematic for a spreading activation account of mediated priming the presence of the mediating concept should underlie the mediated priming effect, regardless of the contextual inconsistency since there is a clear direct relationship between the mediating concept and both the prime and target.

Alternatively, contextual encoding of word relationships is the basic mechanism in the HAL memory model used by Livesay and Burgess (1997) to evaluate McKoon and Ratcliff's hypotheses about semantic distance and lexical co-occurrence. According to Livesay and Burgess, a prime and target have to have contextual consistency in order for a priming effect to occur.

A potential limitation to Livesay and Burgess' conclusions was their use of the lexical decision task. McKoon and Ratcliff argue that the lexical decision task provides the best test of their compound-cue theory and Livesay and Burgess used it because it can be maximally sensitive to semantic relationships. However, a potential problem with the lexical decision results is that an inhibitory component can be part of the lexical decision process (Neely, 1991). The possibility that an inhibitory process may have been involved in their results is suggested by the complete lack of a priming effect with the CI

prime-target pairs. These CI items constituted about 50% of the total set of prime-target pairs. McKoon and Ratcliff's hypotheses that weak semantic relatedness and lexical co-occurrence may not have been adequately tested if the mediated priming effect was artificially attenuated in the CI condition as a function of the lexical decision process. Thus, the goal of this paper is to further investigate the nature of the mediated priming effect in the context of McKoon and Ratcliff's hypotheses. In the experiments reported in this paper, we used the prime-target pairs originally used by Balota and Lorch (1986), also used by Livesay and Burgess (1997), and employ a naming latency procedure. In Experiment 1, we attempt to replicate, with the naming procedure, our original findings that we obtained with the lexical decision task - mediated priming with the CC items, but not with the CI pairs. In Experiment 2, we evaluate the weak semantic relatedness and the lexical co-occurrence hypotheses as possible explanations of the mediated priming effect. If the naming task provides a better measure of the initial bottom-up activation of word meaning (see Neely, 1991), then naming may provide a better test of McKoon and Ratcliff's ideas.

Experiment 1

Naming latency is often considered to be less encumbered by post-lexical and strategic processes that may enhance or reduce a basic semantic priming effect (Neely, 1991). Balota and Lorch (1986; see also McNamara and Altarriba, 1988) argue that the naming task is less likely to have the problem of strategic processing (post-access checking) that is seen in the lexical decision task. They claim that the lexical decision task has two processes, a spreading activation process and the post-access check of the relationship between the prime and the target. This post-access check can be influenced for a mediated prime-target pair if there are directly related items present in the list. Participants might fail to detect a relation between a mediated prime-target pair if very strong directly related items appear in the same list. However, this problem should not be present for a naming task. The first experiment, in this series of experiments, is a replication of the mediated priming effect using a naming task.

Experiment 1a

Methods

Participants. Forty-five University of California, Riverside undergraduates participated as part of a course requirement. All participants were right-handed, native speakers of English with normal or corrected-to-normal vision.

Materials. Forty-eight prime-target pairs were taken from Balota and Lorch (1986). Each test list consisted of 54 total items, 16 mediated trials, 16 unrelated trials, 16 directly related trials and 6 filler trials. Unrelated prime-target pairs were generated by quasi-randomly pairing targets with primes from the 48 original pairs. For example, the prime *lion* in the mediated pair *lion-stripes* was replaced with *breeze* to form the unrelated pair *breeze-stripes*; *breeze* was originally paired with *blow*. The prime words were counterbalanced; a target preceded by a mediated prime on list 1 would be preceded by an unrelated item on list 2 and a directly related item on list 3.

Procedures. The stimuli were presented on a computer monitor; participant responses were collected via a microphone connected to the computer by a Digitry CTS system. Each trial began with a fixation cross presented for 500 ms. Following the fixation cross, a prime word was presented for 350 ms, immediately followed by a target word; the target word remained on the screen until participant answered or 2500 ms had elapsed. Participants simply had to name the word that appeared on the screen. If a participant failed to respond, or did not speak load enough for the microphone to detect their voice the computer would beep and the word time-out would appear on the screen. The participants were then instructed to speak louder on the next trial.

