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Prospective and Retrospective Processing in Associative Mediated Priming

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Abstract

Mediated priming refers to the faster word recognition of a target (e.g., MILK) following presentation of a prime (e.g., PASTURE) that is related indirectly via a connecting "mediator" (e.g., cow). Association strength may be an important factor in whether mediated priming occurs prospectively (with target activation prior to its presentation) or retrospectively. Mediated priming effects were compared for items having a strong (e.g., ICEBERG – cold – HOT) versus weak (e.g., CAMEL – desert – HOT) mediator-target association. Priming obtained for both strong and weak mediator-target association conditions in lexical decision tasks (LDTs) conducive to retrospective processing, but only for the stronger items in more automatic LDTs. Results extend recent findings of mediated priming via retrospective processing (e.g., Jones, 2010), and further suggest that a strong mediator-target association is necessary in order for mediated priming to occur prospectively by spreading activation.

KEYWORDS: mediated priming, associative priming, compound-cue, expectancy, spreading activation, lexical decision task

Mediated or indirect priming has been demonstrated by faster recognition of a target (e.g., SUN) following the presentation of an indirectly related prime (e.g., CRATER) via a connecting "mediator" (e.g., moon).[1] One factor likely influencing the occurrence of mediated priming is the association strength between the prime-mediator and mediator-target links. Association strength is most commonly measured as the proportion of a sample in a free association task producing a particular concept (e.g., MOON) in response to a presented concept (e.g., NIGHT). In pure mediated priming, the mediator shares no more than a weak association strength (< .10; Hutchison, 2003) between prime and mediator and between mediator and target (Jones, 2010; e.g., WIND – kite – STRING). More typically, however, there is a strong association (≥ .20; Hutchison, 2003) between prime and mediator (e.g., CRATER and moon) and between mediator and target (e.g., moon and SUN). Association strength is an important factor in whether priming occurs prospectively or retrospectively. Prospective processing refers to the pre-activation of the target prior to its presentation, whereas retrospective processing refers to target activation only after target presentation.

Mediated priming has been attributed to the prospective and automatic (i.e., without conscious awareness) spread of activation from a prime to an associated and non-presented mediator and then to a target (e.g., DAY → night → MOON; Balota & Lorch, 1986; Bennet & McEvoy, 1999; Kreher, Holcomb, & Kuperberg, 2006; McNamara, 1992b, 1994, 2005; McNamra & Altarriba, 1988; Sayette, Hufford, & Thorson, 1996; Richards & Chiarello, 1995; Shelton & Martin, 1992).[2] However, some accounts have suggested a retrospective process may be involved (Chwilla, Kolk, & Mulder, 2000; Hill, Strube, Roesch-Ely, & Weisbrod, 2002; Hutchison & Davis, 2010; Jones, 2010; Sass, Krach, Sachs, & Kircher, 2009; Weisbrod et al., 1999). The purpose of the current study was to investigate a key factor that may influence the extent of retrospective versus prospective processing in mediated priming – namely, the presence or absence of a strong association between mediator and target.

Priming Paradigms Favoring Prospective versus Strategic Processing

In addition to association strength, the selection of priming paradigm also influences the extent of prospective versus retrospective processes (for reviews see Hutchison, 2002; Jones & Estes, 2011; Neely, 1991). In general, tasks which entail explicit pairing of prime and target either simultaneously or subsequently within the same trial facilitate retrospective processing (McNamara & Altarriba, 1988; Jones, 2010). In contrast, tasks that require naming the prime or making a lexical decision on individually presented primes and targets (McNamara & Altarriba, 1988; Shelton & Martin, 1992) obscure the participant's ability to notice prime-target pairings and thus have been used to detect prospective processing. Because no conscious awareness of prime-target pairings is required to yield reliable priming, these tasks are generally considered to be more automatic. Masked priming tasks with very brief prime presentation (i.e., typically 30 to 66 ms) and a forward visual mask (########) prior to prime presentation (de Groot, 1983; Perea & Rosa, 2002a) also have been found to preclude or limit retrospective processing. As described in the next section, a variety of lexical decision tasks (LDTs) can be used in order to better determine the extent of retrospective processing involved.

Mediated Priming via Retrospective Processing

Jones (2010) demonstrated mediated priming in the absence of a strong association between prime and mediator (e.g., WIND and kite) or between mediator and target (e.g., kite and STRING). Reliable mediated priming was obtained in a double LDT in which participants judged whether the simultaneously presented prime and target letter strings were real words in the English language. Mediated priming was also found in a standard LDT, in which participants judged whether target letter strings were real words following presentation of a neutral (********) or unrelated prime. Priming effects in the standard LDT were reliable within a1000 ms stimulus onset asynchrony (SOA; i.e., delay between prime and target presentation) and to a slightly less robust extent within a short (200 ms) SOA. However, pure mediated priming was not reliable in a continuous LDT, in which participants judged whether each individually presented letter string was a real word. Note that participants were able to detect the prime-target pairings in the double and standard LDTs but not in the continuous LDT. Hence, pure mediated priming occurred retrospectively (following target presentation). Further analyses suggested a semantic matching process in which there is a search for a plausible mediator (e.g., kite) between prime and target, rather than a search for a relation as Neely and Keefe (1989) had originally proposed in their model.

Patterns of activation found in neuroscience studies using event-related potential (Chwilla, Kolk, & Mulder, 2000; Hill et al., 2002) and functional magnetic resonance imaging (Sass et al., 2009) also suggest that semantic matching or another retrospective process (e.g., post-lexical integration) may be involved in associative mediated priming. N400 priming effects are represented by smaller negative amplitudes approximately 400 ms following a stimulus that is expected or related to prior context (e.g., a prime word), and are thought to reflect primarily retrospective processes (Chwilla, Hagoort, & Brown, 1998; Chwilla et al., 2000; Hill et al., 2002; Koivisto & Revonsuo, 2001; Rugg & Doyle, 1994; but see Franklin et al., 2007; Kreher et al., 2006; and Weisbrod et al., 1999). Chwilla et al. (2000) and Hill et al. (2002) concluded that the N400 effect found for their mediated items (e.g., LION - tiger – STRIPES) was due to a post-lexical integration process. Furthermore, as in Jones (2010), this controlled process was found in both short (150 ms) and long (700 ms) SOAs (Hill et al., 2002).

Another possible retrospective mechanism is the formation within a short-term buffer of a compound consisting of prime and target with more familiar compounds producing faster RTs (Ratcliff & McKoon, 1988). McKoon and Ratcliff (1992) went as far as to claim that mediated priming was simply “priming between directly related weak associates” (p. 1165). They described familiarity as the extent to which prime and target were connected together in long-term memory and advocated using universal co-occurrence measures rather than subjective familiarity ratings to assess this construct. Indeed, a greater co-occurrence in natural language of mediated than unrelated prime-target pairs could explain any obtained mediated priming, and thus these co-occurrences should be considered (Livesay & Burgess, 1998).

Mediated Priming via Prospective Processing

Spreading activation models (Anderson, 1983; Collins & Loftus, 1975) predict that priming should decrease as distance (the number of nodes, links, or associative steps between prime and target) increases (e.g., McNamara, 1992b, 1994, 2005). Consequently, priming between a directly and strongly associated mediator (e.g., moon) and target (e.g., SUN) is greater than the priming between the indirectly related prime (e.g., CRATER) and target (e.g., SUN). This finding has been interpreted as decreasing activation over intervening nodes (de Groot, 1983; Hill et al., 2002; McNamara & Altarriba, 1988; McNamara, 1992a, 1992b; Weisbrod et al., 1999). McNamara (1992b) found more robust priming for directly associated pairs (e.g., TIGER → STRIPES; 30 ms), in comparison to two-step mediated (e.g., LION → tiger → STRIPES; 15 ms) and three-step mediated (e.g., MANE → lion → tiger → STRIPES; 10 ms) items. Most of these studies suggest spreading activation occurs in a linear forward fashion (i.e., from prime to mediator to target). However, the ACT* model of spreading activation (adaptive control of thought; Anderson, 1983) proposes that some activation can spread back from a target node to its source node and then back from the source node to the target until an asymptotic level of activation is reached – a process referred to as reverberation. It is unlikely, though, that strong backward association strength (BAS) will be able to compensate for weak forward association strength (FAS) in activating a target concept. Indeed, prior studies (Hutchison, 2002; Kahan, Neely, & Forsythe, 1999; Shelton & Martin, 1992) have failed to find reliable backward priming effects (e.g., BABY → STORK) in tasks permitting only prospective processing. However, backward association strength may facilitate direct *forward* priming at longer SOAs. In direct forward priming (prime → target), in which the FAS ≥ BAS between prime and target (e.g., GLOVE → HAND), BAS (e.g., the proportion producing “glove” in response to “hand” in a free association task) was related to semantic priming in LDTs at long SOAs (i.e., 1250 ms; Hutchison, Balota, Cortese, & Watson, 2008), and thus may facilitate associative mediated priming.

Priming may also occur prospectively via the generation of a set of potential targets following a prime (Becker, 1980; Neely, 1977, 1991). For example, upon activation of the mediator concept moon, participants may anticipate the targets SUN, STAR, FULL, and NIGHT. The generation of an expectancy set is thought to be a slow process that takes approximately 200 ms to emerge (Becker, 1980) and requires even longer to fully develop (Chwilla et al., 1998; De Groot, 1984; den Heyer, Briand, & Smith, 1985; Estes & Jones, 2009). Targets that are strongly associated to the preceding concept (either the prime or possibly the activated mediator) are more likely to be included in the expectancy set (Estes & Jones, 2009; Jones & Estes, 2011). Expectancy cannot wholly explain mediated priming, because indirectly related targets (SUN) are not likely to be in the set generated for their primes (CRATER). However, at long SOAs, target RTs may be facilitated in a manner much like that described by Neely and Keefe’s (1989; Neely,

1991) hybrid three-process theory, which incorporates spreading activation, expectancy, and semantic-matching. For example, presentation of the prime CRATER would likely activate the strongly associated mediator, moon. Then, with ample time between prime and target presentation, participants would be able to generate a set of anticipated targets (e.g., SUN, START, FULL, NIGHT) that they could then compare with the presented target. Targets that matched one of the items in the generated expectancy set would yield faster RTs than targets that had not been anticipated prior to their presentation.

