Journal of Experimental Psychology:
Learning, Memory, and Cognition
2010, Vol. 36, No. 1, 135–146

0278-7393/10/$12.00 DOI: 10.1037/a0017517

Pure Mediated Priming: A Retrospective Semantic Matching Model

Lara L. Jones
Wayne State University

Mediated priming refers to the activation of a target (e.g., *stripes*) by a prime (e.g., *lion*) that is related indirectly via a connecting mediator (e.g., tiger). In previous mediated priming studies (e.g., McNamara & Altarriba, 1988), the mediator was associatively related to the prime. In contrast, pure mediated priming (e.g., *spoon* → *can*) lacks a strong association between prime and mediator (e.g., *spoon* → soup) and between mediator and target (e.g., soup → *can*). This study establishes the existence of pure mediated priming and assesses which semantic priming model (spreading activation, compound-cue, or semantic matching) accounts for the results. Pure mediated priming occurred in 3 experiments across double and standard lexical decision tasks. However, such priming did not occur in a continuous lexical decision task, which precludes strategic processing. Overall, results indicate that a modified retrospective semantic matching model provides the best theoretical explanation of pure mediated priming.

Keywords: mediated priming, semantic priming, associative priming, semantic matching, spreading activation

Mediated priming refers to the activation of a target (e.g., *cheese*) by a prime (e.g., *cat*) that is related indirectly via a connecting *mediator* (e.g., mouse). Prior mediated priming studies have argued that mediated priming could be explained either by spreading activation from prime to mediator then from mediator to target (e.g., *cat* → mouse → *cheese*; Balota & Lorch, 1986; de Groot, 1983; McNamara & Altarriba, 1988) or by the formation of a weakly related compound between prime and target (McKoon & Ratcliff, 1992; Ratcliff & McKoon, 1988). No previous study has found reliable mediated priming in the absence of a strong prime–mediator association. Thus, an association-based spreading activation model would appear to be the most suitable explanation of mediated priming. However, because previous studies did not control for prime–target co-occurrence, the compound-cue model remains a tenable model of mediated priming. Additionally, both proponents of the spreading activation and the compound-cue mediated priming models agree that beyond association and co-occurrence, semantic relatedness needs to be considered (McNamara, 1994; Ratcliff & McKoon, 1994). In order to isolate the effects of semantic relatedness in mediated priming, the stimuli in the current study were controlled for both association and co-occurrence. Hence, the current study investigated *pure mediated priming* ("pure" cf. McNamara, 2005, p. 83), defined as the activation of a target by a prime via an intervening concept (e.g., *morning* → coffee → *bean*), with not more than a weak association between prime and mediator or between mediator and target.

Portions of this research were presented at the 49th annual meeting of the Psychonomic Society in Chicago, IL.

I thank Jim Neely and Ken Forster for their valuable comments and suggestions on this article and Michael N. Jones for generously providing the BEAGLE model cosines. I am also grateful to Zachary Estes, Richard Marsh, and Adam Goodie for their insightful suggestions on various earlier drafts of this article.

Correspondence concerning this article should be addressed to Lara L. Jones, Department of Psychology, Wayne State University, 5057 Woodward Avenue, 7th Floor, Detroit, MI 48202. E-mail: larajones@wayne.edu

The semantic matching model (Neely, 1977; Neely & Keefe, 1989; Neely, Keefe, & Ross, 1989; see de Groot, 1985, for similar model) does not require an association between prime and target. This model proposes that a search for a meaningful relation between prime and target facilitates target recognition. Across four experiments, the semantic matching model along with the spreading activation and compound-cue models were evaluated as potential explanations of pure mediated priming.

A Brief Review of Mediated Priming Studies

Prior mediated priming studies (e.g., Balota & Lorch, 1986; Bennet & McEvoy, 1999; de Groot, 1983; McKoon & Ratcliff, 1992; McNamara, 1992a, 1992b, 1994; McNamara & Altarriba, 1988; Ratcliff & McKoon, 1994; Shelton & Martin, 1992) either have supported a spreading activation account of mediated priming or have claimed that "mediated priming" does not exist but rather is simply due to a compound-cue formation between prime and target. However, two recent studies (Chwilla, Kolk, & Mulder, 2000; Sass, Krach, Sachs, & Kircher, 2009) provided initial evidence that a semantic matching model may serve as a tenable model for pure mediated priming.

Mediated priming has been found for items sharing associative relations between the prime and mediator link in a continuous (a.k.a. single or sequential) presentation lexical decision task (LDT), in which participants respond to every letter string and thus are not aware of the prime–target pairings (Bennet & McEvoy, 1999; McNamara & Altarriba, 1988; Shelton & Martin, 1992). Hence, these studies supported a spreading activation account of mediated priming. Using a double LDT, in which participants indicate whether the simultaneously displayed prime and target are real words, McNamara and Altarriba (1988) found that mediated pairs (e.g., *thumb foot*) were processed reliably faster than the unrelated control items. However, reliable mediated priming occurred when the only related pairs in the test list were mediated pairs but not when both directly associated and mediated items were included. Chwilla and Kolk (2002, Experiment 1) replicated this list effect result using different stimuli (see also Sass et al., 2009). This mediated only- versus mixed-list effect suggests that mediated priming may utilize strategic processes if available (e.g., using the stronger associative relation to guide the lexical decisions). Thus, this list effect indirectly supports retrospective strategic models (e.g., semantic matching) as an explanation of pure mediated priming over spreading activation models, which posit automatic processing.

According to McKoon and Ratcliff (1992), the debate over the existence of mediated priming rested largely on whether co-occurrence or association served as the best measure of conceptual distance. They argued that the closest approximation to prime–target familiarity measures the frequency of co-occurrence in large samples of written language. Evidence for the influence of co-occurrence in mediated priming is equivocal. Using the hyperspace analogue to language (HAL) model of memory (Burgess & Lund, 2000), Livesay and Burgess (1998) assessed the co-occurrence of the mediated and control items used by Balota and Lorch (1986) and found that the magnitude of mediated priming was not related to lexical co-occurrence ($r = .013$). Chwilla and Kolk (2002) used latent semantic analysis (LSA) to assess co-occurrence. However, their mediated items were much higher in co-occurrence than their unrelated control items for both Experiment 1 (.186 vs. .082) and Experiment 2 (.115 vs. .072). Thus, their findings did not rule out the compound-cue model as a plausible explanation of mediated priming.

Recent neuroscience studies on mediated priming seem to support a semantic matching or other postlexical integration process in mediated priming. Event-related potential priming studies have demonstrated that the N400 effect primarily reflects postlexical integration processes (for discussion see Chwilla, Hagoort, & Brown, 1998, and Chwilla et al., 2000). In these event-related potential studies, the N400 priming effect is represented by smaller amplitudes approximately 400 ms after stimulus onset when a word immediately follows a related word than when it follows an unrelated one (Chwilla et al., 1998). Using a standard LDT, wherein participants respond to only the target following prime presentation, Chwilla et al. (2000) found an N400 effect for mediated targets (e.g., *lion* → tiger → *stripes*) and concluded this effect was due to postlexical integration. In an fMRI study (Sass et al., 2009), activation was found in the right insula and right supramarginal gyrus for mediated pairs (*anvil* → *nail*), which reflected greater working memory capacity and attentional demands indicative of a postaccess search strategy.

Potential Models of Pure Mediated Priming

Spreading Activation Models

In the Collins and Loftus (1975) model, the target is in a preactivated state after activation spreads from the prime, but in ACT* (adaptive control of thought; Anderson, 1983) both prime and target must be sources of attention for heightened target activation to occur (McNamara, 2005). The simultaneous activation of both prime and target is aided by *reverberation*, in which activation can spread back and forth between target and source nodes until an asymptotic level of activation is reached. The ACT* model predicts that asymptotic target activation "is determined by associations in the forward and backward directions" (McNamara, 1992b, p. 1177), although overall priming will be weaker if the forward association is weak (McNamara, 2005). Nonetheless, both backward and forward association must be considered when evaluating spreading activation as an explanation for pure mediated priming.