Results and discussion

A one-way analysis of variance (ANOVA) with three levels was performed for both subject (F_1) and item (F_2) analyses. There was direct priming effect; reaction times to directly related pairs (575 ms) were faster than to unrelated pairs (598 ms), $F_1(1, 44) = 18.43$, $p < .0001$; $F_2(1, 46) = 15.06$, $p < .0003$. There was also a robust mediated priming effect; reaction times to mediated pairs (589 ms) were faster than to unrelated pairs (598 ms), $F_1(1, 44) = 4.11$, $p < .048$; $F_2(1, 46) = 4.27$, $p < .044$. These results are consistent with those found by Balota and Lorch (1986) and replicate our earlier results (Livesay & Burgess, 1997).

Experiment 1b

There appear to be contextual differences among the original Balota and Lorch (1986) stimuli used in these experiments (Livesay & Burgess, 1997). We have found that their stimuli separate into two broad classes of items, contextually-consistent (CC) and contextually-inconsistent (CI). The above naming results were divided into CC and CI pairs; the following is a re-analysis of the reaction-time data, based on this distinction.

Methods

This experiment used the same categorization of word pairs as Livesay & Burgess (1997). New analyses of the priming effects were conducted using this CC/CI distinction.

Results and Discussion

Figure 1 illustrates the differences in the magnitude of

priming (direct and mediated) by contextual consistency.

Contextually Consistent Pairs. There was a priming effect for both direct and mediated pairs. Mediated prime-target pairs were responded to faster (588 ms) than unrelated prime-target pairs (604 ms), F_1 (1, 44) = 6.50; $p < .014$, F_2(1, 23) = 4.80, $p < .038$. Directly related prime-target pairs were responded to faster (576 ms) than unrelated pairs (604 ms), F_1(1, 44) = 18.81, $p < .0001$; F_2(1, 23) = 10.83, $p < .0032$.

Contextually Inconsistent Pairs. Unlike the CC condition, there was not a priming effect for these mediated prime-target pairs, $Fs < 1.0$. Although there was no mediated priming with these pairs, there was a priming effect for the directly related pairs. Directly related prime-target pairs, were responded to faster (573 ms) than unrelated pairs (592 ms), F_1(1, 44) = 6.50, $p < .014$, F_2 (1, 22) = 4.52, $p < .045$.

It appears that the overall mediated priming effect is being carried by only half of the stimuli, the CC related items. Mediated priming is difficult to obtain and the effect depends on methodological issues such as task and the presence of directly related items in the experimental list with the mediated pairs (Balota & Lorch, 1986; McNamara & Altarriba, 1988). Livesay and Burgess (1997) found that these CI pairs did not obtain priming when subjects used a lexical decision task. The results of Experiment 1b demonstrate that this lack of mediated priming is not due to the task; but, rather, the nature of the prime-target pairs. We now turn to a direct test of the weak semantic relatedness and lexical co-occurrence hypotheses.

Experiment 2

McKoon and Ratcliff (1992) argue, from the perspective of compound-cue theory, that mediated priming occurs because mediated prime-target pairs are directly, but weakly related. They further claim that this relationship is due to either semantic relatedness or lexical co-occurrence. They maintain that semantic relatedness is a measure of familiarity; priming occurs for items that have a high degree of semantic relatedness. Thus, according to McKoon and Ratcliff, mediated priming occurs due to the familiarity of the prime and the target presumably because of some already existing relationship. This existing relationship is a weak, but still direct, relationship. As a result, such priming would not be truly mediated.

Distance metrics have often been used to measure semantic similarity; items close together in memory are more semantically related than those items far apart in memory. The Hyperspace Analogue to Language (HAL, Burgess & Lund, 1997; Lund and Burgess, 1996) is a model of semantic similarity; thus items that are closely related should be close together in meaning space because they appear in similar contexts. Thus, mediated prime-target pairs should be closer together in this meaning space if the HAL model reflects McKoon and Ratcliff's hypothesis. Of course, there can also be "true" mediated priming in a high-dimensional model like HAL. True mediated priming should occur because a mediating prime occurs in similar contexts as the related mediator, which should, in turn, have a contextual history with the target item. Therefore, mediated prime-target pairs do not have to be close together in semantic space to show priming, they simply need to share similar context space to show priming.