Time Course of Priming for Strong and Weak Associates

Because strong associations will be activated to threshold faster than weak associations (Lorch, 1982), association strength is critical for concept activation. Priming effects for items lacking a strong association tend to be larger at longer SOAs ranging from 500 to 1000 ms than at shorter SOAs less than 300 ms (e.g., Estes & Jones, 2009; Jones, 2010; McRae & Boisvert, 1998). In a cortical based network model, both direct and mediated priming effects were a function of association strength and SOA, with effects becoming less dependent on association strength at longer SOAs up to 1000 ms (Brunel & Lavigne, 2008). In empirical studies, priming effects for strong direct associates emerge quickly at short (< 300 ms) SOAs (e.g., de Groot, Thomassen, & Hudson, 1982; Perea & Rosa, 2002b). At longer SOAs, priming effects tend to increase with neutral primes or remain constant with unrelated primes (e.g., de Groot, 1985; de Groot, Thomassen, & Hudson, 1986; Estes & Jones, 2009; Perea & Rosa, 2002b).

Priming for these strong associates is frequently attributed to the prospective processes of automatic spreading activation, and/or expectancy generation, although post-lexical retrospective processes like the ACT* model may also explain results, especially when there is a strong BAS from target to prime. At short SOAs (e.g., 167 ms, Hutchison, Neely, & Johnson, 2001), associative priming effects are thought to be mostly due to the prospective process of automatic spreading activation. At long SOAs, associative priming effects are more likely due to expectancy given that: (1) spreading activation decays with time (McNamera, 2005; Perea & Rosa, 2002b), and (2) it is easier to generate potential targets with longer delays between prime and target presentation (Hutchison et al., 2001; Neely, 1977). Indeed, Neely (1991) proposed the use of long SOAs as one mechanism for dissociating spreading activation, semantic matching, and expectancy processes.

Unfortunately, relatively few studies have investigated even direct priming at SOAs > 1500 ms, much less indirect priming. However, one unpublished experiment from the author's dissertation (Jones, 2007, Experiment 5) used a standard LDT and pronounceable non-word neutral primes (e.g., CABE) to investigate mediated priming for "pure" items lacking an association in either link (e.g., MORNING – coffee – BEAN). Mediated priming was reliable at a 1000 ms SOA (26 ms) but not at a 2000 ms SOA (-1 ms). Hence, this result suggests (albeit via a null effect) that pure mediated priming like pure direct priming is eliminated at long SOAs > 1500 ms that are favorable to a prospective expectancy process but not to retrospective processes like semantic matching (Estes & Jones, 2009; Neely, 1991).

Association Strength in Mediated Priming

Though some studies have shown robust mediated priming effects (e.g., Bennet & McEvoy, 1999; McNamara & Altarriba, 1988; Shelton & Martin, 1992; Weisbrod et al., 1999), other studies have failed to find mediated priming in a LDT (e.g., Balota & Lorch, 1986; de Groot, 1983). One often cited reason for the failure to find mediated priming is a list effect produced by the inclusion of both directly and indirectly related (i.e., mediated) items within the same experimental list (Chwilla & Kolk, 2002; McNamara & Altarriba, 1988; Sass et al., 2009).

In these "mixed" experimental lists, the inclusion of directly related associates (e.g., DAY – NIGHT) may overshadow the weaker indirect priming effects.

Surprisingly, however, association strength in mediated priming has not been systematically tested. Such an investigation would further illuminate the importance of association in spreading activation. Specifically, is a strong association in the first link between prime and mediator sufficient for activating a target that is only weakly related to the mediator? Because activation decays rapidly with distance as posited by spreading activation theories (McNamara, 2005), it is likely that a strong association between mediator and target is required for mediated priming to occur via prospective processing (i.e., further spread of activation from mediator to target at short SOAs < 200 ms; or the generation of an expectancy set at longer SOAs; > 300 ms). The null results from de Groot (1983, Experiment 7) support this hypothesis. De Groot interpreted the null effect of Experiment 7, as suggesting "that the activation originating at the prime's memory representation stops after having reached the representation of words directly related to the prime" (p. 430). Although activation may have spread from the prime to the closest neighbor node (i.e. the mediator), de Groot suggested that this activation may have decayed to the point of not having the minimal amount of activation necessary to spread further from the mediator to the target. Indeed, as shown in Table 1, the items used in de Groot's Experiment 7 had only weak mediator-target association strengths. However, considering the small mediated priming effect size (15 ms), the lack of reliable facilitation in de Groot's (1983) Experiment 7 may have been due to a lack of power (Balota & Lorch, 1986); there were only 18 participants and 21 items in the experiment. Nonetheless, de Groot raises an intriguing question regarding the importance of mediator-target association strength.

Table 1 presents a summary of forward and backward association strengths for each link in the prime-mediator-target items used in several mediated priming experiments along with the obtained mediated priming effects. Two patterns emerge from this collection of mediated priming studies. First, mixed list of directly related and mediated items curtailed priming in the double LDT, but not in the more automatic continuous or standard LDT (Balota & Lorch, 1986; Bennet & McEvoy, 1999; de Groot, 1983; McNamara & Altarriba, 1988; Weisbrod et al., 1999). Second, no association was required in the double and standard LDTs, whereas mediated priming occurred in the more automatic LDTs (continuous and masked prime LDT) only when strong FAS were present within both prime-mediator and mediator-target links (Bennett & McEvoy, 1999; de Groot, 1983; Jones, 2010; McNamara & Altarriba, 1988).[3]

Overview of Experiments

Mediator-target association strength was manipulated to test the role of prospective versus retrospective processing in mediated priming across several LDT paradigms ranging from a double LDT (Experiment 1), a standard LDT across three SOAs (200, 1000, and 1800; Experiments 3 and 4), and a more automatic continuous LDT (Experiment 2). Reliable mediated priming was predicted in all LDT paradigms for the strongly associated mediator-target items. However, for the weakly associated mediator-target items, priming was not expected in the continuous LDT due to the failure for activation to further spread across the weakly associated mediator-target link (de Groot, 1983). In Experiments 3 and 4, mediated priming was expected to occur for both mediator-target association conditions at the optimal 1000 ms SOA. However, priming was expected to occur to a lesser extent at the short (200 ms) and long (1800 ms) SOAs for the weaker items in comparison to the stronger items.

Experiment 1

Because the simultaneous presentation of prime and target in the double LDT facilitates retrospective processing, strong mediator-target association strengths are not necessary, and therefore mediated priming is expected to occur within both the strong (e.g., CRATER – moon – SUN) and weak (e.g., STORM – rain – SUN) mediator-target association conditions. Due to the mixed list effect that is likely to occur in a double LDT from the inclusion of more strongly associated items within the same list as less associated items (McNamara & Altarriba, 1988), mediator-target association strength was a between-participants factor in Experiment 1.

Method

Participants. Undergraduates at Francis Marion University (*N* = 66) participated. In this and all subsequent experiments, participants were native speakers of English and were compensated with credit towards their Psychology course. Participants in Experiment 1 were assigned to either the strong (*N* = 30) or weak (*N* = 36) mediator-target association condition.

Materials and Design. Prime-mediator-target triads consisted of items that were sampled from Bennett and McEvoy (1999) and McNamara and Altarriba (1988) or created by the author. The forward and backward association strengths were assessed for both the prime-mediator and mediator-target links using the online University of South Florida association norms (Nelson et al., 1998). The same 60 targets were used to create new primes and mediators that had only a weak mediator-target associative link but an equally strong associative prime-mediator link (see Appendix for each item's association strengths and the means in each mediator-target condition). There were two prime-target items that were inadvertently duplicated in the strong and weak association mediator-target conditions (FINE – good – BAD; ATTEND – go – STOP). These two items appeared in all experimental lists but were removed prior to analyses in this and all subsequent experiments. Paired-samples t-tests on the remaining 58 targets confirmed that prime-mediator association strength was equivalent between the strong and weak associative items in both the forward, $t(57) = .57$, $p = .57$, and backward, $t(57) = 1.02$, $p = .31$, directions. Importantly, the manipulated mediator-target association strength was reliably higher for the strong than the weak associative items in both the forward, $t(57) = 16.54$, $p < .001$, and backward, $t(57) = 6.02$, $p < .001$, directions. There was no association between prime and target in any of the items (i.e., association strengths = 0.00).

Priming effects tend to be larger for targets following related primes that are short and have few orthographic neighbors (Hutchison et al., 2008). Hence, the length and orthographic neighborhoods of the mediated primes were assessed using the English Lexicon Project (ELP; Balota et al., 2007; http://elexicon.wustl.edu/) in order to ensure these potential confounding variables were equivalent between the mediator-target association strength conditions. Paired samples t-tests comparing the strong association and corresponding weak association mediated primes revealed equivalent word lengths ($M = 5.88$ *vs*. $M = 5.77$; $p = .74$), and equivalent orthographic neighborhoods ($M = 3.79$ vs. $M = 3.67$, $p = .90$).

