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Is there a "strength effect" in automatic semantic priming?

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According to spreading activation models of automatic priming, highly related associates should yield stronger priming effects than weakly related associates. The strength of relations is usually based on word association norms. However, this strength effect has been found in some studies but not in others. The present study suggests that one factor that might be responsible for this inconsistency is whether the weak associate is the primary or nonprimary response in the word association norms. This possibility was explored by comparing priming effects of weak nonprimary and primary associates with those of strong primary associates. Comparable priming effects were found for the strong and weak primary associates whereas the weak nonprimary associates did not yield any priming effects. These results were obtained both in paired (Experiment 1) and single (Experiment 2) presentation priming procedures. Thus, the rank of the associate is an important factor in predicting the magnitude of the priming effect.

The semantic/associative priming effect is a robust phenomenon in which a response to a target word is faster and often more accurate if this response is preceded by a related word (e.g., *church* preceded by *priest*). One of the traditional accounts of this effect is the spreading activation theory (Anderson, 1983; Collins & Loftus, 1975; Neely, 1977, 1991; Posner & Snyder, 1975). According to this account words are represented in the mental lexicon as individual units or *nodes*. Semantically or associatively related representations are closely located to each other or interconnected by strong links. Presentation of a word leads to the activation of its mental representation. This activation spreads to neighboring representations, thus lowering their identification threshold. If one of these activated nodes is presented as a target, its recognition will be facilitated.

One of the assumptions derived from the spreading activation account is that the priming effect would be modulated by the strength of the associative relation between the prime and the target. Pairs that are more strongly related should produce more priming effects than pairs that are only weakly related. This conjecture stems from the fact that most theories of spreading activation assume that activation decreases as the associative distance between the prime and the target increases. As a result, the priming effect should vary as a function of the associative strength between word pairs.

However, this *strength effect* has been reported in several studies (e.g., Cañas, 1990; de Groot, Thomassen, & Hudson, 1982; Warren, 1974) but not in others (e.g., Fischler, 1977; Koriat, 1981; Warren, 1977). Some researchers have attempted to attribute the inconsistencies to the different tasks that have been used, claiming, for example, that it is observable in naming but elusive in lexical decision tasks (Burt, Walker, Humphreys, & Tehan, 1993). Others have ascribed the evasiveness of the effect to the great variability in the mean associative strength of the prime–target groups across different experiments (de Groot et al., 1982). Still others have endeavored to resolve the conflicting results by distinguishing between studies with short and long stimulus onset asynchrony (SOA), asserting that strength effects are usually found with short SOAs (Cañas, 1990).

Each of these arguments might explain the discrepant results that exist in the literature, but a further investigation of the issue is warranted because the arguments addressing the discrepancies are all post hoc and have not been tested empirically. Cañas's (1990) study is probably the only one that manipulated different factors that might have influenced the strength effect, such as the relatedness proportion, SOA, and the relative proportion of strong and weak related pairs. However, his study focused mainly on defining the factors that influence the strength effect when word processing is performed under strategic and controlled conditions. He did not examine prospective sources affecting this effect under automatic conditions. Yet, a study of the strength effect under conditions that encourage automatic processing is necessary in order to tap lexical internal structure and processing.

One potential source for the conflicting findings, thus far overlooked, is the location of the associate in the association hierarchy. The evaluation of associative strength

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is generally based on discrete word association norms in which participants are presented with a stimulus word and are asked to respond with the first word that comes to mind (Clark, 1970; de Groot, 1989; Szalay & Deese, 1978). The frequency of responses with the same word to the specific stimulus word determines the associative strength between a stimulus word and a response word. Strong associates are response words that were given by a large proportion of the participants, whereas weak associates are words that were given as a response by a small proportion of the participants. But, whereas strong associates are usually also the primary response, weak associates could either be the primary *or* a nonprimary response. An example of the former type of weak associates is the word *train*, which is the most frequent response to the word *whistle*, although produced by only 11% of the participants. An example to the latter type of weak associates is the word *banana*, which is also given by 11% of the participants as an association to *yellow*, but the words *green, sun*, and *color* precede it with higher frequency (values are taken from Rubenstein, Anaki, & Henik, 2003).