Neither model attributed the spread of activation to associative strength. However, association strength is especially important for concept activation in nonstrategic tasks such as the continuous LDT, because there is a minimal threshold required for activation, and "strong associations will be activated to threshold faster than weak associations" (Lorch, 1982, p. 469).

Compound-Cue Model

The compound-cue model (Ratcliff & McKoon, 1988) assumes that a prime (e.g., *coffee*) and target (e.g., *bean*) are combined within a short-term buffer to form a compound cue (e.g., *coffee bean*). Familiarity is based on the extent to which the prime and target are "directly connected to each other in memory or are directly connected to one or more common images" (Ratcliff & McKoon, 1988, p. 386), and higher familiarity leads to faster target response times (RTs).

According to the compound-cue model, "the presence or absence of mediating concepts is irrelevant" (McKoon & Ratcliff, 1992, p. 1170). Rather, priming should occur only when two concepts are either directly connected to each other or are separated by no more than one associate (Ratcliff & McKoon, 1988). The existence of three-step priming (e.g., *mane* → lion → tiger → *stripes*) found by McNamara (1992b) and Chwilla and Kolk (2002, Experiment 2) challenged the claim that priming would not occur when concepts were separated by more than one associate. Regarding the "direct connection" condition for priming, McKoon and Ratcliff (1992) suggested that nonassociated primes and targets of mediated pairs may be weakly but directly connected in accordance with their frequency of co-occurrence in natural language. If the familiarities of the mediated and nonmediated pairs are equivalent, then the amount of target facilitation should also be equivalent. Familiarity encompasses not only association but also co-occurrence. Therefore, reliable universal measures of these two factors are necessary to equate familiarity between the mediated and nonmediated (i.e., control) prime–target pairs.

Semantic Matching Model

Semantic matching (a.k.a. postlexical integration; de Groot, 1984, 1985) proposes a search for a meaningful relation between prime and target (Neely, 1977, 1991; Neely & Keefe, 1989; Neely et al., 1989). Upon target presentation in an LDT, participants are biased to respond that the stimulus is a word if prime and target are related and to respond that it is a nonword if prime and target are not related.

Reliable pure direct priming effects indicative of semantic matching have been demonstrated at short stimulus onset asynchronies (SOAs) of 300 ms or less (Bueno & Frenck-Mestre, 2008; Estes & Jones, 2009; Hutchison, Neely, & Johnson, 2001; Neely, 1977; Perea & Gotor, 1997; Perea & Rosa, 2002; Smith, Briand, Klein, & den Heyer, 1987), with these effects typically still reliable at longer SOAs of 1,000 to 1,500 ms (e.g., Estes & Jones, 2009;

McRae & Boisvert, 1998; Smith et al., 1987). Similarity between prime and target is one factor determining whether semantic priming occurs at short SOAs. McRae and Boisvert (1998) found priming for highly similar category comembers (*goose* → *turkey*) at both short (250 ms) and long (750 ms) SOAs, whereas priming for less similar items (*robin* → *turkey*) occurred only at the long SOAs.

Semantic matching models have typically described a search for a plausible relation between a prime (e.g., *lion*) and target (e.g., *stripes*). However, if the search for a "relation" could be expanded to also include a search for a plausible mediator (e.g., tiger), then semantic matching could conceivably account for pure mediated priming.

Automatic Versus Strategic Processing

One distinguishing factor of the above models is the extent to which strategic versus automatic processing occurs. Automatic processing takes place without conscious attention, whereas strategic processing is characterized by conscious attention and is often (but not always) slower acting. Prospective models (e.g., spreading activation), in which the target is activated prior to its presentation, predict priming in either automatic or strategic tasks. Retrospective models (e.g., semantic matching), in which the target is activated after its presentation, typically predict that priming can occur only in more strategic tasks in which the prime–target pairing is explicit. Semantic priming is thought to entail both automatic and strategic processing (McNamara, 2005; Neely et al., 1989). The experimental task is one factor influencing the extent of strategic processing. Standard and double LDTs, which make the prime–target pairing explicit, permit the strategic process of semantic matching. In contrast, continuous LDTs do not allow for the strategic process of checking for a relation or concept that connects prime and target. Thus, priming that occurs in a continuous LDT indicates automatic processes, whereas priming that occurs only in standard and continuous LDTs indicates strategic processing.

The type of semantic relation between prime and target (or in the case of mediated priming, between prime and mediator and between mediator and target) is another important factor influencing strategic processing (McNamara, 2005). Most associatively related pairs are also semantically related, and hence, priming can occur for these items in tasks that require either automatic or strategic processing. In contrast, semantic pairs lacking more than a weak association typically do not exhibit priming in a continuous LDT (Moss, Ostrin, Tyler, & Marslen-Wilson, 1995; Shelton & Martin, 1992).

Overview of Experiments

This study investigates the occurrence of pure mediated priming using instrumental relations between prime and mediator (e.g., *spoon* → soup) and integrative relations between mediator and target (soup → *can*). *Pure* refers to any meaningful connection between two concepts having no association or only a weak association (≤.10; cf. Hutchison, 2003), and *associated* refers only to concepts sharing a strong association (>.20). Categorical relations would be difficult to use in a mediated priming task, because a categorically related prime and mediator (e.g., *sofa* and chair) would possibly yield a semantically related prime and target (e.g., *sofa* and *desk*). To minimize the possibility of a direct relation between prime and target, instrumental relations were used between the prime and mediator (e.g., *soap* and shower; Moss et al., 1995), and integrative relations were used between mediator and target (e.g., shower and *curtain*; Estes & Jones, 2009). Instrumental relations are those for which "the intended function of the prime is to perform some action on the target" (Moss et al., 1995, p. 867; e.g., *broom* → *floor*, "sweeping"). Instrumental relations have shown robust priming effects (>30 ms) in previous studies even in the absence of strong associations between prime and target (Hare, Jones, Thomson, Kelly, & McRae, 2009; Moss et al., 1995). Integrative relations refer to those that enable the linking of prime and target into a sensible combination (Coolen, van Jaarsveld, & Schreuder, 1991; Estes & Jones, 2009; e.g., *company* → *car*, a car that is "owned by" a company). The integrated combination (e.g., *cage mouse*) represents a particular subclass of the head noun (e.g., *mouse*) that is defined by a relation (e.g., "inhabits"; L. L. Jones, Estes, & Marsh, 2008) and that can be contrasted from other entities (e.g., *field mouse*) sharing that relation. Integrative relations differ from the more frequently used categorical comembers or synonyms in that the two concepts are lacking in featural similarity. But integrative and categorical relations are similar in that they share the same general time course of activation, one that is distinct from associative relations (Estes & Jones, 2009).

Experiment 1 used the highly strategic double LDT, whereas Experiment 2 used the continuous LDT to prevent strategic processing. Experiments 3 and 4 used a standard LDT to investigate the time course of pure mediated priming. Evidence of pure mediated priming (e.g., *spoon* → soup → *can*) would have several implications for the semantic priming models discussed. Because prime–target familiarity is equated between the experimental and unrelated control items, the mere existence of pure mediated priming would challenge the compound-cue model. Evidence of pure mediated priming in the strategic double and standard LDTs (Experiments 1, 3, and 4) but not the automatic continuous LDT (Experiment 2) would support the semantic matching model and would challenge the spreading activation model as an explanation of pure mediated priming.

