Mediated Priming in High-dimensional Meaning Space: What is "Mediated" in Mediated Priming?

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Abstract

Four experiments are presented that demonstrate that mediated priming (e.g., *lion stripes*) does not rely on weak, although direct, semantic relationships or lexical co-occurrence as suggested by McKoon and Ratcliff (1992). A view of mediation in priming consistent with a distributed view of memory is presented that relies on shared contexts between the prime and target. Not all mediated items appear to share contexts, and ones that do not also do not show mediated priming. The focus on contextual mediation is consistent with how word meanings are acquired as modeled by the HAL memory model.

Mediated priming (MP) is a reliable effect, but one that is sensitive to a range of experimental conditions (Balota & Lorch, 1986; McKoon & Ratcliff, 1992; McNamara, 1992). Balota and Lorch (1986) were able to show a mediated priming effect in a naming latency task, but had difficulty finding the MP effect in a lexical decision task when directly related prime-target pairs were present in the list.

The MP effect has traditionally been explained within a spreading activation framework of memory. Spreading activation works within a semantic memory network of interconnected nodes, each node representing a concept. These concept nodes are more strongly connected if they are related by prior association or if they share semantic features. To retrieve a concept from memory, a node must be activated; this activation will spread to directly related concepts. Therefore, when presented with the prime-target pair, *lion* followed by *stripes*, priming will occur because *lion* is closely related to *tiger* and *tiger* is closely related to *stripes*. Thus, according to spreading activation, MP occurs because of a multi-step activation from the prime (*lion*) through the mediating concept (*tiger*) to the target (*stripes*).

McKoon and Ratcliff (1992), using the compound cue theory of retrieval, suggest an alternative explanation for the MP effect. They argue that MP is not "mediated," but, instead, any priming is due to weak (although direct) relationships in memory. McKoon and Ratcliff propose that all priming (mediated and direct) is guided by two factors, semantic relatedness and lexical co-occurrence. These two factors should positively correlate with MP; closer semantic relatedness and increasing lexical co-occurrence should predict larger priming effects.

McKoon and Ratcliff's (1992) assertions raise a theoretically important issue. Does true "mediated" priming (multi-step activation) exist? In an effort to address this question, we first replicate the MP effect using the lexical decision task. Following the replication study, we examined possible stimulus differences that may contribute to the subtlety of this effect. Finally, and most critically, we investigated the explanations of MP, as suggested by McKoon and Ratcliff, relying on the Hyperspace Analogue to Language (HAL) model of memory (Burgess & Lund, in press; Lund & Burgess, 1996) to generate semantic relatedness measures and lexical co-occurrence frequencies.

Experiment 1 is a replication of the basic priming effect. Experiment 2 addressed the issue of stimuli differences and introduces the notion of contextual consistency that we will argue underlies the MP effect. The critical manipulations are Experiment 3 and 4 which use the item priming data from Experiment 1 to address the claims of McKoon and Ratcliff concerning the weak, yet direct, relatedness of mediated primes and targets. Experiment 3 directly tested the semantic relatedness issue, and Experiment 4 addressed the issue of lexical co-occurrence frequency.

Experiment 1: Replicating the Mediated Priming Effect

Balota and Lorch (1986) have shown that MP will not occur in a lexical decision task when the lists contain both directly related and mediated pairs, but it does occur in a naming task with both types of prime-target pairs. They account for this difference by hypothesizing that strategic decision processes may occur during a lexical decision task that will effect the outcome of the priming results. 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. The second process will be influenced for a mediated prime-

target pair if there are directly related items present in the list as well. Subjects might fail to detect a relation between a mediated prime-target pair if there are very strong, obvious relations between directly related items. McNamara and Altarriba (1988) directly tested this list problem. With lexical decision, they found MP in a list with only mediated and unrelated trials but not with direct, mediated, and unrelated trials. Therefore, in Experiment 1, we have removed the directly related prime-target pairs to reduce this problem.