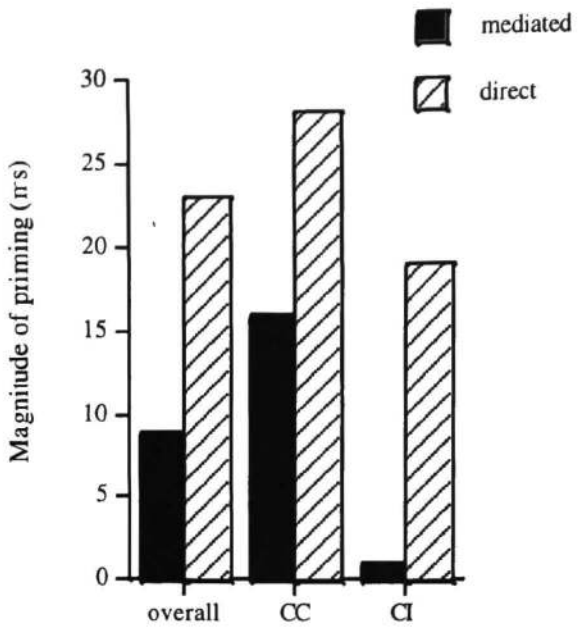

Figure 1. Magnitude of mediated and direct priming as a function of stimuli categorization, all stimuli (overall), contextually consistent (CC) and contextually inconsistant (CI)

In addition, similarity of any compound can be directly measured using lexical co-occurrence. Familiarity (words, images, etc.) is based on the number of times the memory system has encountered the two items together. Therefore, according to McKoon and Ratcliff (1992), there should be a positive relationship between the frequency of lexical co-occurrence and magnitude of priming.

We will address these two issues raised by McKoon and Ratcliff (1992) using the HAL memory model to supply semantic relatedness measures (as shown through distance measures) and local lexical co-occurrence information. The following two experiments are a re-analysis of the naming latency data, correlating the magnitude of mediated priming with semantic distance and lexical co-occurrence data obtained from the HAL memory model.

Experiment 2a
Semantic Relatedness Hypothesis

Methods

Semantic distances (RCU's: Riverside Context Units; see

Lund and Burgess, 1996) were computed for all word pairs used in Experiments 1a (mediated - target, unrelated - target, related - target) using the HAL memory model. Distances were also calculated for conditions not present in the experiments -- the mediated-related items (e.g., lion-tiger), unrelated-related items and unrelated-mediated. The pairs were also separated by contextual consistency as in Experiment 1b.

Results

Figure 2 contains the mean semantic distances for all word pairing conditions (including word pairing conditions not seen by subjects) separated by contextual consistency. As expected, the directly related prime-target pairs in both the consistent and inconsistent conditions are closer in high-dimensional meaning space than are the unrelated prime-target pairs. However, contrary to the predictions of McKoon and Ratcliff, mediated prime-target pairs in both the CC and CI conditions are further apart in the high-dimensional space than are the unrelated prime-target pairs.

More importantly, McKoon and Ratcliff would predict a negative correlation between semantic distance of the mediated prime and target word and amount of mediated priming, however, we found a significant positive correlation, $r = .43$, $p < .0021$. This suggests that as the amount of mediated priming increases, the further apart in distance the mediated prime word becomes from the target word. When the mediated prime-target pairs are again split into the CC and CI conditions, the CC items are still correlated ($r = .60$, $p < .0016$), while the CI pairs are not reliably correlated ($r = .18$, $p < .40$).

Experiment 2b
Lexical Co-occurrence Hypothesis

Methods

To test the lexical familiarity hypothesis, lexical co-occurrence frequencies (the frequency of two items occurring together in HAL's ten-word moving window) for mediated prime-target pairs were extracted from the ~131 million word text corpus used as the input for HAL.

Results

Correlations were calculated between the priming effect obtained for each mediated prime-target pair and directly related prime-target pair in Experiments 1 and the lexical co-occurrence frequency of that word pair. Again, the results did not support the predictions of McKoon and Ratcliff. There was no correlation between magnitude of mediated priming and co-occurrence frequency ($r = -.090$, $p > .54$). This pattern of results does not change when the correlations are computed separately for the context-consistent and the context-inconsistent items. CC mediated pairs did not correlate with co-occurrence frequency ($r = -.11$, $p > .58$). An analogous set of results was obtained for the CI items (mediated: $r = -.32$, $p > .13$).