Global co-occurrence between each prime-target pair was assessed using Latent Semantic Analysis (LSA; Landauer, Foltz, & Dumais, 1998; http://lsa.colorado.edu/) using the default topic space of "General Reading up to 1st year of college." Within each mediator-target condition, control items were created by re-pairing the primes with new targets (ANT – SUN; KEY – SUN) such that the prime-target LSA values would match those of the mediated items as closely as possible. Though LSA does not predict differences in target RTs among related items (Hutchison et al., 2008), higher LSA values for mediated than unrelated prime-target pairs could explain any obtained mediated priming (e.g., Chwilla & Kolk, 2002). A 2 (Relation: mediated, unrelated) × 2 (Mediator-Target Association: strong, weak) repeated measures ANOVA confirmed that mean LSA cosines for the 58 prime-target pairs used in the current study (see Table 2) were equivalent between the mediated and unrelated items, $F < 1$, $p = .40$, and between the strong and weak mediator-target association conditions, $F < 1$, $p = .81$. Moreover, this lack of a difference between the mediated and unrelated conditions was consistent across the two mediator-target association conditions, $F < 1$, $p = .87$.

To further assess whether any obtained mediated priming could be attributed to the formation of a compound-cue between the presented primes and targets, Google hits were also compared between the strong and weak association conditions. Google hits take word order into account and thus have been used as a measure of a word pair's local co-occurrence, familiarity, or frequency in American English (e.g., Jones, 2010; Wisniewski & Murphy, 2005). A 2 (Relation) × 2 (Mediator-Target Association) repeated measures ANOVA on the Google hits (shown in Table 2) indicated no difference between the mediated and unrelated items, $F < 1$, $p = .80$, or between the strong and weak mediator-target conditions, $F < 1$, $p = .27$. The lack of difference between the mediated and unrelated pairs were consistent across the mediator-target association conditions as suggested by the lack of interaction, $F < 1$, $p = .77$.

Finally, both local co-occurrence (LSA) and global co-occurrence (Google hits) were assessed between mediators and targets. The strong association between prime and mediator in both mediator-target association conditions increase the likelihood that the mediator will be accessed. However, there may be greater local and global co-occurrence between strongly associated mediator-targets than weakly associated ones.[4] If that is indeed the case, then any potential greater priming effects obtained for the stronger items in comparison to the weaker items could be due local or global co-occurrence rather than to the difference in mediator-target association strength. Mediator-target local co-occurrence (Google hits) is especially important.

Because higher Google hits represent more frequent usage of a word pair (e.g., moon – SUN) in everyday American English, participants would be more likely to include the target in the mediator's expectancy set.[5] Table 3 shows the mean LSA cosines and Google hits for the mediator-target pairs within each association condition. Paired-samples t-tests on the LSA cosines for the mediator-target pairs showed reliably higher global co-occurrences for the strong than for the weak association conditions, $t(57) = 4.21$, $p < .001$. More importantly, however, the local co-occurrence or mediator-target pair frequencies (Google hits) were equivalent between the strong and weak association conditions, $t < 1$, $p = .78$.

To further investigate the extent to which various prospective (spreading activation, expectancy) and retrospective (semantic matching/post-lexical integration, compound-cue) processes could explain the anticipated faster response times for the mediated items, additional item analyses follow each experiment. Specifically, correlations were assessed between the mediated RTs and each of the following: prime-target LSA; prime-target Google; mediator-target LSA; mediator-target Google; prime-mediator FAS; prime-mediator BAS; mediator-target FAS; mediator-target BAS.

In Experiment 1, there were two experimental lists within each between-participants mediator-target association condition. On each list, 30 targets (e.g., SUN) were paired with a mediated prime (CRATER in the strong association mediator-target condition or STORM in the weak association mediator-target condition), and 30 targets were paired with the LSA matched unrelated prime (ANT or KEY, respectively). Sixty filler items consisting of 30 non-word – word pairs (e.g., TRUP – ROCK) and 30 word – non-word pairs (e.g., ROSE – BIFE) were also included. Non-word targets were selected using the ELP (Balota et al., 2007) such that they would be equivalent in length to the word targets.

Procedure. A double LDT was used in which participants indicated whether both letter strings were real words in the English language. The prime (e.g., CRATER or STORM) was first presented for 100 ms in 22-point red Arial font on a black background and was horizontally centered just above the vertical midpoint of the screen. Then the target (e.g., SUN) was centered just below the prime until a response was provided (J key for "yes" or F key for "no"). A 1000 ms inter-trial interval (ITI) separated each trial, and 10 practice trials preceded the 120 experimental trials. Order of the experimental trials was randomized across participants.

Results and Discussion

Response times (RTs) from incorrect trials were omitted from analyses (2.8% of the data), as well as RTs greater than 2000 ms and any remaining RTs more than 2.5 SDs above or below each participant's condition mean (5.9%).[6] Accuracies and RTs were analyzed in an ANOVA with relation (mediated or unrelated) as a within-participants and within-items factor and mediator-target association strength (strong or weak) as a between-participants and within-items factor. Accuracies were slightly higher for the strong (M = .98, SE = .005) than for the weak (M = .97, SE = .007) mediator-target association conditions, $F_p(1, 64) = 5.64$, $p < .05$, and $F_i(1, 57) = 7.01$, $p = .01$. No other effects for accuracies were reliable (all ps > .80).

Mean and SDs for the response times (RTs) are reported in Table 4 for each of the four relation × mediator-target association conditions along with the priming effects (unrelated RTs – mediated RTs). Consistent with prior studies (e.g., Jones, 2010; McNamara & Altarriba, 1988), RTs were faster (95% CI: 29 ± 16 ms) for the mediated (M = 881, SE = 17) than the unrelated pairs (M = 909, SE = 18), $F_p(1, 64) = 12.82$, $p < .001$, $\eta_p^2 = .17$, and $F_i(1, 57) = 7.66$, $p < .01$. Mediated priming was reliable within the strong mediator-target condition, $F_p(1, 29) = 9.60$, $p < .01$, $\eta_p^2 = .25$, and $F_i(1, 57) = 4.22$, $p < .05$, and approached significance in the weak condition,

$F_p(1, 35) = 3.58$, $p < .07$, $\eta_p^2 = .09$, and $F_i(1, 57) = 2.51$, $p = .12$. Neither the main effect of mediator-target association (*p*s > .45) nor the interaction (*p*s > .25) was reliable.

Correlation Analyses. For this and all subsequent experiments, correlations are reported between the mediated pair RTs and each association and co-occurrence measure described in the Materials section. Across both mediator-target association conditions, only the prime-target Google hits were related to mediated RTs, $r = -.30$, $p = .001$. This correlation remained significant within the strong association condition, $r = -.36$, $p < .01$, and marginally significant within the weak association condition, $r = -.23$, $p = .087$.

Hence, although mediator-target association was not required for mediated priming in the double LDT, priming effects were slightly though not significantly facilitated for items having a strongly associated mediator-target link as demonstrated by the more robust effect for the stronger items. The influence of only the prime-target local co-occurrence (i.e., prime-target Google hits) suggests that a retrospective compound-cue process (McKoon & Ratcliff, 1992) may be responsible for the obtained mediated priming in this experiment. Indeed, double LDTs entail the simultaneous presentation of and response to prime-target pairs rather than just targets. That is, a double LDT would facilitate the formation of such a prime-target compound (e.g., PASTURE – MILK) and in turn the search for this compound in long-term memory. Hence, this compound-cue formation in mediated priming may be limited to the double LDT, in which the prime and target are simultaneously presented.

Experiment 2A

In order to assess whether a strong mediator-target association was necessary for mediated priming to occur prospectively, a continuous LDT was used. Because participants respond to each individually presented prime and target, they are not aware of prime-target pairings and consequently are not able to use a retrospective processing strategy such as compound-cue formation or semantic matching. Indeed, Shelton and Martin (1992) failed to find backward priming (e.g., BABY → STORK) in a continuous LDT, which suggests backward priming must occur retrospectively. Moreover, direct and mediated items that are only weakly associated do not typically exhibit priming in a continuous LDT (Jones, 2010; Moss et al., 1995; Shelton & Martin, 1992). Hence, mediated priming was predicted for only the strongly associated mediator-target items.

As shown in Table 1, within a continuous LDT paradigm, previous studies obtained reliable mediated priming within a mixed list that also included directly associated items and a mediated only list. Thus, it is unlikely that the anticipated lack of mediated priming for the weakly associated mediator-target items would be due to the inclusion of more strongly associated items. Nevertheless, to ensure that the anticipated failure to obtain priming for the weaker items was not due to any list context effects, the experiment was conducted first with a blocked design (Experiment 2A) and then with an unblocked mixed-list design (Experiment 2B). Given that a continuous LDT does not permit retrospective processing, mediated priming was expected to obtain for only those items having a strong mediator-target association.

Method

Participants. Sixty-four Francis Marion University undergraduates participated.

Materials and Design. The same materials were used as in Experiment 1. Both relation and mediator-target association were within-participants, with separate blocks for the mediator-target association strengths. Each mediator-target association block included 15 mediated and 15 unrelated prime-target pairs (30 word-word pairs) in addition to 30 word – non-word, 30 non-word –word, and 30 non-word–non-word filler trials for a total of 120 trials per block (240 experimental trials). Across four counterbalanced experimental lists, targets (SUN) were paired with each of the four possible primes (mediated primes: CRATER or STORM; unrelated primes: ANT or KEY), and appeared only once on each list.

Procedure. A continuous LDT task was used in which participants judged whether each individually presented prime and target was a real word. On each trial, prime and target letter strings were centered in red Arial font on a black background until participants provided a response. A 1000 ms blank screen followed after participants had responded to the prime (prior to target presentation), and a 1000 ms blank screen inter-trial interval (ITI) followed the target response prior to prime presentation on the next trial. Hence, participants were not aware of the prime-target pairings. Trial order was randomized across participants for the 60 trials within each block. Participants completed 10 practice trials prior to the first block of experimental trials.