A successful replication of McNamara and Altarriba should show faster response times for mediated prime-target pairs in comparison to unrelated prime-target pairs.

Methods

Participants. Thirty-one 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 70 items, 16 mediated trials, 16 unrelated trials, 32 nonword trials and 6 warmup 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*. Sixteen of the 32 nonword trials were generated by using the directly related primes and replacing the target word with a pronounceable nonword (e.g., *pledded, kivied*). The other 16 nonword trials were generated by choosing 16 common nouns as primes and generating 16 nonword targets.

Prime words were counterbalanced. A target word preceded by mediated prime on one list would be preceded by an unrelated item on another list, and on the third list would be changed to a nonword, preceded by a directly related prime.

Procedures. The stimuli were presented on a computer monitor; participants' lexical decisions were made using a button response box. 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 a participant responded (*yes*, a word, or *no*, a nonword) or until 2500 ms had elapsed. Accuracy feedback was provided, as well as time-out information.

Results and Discussion

A one-way analysis of variance (ANOVA) was performed for both subject and item means. In the subject analysis, lexical decisions were made more quickly for the mediated prime-target pairs (538 ms) than for the unrelated prime-target pairs (560 ms), F (1, 28) = 11.36, $p < .0022$. However, no reliable priming was found in the item analysis, although the magnitude of the MP effect was similar to the subject analysis (mediated items, 545 ms; unrelated items, 569 ms; F (1, 92) = 2.42, $p < .123$. The difficulty in obtaining the item priming led to an investigation of the relationship between the prime and the target with the mediated priming items.

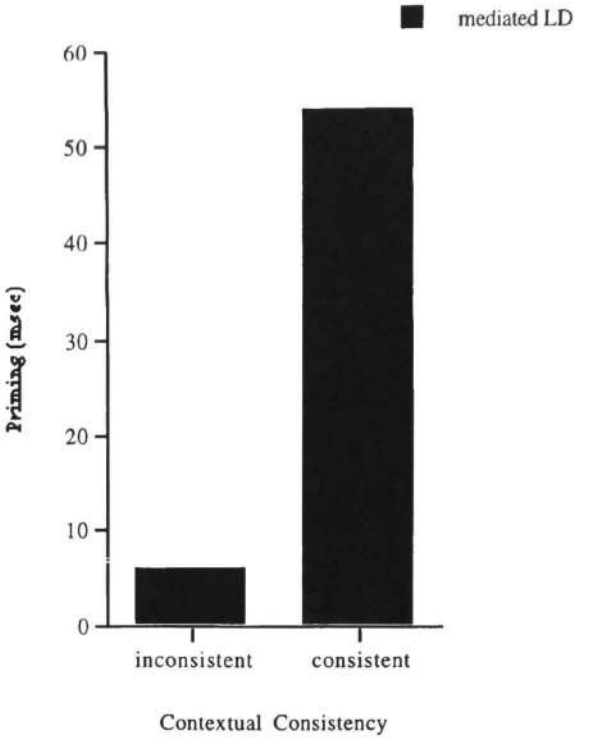

Figure 1. Priming (unrelated RT related RT) as a function of contextual consistency.

Experiment 2: The Nature of the Prime-Target Pair

While examining the stimuli for Experiments 1, the authors noticed that not all mediated prime-target pairs were qualitatively the same. For example, the pair *lion-stripes* seemed different from *summer-snow*. One way in which these two pairs (and others) differ is their contextual consistency. We argue that, for example, *lion-stripes*, while not directly related are contextually consistent, that is, *lion* and *stripes* have in common a context in which they are likely both discussed (i.e., *tigers*). Conversely,

summer-snow appears to be contextually inconsistent, that is, *summer* and *snow* are less likely to be discussed in the same context. If this hypothetical distinction has some cognitive reality, perhaps the MP effect is being carried by only a subset of prime-target pairs. This is an important distinction at a theoretical level because contextual consistency involves representational mediation in our model (discussed more below). It is also important methodologically if there is some systematic representational reason behind the difficulty in obtaining MP effects. Experiment 2 addressed this concern by categorizing the mediated prime-target pairs into contextually-consistent and contextually-inconsistent stimuli groups and reanalyzing the priming effects for the lexical decision experiment.