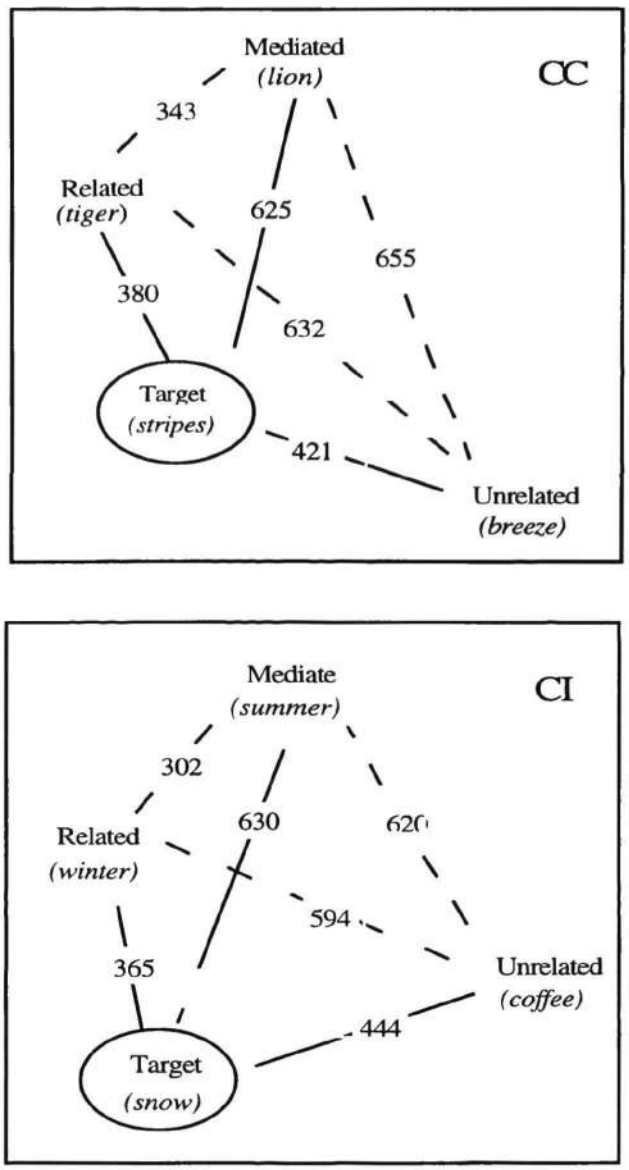

Figure 2. Two-dimensional multidimensional scaling solution for semantic distances between word pairs for consistent (CC) and inconsistent (CI) categories.

Discussion

The results of Experiments 2a and 2b do not support McKoon and Ratcliff's (1992) claims about the putative relationship between the so-called mediated priming effect and weak semantic relatedness and lexical co-occurrence. We will argue in the general discussion that the best account of mediated priming is, in fact, a conceptual mediation process.

General Discussion

The results obtained in this series of experiments, using the naming latency task, are parallel to the results we obtained

earlier using a lexical decision task (Livesay & Burgess, 1997). We replicated the mediated priming effect for a naming latency task, and again demonstrated that not all stimuli are created equal. The categorization of stimuli into the CC and CI groups showed the same results as the previous work using the lexical decision task; CC items maintained the mediated priming effect while CI items did not. Moreover, a directly related (e.g., *tiger-stripes*) priming effect was maintained for both the CC and CI pairs. Thus, it cannot be argued that the CI items had a non-representative unrelated condition. These results appear to be robust and were obtained with both naming and lexical decision. A possible task difference was of potential concern because of the difference in the pattern of priming between the CC and CI items. Although we did not explicitly check for an inhibitory component with a neutral condition, inhibition is more likely to show up with a lexical decision task due to the decision component. Getting the same pattern of results with the naming task further supports our earlier contention that there is a real difference in the nature of these "mediated" pairs. Later we speculate on what we think is the contextual difference between these CC and CI word pairs.