Results and Discussion

RTs from incorrect trials were excluded from analyses (1.0% of the data), as well as outliers greater than 1500 ms and any remaining RTs more than 2.5 SDs above each participant's condition mean (an additional 4.4% of the data).[5] Target accuracies and RTs were analyzed in a 2 (Relation; within-participants) × 2 (Mediator-target association; between-participants) repeated-measures ANOVA with both factors within-items. Accuracies were at ceiling ($.987 \leq Ms \leq .993$), and there were no main effects or interactions ($ps > .10$).

Mean target RTs for each of the four relation × mediator-target association conditions are shown in Table 4. RTs were faster overall within the strong mediator-target condition ($M = 611$, $SE = 10$) than in the weak ($M = 625$, $SE = 12$), $F_p(1, 63) = 3.97$, $p = .05$, $\eta_p^2 = .06$, and $F_i(1, 57) = 11.51$, $p = .001$, $\eta_p^2 = .17$. The main effect of relation was not reliable, $F_p(1, 63) = 1.57$, $p = .21$, and $F_i(1, 57) = 1.08$, $p = .30$. Notably, however, the predicted interaction was reliable (albeit marginally by participants), $F_p(1, 63) = 3.52$, $p = .06$, $\eta_p^2 = .05$, and $F_i(1, 57) = 4.71$, $p < .05$. Specifically, within the strongly associated mediator-target condition, target RTs were faster (95% CI: 16 ± 13 ms) for the mediated than the unrelated items, $F_p(1, 63) = 6.64$, $p < .05$, $\eta_p^2 = .10$, and $F_i(1, 57) = 4.71$, $p < .05$. But within the weak condition, mediated priming did not occur, $F_p < 1$, $p = .59$, and $F_i < 1$, $p = .38$.

Correlation Analyses. Mediated target RTs across both mediator-target conditions were related to the forward ($r = -.24$, $p < .01$) but not the backward ($r = -.02$, $p = .86$) mediator-target association strengths. Moreover, in contrast to the results of Experiment 1, the obtained mediated priming was likely not due to the formation of a compound-cue given the lack of explicit pairing between prime and target and given that there was no relationship between mediated target RTs and the widely ranging prime-target Google hits ($r = -.11$, $p = .24$) or the prime-target LSA cosines ($r = -.02$, $p = .83$). Finally, RTs were not reliably related to either the mediator-target LSA cosines ($r = -.13$, $p = .15$) or to the mediator-target Google hits ($r = -.08$, $p = .41$).

The mediated priming found in the strong association mediated-target condition corroborates previous findings of associative mediated priming (e.g., Bennet & McEvoy, 1999; de Groot, 1983; McNamara, 1992b, 1994; McNamra & Altarriba, 1988; Shelton & Martin, 1992). The null result for the weakly associated mediator-target condition replicates the failure to find an effect of mediated priming in a continuous LDT (Jones, 2010) as well as other more automatic tasks (e.g., naming task, Balota & Lorch, 1986; masked priming LDT, de Groot, 1983). Target RTs were related to only mediator-target FAS (but not BAS), thus the most likely process was a prospective spreading activation from the prime (e.g., PASTURE) to mediator (e.g., cow) and then from mediator to target (e.g., MILK) without any of the ACT* model's proposed reverberation. Hence, these results support de Groot's (1983) speculation that spreading activation in a LDT will cease at the mediator unless there is also a strong association between mediator and target.

Experiment 2B

Method

Participants. Seventy-one Wayne State University undergraduates participated.

Materials, Design, and Procedure. The same materials and procedure were used as in Experiment 2A with the exception that presentation order was randomized across participants for all 240 trials rather than randomized within separate blocks for each mediator-target association.

Results and Discussion

The data were trimmed as described in Experiment 2A. RTs for incorrect trials (1.2% of the data) were removed prior to analyses, as well as outlier RTs which constituted an additional 4.5% of the data. Target accuracies and RTs were analyzed in a 2 (Relation) × 2 (Mediator-target association) ANOVA. There were no reliable main effects or interactions for the accuracies (*p*s > .25), which were at ceiling (.986 ≤ *M*s ≤ .991).

Mean target RTs for each of the four relation × mediator-target association conditions are shown in Table 4. Results were consistent with those found in Experiment 2A. The main effect of relation again was not reliable, $F_p(1, 70) = 1.12$, $p = .29$ and $F_i(1, 57) = 2.60$, $p = .11$, nor was the main effect of mediator-target association strength, $F_p(1, 70) < 1$, $p = .90$ and $F_i(1, 57) < 1$, $p = .86$. However, the predicted interaction between mediator-target association strength and relation was significant, $F_p(1, 70) = 5.39$, $p < .05$, $\eta_p^2 = .07$, and $F_i(1, 58) = 4.98$, $p < .05$. Within the strongly associated mediator-target condition, target RTs were faster (95% CI: 15 ± 13 ms) for the mediated than for the unrelated items, $F_p(1, 70) = 5.22$, $p < .05$, $\eta_p^2 = .07$, and $F_i(1, 57) =$

8.68, $p < .01$. But within the weak condition, mediated priming did not occur, $F_p < 1$, $p = .48$ and $F_i < 1$, $p = .64$.

Correlation Analyses. As in Experiment 2A, mediated target RTs across both mediator-target association conditions were related (albeit weakly and marginally) to the forward ($r = -.15$, $p = .10$) but not the backward ($r = -.05$, $p = .60$) mediator-target association strengths. Once again, compound-cue formation between prime and target did not seem to be a viable explanation given the lack of relationship with either prime-target LSA cosines ($r = -.02$, $p = .83$) or Google hits ($r = -.07$, $p = .45$). However, RTs were marginally related to mediator-target Google hits ($r = -.16$, $p = .08$), and thus the obtained mediated priming could be explained by a prospective spreading activation process as in Experiment 2A or more likely, by a combination of spreading activation, expectancy generation, and matching as posited by the previously discussed three-process theory (Neely & Keefe, 1989).

Overview of Experiments 3 and 4

Experiments 3 and 4 used a standard LDT to further investigate the importance of mediator-target association strength in mediated priming. In a standard LDT participants respond only to the target letter strings, and thus a standard LDT offers the additional benefit of manipulating the SOA or delay between prime and target to assess the time course of activation. Because there is no perfect control prime, neutral primes (blank screen) were used in Experiment 3 and unrelated primes were used in Experiment 4. As in the double LDT, participants are aware of prime-target pairings, but as in the continuous LDT primes and targets are presented individually on the screen. Thus, standard LDTs fall between continuous and double LDTs in the amount of strategic processing required. Hence, to further investigate the extent of prospective and retrospective processing, the time course of mediated priming was investigated across three

SOAs – 200, 1000, and 1800 ms. At a long 1000 ms SOA, mediated priming is likely to occur either via prospective and/or retrospective processing and thus to an equal extent within both mediator-target association conditions. However, at a short SOA of 200 ms, retrospective processing is limited though still possible (e.g., Chwilla, Hagoort, & Brown, 1998; de Groot, 1984, 1985; Estes & Jones, 2009; Jones, 2010; for review see Hutchison, 2003). That is, semantic processing of the prime is not likely to have completed prior to target presentation, thereby lessening the extent to which a set of expected targets could be generated or the extent to which a post-lexical integrative or semantic matching process could occur (e.g., de Groot et al., 1982; Hutchison, Neely, & Johnson, 2001). Thus, at a short 200 ms SOA, mediated priming effects were expected to be reliable for the strongly associated mediator-target items, but not necessarily for the weaker items.

Experiment 3

Method

Participants. Wayne State University undergraduates (N = 198) were divided among three SOA conditions: 200 ms (n = 80), 1000 (n = 56), and 1800 (n = 62).

Materials and Design. The same 60 mediated items were used as in Experiment 1. However, for the control condition, the unrelated primes were replaced with a neutral baseline prime consisting of a blank screen. Although all neutral baseline primes have their various disadvantages (Jonides & Mack, 1984; McNamara, 2005, Neely, 1991), Bodner, Masson, and Richard (2006) found that a 45 ms blank screen baseline eliminated the tendency for slower responses on baseline trials than on unrelated-prime trials. Hence, a blank screen baseline was adopted for this reason and to provide an alternative baseline to the ******** neutral prime used in Jones (2010). Filler items consisted of 30 word – non-word pairs (e.g., JOB – FEG) and 30 baseline – non-word pairs (e.g., <blank screen> – BOAM) prime-target pairs. Trials consisted of 30 mediated pairs (15 per mediator-target association), 30 baseline pairs (with a blank screen as the neutral prime), 30 word – non-word filler pairs, and 30 baseline – non-word filler pairs for a total of 120 trials. Prime-types were counterbalanced across four experimental lists.

Procedure. Participants pressed the spacebar to begin each trial. Next a blank screen appeared for 200 ms followed by a red 22-point fixation plus sign (+) for 500 ms. Then the prime word or a blank screen appeared for 150 ms, followed by a 50 ms blank screen for the 200 ms SOA, or a 850 ms blank screen for the 1000 ms SOA, or a 1650 ms blank screen for the 1800 ms SOA. Prime words were presented in red Arial font and were vertically and horizontally centered on a black screen. Targets appeared in white font until participants indicated whether the letter string was a real word by pressing the J key for "yes" or the F key for "no". As before, a 1000 ms inter-trial interval separated each trial, and 10 practice trials preceded the experimental trials. Presentation order of all 120 trials was randomized across participants.