Methods

The authors categorized mediated prime-target pairs as either contextually consistent or contextually inconsistent using linguistic intuition. The authors separately categorized each mediated prime-target pair and then compared their decisions. There were only two items that were not initially agreed upon; the raters then discussed those two items and came to an agreement on their categorization. This procedure resulted in 25 consistent pairs and 23 inconsistent pairs.

Results

New analyses were conducted using item means separating the mediated pairs by the contextually-consistent /inconsistent distinction and were performed for both the lexical decision and naming results. Figure 1 illustrates the differences in the magnitude of priming (direct and mediated), separated by task (lexical decision or naming) and by contextual consistency. For the contextually-consistent pairs in a lexical decision task, there was a MP effect (54 ms); mediated pairs (539 ms) were responded to faster than unrelated pairs (593 ms), F (1, 47) = 6.13, $p <$ .017. However, no priming was found for the contextually-inconsistent pairs, $F < 1.0$.

Discussion

Mediated priming is a fragile effect. Reliably obtaining MP seems to be highly dependent on the task and list construction. This difficulty may be due, in part, to the differences in the nature of these "mediated" pairs. Approximately half of the mediated items do not show a relatedness effect. The methodological conclusion is obvious any MP effect an investigator would hope to obtain is roughly halved by a subset of these items. Ratcliff and McKoon (1994) claim that "...free association is not a veridical measure of distance in memory, and so priming effects should be explained using other measures such as co-occurrence statistics or other relatedness judgment..." (p. 178). According to their view, the so-called MP effect is actually due to weak semantic relatedness or to lexical associations. We test these hypotheses in Experiments 3 and 4.

Experiment 3: Weak Semantic Relatedness Hypothesis

Ratcliff and McKoon (1994) suggest one dimension of memory that could underlie MP is semantic relatedness. Semantic relatedness gives rise to a measure of familiarity; priming occurs for compounds that have a high degree of familiarity in long-term memory. One method of measuring semantic relatedness is to use a distance metric in memory; items that are closer together in memory will be more semantically related than those far apart. McKoon and Ratcliff claim that "mediated" pairs are weakly, although directly, related; therefore, mediated prime-target pairs should be closer in memory than unrelated pairs.

HAL is a model of semantic similarity; items that are similar in meaning will be close together in meaning space because similar items occur in similar contexts (Burgess & Lund, 1997; Lund & Burgess, 1996). Directly related prime-target pairs should be close together in this meaning space because they share a high degree of semantic similarity (a naturally emergent property of the contexts in which words are used). Like the localist account, in our model, MP occurs because mediating primes share contexts with related primes, which share context with target items. HAL should provide a reasonable test of the hypothesis that distributed representations, such as HAL's, can provide an account of MP that does not hinge on the mediated prime and its target being close in memory space. If McKoon and Ratcliff's claims are correct, we should see context distances for mediated prime-target pairs that are closer together than unrelated prime-target pairs.

Methods

Semantic distances (RCU's: Riverside Context Units; see Lund and Burgess, 1996) were computed for all word pairs used in Experiments 1 (mediated - target, unrelated - target) using the HAL memory model. Distances were also calculated for a condition not present in the experiments - the mediated related items (e.g., *lion-tiger*). The pairs were also separated by contextual consistency as in Experiment 2.