The elegance of McKoon and Ratcliff's (1992) compound-cue theory is that it makes a clear set of predictions concerning both lexical co-occurrence and semantic relatedness with respect to the notion of mediated priming. In compound-cue theory there is no such phenomenon as mediated priming. Familiarity of the prime and target compound is the mechanism by which priming occurs. McKoon and Ratcliff have suggested that semantic relatedness or lexical co-occurrence are plausible measures of familiarity. According to compound-cue theory, the locus of the mediated priming effect has to be with some type of direct (although weak) relationship between the prime and target - not the relationship between the prime and mediator and target. In Experiments 2a and 2b we tested this hypothesis with two types of relationships that McKoon and Ratcliff (1992) suggest might form the locus of the mediated priming effect: semantic relatedness and lexical co-occurrence. When these hypotheses were explicitly tested neither semantic relatedness (Experiment 2a) or lexical co-occurrence (Experiment 2b) were predictors of priming magnitude. Before we turn to a characterization of mediated priming in high-dimensional space, it is important to consider several potential objections to these results.

Without a familiarity with the HAL model of memory, the question could be raised as to the models veracity in modeling semantic priming effects. Investigators, using the HAL model have directed their attention to a broad range of cognitive phenomena; the domain of priming effects is probably the most widely investigated. HAL has been used to model the basic semantic priming effect with categorically related items (Lund, Burgess, & Atchley, 1995) and has been used to show a dissociation between semantic and associative priming (Lund, Burgess, & Audet, 1996). Furthermore, HAL's representations have been successful at modeling the semantic paralexias made by deep dyslexics (Buchanan, Burgess, & Lund, 1996). Another potential objection is that mediated relationships are too abstract to be reflected in HAL's representational framework. However, this would seem unlikely given that HAL has been used to model priming with words that are abstract in nature (Burgess & Lund, 1997). Figure 2 illustrates how the distance metric in HAL could be used to support the modeling of mediated priming in a processing model. The top frame of Figure 2 (illustrating the CC condition that obtained mediated priming) illustrates the distances between possible combinations of word classes used in the experiment. The shortest distances involved the word related to both the mediated prime and its target (shown here as the Related word or mediator - not actually seen by subjects in an experiment). It can be seen that these distances are relatively short (343 and 380 RCUs). The distance representing the relationship between the mediated primes and their respective targets is quite long (655 RCUs). Given that mediated priming occurs with human subjects, it becomes clear why there was a lack of a relationship between the distance metric and priming when evaluating the mediated condition. Distances tend to be quite long in these cases which provides a strong counter-argument to the idea that "weak" semantic relationships that are also direct would provide the locus of the mediated priming effect. As a result, in HAL, any mediated priming effect will involve the shorter distances between the mediator and the prime and target - the definition of true mediated priming. In fact, in a mathematical model of the priming process that used HAL meaning representations, mediated priming was successfully modeled (Burgess & Lund, 1998).

In a processing model, simply using the distances would not be sufficient to account for a mediated priming effect since the distances from the prime to the target through the mediator is slightly longer than the distance from the prime to the unrelated target. Other considerations are crucial for a full model of the priming process decay rates, onset of activation, word activation thresholds. HAL's representations, in conjunction with these other components, provide a plausible component in accounting for mediated priming (Burgess & Lund, 1998).

So how does mediated priming occur? According to the HAL model of meaning representation, words acquire meaning by virtue of the contexts in which they appear, not by local co-occurrence. Concepts that share similar contexts have the potential for mediation. For mediated priming to occur, two apparently unrelated items, need to have some shared contextual history that would provide the arena for mediation in a high-dimensional space. Mediated priming does not rely on close semantic distances, but rather, shared context space. Such an argument is supported by the different pattern of priming results obtained for the CC and CI items. Those items with shared contexts (CC condition)

demonstrated the mediated priming effect; those items with no apparent shared context (CI condition) did not.

These results are somewhat problematic for a simple, localist, spreading activation account of mediated priming - the presence of the mediating concept should underlie the mediated priming effect, regardless of the contextual inconsistency since there is a clear direct relationship between the mediating concept and both the prime and target. Contextual encoding of word relationships is the basic mechanism in the HAL memory model, but not necessarily in a localist model. Localist accounts of mediated priming will need to more clearly predict how mediated priming can occur for some word pairs (CC), but not others (CI).

In the HAL model, a word's contextual history is the basis for meaning. The experiments reported here suggest that this contextual history of meaning is crucial in both determining the viability of stimuli in experiments and in addressing theoretical issues.

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