Results and Discussion

RTs from incorrect trials (1.4% of the data) were excluded from analyses as well as RTs greater than 1500 ms and any remaining RTs more than 2.5 SDs above or below each participant's condition mean (an additional 4.8%). In both Experiments 3 and 4, accuracies and RTs were analyzed in a 2 (Relation; within-participants) × 2 (Mediator-Target Association Strength; within-participants) × 3 (SOA: 200, 1000, 1800; between-participants) ANOVA across participants (F_p) and items (F_i). All factors were within-items. Accuracies were at ceiling (*M*s > .98), and there were no reliable main effects or interactions (*p*s > .10).

Mean target RTs and priming effects (baseline RTs – mediated RTs) for each of the four relation × mediator-target association conditions are shown in Table 5. Overall, target RTs were

29 ms faster following the mediated primes (M = 654, SE = 8) than the baseline (blank screen) primes (M = 683, SE = 8), $F_p(1, 195) = 61.98$, $p < .001$, $\eta_p^2 = .24$, and $F_i(1, 57) = 71.60$, $p < .001$, $\eta_p^2 = .56$. The three-way interaction did not reach conventional levels of significance, $F_p(2, 195) = 1.83$, $p = .16$, and $F_i(2, 114) = 1.09$, $p = .34$. However, a relation × SOA interaction, $F_p(2, 195) = 12.84$, $p < .001$, $\eta_p^2 = .12$, and $F_i(2, 114) = 13.91$, $p < .001$, $\eta_p^2 = .20$, indicated overall greater mediated priming effects at the longer 1000 ms and 1800 ms SOAs in comparison to the shorter 200 ms SOA (see Table 5). To investigate this interaction further along with the *a priori* hypotheses (i.e., no or reduced priming for the weaker items at the short 200 ms SOA, but reliable priming for both the strong and weak items at the 1000 ms SOA), three separate ANOVAs (relation × mediator-target association) were conducted within each SOA.

For the 200 ms SOA, only the interaction between relation and mediator-target association, $F_p(1, 79) = 7.62$, $p = .007$, $\eta_p^2 = .09$, and $F_i(1, 57) = 4.14$, $p < .05$, $\eta_p^2 = .07$, was reliable. As shown in Table 5, the strongly associated mediator-target items exhibited reliable priming (95% CI: 15 ± 11 ms), F_p (1, 79) = 6.07, p < .05, $\eta_p^2 = .07$, and $F_i(1, 57) = 5.14$, p < .05, $\eta_p^2 = .07$, with no priming found for the weaker items $F_p < 1$, $p = .34$, and $F_i < 1$, $p = .50$. These results corroborate the pattern of results found in the continuous LDT (Experiments 2A and 2B) with priming found for the strong but not the weak mediator-target association items. More specifically, results demonstrate that a strong association in both links may be needed in order for mediated priming to occur within a short time frame typically consistent with more automatic processing (i.e., < 300 ms).

In contrast, for the 1000 ms SOA, there was a robust main effect of relation with faster target RTs (95% CI: 14 ± 11 ms) following the mediated than the neutral primes, $F_p(1, 55) = 42.69$, $p < .001$, $\eta_p^2 = .44$, and $F_i(1, 57) = 51.44$, $p < .001$. Moreover, this priming effect was consistent across both mediator-target association strengths, as indicated by the lack of an interaction, $F_p < 1$, $p = .89$, and $F_i < 1$, $p = .75$. Further analyses revealed equivalent and robust priming effects for the strong, $F_p(1, 55) = 27.14$, $p < .001$, $\eta_p^2 = .33$, and, $F_i(1, 57) = 26.87$, $p < .001$, and the weak $F_p(1, 55) = 25.06$, $p < .001$, $\eta_p^2 = .31$, and, $F_i(1, 57) = 29.89$, $p < .001$, mediator-target association strengths.

Priming effects were still quite robust at the 1800 ms SOA, with faster target RTs following the mediated than the baseline primes, $F_p(1, 61) = 24.08$, $p < .001$, $\eta_p^2 = .28$, and $F_i(1, 57) = 32.80$, $p < .001$. The priming effects again were consistent across both mediator-target associations, $F_p < 1$, $p = .89$, and $F_i < 1$, $p = .78$. Indeed, priming effects were reliable within both the strong, $F_p(1, 61) = 17.16$, $p < .001$, $\eta_p^2 = .22$, and, $F_i(1, 57) = 19.27$, $p < .001$, and the weak $F_p(1, 61) = 15.21$, $p < .001$, $\eta_p^2 = .20$, and, $F_i(1, 57) = 11.87$, $p = .001$, mediator-target association conditions. As predicted, mediated priming was reliable only for the strongly associated mediator-target items at the 200 ms SOA, whereas priming was reliable for both mediator-target association conditions at the longer 1000 and 1800 ms SOAs. Further item analyses were conducted to better investigate the influence of association strengths and co-occurrence on target RTs, and in turn the likely prospective and/or retrospective processes involved at each SOA for each mediator-target association condition.

Correlation Analyses. Within the 200 ms SOA condition, there were no reliable relationships with any of the association or co-occurrence variables (rs < .11, ps ≥ .24). Possible explanations for this null finding are reserved for the General Discussion.

Within the 1000 ms SOA, only the prime-mediator BAS was reliable ($r = -.19$, $p < .05$). Though BAS was weak overall and for most of the individual items (see Appendix), there were 12 items that were moderately associated (i.e., association strengths between .10 and .19) and 4 items that were strongly associated (i.e., association strengths > .20). Thus, the correlation could be somewhat inflated due to these 16 items. However, this was not the case, as the correlation was stronger in the absence of these 16 moderate and strongly associated items ($r = -.29$, $p < .01$). Hence, the mediated priming at the 1000 ms SOA was most likely due to a retrospective process such as the ACT* model's posited reverberation (i.e., backward spreading activation, in this case from mediator to prime) or to semantic matching. No other correlations even approached significance (rs $< \pm .09$, ps $\geq .45$).

Within the 1800 ms SOA, mediated target RTs were reliably related to mediator-target Google hits ($r = -.26$, $p < .01$). This correlation may reflect a greater likelihood of targets being included in the expectancy sets of the mediators in the stronger mediator-target condition than in the weaker one (e.g. inclusion of SUN would be more likely in the expectancy set for the strong mediator, moon, than for the weaker mediator, rain).

Experiment 4

Because priming effects may be inflated when neutral primes are used (de Groot, 1982; Jonides & Mack, 1984), Experiment 4 aimed to replicate the general pattern of findings in Experiment 3 using unrelated primes in place of the blank screen neutral primes. As in Experiment 3, priming effects were expected to be greater for the strongly associated mediator-target items than the weaker items at the short 200 ms SOA, but equivalent at the 1000 ms SOA. Moreover, for the strongly associated mediator-target items, reliable priming was predicted for each of the three SOAs. In contrast, for the weakly associated items, reliable priming was expected at only the longer SOAs.

Methods

Participants. Wayne State University undergraduates ($N = 201$) were assigned to one of three SOA conditions: 200 ms ($n = 69$), 1000 ($n = 71$), and 1800 ($n = 61$).

Materials and Procedure. The same experimental items were used as in Experiment 3. However, for the control condition, the neutral (blank screen) primes were replaced with the unrelated primes used in Experiments 1 and 2. Filler items consisted of 60 word – non-word pairs (e.g., JOB – FEG). The same procedure was used as in Experiment 3.

Results and Discussion

RTs from incorrect trials (1.2% of the data) were excluded from analyses as well as RTs greater than 1500 ms and any remaining RTs more than 2.5 SDs above or below each participant's condition mean (an additional 5.3% of the data). As in Experiment 3, accuracies and RTs were analyzed separately in a 2 (Relation) × 2 (Mediator-Target Association) × 3 (SOA) repeated-measures ANOVA. Accuracies were at ceiling (*M*s > .98), and there were no reliable main effects or interactions (*p*s > .10).

Mean target RTs and priming effects for each of the four relation × mediator-target association conditions are shown in Table 5. With the exception of the 1800 ms SOA, the pattern of results replicated that of Experiment 3. Overall, target RTs were faster (95% CI: 10 ± 6 ms) following mediated ($M = 654$, $SE = 6$) than baseline ($M = 664$, $SE = 7$) primes, $F_p(1, 198) = 9.98$, $p < .01$, $\eta_p^2 = .05$, and $F_i(1, 57) = 12.86$, $p = .001$, $\eta_p^2 = .18$. There was also a main effect of SOA (albeit not quite reliable by participants) with longer target RTs at the 200 ms SOA ($M = 671$, $SE = 4$) and 1800 ms SOA ($M = 665$, $SE = 3$) than the 1000 ms SOA ($M = 641$, $SE = 3$), $F_p(2, 198) = 2.19$, $p = .11$, and $F_i(1, 57) = 39.17$, $p = .001$, $\eta_p^2 = .41$. Although the three-way interaction was not reliable, $F_p < 1$, $p = .50$, and $F_i < 1$, $p = .71$, the combined effects of relation and mediator-target association on RTs were assessed at each SOA in order to assess whether results replicated the pattern found in Experiment 3 (i.e., no priming for the weaker items at the short SOA).

Within the 200 ms SOA, the overall main effect of relation was not reliable, $F_p(1, 68) = 1.48$, $p = .23$, and $F_i(1, 57) = 2.83$, $p = .10$. However, there was a trend towards an interaction, $F_p(1, 68) = 3.16$, $p = .08$, $\eta_p^2 = .04$, though not by items $F_i(1, 57) = 1.25$, $p = .27$, indicating mediated priming for the strongly associated mediator-target items, $F_p(1, 68) = 3.16$, $p = .08$, $\eta_p^2 = .04$, and $F_i(1, 57) = 3.99$, $p = .05$, $\eta_p^2 = .07$, but not for the weaker items, *F*s < 1, *p*s = .91. Hence, results once again demonstrated that a strong association may be required in the mediator-target link in order for mediated priming to occur at this short SOA.