Experiment 1

The double LDT is the most strategic LDT given that relation checking is facilitated by the continued availability of the prime upon the subsequent target presentation. Hence, a double LDT was used in Experiment 1 as a first test of pure mediated priming. Using the online University of South Florida association norms (Nelson, McEvoy, & Schreiber, 1998), mediated (e.g., *grill* → *thigh*) and control prime–target pairs (e.g., *spoon* → *thigh*) were equated for association (i.e., with all association values = 0). Mediated and control items were also equated on co-occurrence using both latent semantic analysis (LSA; Landauer, Foltz, & Laham, 1998) and Google. Google hits provide a more direct measure of word pair frequency in everyday English and are highly correlated with familiarity ratings (Murphy & Wisniewski, 2006; Wisniewski & Murphy, 2005). Finally, whereas LSA does not take word order into account (i.e., *spatula blueberry* has the same LSA value of .21 as does *blueberry spatula*), Google hits depend on the word order when the word pair is presented within quotations (e.g., *"spatula blueberry"* = 1,220 hits and *"blueberry spatula"* = 39 hits).

With equated measures of familiarity, the compound-cue model predicted no difference in RTs. To reduce the possibility of spreading activation, forward and backward associations between prime and mediator and between mediator and target were weak (all ≤.10). Association strengths for the prime–mediator and mediator–target links are shown in Table 1.

Method

Participants. For each of the following experiments, all participants were undergraduates at the University of Georgia (except where otherwise stated), all participated for partial course credit in an introductory psychology course, and all were native speakers of English. Thirty-seven undergraduates participated in Experiment 1. Sixty-eight additional undergraduates participated in the two norming tasks described below.

Materials. The complete set of items used in Experiments 1–4 is shown in the Appendix. Thirty initial prime–mediator pairs sharing a nonassociative instrumental relation were sampled from Moss et al. (1995) or created using the same criterion (i.e., the prime could be used to [fill in verb] the mediator; e.g., a *grill* could be used to cook a chicken). Targets (e.g., *thigh*) could be easily combined with the mediator (e.g., chicken) to produce an integrative relation (e.g., "part-of"). To ensure that the integrative relations were indeed integrative, participants ($n = 32$) rated the extent to which two concepts could be "linked together to produce a sensible phrase" on a scale from 1 (*not linked*) to 7 (*tightly linked*; cf. Solomon & Pearlmutter, 2004). Participants provided these ratings for the integrative mediator–target pairs (e.g., chicken *thigh*) of each item and, for comparison, also the instrumental prime–mediator pairs (e.g., *grill* chicken). Presentation order was randomized across participants. Integrative ratings were reliably higher for the integrative mediator–target link ($M = 5.39$, $SE = 0.17$) than for the instrumental prime–mediator link ($M = 4.72$, $SE = 0.20$; $p < .001$). Hence, the integrative relation used was both qualitatively and quantitatively different from the instrumental relation.

A norming procedure adapted from de Groot (1983) was used to test the likelihood of activation for the author-generated mediators. Prime and target words were separated by a blank line (e.g., *grill* _____ *thigh*), and participants ($n = 36$) typed a word that "connected the first word to the last word." For each prime–target pair, the modal response served as the mediator in the final item set ($M = .41$; range = .17 to .83). One of these pairs (e.g., *plow fort*) lacked a modal response and was deleted prior to all analyses, making a final set of 29 experimental items, though all 30 mediated items were included in the experiments. Note that this mediator frequency proportion (.41) is much lower than de Groot's proportion (.90; first item set). This difference is likely due to the strong forward association in de Groot's stimuli between prime and mediator (.47) and between mediator and target (.24).

The mediated triads (e.g., *spoon* → soup → *can*) were divided into two lists of 15 items each, and control items were created for each subset by re-pairing the primes (e.g., *spoon*) with different targets (e.g., *thigh*) within that list such that the co-occurrence (i.e., LSA value) of the unrelated prime–target pair matched that of the mediated prime–target pair as closely as possible. A paired-samples *t* test confirmed that LSA scores were equivalent between the mediated ($M = .139$, $SD = .126$) and control ($M = .138$, $SD = .106$) pairs ($p = .91$). Google hits were also assessed as a second and more direct co-occurrence measure. One control item, *ticket can*, had more than 3.5 times as many hits as the item with the second most hits, *plate color*. With the exclusion of this outlier and its corresponding mediated item, *soup can*, a paired-samples *t* test confirmed that Google hits were equivalent between the mediated ($M = 8{,}177$ hits, $SD = 2{,}628$) and unrelated ($M = 7{,}364$ hits, $SD = 3{,}747$) prime–target pairs ($p = .92$).

Thirty filler items were also included, consisting of 15 nonword–word (e.g., *feap thumb*) and 15 word–nonword (e.g., *dinner ellion*) prime–target pairs.

Procedure. The procedure was modeled closely after the double LDT used by McNamara and Altarriba (1988, Experiment 1). The prime (e.g., *grill*) was presented by itself for 100 ms in 22-point red font on a black background and was horizontally centered just above the vertical midpoint of the screen. Next the target word (e.g., *thigh*) was presented in the same font just below the prime (i.e., vertically and horizontally centered). Both prime and target remained on the screen while participants indicated whether both words were real words in the English language by pressing the *J* key for "yes" or the *F* key for "no." A 1,000-ms intertrial interval separated each trial, and 10 practice trials preceded the 60 experimental trials. In all four experiments, presentation order for the experimental trials was randomized across participants.

Results and Discussion

Paired-samples *t* tests were used in analyzing both RTs and accuracies. In this and all subsequent experiments, RTs from incorrect trials were excluded from all analyses, as well as RTs greater than 1,500 ms and any remaining RTs more than 2.5 *SD*s above or below each participant's condition mean. Across exper-

Table 1
Association Strengths for Experimental Stimuli

		Forward			Backward		
Link	Example	*M*	*SD*	Max	*M*	*SD*	Max
prime → mediator	*ticket* → show	.037	.051	.218	.020	.069	.365
mediator → target	show → *dog*	.020	.031	.138	.099	.172	.552

Note. Forward and backward association values are free association probabilities from Nelson, McEvoy, and Schreiber (1998). All of the minimum association strengths were .000; therefore, maximums are reported instead of ranges.

iments, this resulted in the removal of no more than 8% of the data. In each experiment, results were analyzed separately by participants (t_p, F_p) and by items (t_i, F_i). Finally, in each experiment, one item (*plow fort*) was removed prior to analyses, leaving 29 items in the set.

Results provided support for the existence of pure mediated priming. The mediated pairs (e.g., *soap curtain*; $M = 880$ ms, $SE = 25$) were recognized 43 ms faster, $\eta_p^2 = .16$, 95% CI [10 to 77], than the unrelated pairs (e.g., *mule curtain*; $M = 923$ ms, $SE = 27$), $t_p(36) = 2.66$, $p < .05$, and $t_i(28) = 2.53$, $p < .05$. Accuracies were at ceiling (both *M*s = .99) and did not differ between conditions (*p*s > .75), thereby indicating that there was no speed–accuracy tradeoff. Thus, these results represent the first evidence of mediated priming that cannot be attributed to a direct weak link between the prime and the target. That is, because the familiarity (i.e., co-occurrence and association) of the prime–target compound cue was equated between the control and mediated items, results challenged the compound-cue model.

The proposed adaptation of the semantic matching model (Neely et al., 1989) requires a check for an interconnecting node (i.e., mediator) that is related to both prime and target. Hence, evidence of mediator activation is required to support a semantic matching model of mediated priming. Because both the prime and target are crucial to the activation of the mediator, offline mediator activation should be greater when both the prime and target are provided in comparison to when only the prime is provided. In support of this claim, the mean production frequency for these mediators was 10 times higher when both the prime and target were provided (i.e., during the norming task; $M = .41$) than when only the prime was presented (as indicated by the Nelson et al., 1998, free association norms; $M = .04$). Thus, both the prime and target were involved in activation of a plausible mediator.