An examination of several studies that did not demonstrate the strength effect reveals that the weak associates comprising the experimental stimuli belong to the first type; that is, they were the most frequent associates (e.g., Fischler, 1977; Koriat, 1981; Warren, 1977). In contrast, studies in which the strength effect was demonstrated used weak associates that were not the primary responses to a stimulus word and were preceded by more frequent associates (e.g., Cañas, 1990; Coney & Serna, 1995; de Groot et al., 1982). Thus, it seems that the location of the response in the response hierarchy is critical to the appearance of the strength effect.

The aim of the present study was to pursue this observation in a more stringent experimental setting. Thus, three types of associated pairs were constructed: strong primary associates with a mean association frequency of 42% (e.g., *elephant–trunk*), weak primary associates with a mean association frequency of 10% (e.g., *violin–music*), and weak nonprimary associates with a mean association frequency of 10% (e.g., *bathtub–foam*). If the relative position of the associate is critical, the priming effects of the strong associates would be larger only when compared with the effects of the weak nonprimary associates, but not when contrasted with the weak primary associates. However, if the determining factor is the association frequency of the associate, the priming effects of the strong primary associates would be greater than the effects of both types of weakly associated pairs.

EXPERIMENT 1

Method

Participants. Forty-two undergraduate students at Ben-Gurion University of the Negev participated in the experiment for course credit. All participants had normal or corrected-to-normal vision and were native Hebrew speakers.

Materials. The critical stimuli consisted of 72 pairs of associates selected from Hebrew association norms (Rubenstein et al., 2003; see the Appendix for the critical stimuli and the description of norms administration). Twenty-four pairs were strongly associated with a mean association frequency of 42% (range 33%–55%). Each associate in this group was the primary associative response given by the participants in the norming procedure. The second group was composed of 24 primary associates with a mean association frequency of 10% (range 7%–12%). The third group consisted of 24 associates with a mean association frequency of 10% (range 7%–13%). In contrast to the associates in the first two groups, the associates in the third group were preceded by three more frequent associates. Because the word pairs in the critical groups differed from each other, both primes and targets were equated on various attributes, such as word length, concreteness, and familiarity. Targets were also equated on backward association and mean response time (RT), which is the response latency of the target word when given as an associate (Table 1).

Two lists were created so that all participants saw each prime and target only once, either in the related or unrelated condition. In each list unrelated pairs were formed by re-pairing the primes and the targets. In addition to the 36 critical unrelated pairs in each list, 36 other unrelated pairs were created to serve as unrelated buffer trials. The inclusion of these fillers yielded a .33 relatedness propor-

Table 1
Characteristics of Critical Stimuli

	Strong (First Associate)		Weak (First Associate)		Weak (Fourth Associate)	
	M	*SE*	*M*	*SE*	*M*	*SE*
Primes						
Familiarity	5.41	.18	5.68	.16	5.82	.17
Concreteness	5.02	.32	5.10	.33	5.54	.22
Length in letters	4.46	.22	4.50	.25	4.42	.19
Targets						
Familiarity	5.75	.20	5.97	.18	6.12	.16
Concreteness	5.06	.38	5.03	.37	5.31	.27
Length in letters	4.00	.21	4.13	.26	3.79	.18
Backward association	.10	.05	.08	.04	.08	.04
Mean RT (msec)	1,505	33.84	1,554	66.65	1,530	64.07

Note—The concreteness and familiarity scores are based on participants' ratings on a scale from 1 (*low concreteness* or *very unfamiliar*) to 7 (*high concreteness* or *very familiar*), following the instructions of Spreen and Schultz (1966) for concreteness ratings and Gernsbacher (1984) for familiarity ratings. Each rating procedure was performed by 100 different participants.

tion (RP) that was designed to minimize strategic influences on the potential priming effects. Finally, 72 word–nonword pairs were added to the two lists. The nonword targets were formed by recombining letters of valid Hebrew words and forming pronounceable but meaningless letter strings. Each nonword target was preceded by a prime word that was not used in the word target condition. Thus, the nonword ratio was 0.5.