In contrast, within the 1000 ms SOA, there was no interaction between relation and mediator-target association strength, $F_p < 1$, $p = .59$, and $F_i < 1$, $p = .56$, but rather an overall main effect of relation with faster target RTs (95% CI: 16 ± 9 ms) following the mediated than unrelated primes, $F_p(1, 70) = 13.14$, $p = .001$, $\eta_p^2 = .16$, and $F_i(1, 57) = 11.86$, $p = .001$. Moreover, mediated priming occurred within both the strong, $F_p(1, 70) = 7.68$, $p < .01$, $\eta_p^2 = .10$, and $F_i(1, 57) = 8.70$, $p < .01$, and the weak mediator-target association condition, $F_p(1, 70) = 5.10$, $p < .05$, $\eta_p^2 = .07$, and $F_i(1, 57) = 4.08$, $p < .05$. Thus, as in Experiment 3, results demonstrated that strong mediator-target association is not required for mediated priming when there is ample time for retrospective processing.

At the 1800 ms SOA, the interaction between relation and mediator-target strength approached significance, $F_p(1, 60) = 3.54$, $p = .06$, $\eta_p^2 = .06$, and $F_i(1, 57) = 1.85$, $p = .18$. As in the 200 ms SOA, target RTs were faster following the mediated primes for the strong mediator-target items, $F_p(1, 60) = 6.27$, $p < .05$, $\eta_p^2 = .10$, and $F_i(1, 57) = 4.13$, $p < .05$, but not for the weaker items, $F_p < 1$, $p = .64$, and $F_i < 1$, $p= .84$. The lack of mediated priming within the 1800 ms SOA for the weaker items in this experiment contrasts with the reliable mediated priming found for these weaker items in Experiment 3, and thereby demonstrates that the choice of baseline condition influences the extent to which priming may occur. In contrast to unrelated primes, neutral primes fail to activate the linguistic system, thereby producing artificially longer RTs for the targets following these neutral primes (de Groot et al., 1982; Jonides & Mack, 1984; McNamara, 2005) and in turn overestimating the true priming effects. This overestimation of priming is even more likely to occur at longer SOAs (i.e., > 1000 ms; de Groot et al., 1982; Jonides & Mack, 1984). The longer target RTs following the neutral (blank screen) primes in the 1800 ms SOA of Experiment 3 (M = 697) in comparison to those following the unrelated primes in the 1800 ms SOA of Experiment 4 (M = 669) further support this alternative explanation and cast doubt as to whether mediated priming can occur for these weaker items at a longer SOA.

Correlation Analyses. As in the previous experiments, correlation analyses were conducted to determine the likely mechanisms behind the obtained priming effects at each SOA. Within the 200 ms SOA, there were again no reliable correlations between mediated target RTs and any of the association or co-occurrence variables (rs ≤ ± .11, ps ≥ .24).

Within the 1000 ms SOA, mediated target RTs were reliably related to mediator-target FAS (r = - .18, p < .05) and mediator-target LSA cosines (r = - .22, p < .05). The relation with mediator-target BAS approached significance (r = -.15, p = .11). No other correlations were reliable (rs ≤ ± .10, ps ≥ .33). Hence, the relationship with mediator-target FAS suggests a prospective spreading activation and/or expectancy process (i.e., the continuation of spreading activation from mediator to target and/or the inclusion of the target in the expectancy set for the activated mediator). The relationship with LSA and the emerging relationship with mediator-target BAS may suggest some additional retrospective processing such as the reverberation in the

ACT* model of spreading activation or a semantic matching process. That is, across association conditions, it may be easier to derive a plausible mediator upon target presentation for mediator-target pairs with higher global co-occurrence (e.g., wet – DRY, horse – RIDE, bread – BUTTER, music – DANCE, with LSA cosines > .70) in comparison to those pairs with lower mediator-target LSA cosines (e.g. rule – BOOK,; field – MOUSE, camp – CHILD, with LSA cosines < .10).

Within the 1800 ms SOA, prime-target Google was marginally significant ($r = -.15$, $p = .103$), but there were no other reliable correlations (rs $\leq \pm .11$, ps $\geq .22$). However, because mediated priming obtained in only the strong mediator-target association condition, further analyses done within only the strong condition showed a relatively robust relationship with mediator-target Google hits ($r = -.48$, $p < .001$). As in the continuous LDT of Experiment 2B, this suggested that the more strongly associated targets were more likely to be included in the set of expected targets following activation of the mediator.

General Discussion

For the items having a weak mediator-target association (e.g., CAMEL – desert – HOT), priming occurred in the double LDT (Experiment 1) and in the 1000 ms SOA of the standard LDTs (Experiments 3 and 4), thereby replicating prior findings of mediated priming attributable to retrospective processing (e.g., Chwilla et al., 2000; Hill et al., 2002; Jones, 2010; Sass et al., 2009). In contrast, for the items having a strong mediator-target association (e.g., ICEBERG – cold – HOT), mediated priming was found in all the LDTs used in this study ranging from a double LDT, in which retrospective processing was greatly facilitated, to a continuous LDT, in which only prospective processing could occur.

Theoretical Implications: One Theory Does Not Fit All

Collectively, results demonstrate that mediated priming can occur via either prospective and/or retrospective processes depending on the mediator-target association strength. As Neely and Keefe (1989; Neely, 1991) noted in their proposed three-process hybrid theory (i.e., spreading activation, semantic matching, and expectancy), multiple processes can explain the existence of a priming effect. The simultaneous presentation of prime and target in the double LDT (Experiment 1) greatly facilitates retrospective processing. Furthermore, only the local co-occurrence (as measured by Google) of the prime-target compound (e.g., ICEBERG – HOT) were related to the RTs for the mediated prime-target pairs. Hence, mediated priming within a double LDT may be at least partially due to the familiarity of this prime-target compound in LTM, as claimed by the compound-cue model (McKoon & Ratcliff, 1992; Ratcliff & McKoon, 1994). In essence, the double LDT task may present a task demand to form such a compound given that the lexical decision is made on the combination of prime and target rather than on just the target. Note, however, that simultaneous presentation of prime and target would not preclude activation of the mediator (e.g., COLD). Indeed, Huff and Hutchison (2011) found activation and subsequent false recall and recognition of critical items (e.g., SNOW) that were indirectly related to unrelated list items (e.g., SLOPE, REINDEER, CORN) that were in turn related to mediators (e.g., SKI, SLEIGH, FLAKE) converging on the critical item.

In the continuous LDT (Experiments 2A and 2B), only prospective processing was available and only for the items with a strong mediator-target FAS. Hence, the current results offer an additional explanation for the failure to find a mediated priming effect in prior LDT experiments (Balota & Lorch, 1986; de Groot, 1983), as the items in those studies also lacked a strong mediator-target association (see Table 1). The occurrence of mediated priming in the continuous LDT for the strongly associated mediated items replicates prior findings (Bennett &

McEvoy, 1999; McNamara, 1992a, 1992b, 1994; McNamara & Altarriba, 1988), and supports prospective spreading activation as one of several viable mechanisms of mediated priming. The reliable correlations between mediator-target FAS and the target RTs further suggested a forward prospective process such as spreading activation. Given the long delay between presentation of and response to the prime and target presentation (approximately 1800 ms), it is likely that the previously described hybrid three-process theory (Neely & Keefe, 1989; Neely, 1991) consisting of spreading activation, expectancy generation, and matching could also explain the obtained results.

In the standard LDTs (Experiments 3 and 4), results were influenced by the mediator-target association strength as well as by the SOA. Within the 1800 ms SOA, the type of baseline prime was also an important factor.

At the 200 ms SOA, mediated priming obtained for only the items having a strong mediator-target association (cf. Experiments 3 and 4). Neither association strength nor any of the other variables were correlated with mediated target RTs. Hence, the underlying mechanism for the mediated priming is not entirely clear. It may be that there was indeed spreading activation from prime to mediator to target, but that the association strengths were too low to yield a reliable correlation with mediated target RTs. Hutchison et al. (2008) found a reliable correlation between association strength and priming, but their items all had forward association strengths (FAS) > .50, whereas the current items had a mean mediator-target FAS of .17 when averaged across both association conditions. Additionally, the mediated priming for only the strongly related items may be due at least in part to retrospective processing by post-lexical integration or semantic matching, both of which may occur rapidly in LDTs with SOAs < 300 ms (Estes & Jones, 2009; Chwilla et al., 1998; de Groot, 1984, 1985; Jones, 2010; Weisbrod et al., 1999).

Notably, using the same 200 ms LDT paradigm, Jones (2010, Experiments 3 and 4) found reliable (albeit weak) mediated priming for pure items lacking an association in either link (e.g., WIND – kite – STRING). So then why was there not also reliable mediated priming in the current study for the weakly associated mediator-target items (e.g., UMBRELLA – rain – WATER)? One possible reason is that identification of the mediator within this short time frame may have been easier in Jones (2010) because all of the items shared an instrumental relation between prime and mediator (e.g., WIND – kite). Indeed, prior research has demonstrated robust priming for such instrumental relations even in the absence of strong associations (Hare, Jones, Thomson, Kelly, & McRae, 2009; Moss et al., 1995; for review see Estes, Golonka, & Jones, 2011).

Mediated priming for the 1000 ms SOA standard LDT were consistent across mediator-target association strength conditions, albeit more robust with the neutral than with the unrelated primes. Correlation analyses across Experiments 3 and 4 suggest a retrospective process such as semantic matching and/or reverberation (cf. ACT*) as the underlying mechanism.