Note that in the double LDT used in Experiment 1, the prime was still perceptually available. Experiment 2 used a continuous LDT, in which the participants responded to individually presented primes and targets. In a continuous LDT, participants are unaware of any prime–target pairings and consequently are unable to check for a mediating concept between prime and target (McNamara & Altarriba, 1988; Moss et al., 1995). That is, a continuous LDT is a prospective task that relies solely on more automatic processes. Therefore, association strength is critical for concept activation in this task. Recall that mediated priming effects have been found using a continuous LDT for stimuli sharing a strong association between prime and mediator and between mediator and target (e.g., *dog* → cat → *mouse*; McNamara & Altarriba, 1988), due to the prospective spread of activation. However, retrospective models of mediated priming predict an absence of pure mediated priming in a continuous LDT.

Experiment 2

If pure mediated priming is caused by spreading activation from prime to target via the mediator (e.g., *soap* → shower → *curtain*), then priming should occur in a continuous LDT.

Method

Participants. Eighty-six undergraduates participated for partial course credit. Thirty-five were enrolled at the University of Georgia and 51 were enrolled at Francis Marion University.

Materials. The 30 experimental items were identical to those used in Experiment 1. Ninety filler items were also included, consisting of 30 nonword–word (e.g., *feap thumb*), 30 word–nonword (e.g., *dinner ellion*), and 30 nonword–nonword (e.g., *snape woap*) prime–target pairs.

Procedure. Prime and target letter strings were centered on a black background in red font until participants provided a response. A 1,000-ms interstimulus interval separated each letter string. Participants completed 10 practice trials prior to the 120 experimental trials.

Results and Discussion

Paired-samples *t* tests were used in analyzing both RTs and accuracies. In contrast to prior continuous LDT results with associative mediated stimuli (e.g., McNamara & Altarriba, 1988; Shelton & Martin, 1992), mediated priming did not obtain for these pure items. Accuracies were at ceiling (*M*s > .98) and did not differ between conditions (both *p*s > .40), thereby indicating that there was no speed–accuracy tradeoff. Recognition of the targets in the mediated pairs (e.g., *soap curtain*; $M = 600$ ms, $SE = 10$) was slower than in the unrelated pairs (e.g., *mule curtain*; $M = 594$ ms, $SE = 9$), though this −6 ms priming effect, 95% CI [−17, 6], was not significant, $t_p(85) = 1.02$, $p = .31$, and $t_i(28) = 0.85$, $p = .40$. The failure to obtain a priming effect in a continuous LDT suggests that pure mediated priming requires retrospective strategic processing, which is not likely to occur in a continuous LDT.

As McNamara (2005) noted, a disadvantage in using the continuous LDT task is that you cannot control the interval of time between prime and target. Furthermore, the standard LDT allows for SOA to be manipulated in order to assess the time course of pure mediated priming. That is, because participants responded to only the target, the duration between prime and target presentation was easily manipulated. A second critical advantage in using the standard LDT in Experiment 3 was that it allows a direct test of facilitation by using a neutral prime rather than an unrelated prime.

Experiment 3

Experiment 3 used a standard LDT in order to investigate whether mediated priming was caused by facilitation (i.e., related primes increasing target activation) or by inhibition (i.e., unrelated primes decreasing target activation). To assess whether any type of semantic priming is the result of facilitation or inhibition, a neutral condition is needed. Using a row of Xs as the neutral condition, Neely (1976) found a 38-ms facilitation semantic priming effect. In contrast, de Groot (1983, Experiment 4) found a 19-ms inhibition mediated priming effect. If pure mediated priming is simply due to inhibition, then no mediated priming should occur in Experiment 3. However, if the mediated priming reflects facilitation, then RTs should be faster for the targets following the mediated primes (e.g., soap → *curtain*) than for those following the baseline neutral primes (e.g., ******** → *curtain*).

A second purpose of Experiment 3 was to provide an initial investigation of the time course of mediated priming. Balota and Lorch (1986) speculated that more time may be needed for activation to spread across multiple links. Thus, any mediated priming found in this study at the 200-ms SOA challenges the Collins and Loftus (1975) spreading activation model, which states that spread of activation decreases with distance, but not Anderson's (1983) ACT* model, which posits fast spreading activation of approximately 1 ms per link. In contrast, recall that pure direct semantic priming studies found reliable semantic priming even at short SOAs of 300 ms or less (e.g., Estes & Jones, 2009; Hutchison et al., 2001). Thus, SOA was varied between short (200 ms) and long (1,000 ms) to determine whether mediated priming could occur rapidly. Given the results of previous pure direct priming studies (e.g., Estes & Jones, 2009; McRae & Boisvert, 1998; Smith et al., 1987), a 1,000-ms SOA was expected to be sufficiently long to produce mediated priming.

Method

Participants. One-hundred eleven undergraduates were divided between the 200-ms ($n = 57$) and the 1,000-ms ($n = 54$) SOAs.

Materials and design. The mediated items were identical to those used in Experiment 1. The primes for the unrelated items were replaced with a row of eight asterisks (********). Thirty additional filler items that had nonword targets were used. Fifteen of these filler items had a real-word prime (e.g., *barn* → *lurmor*); the rest had a neutral prime (e.g., ******** → *tabe*). A mixed design was used with SOA (200 ms, 1,000 ms) as a between-participants factor and relation (mediated, neutral) as a within-participants factor. Relation was counterbalanced across two lists, such that each target was presented with a mediated and a neutral prime.

Procedure. To begin each trial, participants were instructed to press the spacebar. A blank screen appeared for 200 ms followed by a red 22-point fixation plus sign, which was centered on a black screen for 500 ms. Next the prime appeared for 150 ms, followed by a blank screen for either 50 ms in the 200-ms SOA condition or for 850 ms in the 1,000-ms SOA condition. The target then appeared in white font until participants provided a response. The *J* key was used to indicate that the target was a real word, and the *F* key was used to indicate a nonword. Trials were separated by a 1,000-ms intertrial interval. Participants completed 10 practice trials prior to the 60 experimental trials.

Results and Discussion

For the participant analysis, a mixed analysis of variance (ANOVA) was used with relation as a within-participants factor and SOA as a between-participants factor. For the item analysis, a repeated-measures ANOVA was used with both relation and SOA as within-participants factors. Accuracies were at ceiling ($.980 <$ all Ms $< .987$), and there were no reliable main effects or interactions in either the participant analysis (all ps $> .20$) or in the item analysis (all ps $> .05$). Mean target RTs for each of the four Prime Type × SOA conditions are shown in Figure 1.

Results provided further support for pure mediated priming. RTs were 24 ms faster for the mediated ($M = 638$ ms, $SE = 10$) than for the neutral ($M = 662$ ms, $SE = 11$) items, $F_p(1, 109) = 13.65$, $p < .001$, and $F_i(1, 28) = 13.59$, $p = .001$. RTs were equivalent between the SOA conditions, $F_p(1, 109) = 0.12$, $p = .73$, and $F_i(1, 28) = 2.06$, $p = .16$. Although the priming effect was somewhat larger in the 1,000-ms SOA, 29 ms, 95% CI [10, 49], $\eta_p^2 = .15$, than in the 200-ms SOA, 18 ms, 95% CI [0.5, 34], $\eta_p^2 = .07$, the Relation × SOA interaction was not reliable, $F_p(1, 109) = 0.97$, $p = .33$, and $F_i(1, 28) = 1.15$, $p = .29$. Moreover, follow-up *t* tests revealed that mediated priming occurred within both the 200-ms SOA, $t_p(56) = 2.06$, $p < .05$, and $t_i(28) = 2.03$, $p = .05$, and the 1,000-ms SOA, $t_p(53) = 3.08$, $p < .01$, and $t_i(28) = 3.20$, $p < .01$.