Results

Figure 2 contains the mean semantic distances for all word pairings separated by contextual consistency (including the

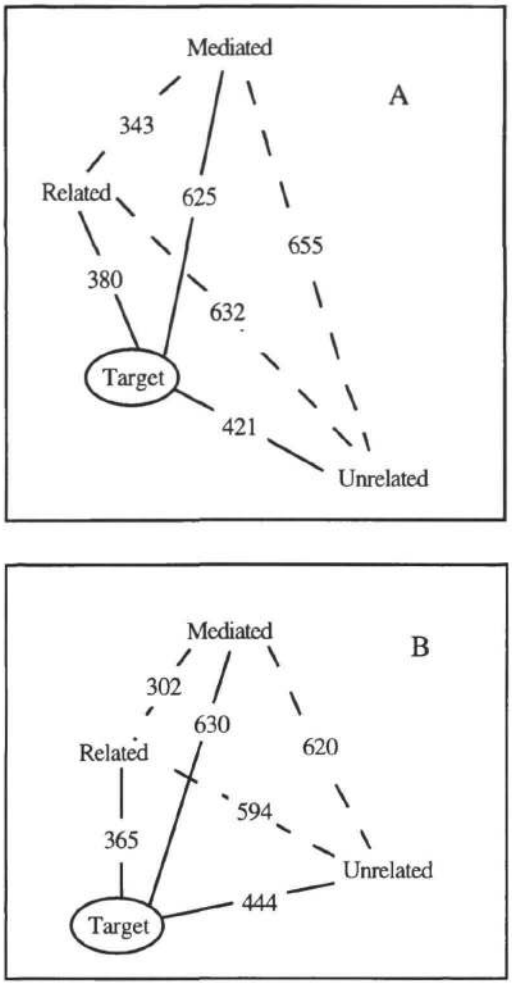

Figure 2: Two-dimensional Multidimensional scaling solution for semantic distances between word pairs for consistent (A) and inconsistent (B) categories.

word pairings not seen by participants - denoted by dashed connection lines). As expected, the directly related prime-target pairs in both the consistent and inconsistent conditions are closer in high-dimensional meaning space than are their respective unrelated prime-target pairs. However, contrary to the predictions of McKoon and Ratcliff, mediated prime-target pairs in both the contextually-consistent and inconsistent conditions are further apart in the high-dimensional space than are the unrelated prime-target pairs.

It should be also noted that in both the context-consistent and the context-inconsistent conditions, the mediated-to-related and the related-to-target items are closer to each other than are the unrelated-to-target items. This result is important since it implies the presence of meaningful relationships that underlie the MP effect in either a distributed or localist account.

Discussion

Ratcliff and McKoon's hypothesis that weak semantic relatedness underlies the MP effect was not supported by these results at least not as HAL represents semantic relatedness. A variety of semantic priming results have been simulated by using the HAL model. A series of studies have shown that HAL replicates the basic semantic priming effect (Lund & Burgess, 1996; Lund, Burgess, & Atchley, 1995; Lund, Burgess, & Audet, 1996). These results are more consistent with the idea that MP occurs because of shared contexts rather than a weak semantic relationship.

One potential problem with this conclusion, however, is Ratcliff and McKoon's other hypothesis regarding lexical co-occurrence. Priming depends on the familiarity of the compound to long-term memory, according to Ratcliff and McKoon (1992). If familiarity with a compound depends on how often a memory system has encountered two particular items, lexical co-occurrence may be a direct measure of familiarity. The semantic distance results using HAL did not support the weak semantic relatedness hypothesis. However, if lexical co-occurrence (first-order association) is the mechanism underlying the MP effect, semantic distance would not be sensitive to MP. Lund et al. (1995) found that semantic distance as computed by the HAL model does not reflect a word priming effect if the nature of the word relationships is strictly associative, that is, the prime-target pairs were not instances of the same category. Furthermore, Lund et al. (1996) found a complete dissociation between semantic relationships (as computed by HAL) and associative relationships (as indexed by simple lexical co-occurrence).

These earlier results provide further credibility to Ratcliff and McKoon's hypothesis about the possible relationship lexical co-occurrence and mediated priming. It is this hypothesis that is tested in Experiment 4.