Results varied at the 1800 ms SOA depending on the type of baseline prime. Reliable mediated priming obtained when the neutral blank screen primes were used in Experiment 3, but not when unrelated primes were used (Experiment 4). As shown in Table 5, target RTs were longer in the 1000 and 1800 ms SOA conditions following the neutral (blank screen) primes of Experiment 3 than when following the unrelated primes of Experiment 4. In turn, the slower target RTs in the neutral prime condition yielded artificially larger priming effects in Experiment 3. The slower target RTs following unrelated compared to neutral primes has also been found in prior direct and mediated priming studies (e.g., de Groot et al., 1986; Jones, 2010). As noted by Antos (1979), the use of non-linguistic primes (e.g., +++++++), may lead participants to initially regard the target as the prime, thereby adding a few milliseconds to the target RTs. Indeed, de

Groot et al., (1982) found longer RTs for both word and pseudoword targets that followed cross primes in comparison to the more linguistic prime “blank.” Jonides and Mack (1984) further argued that repetition of a prime stimulus like “blank” may reduce the attention given to the prime. Consequently, Experiment 3 followed the reasoning of Bodner et al. (2006) in using a no-prime (i.e., blank screen) as the baseline in Experiment 3. Yet this no-prime baseline was also problematic at this long SOA given the failure to replicate the reliable mediated priming for the same weaker items using an unrelated prime in Experiment 4 or with a pronounceable non-word prime in Jones (2007). Thus, the priming found for the weak items in Experiment 3 likely was an experimental artefact of the longer target RTs resulting from the failure of the no-prime baseline to have the same alerting function as the mediated prime. Note, however, that these baseline primes were not problematic at the short 200 ms SOA, in which RTs were similar between Experiments 3 and 4. Based on the results of Experiments 3 and 4 as well as a prior experiments (de Groot et al., 1982; Jones, 2007), the use of a repetitive prime (e.g., ********) or no-prime should be avoided when assessing mediated priming at longer SOAs > 1000. Instead, as recommended by McNamara (2005), the use of pronounceable non-words may be a better option for the baseline prime in future mediated priming studies, at least within long SOAs.

Future studies using additional methods (e.g., lateralized LDTs, ERP, fMRI) may serve to pinpoint the underlying neural regions associated with prospective versus retrospective processes in mediated priming. Results of one lateralized LDT study (Yochim, Kender, Abeare, Gustafson, & Whitman, 2005) found mediated priming (with strong associations in both links) at a short 215 ms SOA only when primes and targets were presented to opposite hemispheres. Yochim and colleagues proposed that this contralateral priming was indicative of an expiration of purely prospective spreading activation prior to 215 ms. Thus, their results are consistent with the current finding of reliable priming for the more strongly mediated items in the 200 ms SOA (Experiments 3 and 4), and also suggested that this priming was due to some retrospective process (i.e., reverberation, post-lexical integration, or semantic matching). As Yochim and colleagues noted, further mediated priming research with shorter SOAs (i.e., < 200 ms) is needed to investigate the possibility that spreading activation expires quickly and gives way to other retrospective processes.

Moreover, incorporation of neuroscientific methods would serve to further investigate the time course of associative mediated priming. For example, just as N400 effects are larger for direct than mediated items (Hill et al., 2002), they may also be larger for items with stronger prime-mediator and mediator-target associations than for items lacking a strong association in one or both links. Such an associative boost may be indicated not only by the amplitudes of the N400 but also by the duration. For instance, Koivisto and Revonsuo (2001) found longer N400 effects for lexically associated directly related pairs (e.g., WIND – MILL), occurring in both 250-375 ms and 375-500 ms time windows, than for semantically similar pairs (e.g., SOFA – BED), occurring in only the 250-375 ms time window. Likewise, there may be a longer window of activation for mediated targets having a strong rather than weak mediator-target association.

Finally, the current study focused on the mediator-target association strength, in order to investigate this as a potential explanation of the discrepancies found in prior studies (i.e., mediated priming in McNamara & Altarriba, 1988, but not in de Groot, 1983). The logical next step is an extensive focus on the role of association between prime and mediator within various LDT paradigms, while holding mediator-target strength constant. Extensive and separate investigations of the association strengths in each link would better inform future studies that could then directly compare the relative impacts of prime-mediator versus mediator-target association strength.

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Appendix

Stimuli and Association Strengths

Strong MT Association	Prime-Mediator		Mediator-Target		Weak MT Association	Prime-Mediator		Mediator-Target	
PRIME – mediator – TARGET	FAS	BAS	FAS	BAS	PRIME – mediator – TARGET	FAS	BAS	FAS	BAS
CEILING – fan – AIR	.17	.03	.24	.00	STARS – sky – AIR	.27	.00	.02	.05
DILEMMA–problem –ANSWER	.61	.00	.20	.00	PURPOSE – reason – ANSWER	.32	.03	.03	.00
LAUGH – cry – BABY	.48	.12	.11	.12	YO-YO – toy – BABY	.42	.00	.02	.00
SLIPPERS – robe – BATH	.12	.06	.18	.00	FEATHERS – bird – BATH	.69	.00	.01	.00
OUTCOME – end – BEGIN	.31	.00	.52	.49	READY – go – BEGIN	.42	.00	.01	.00
CEREMONY – wedding – BELL	.44	.01	.15	.00	PRIEST – church – BELL	.38	.00	.03	.05
RATTLE – snake – BITE	.46	.09	.28	.00	DENTIST – teeth – BITE	.46	.06	.02	.10
FABLE – story– BOOK	.48	.01	.42	.00	POLICY – rule – BOOK	.39	.01	.01	.00
STAMP – mail– BOX	.24	.07	.13	.00	DUNE– sand – BOX	.57	.02	.00	.00
DOUGH – bread – BUTTER	.31	.06	.49	.36	HUSK– corn – BUTTER	.64	.12	.03	.00
BROIL – bake – CAKE	.27	.05	.40	.03	CELERY – carrot – CAKE	.22	.08	.02	.00
NITROGEN – gas – CAR	.29	.00	.38	.04	HANDCUFFS – police – CAR	.35	.00	.05	.00
GUARDIAN – parent – CHILD	.54	.06	.23	.04	TENT – camp – CHILD	.46	.13	.03	.00
TUXEDO – prom – DANCE	.29	.01	.22	.00	SYMPHONY –music – DANCE	.33	.00	.03	.10
SOAP – clean – DIRTY	.24	.00	.53	.29	ORDERLY – neat – DIRTY	.22	.00	.04	.00
SLIPPERY – wet – DRY	.80	.01	.46	.50	PIGMENT – skin – DRY	.30	.00	.02	.03
COMPANION – friend – ENEMY	.64	.03	.22	.31	LOVE – hate – ENEMY	.46	.41	.02	.10
KNUCKLE – fist – FIGHT	.26	.05	.36	.09	CUSHION – pillow – FIGHT	.19	.03	.04	.00
GLOVE – hand – FINGER	.55	.05	.36	.27	HEEL – toe – FINGER	.20	.01	.03	.09
CABIN – log – FIRE	.42	.11	.27	.00	FOSSIL – fuel – FIRE	.17	.00	.01	.00
HOE – garden – FLOWER	.29	.00	.39	.04	COCOON – butterfly – FLOWER	.41	.02	.04	.00
DAGGER – knife – FORK	.61	.00	.33	.37	DRESSING – salad – FORK	.43	.20	.02	.00
DRAW – picture – FRAME	.22	.00	.32	.81	CANVAS – painting – FRAME	.11	.01	.01	.00
SHUTTER – window – GLASS	.48	.00	.26	.14	CORK – wine – GLASS	.52	.00	.04	.00
PEARL – necklace – GOLD	.27	.09	.22	.02	RUBY – diamond – GOLD	.25	.01	.04	.03
MOLD – green – GRASS	.20	.00	.25	.36	SCARECROW – straw – GRASS	.13	.00	.02	.00

Appendix (continued)

Strong MT Association PRIME – mediator – TARGET	Prime-Mediator FAS	Prime-Mediator BAS	Mediator-Target FAS	Mediator-Target BAS	Weak MT Association PRIME – mediator – TARGET	Prime-Mediator FAS	Prime-Mediator BAS	Mediator-Target FAS	Mediator-Target BAS
MOW – grass – GREEN	.28	.08	.36	.25	BONUS – money – GREEN	.29	.00	.06	.01
CHARCOAL –grill–HAMBURGER	.25	.00	.22	.00	CUCUMBER–pickle –HAMBURGER	.24	.10	.03	.00
PASTRY – doughnut – HOLE	.15	.00	.38	.02	BELLY – button – HOLE	.20	.01	.07	.02
ICEBERG – cold – HOT	.30	.00	.41	.68	CAMEL – desert – HOT	.28	.00	.05	.00
PORCELAIN – doll – HOUSE	.31	.00	.31	.02	BARK – dog – HOUSE	.57	.00	.02	.01
LIPS – kiss – HUG	.43	.00	.22	.41	PASSION – love – HUG	.61	.00	.01	.13
PEEL – orange – JUICE	.57	.00	.24	.66	LETTUCE – tomato – JUICE	.29	.06	.03	.00
SHOULDER – arm – LEG	.34	.00	.67	.50	FRIED – chicken – LEG	.31	.08	.04	.00
CANCER – death – LIFE	.29	.00	.27	.49	LUNG – breathe – LIFE	.36	.05	.04	.00
SACK – bag – LUNCH	.44	.11	.22	.01	SEMESTER – school – LUNCH	.32	.00	.00	.01
PASTURE – cow – MILK	.47	.04	.35	.39	CRUMB – cookie – MILK	.16	.04	.03	.04
ANT – hill – MOUNTAIN	.31	.00	.43	.27	LAVA –volcano – MOUNTAIN	.39	.18	.02	.00
DOG – cat – MOUSE	.67	.51	.26	.54	PLOW – field – MOUSE	.25	.00	.03	.00
DOCUMENT – paper – PENCIL	.41	.00	.16	.00	RAZOR – sharp – PENCIL	.31	.03	.01	.08
TERMINAL – airport – PLANE	.34	.00	.76	.00	CONDUCTOR – train – PLANE	.28	.00	.05	.05
CELERY – carrot – RABBIT	.22	.08	.21	.02	DOUGHNUT – hole – RABBIT	.38	.02	.03	.00
CUT – blood – RED	.17	.03	.34	.05	HEN – rooster – RED	.20	.31	.02	.00
FORGIVE – forget – REMEMBER	.64	.01	.53	.49	LETTER – note – REMEMBER	.30	.00	.00	.00
RANCH – horse – RIDE	.34	.00	.26	.37	PILOT – plane – RIDE	.73	.00	.03	.00
POLE – vault – SAFE	.24	.05	.26	.02	KEY – lock – SAFE	.26	.41	.02	.04
FLUSH – toilet– SEAT	.42	.07	.20	.02	BUMPER – car – SEAT	.65	.00	.00	.00
FINGERNAIL – polish – SHINE	.27	.00	.32	.02	CEILING – floor – SHINE	.22	.16	.04	.00
ZIPPER – pants – SHIRT	.43	.02	.19	.27	ZEBRA – stripe – SHIRT	.46	.05	.05	.00
ELEPHANT – big – SMALL	.17	.00	.64	.35	PARENT – child – SMALL	.23	.04	.04	.00
CRACKLE – pop – SODA	.61	.01	.43	.44	TIN – can – SODA	.50	.07	.07	.03
CRATER – moon – SUN	.40	.00	.30	.15	STORM – rain – SUN	.37	.05	.06	.00
COUCH – chair – TABLE	.29	.11	.31	.76	CAFFEINE – coffee – TABLE	.49	.08	.02	.00
SEAFOOD – lobster – TAIL	.14	.14	.12	.00	HAM – pig – TAIL	.19	.03	.01	.00