Nonword Facilitation Effect

The nonword facilitation effect is exhibited by faster RTs for nonword targets following a real-word prime than a neutral prime (de Groot, 1984; Neely et al., 1989). The faster RTs occur because a real-word prime will initiate lexical processing, whereas a nonword baseline prime will delay lexical processing until target presentation. This nonword facilitation effect has been found to be stronger at longer than shorter SOAs (Neely, 1991; Neely &

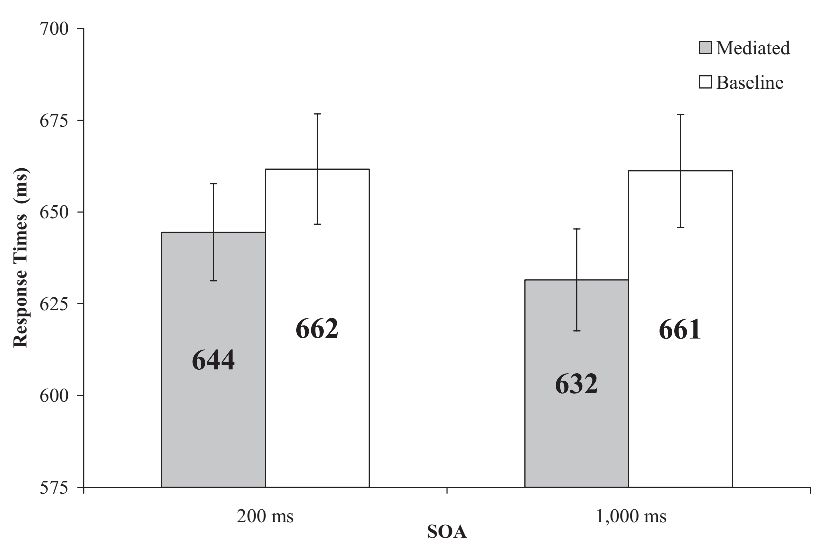

Figure 1. Response times ($M \pm SE$) in Experiment 3. SOA = stimulus onset asynchrony.

Keefe, 1989). This may be because participants have more time to process the meaning of a real-word prime at these longer SOAs. Hence, when a nonword target is presented, it will be rejected more quickly following a real-word prime than following a baseline prime. A mixed ANOVA with prime type as the within-participants factor and SOA as the between-participants factor was done to investigate the possibility of a nonword facilitation effect across SOA conditions.

Results demonstrated an overall nonword facilitation effect. RTs were 13 ms, 95% CI [1, 25], faster for nonword targets following word primes (M = 799 ms, SE = 13) than for targets following neutral primes (M = 812 ms, SE = 12), $F(1, 109) = 4.50$, $p < .05$, $\eta_p^2 = .04$. Also, these nonword targets were more accurately recognized following word primes (M = .93, SE = .01) than neutral primes (M = .90, SE = .01), $F(1, 109) = 10.72$, $p < .001$, $\eta_p^2 = .09$. No differences were found between SOAs for either accuracies (p = .54) or RTs (p = .97).

A lack of an interaction demonstrated that the differences in accuracies between prime types were consistent across SOAs (p = .39). However, for the RT measure, a reliable SOA × Relation interaction, $F(1, 109) = 8.57$, $p < .05$, $\eta_p^2 = .07$, indicated that the nonword facilitation effect was not consistent across SOAs. In the 1,000-ms SOA, targets were 31 ms faster, 95% CI [15, 46], following the word primes (M = 789 ms, SE = 18) than the neutral primes (M = 820 ms, SE = 16), $t(53) = 4.00$, $p < .001$, whereas the nonword facilitation effect did not occur within the 200-ms SOA (p = .60). Hence, the obtained nonword facilitation effect for RTs at the 1,000-ms SOA but not at the 200-ms SOA is consistent with prior findings of an increased effect for longer SOAs (Antos, 1979; Neely, 1991).

In sum, Experiment 3 provided even stronger support for pure mediated priming by using a less strategic standard LDT rather than the double LDT. The lack of an interaction between SOA and relation and the reliable priming found within each SOA suggests that pure mediated priming has emerged by this shorter 200-ms SOA and is maintained at least through a 1,000-ms SOA. A semantic matching process, whereby a retrospective search for a plausible mediator (i.e., related to both prime and target) occurs, could account for these results. Finally, these results suggest that pure mediated priming is due to facilitation by the indirectly related prime as opposed to inhibition from unrelated primes.

However, there is one alternative explanation to account for the priming effect found in Experiment 3. Since Neely (1976) introduced the neutral baseline, several researchers (e.g., Antos, 1979; Jonides & Mack, 1984) have criticized the nonlinguistic nature of nonword neutral stimuli (e.g., ********; see Neely, 1991, pp. 278–280, and McNamara, 2005, pp. 58–62, for reviews on this controversy). To better assess the facilitative nature of pure mediated priming, nonrepetitive neutral primes (e.g., pronounceable nonwords) should be used in subsequent studies (McNamara, 2005).

Experiment 4

Experiment 4 served to replicate the pure mediated priming effect found in Experiment 3 using unrelated word primes instead of nonword neutral primes.

Method

Participants. One-hundred twenty-three undergraduates were divided between the 200-ms (n = 63) and 1,000-ms (n = 60) SOAs.

Materials. The mediated items were identical to those used in Experiments 1 and 2. The primes for the unrelated items were the same as those used in Experiment 1 (e.g., *mule* → *curtain*). All 30 filler items consisted of real-word primes followed by nonword targets (e.g., *barn* → *lurmor*; *memory* → *tabe*).

Procedure. The procedure was the same as in Experiment 3.

Results and Discussion

As in Experiment 3, analyses consisted of 2 (SOA) × 2 (relation) repeated-measures ANOVAs and planned comparisons within each SOA. There were again no reliable main effects or interactions for the accuracy measure (.969 ≤ all Ms ≤ .981, ps > .05 by participants and ps > .15 by items), so only the RTs are reported. All four conditions' RT means are shown in Figure 2.

Results replicated those of Experiment 3, thereby further supporting pure mediated priming. Target RTs were a reliable 17 ms faster following mediated primes (M = 638 ms, SE = 11) than following unrelated primes (M = 656 ms, SE = 12), $F_p(1, 121) = 12.13$, $p = .001$, and $F_i(1, 28) = 7.95$, $p < .01$. RTs were again nearly identical between SOAs, $F_p(1, 121) = 0.04$, $p = .84$, and $F_i(1, 28) = 0.41$, $p = .53$. As in Experiment 2, there was no Prime Type × SOA interaction, $F_p(1, 121) = 0.07$, $p = .79$, and $F_i(1, 28) = 0.18$, $p = .67$. Moreover, planned t tests revealed reliable mediated priming within both the 200-ms SOA, 95% CI [4, 29], $t_p(62) = 2.65$, $p = .01$, $\eta_p^2 = .10$, though not by items, $t_i(28) = 0.82$, $p = .42$, and the 1,000-ms SOA, 95% CI [3, 36], $t_p(59) = 2.34$, $p = .02$, $\eta_p^2 = .09$, though marginal by items, $t_i(28) = 1.77$, $p < .10$.

The mediated priming effect in Experiment 4 indicated that the mediated priming found in Experiment 3 was not just an artifact of the neutral condition. The pattern of results replicated that of Experiment 3: The mediated priming effect was consistent across the 200-ms and 1,000-ms SOAs. Hence, the results of Experiments 3 and 4 demonstrate that pure mediated priming emerges rapidly and is maintained at a long 1,000-ms SOA. The following posttest investigated whether the semantic matching model could account for these results.

Posttest

Recall that associative priming posits decay in activation with increased distance—a prediction that has been supported by McNamara's (1992a) finding of more robust priming for associatively related prime–target pairs (30 ms) than for associative mediated pairs (15 ms; see also de Groot, 1983; Shelton & Martin, 1992). However, there is no reason to suspect that semantic matching for a relation should be any faster than semantic matching for a concept. Hence, the search for a plausible relation that links a directly related mediator and target (e.g., shower → *curtain*; a *curtain* "located in" a shower) should not require any more time than the search for a plausible mediator (e.g., shower) that links the indirectly related prime and target (e.g., *soap* → *curtain*).