Experiment 4: Lexical Co-occurrence Hypothesis

Priming, according to McKoon and Ratcliff (1992; Ratcliff & McKoon, 1994), depends on the familiarity of the compound to long-term memory. Familiarity with a compound is based on how often a memory system has encountered those two particular items together. Therefore, lexical co-occurrence should be a direct measure of familiarity. If lexical co-occurrence is, as McKoon and Ratcliff suggest, a direct measure of familiarity, then there should be a positive relationship between lexical co-occurrence frequency and priming magnitude.

Methods

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 ~300 million word text corpus used as the input for HAL and correlated with priming magnitude.

Results and Discussion

Correlations were calculated between the priming effect obtained for each mediated prime-target pair in Experiment 1 and the lexical co-occurrence frequency of that word pair. The results did not support the lexical co-occurrence hypothesis suggested by McKoon and Ratcliff. There was no correlation between MP and co-occurrence frequency for (r = .013, p > .91). The nature of this correlation does not change when the correlations are computed separately for the context-consistent and the context-inconsistent items. The contextually consistent pairs did not correlate with co-occurrence frequency (r = .013, p > .94), nor was there a correlation between the contextually-inconsistent pairs and co-occurrence frequency (r = -.27, p > .21).

Although lexical co-occurrence is a plausible constraint in memory organization, we found that it does not appear to be the driving force behind the MP effect as suggested by McKoon and Ratcliff.

General Discussion

We replicated the basic MP effect and uncovered a possible peculiarity with the stimuli used in these experiments that might explain the fragility of this effect. The categorization of the mediated pairs into context-consistent and context-inconsistent stimuli is important for both methodological and theoretical reasons. We demonstrated that context-inconsistent pairs do not show mediated priming. Functionally, this attenuates the priming effect by about half. The magnitude of the MP effect when calculated using both the contextually-consistent and inconsistent items was 24 ms. For the contextually-consistent items only, the MP effects was 54 ms. Theoretically, these items do not prime, our argument goes, because the primes and targets do not share mediating contexts (as do the context-consistent items).

Mediated priming from a localist perspective is straightforward; however, we believe a cautionary note is in order. From a localist perspective, the context inconsistent items are as plausible for mediation as are the context-consistent items. However, only the context-consistent set shows the MP effect. This theoretical dilemma is useful to those who would argue that distributed representations are a more parsimonious account of meaning in memory. The context-consistency view supports the plausibility of a distributed view of mediated effects which has not been articulated until now.

The HAL model provides a clear account of this distinction. Words acquire meaning as a function of the contexts they appear in, not local co-occurrences (Lund et al., 1995, 1996). Representations that evolve from similar contexts have the potential for mediation. In a memory model like HAL, *lion* will prime *stripes* because *lion* has shared contexts with *tiger* and *tiger* has shared contexts with *stripes*. We conclude that MP occurs as a function of the contexts shared (or mediated) by the prime, the mediator, and the target. This context view (see Burgess & Lund, 1997) further stipulates that the local associations are of minimal importance. Thus, from this point of view, it was not surprising that MP and co-occurrence did not correlate. Nor is it surprising that local co-occurrence did not predict direct priming (see Lund et al., 1996). McKoon and Ratcliff contend that true MP does not exist and suggest that direct, but weak, semantic relatedness and/or lexical co-occurrence can explain the effect. In Experiments 3 and 4, we explicitly test these ideas using the HAL memory model and failed to support that direct, albeit weak, semantic relatedness and lexical co-occurrence can explain the effect. When examining semantic relatedness, it was found that primes and targets in the directly related conditions were closer than the prime-target pairs in the unrelated conditions, which is required to motivate the MP effect. However, contrary to McKoon and Ratcliff's prediction, mediated-target pairs are actually further apart in the high-dimensional semantic space than the unrelated-target pairs. Thus, MP cannot be explained by directly, although weakly related, prime-target pairs.

What is mediated in MP? To the extent that the HAL model of representing meaning can be exploited here, meaning arises as a function of the contexts in which words appear. For mediated priming to occur, the two otherwise unrelated words have to have some history of shared context. A distributed model like HAL offers an explicit account of this process and representational structure.

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