Appendix (continued)

Strong MT Association	Prime-Mediator		Mediator-Target		Weak MT Association	Prime-Mediator		Mediator-Target	
PRIME – mediator – TARGET	FAS	BAS	FAS	BAS	PRIME – mediator – TARGET	FAS	BAS	FAS	BAS
ONION – cry – TEARS	.21	.00	.22	.49	WORKOUT – sweat – TEARS	.16	.00	.03	.03
JAW – mouth – WASH	.25	.00	.20	.00	SCALP – hair – WASH	.38	.00	.02	.00
ROW – boat – WATER	.74	.02	.36	.00	UMBRELLA – rain – WATER	.70	.04	.06	.00
CHAIN – saw – WOOD	.22	.00	.19	.01	STEEL – metal – WOOD	.31	.12	.01	.02
***M*s**	**.37**	**.04**	**.31**	**.21**		**.35**	**.05**	**.03**	**.02**
*SD*s	.16	.07	.14	.23		.15	.09	.02	.03

Notes: MT = Mediator-Target link; FAS = Forward Association Strength; BAS = Backward Association Strength. All association

Strengths are based on the Nelson et al. (1998) norms.

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Footnotes

1. Throughout the paper, SMALL CAPS are used to indicate experimentally presented primes and targets, and lowercase is used to indicate non-presented mediators.
2. Arrows are presented between concepts when referring to a prospective process such as spreading activation or expectancy generation, whereas dashes are used between concepts to reflect retrospective processes.
3. Balota and Lorch (1986) found mediated priming in a mixed list pronunciation task, which is also considered to be a more automatic task than the LDT in that pronunciation tasks are not prone to strategic influences such as the presence of the more strongly related direct prime-target pairs.
4. I thank an anonymous reviewer for raising this point.
5. The proposed connection between mediator-target Google hits and expectancy processing is speculative and is limited to tasks favoring the generation of an expectancy set (i.e., standard LDT tasks with long SOAs > 1500 ms).
6. In Experiment 1, an initial data trimming maximum of 2000 ms was used because participants were judging whether both the prime and target were real words in the English language. However, in all subsequent experiments, this initial data trimming criteria was lowered to 1500 ms, because lexical decisions were made for singly presented letter strings.

Table 1. *Summary of Prior Mediated Priming Effects by Task and the Associative Strengths of the Stimuli*

LDT	Experiment (List type)	Priming Effect (ms) (Unrelated – Mediated)	Prime-Mediator Link Forward	Prime-Mediator Link Backward	Mediator-Target Link Forward	Mediator-Target Link Backward
Double	B&L, Exp. 2 (mixed)	7	.29 (.21)	.24 (.20)	.10 (.11)	.16 (.18)
	M&A, Exp. 1 (mixed)	2	.28 (.26)	.05 (.11)	.27 (.22)	.24 (.21)
	M&A, Exp. 1 (mediated)	21*	.28 (.26)	.05 (.11)	.27 (.22)	.24 (.21)
	Jones, 2010, Exp. 1 (mediated)	43*	.04 (.05)	.02 (.07)	.02 (.03)	.10 (.17)
Standard	De Groot, 1983[a], Exp. 1 (mixed)	19*	.47 (.19)	n/a	.24 (.13)	n/a
	De Groot, 1983, Exp. 2 (mediated)	18*	.47 (.19)	n/a	.24 (.13)	n/a
	Weisbrod et al., 1999[b] (mixed)	43*	.28 (.23)	.19 (.19)	.20 (.24)	.20 (.20)
	Jones, 2010, Exp. 4 (mediated)	17*	.04 (.05)	.02 (.07)	.02 (.03)	.10 (.17)
Continuous	B&E[a] (mixed)	16*	.37 (.17)	.03 (.06)	.38 (.16)	.29 (.24)
	M&A, 1988, Exp. 2 (mixed)	22*	.28 (.26)	.05 (.11)	.27 (.22)	.24 (.21)
	M&A, 1988, Exp. 2 (mediated)	14*	.28 (.26)	.05 (.11)	.27 (.22)	.24 (.21)
	Jones, 2010, Exp. 2 (mediated)	-6	.04 (.05)	.02 (.07)	.02 (.03)	.10 (.17)
Masked Prime	De Groot, 1983, Exp. 7	-2	.65 (.13)	n/a	.05 (.07)	n/a

Notes: * $p < .05$; B&L = Balota & Lorch, 1986; M&A = McNamara & Altarriba, 1988; B&E = Bennett & McEvoy, 1999; Association strengths were taken from original study or were assessed using the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1998) for the studies not reporting these values. [a]Only the forward association strengths were reported in the De Groot (1983) study. [b]Because this study consisted of German words, the association strengths taken from the Nelson et al. norms provide only an estimate of the actual association strengths.

Table 2. *Means, SDs, Minimum, and Maximum LSA Cosines and Google Hits for Prime-Target Pairs*

Prime-Target Pair	**Example**	**LSA**				**Google Hits (× 1000)**			
		M	**SD**	**Min**	**Max**	**M**	**SD**	**Min**	**Max**
Strong Mediator-Target Association									
Mediated	ROW–WATER	.17	.14	-.07	.63	105	268	0.08	1800
Unrelated	PEEL–WATER	.17	.13	-.02	.57	104	389	0.01	2840
Weak Mediator-Target Association									
Mediated	UMBRELLA–WATER	.17	.12	.00	.53	55	116	0.06	657
Unrelated	FOSSIL–WATER	.16	.10	.00	.42	75	262	0.05	1780

Note. SD = Standard Deviation; Google hits were assessed on November 7th, 2010.

Table 3. *Means, SDs, Minimum, and Maximum LSA Cosines and Google Hits for Mediator-Target Pairs*

Mediator-Target Association Strength	Example	LSA				Google Hits (× 1000)			
		M	SD	Min	Max	M	SD	Min	Max
Strong	boat–WATER	.40	.21	.10	.78	1342	2041	12	9120
Weak	rain–WATER	.26	.14	.03	.73	1311	2554	3	12200

Note. SD = Standard Deviation; Google hits were assessed on November 7th, 2010.

Table 4. *Means and (SEs) of Response Times (ms), and Priming Effects, Experiments 1and 2*

Experiment, Task	Strong Associative MT	Weak Associative MT
Experiment 1, Double LDT		
Unrelated	911 (32)	908 (20)
Mediated	873 (29)	887 (19)
Priming Effect	**38********	**21**[#]
Experiment 2A, Continuous LDT (blocked design)		
Unrelated	619 (11)	622 (12)
Mediated	603 (9)	626 (13)
Priming Effect	**16****	**-4**
Experiment 2B, Continuous LDT		
Unrelated	600 (9)	591 (9)
Mediated	585 (7)	595 (9)
Priming Effect	**15***	**-4**

Notes: [#] $p < .10$; * $p < .05$; ** $p < .01$; MT = mediator-target

Table 5. *Means and (SEs) of Response Times (ms), and Priming Effects, Experiments 3 and 4*

			SOA					
			200		1000		1800	
Exp't	**MT Asssoc**	**Prime-type**	**M**	**SE**	**M**	**SE**	**M**	**SE**
3	Strong	Baseline	674	13	681	15	692	14
		Mediated	660	12	635	15	655	14
		Priming Effect	**14***		**46****		**37****	
	Weak	Baseline	667	12	681	15	702	14
		Mediated	673	13	633	15	665	14
		Priming Effect	**-6**		**48****		**37****	
4	Strong	Unrelated	678	13	643	13	674	13
		Mediated	662	11	624	11	657	12
		Priming Effect	**16***		**19***		**17***	
	Weak	Unrelated	673	13	654	13	664	14
		Mediated	674	12	640	12	668	13
		Priming Effect	**-1**		**14***		**-4**	

Notes: * $p < .05$; ** $p < .01$; MT = mediator-target