Fifty-three additional undergraduates participated in a posttest to examine this hypothesis. Using a standard LDT with a 1,000-ms

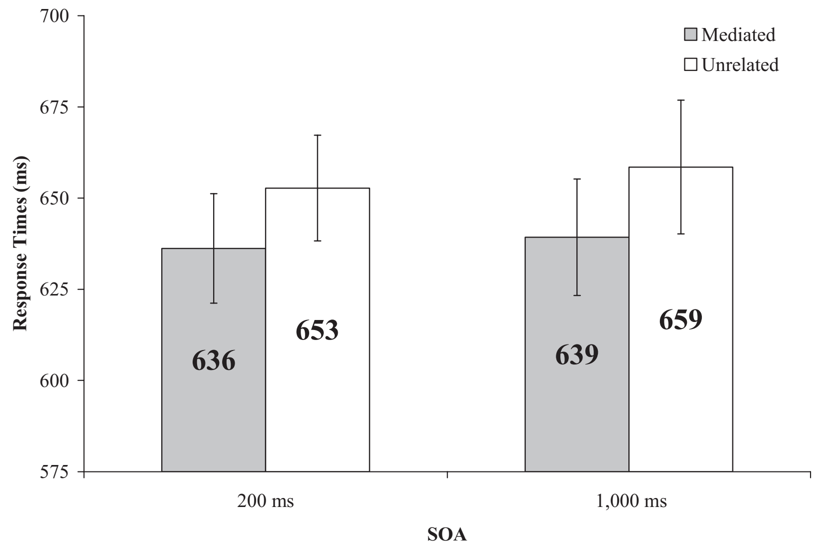

Figure 2. Response times ($M \pm SE$) in Experiment 4. SOA = stimulus onset asynchrony.

SOA, the mediator → target direct priming effects were compared to the mediated priming effects found for these items in the 1,000-ms SOA condition of Experiment 4. The directly related integrative mediator–target pairs (e.g., shower → *curtain*; M = 618 ms, SE = 13) were 23 ms faster, 95% CI [6, 40], than the unrelated control pairs (e.g., *food* → *curtain*; M = 641 ms, SE = 13), $t_p(52) = 2.70$, $p < .01$, and $t_i(28) = 2.91$, $p < .01$. More importantly, a 2 (priming: direct, mediated) × 2 (relation: related, unrelated) interaction confirmed that the priming effects were equivalent between the mediated priming found in Experiment 4 (20 ms; $\eta_p^2 = .09$) and the direct mediator to target priming (23 ms; $\eta_p^2 = .12$), $F_p(1, 111) = 0.07$, $p = .79$, and $F_i(1, 28) = 0.01$, $p = .93$. Thus, the magnitude of the priming effects was not affected by whether the semantic matching process entailed a search for a plausible relation or for a mediator. Although a null interaction should be interpreted with caution, these equivalent priming effects further distinguish pure mediated priming from associative mediated priming; associative mediated priming produces priming effects that are lower in magnitude than those in associative direct priming (de Groot, 1983; McNamara, 1992a; Shelton & Martin, 1992).

General Discussion

In contrast to the stimuli in prior studies of mediated priming (e.g., Balota & Lorch, 1986; Chwilla et al., 2000; McNamara & Altarriba, 1988), the stimuli used in the current study had prime–mediator and mediator–target pairs that were only weakly associated. The stimuli had an instrumental relation between prime (e.g., *spoon*) and mediator (e.g., soup) and an integrative relation between mediator and target (e.g., *can*). Experiment 1, using a double LDT, yielded a robust 43 ms ($\eta_p^2 = .16$) mediated priming effect. However, no mediated priming effect was found in the continuous LDT used in Experiment 2. Experiment 3, using a standard LDT with a neutral baseline condition (i.e., ********), demonstrated that pure mediated priming was due to facilitation that occurred at 200-ms and 1,000-ms SOAs. Experiment 4 replicated the pure mediated priming found across these SOAs using the same unrelated primes as in Experiment 1.

In summary, pure mediated priming occurred in three experiments and two different LDT paradigms (double and standard) but did not occur in a continuous LDT task that does not permit strategic processing. Thus, this study is the first to use pure semantic relations between prime and mediator, and it therefore expands the applicability of mediated priming to a broader range of relations, namely integrative and instrumental.

Pure Mediated Priming Is Retrospective and Strategic

Prior semantic priming studies collectively suggest that target activation occurs immediately (at short SOAs < 300 ms; e.g., Estes & Jones, 2009; Neely, 1977; Perea & Rosa, 2002; Smith et al., 1987). This activation increases or is maintained through longer SOAs (i.e., 1,000 ms; Estes & Jones, 2009; Smith et al., 1987). Thus, the priming found at the 200-ms and 1,000-ms SOAs in the current study is highly consistent with that of previous studies reflecting retrospective priming. More specifically, results demonstrated reliable target activation not only within the strategic double LDT paradigm (Experiment 1) but also within the standard LDT at short SOAs of 200 ms as well as long SOAs of 1,000 ms (Experiments 3 and 4).

The Collins and Loftus (1975) spreading activation model predicts that activation must spread from prime to mediator to target. The stimuli in all four experiments had weak forward association strengths (≤.05) between prime and mediator and between mediator and target, thereby making this spread of activation less likely. Moreover, mediated priming did not occur in the continuous LDT, which precludes strategic processing (McNamara, 2005). Therefore, prospective spreading activation models (Collins & Loftus, 1975) are unlikely to account for pure mediated priming.

Recall that the ACT* model has a retrospective component whereby target activation is increased following target presentation due to the reverberation from target back to the source node (i.e., the mediator). The increased activation of the mediator by the target would have enabled further spread of activation from the mediator to the target. Although there is no established minimal threshold of association that would produce such reverberation, previous mediated priming studies suggest a minimal threshold of greater than .20, or a strong association by Hutchison's (2003) criteria. For instance, Balota and Lorch (1986, LDT experiment) failed to find mediated priming for stimuli that had moderately associated mediator–target links (forward = .10, backward = .16). In contrast, McNamara and Altarriba (1988) found mediated priming using stimuli having strong mediator–target associations (forward = .27, backward = .23). So given that in the current study the backward association between mediator and target was weak (≤.10), it is unlikely that this reverberation from target to mediator would have occurred. Because Experiments 1 and 4 used unrelated control items that were matched for co-occurrence using LSA and Google, the compound-cue model is also not a viable explanation of the current pure mediated priming results.

The Retrospective Semantic Matching Model of Mediated Priming

Recall that retrospective semantic matching entails a search for a relation between prime and target (Neely, 1977). The expanded semantic matching model predicts that following target presentation, a search begins for a conceptual node (i.e., a mediator) that is related to both prime and target. As demonstrated by the posttest, the facilitated target activation following the search for a mediator node did not differ in magnitude from the target activation produced by the search for a relation between the directly related prime and mediator.

The semantic matching model differs from the retrospective ACT* model in at least two aspects. Whereas semantic matching refers to a retrospective *search for a relation* between target and prime (McNamara, 2005), the ACT* model proposes a *spread of activation* reverberation between target and prime (i.e., prime to target, target to prime). Second, a search for a relation (or mediator) posits strategic processing, whereas spreading activation describes an automatic (i.e., nonvolitional) process that is facilitated by associative relations. The mediated priming effect size in the double LDT in Experiment 1 was more robust ($\eta_p^2 = .16$) than in the standard LDTs in Experiments 3 and 4 ($.07 \geq \eta_p^2 \leq .10$ for the 200-ms SOA and $.09 \geq \eta_p^2 \leq .15$ for the 1,000-ms SOA). The difference in effect sizes may have reflected the easier ability in the double LDT to strategically check for a mediator that is related to both prime and target.

Implications for Computational Models

One recent computational model, the BEAGLE model (bound encoding of the aggregate language environment; M. N. Jones & Mewhort, 2007), has been used to explain the mediated priming found by Balota and Lorch (1986). This model represents both meaning and word order from the unsupervised experience with natural language. Like the semantic matching model of mediated priming, the BEAGLE model also posits that mediated priming does not require a process like spreading activation. Rather, the BEAGLE model, like the compound-cue model, attributes mediated priming to the direct similarity between prime and target. This similarity is the result of shared contexts between the prime and mediator and between the mediator and target. Even though the prime and target (e.g., *lion* and *stripes*) may never co-occur in text, the representations of both concepts have elements (e.g., the co-occurrence with tiger) that serve to increase the prime and target similarity.

The BEAGLE model successfully predicted the mediated priming found in Balota and Lorch (1986). The cosines representing lexical similarity (essentially global co-occurrence as explained above) were found to be higher for the mediated than for the unrelated pairs in Balota and Lorch's stimuli (M. N. Jones & Mewhort, 2007, Table 13). In contrast, the prime–target pairs used in the current study were equated on co-occurrence (as measured by both LSA and Google hits) between the mediated and unrelated pairs. It is important to note that the lexical similarity cosines used in the BEAGLE model overcome the word order problem of the LSA measure (i.e., equivalent LSA values for *spatula blueberry* and *blueberry spatula*). Also, the BEAGLE model's cosines are a more global measure of co-occurrence than are the Google hits used in the current study. Thus, the LSA and Google measures of co-occurrence used in the current study do not necessarily correspond to the BEAGLE model's lexical similarity measure, which incorporates the advantages of LSA and Google into one convenient measure.

The BEAGLE model predicted greater priming for prime–target pairs sharing a mediated relation than for unrelated pairs (M. N. Jones & Mewhort, 2007). This prediction was supported by the correspondence of BEAGLE's lexical similarity cosines with the RTs from the Balota and Lorch (1986) study, and it would likely hold for other mediated stimuli sharing associative relations between links. To determine whether the BEAGLE model could account for the obtained pure mediated priming, lexical similarity cosines were obtained for the current items. Contrary to the results found for Balota and Lorch's stimuli, cosines were equivalent between the mediated ($M = .27$, $SD = .06$) and unrelated ($M = .26$, $SD = .08$) items, $t(25) = 0.52$, $p = .61$.[1] Hence, for pure mediated priming, the retrospective semantic matching model may provide a better explanation than the BEAGLE model, which predicted no pure mediated priming.

The BEAGLE model also predicted the greater priming effects found in Balota and Lorch's (1986) study for the directly related than for the mediated stimuli. Recall that the posttest following Experiment 4 found no difference in the facilitation between the directly related mediator–target pairs (e.g., fish → *pond*) and the mediated prime–target pairs (e.g., *pole* → *pond*). Conversely, the BEAGLE model's cosines for the direct versus unrelated items used in this posttest predicted greater direct priming (direct–unrelated = .095) than mediated priming (mediated – unrelated = .009), $F(1, 25) = 8.37$, $p < .01$, $\eta_p^2 = .25$. Thus, the similar facilitative priming effects for direct and mediated items found in the posttest were consistent with the retrospective semantic matching model but not with the BEAGLE model.

[1] For brevity, results are presented only for the cosines based on the TASA (Touchstone Applied Science Associates; see Landauer et al., 1998) corpus. Analyses revealed the same pattern of results for the cosines based on the Wiki corpus.

Implications for Future Mediated Priming Studies

In addition to the implications for the classic semantic priming models and more recent computational models, the existence of pure mediated priming (e.g., *wind* → kite → *string*) contributes to the discussion in the semantic priming literature over the importance of association in concept activation (Hutchison, 2003; Lucas, 2000). It must be emphasized that the purpose of this study was not to discount spreading activation as a viable mechanism of associative mediated priming.

The current study manipulated the extent to which strategic processing was available by varying the type of LDT (double, standard, or continuous). Future research is needed to investigate additional factors (e.g., shorter SOAs, masked priming, relatedness proportion) that facilitate or disrupt the extent to which strategic processes may be used in mediated priming. For instance, semantic priming effects are greater when there is a high relatedness proportion in prime–target pairs than when there is a low relatedness proportion (e.g., Bodner & Masson, 2003; Estes & Jones, 2009; Hutchison et al., 2001; Neely et al., 1989).

Conversely, masked priming disrupts the retrospective matching process between prime and target by eliminating conscious awareness of the prime (Forster, 1999, 2009). In masked priming, a pattern (e.g., ######) is displayed for approximately 500 ms either prior to or following a prime that is presented for only 40 to 60 ms. Despite individuals' unconscious awareness of the prime, some studies have found masked semantic priming (e.g., Bodner & Masson, 2003; Perea & Gotor, 1997; see McNamara, 2005, for discussion). The occurrence of pure mediated priming in the absence of prime awareness would challenge a semantic matching account of pure mediated priming. Perea and Gotor (1997) found reliable priming using a forward masking procedure at a short SOA of 67 ms for highly similar synonyms lacking an associative relation (e.g., *shop* → *store*). Notably, these results were not attributed to a semantic matching process. Rather, the briefly presented prime may have activated the lexical representation, which in turn activated the semantic representation upon presentation of the target. Other facilitating factors in these experiments, such as high similarity (Perea & Gotor, 1997) and a high relatedness proportion (Bodner & Masson, 2003), may have increased the likelihood of activation from the lexical to the semantic representation. Hence, in the absence of such facilitating factors, it is unlikely that pure mediated priming would occur within a masked priming paradigm.

References

Anderson, J. R. (1983). A spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behavior, 22,* 261–265.

Antos, S. J. (1979). Processing facilitation in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 527–545.

Balota, D. A., & Lorch, R. F. (1986). Depth of automatic spreading activation: Mediated priming effects in pronunciation but not in lexical decision. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 336–345.

Bennet, D. J., & McEvoy, C. L. (1999). Mediated priming in older and younger adults. *Experimental Aging Research, 25,* 141–159.

Bodner, G. E., & Masson, M. E. J. (2003). Beyond spreading activation: An influence of relatedness proportion on masked semantic priming. *Psychonomic Bulletin & Review, 10,* 645–652.

Bueno, S., & Frenck-Mestre, C. (2008). The activation of semantic memory: Effects of prime exposure, prime–target relationship, and task demands. *Memory & Cognition, 36,* 882–898.

Burgess, C., & Lund, K. (2000). The dynamics of meaning in memory. In E. Dietrich & B. Arthur (Eds.), *Cognitive dynamics: Conceptual and representational change in humans and machines* (pp. 117–156). Mahwah, NJ: Erlbaum.

Chwilla, D. J., Hagoort, P., & Brown, C. M. (1998). The mechanism underlying backward priming in a lexical decision task: Spreading activation versus semantic matching. *Quarterly Journal of Experimental Psychology, 51*(A), 531–560.

Chwilla, D. J., & Kolk, H. H. J. (2002). Three-step priming in lexical decision. *Memory & Cognition, 30,* 217–225.

Chwilla, D. J., Kolk, H. H. J., & Mulder, G. (2000). Mediated priming in the lexical decision task: Evidence from event-related potentials and reaction time. *Journal of Memory and Language, 42,* 314–341.

Collins, A. M., & Loftus, E. F. (1975). A spreading activation theory of semantic processing. *Psychological Review, 82,* 407–428.

Coolen, R., van Jaarsveld, H. J., & Schreuder, R. (1991). The interpretation of isolated novel nominal compounds. *Memory & Cognition, 19,* 341–352.

de Groot, A. M. B. (1983). The range of automatic spreading activation in word priming. *Journal of Verbal Learning and Verbal Behavior, 22,* 417–436.

de Groot, A. M. B. (1984). Primed lexical decision: Combined effects of the proportion of related prime–target pairs and the stimulus-onset asynchrony of prime and target. *Quarterly Journal of Experimental Psychology, 36*(A), 253–280.

de Groot, A. M. B. (1985). Word context effects in word naming and lexical decision. *Quarterly Journal of Experimental Psychology, 37*(A), 281–297.

Estes, Z., & Jones, L. L. (2009). Integrative priming occurs rapidly and uncontrollably during lexical processing. *Journal of Experimental Psychology: General, 138,* 112–130.

Forster, K. I. (1999). The microgenesis of priming effects in lexical access. *Brain and Language, 68,* 5–15.

Forster, K. I. (2009). The intervenor effect in masked priming: How does masked priming survive across an intervening word? *Journal of Memory and Language, 60,* 36–49.

Hare, M., Jones, M., Thomson, C., Kelly, S., & McRae, K. (2009). Activating event knowledge. *Cognition, 111,* 151–167.

Hutchison, K. A. (2003). Is semantic priming due to association strength or featural overlap? A microanalytic review. *Psychonomic Bulletin & Review, 10,* 785–813.

Hutchison, K. A., Neely, J. H., & Johnson, J. D. (2001). With great expectations, can two "wrongs" prime a "right"? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 1451–1463.

Jones, L. L., Estes, Z., & Marsh, R. L. (2008). An asymmetric effect of relational integration on recognition memory. *Quarterly Journal of Experimental Psychology, 61,* 1169–1176.

Jones, M. N., & Mewhort, D. J. K. (2007). Representing word meaning and order information in a composite holographic lexicon. *Psychological Review, 114,* 1–37.

Jonides, J., & Mack, R. (1984). On the cost and benefit of cost and benefit. *Psychological Bulletin, 96,* 29–44.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). Introduction to latent semantic analysis. *Discourse Processes, 25,* 259–284.

Livesay, K., & Burgess, C. (1998). Mediated priming in high-dimensional semantic space: No effect of direct semantic relationships or co-occurrence. *Brain and Cognition, 37,* 102–105.

Lorch, R. F., Jr. (1982). Priming and search processes in semantic memory: A test of three models of spreading activation. *Journal of Verbal Learning and Verbal Behavior, 21,* 468–492.

Lucas, M. (2000). Semantic priming without association: A meta-analytic review. *Psychonomic Bulletin & Review, 7,* 618–630.

McKoon, G., & Ratcliff, R. (1992). Spreading activation versus compound cue accounts of priming: Mediated priming revisited. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1155–1172.

McNamara, T. P. (1992a). Priming and constraints it places on theories of memory and retrieval. *Psychological Review, 99,* 650–662.

McNamara, T. P. (1992b). Theories of priming: I. Associative distance and lag. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1173–1190.

McNamara, T. P. (1994). Theories of priming: II. Types of primes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 507–520.

McNamara, T. P. (2005). *Semantic priming: Perspectives from memory and word recognition.* New York, NY: Psychology Press.

McNamara, T. P., & Altarriba, J. (1988). Depth of spreading activation revisited: Semantic mediated priming occurs in lexical decisions. *Journal of Memory and Language, 27,* 545–559.

McRae, K., & Boisvert, S. (1998). Automatic semantic similarity priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 558–572.

Moss, H. E., Ostrin, R. K., Tyler, L. K., & Marslen-Wilson, W. D. (1995). Accessing different types of lexical semantic information: Evidence from priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 863–883.

Murphy, G. L., & Wisniewski, E. J. (2006). Familiarity and plausibility in conceptual combination: Reply to Gagné and Spalding (2006). *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 1438–1442.

Neely, J. H. (1976). Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes. *Memory & Cognition, 4,* 648–654.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General, 106,* 226–254.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264–336). Hillsdale, NJ: Erlbaum.

Neely, J. H., & Keefe, D. E. (1989). Semantic context effects on visual word processing: A hybrid prospective–retrospective processing theory. In G. H. Bower (Ed.), *The Psychology of learning and motivation: Advances in research theory* (Vol. 24, pp. 207–248). New York, NY: Academic Press.

Neely, J. H., Keefe, D. E., & Ross, K. L. (1989). Semantic priming in the lexical decision task: Roles of prospective prime-generated expectancies and retrospective semantic matching. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 1003–1019.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). *The University of South Florida word association, rhyme, and word fragment norms.* Retrieved from http://w3.usf.edu/FreeAssociation/

Perea, M., & Gotor, A. (1997). Associative and semantic priming effects occur at very short SOAs in lexical decision and naming. *Cognition, 62,* 223–240.

Perea, M., & Rosa, E. (2002). The effects of associative and semantic priming in the lexical decision task. *Psychological Research, 66,* 180–194.

Ratcliff, R., & McKoon, G. (1988). A retrieval theory of priming in memory. *Psychological Review, 95,* 385–408.

Ratcliff, R., & McKoon, G. (1994). Retrieving information from memory: Spreading activation theories versus compound-cue theories. *Psychological Review, 101,* 177–184.

Sass, K., Krach, S., Sachs, O., & Kircher, T. (2009). Lion – tiger – stripes: Neural correlates of indirect semantic priming across processing modalities. *NeuroImage, 45,* 224–236.

Shelton, J. R., & Martin, R. C. (1992). How semantic is automatic semantic priming? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1191–1210.

Smith, L. C., Briand, K., Klein, R. M., & den Heyer, K. (1987). On the generality of Becker's verification model. *Canadian Journal of Psychology, 41,* 379–386.

Solomon, E. S., & Pearlmutter, N. J. (2004). Semantic integration and syntactic planning in language production. *Cognitive Psychology, 49,* 1–46.

Wisniewski, E. J., & Murphy, G. L. (2005). Frequency of relation type as a determinant of conceptual combination: A reanalysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 169–174.

(*Appendix follows*)

Appendix

Stimuli in Experiments 1, 2, 3, and 4

Mediated (*prime* → mediator → *target*)	Unrelated (*prime* → *target*)
broom → clean → *drain*	*grill* → *drain*
oven → bread → *basket*	*broom* → *basket*
spoon → soup → *can*	*ticket* → *can*
fork → breakfast → *bacon*	*oven* → *bacon*
ax → wood → *stove*	*rake* → *stove*
library → research → *experiment*	*fork* → *experiment*
microwave → popcorn → *bag*	*horse* → *bag*
rake → plant → *seed*	*razor* → *seed*
razor → cut → *muscle*	*microwave* → *muscle*
ticket → show → *dog*	*spatula* → *dog*
spatula → pancake → *blueberry*	*road* → *blueberry*
road → car → *door*	*recipe* → *door*
recipe → cake → *crumb*	*ax* → *crumb*
horse → carriage → *wheel*	*library* → *wheel*
grill → chicken → *thigh*	*spoon* → *thigh*
needle → blood → *bank*	*pipe* → *bank*
trap → bear → *cave*	*knife* → *cave*
button → clothes → *closet*	*zipper* → *closet*
knife → bread → *loaf*	*freezer* → *loaf*
soap → shower → *curtain*	*mule* → *curtain*
freezer → ice → *sculpture*	*scissors* → *sculpture*
mule → field → *flower*	*wind* → *flower*
plate → food → *weight*	*button* → *weight*
zipper → clothes → *hanger*	*soap* → *hanger*
pipe → air → *balloon*	*pole* → *balloon*
wind → kite → *string*	*ladder* → *string*
ladder → tree → *nest*	*trap* → *nest*
scissors → paper → *color*	*plate* → *color*
pole → fish → *pond*	*needle* → *pond*

Received September 12, 2008
Revision received August 24, 2009
Accepted August 28, 2009 ■