Procedure. Participants were tested individually, seated approximately 50 cm from a computer screen. Stimuli were displayed on an Olivetti color monitor controlled by Micro Experimental Laboratory (MEL2) software (Schneider, 1988) implemented in an Olivetti M290-30 PC compatible computer.

Each trial began with a 250-msec fixation mark (+) presented at the center of the screen. Following the offset of the fixation mark, the prime appeared for 100 msec in the center of the screen. The target stimulus appeared after 100 msec of a blank screen display and remained until the participant responded. The intertrial interval was 500 msec.

Participants were asked to respond as quickly and accurately as possible by pressing a red key ("Z" key) with their left hand on the computer keyboard if the target stimulus was a nonword and a green key ("/" key) with their right hand if the target was a word. A set of 20 practice trials was composed, containing the same proportion of trials for each condition as in the experiment. The results of these trials were not included in the analysis.

Results and Discussion

Only RT data from correct responses were entered into the analyses. RTs greater than 2.5 *SD* above or below each participant's mean RT in each condition were discarded, resulting in the loss of 2.4% of the data. The mean RT and error rate of the participants as a function of condition are presented in Table 2.

A one-way analysis of variance (ANOVA) was performed on participants' (F_1) and items' (F_2) mean priming scores (unrelated target − related target) in the different associative strength conditions (strong [first associate], weak [first associate], weak [fourth associate]). This analysis yielded a significant effect [$F_1(2,82) = 3.17$, $MS_e = 2{,}758, p < .05$, $F_2(2,69) = 3.02$, $MS_e = 4{,}319$, $p < .05$]. Planned comparisons revealed larger priming effects for the primary strong associates than for the nonprimary weak associates [$F_1(1,41) = 4.59, MS_e = 5{,}879$, $p < .05$, $F_2(1,69) = 5.07$, $MS_e = 4{,}319, p < .05$]. Primary weak associates also yielded greater priming effects than nonprimary weak associates [$F_1(1,41) = 3.82$, $MS_e = 6{,}660, p = .05$, $F_2(1,69) = 3.91$, $MS_e = 4{,}319$, $p < .05$]. Finally, no differences were found between the effects of primary strong and weak associates.[1] The priming effects of the two primary associate groups were significant and differed from zero [primary strong associates, $t_1(41) = 2.58, SE = 11.72, p < .01, t_2(23) = 2.91$, $SE = 10.57, p < .01$; primary weak associates, $t_1(41) = 2.60$, $SE = 11.27, p < .01$, $t_2(23) = 2.00$, $SE = 12.79$, $p = .05$]. No reliable effects were found in the nonprimary weak associates group.

Analyses of the error rate did not reveal significant differences in the priming effects between the three associative strength conditions. Although the trends in the error data were consistent with the pattern in the RT data, no significant priming effects were observed when each group was analyzed separately.

The results of this experiment show reliable strength effects when weak nonprimary associates are compared with strong primary associates, thus replicating previous studies demonstrating strength effects using a similar type of stimuli (e.g., de Groot et al., 1982). In accordance with past research that did not demonstrate the strength effect (e.g., Koriat, 1981), the present results also show that the priming effects of the primary weak associates did not differ from the effects of primary strong associates. Thus, the associate position in the response hierarchy appears to be a critical factor in obtaining the strength effect. The present results, however, seem to indicate that the source of this effect is not dependent on the proportion of participants who supplied the specific associate in response to a stimulus word. Rather, the effect appears to rely on the position of the associate in the response hierarchy; the priming effects of associates that are ranked as primary responses will be comparable in spite of different proportions of responders. Moreover, priming effects of primary associates will be greater than those of nonprimary associates even though the proportion of responders is similar.[2]

The position of the associate in the response hierarchy is offered as a sole account for the pattern of results reported in Experiment 1. An alternative account of the data might suggest that the critical conditions differed in their semantic type relationship. Several types of se-

Table 2
Mean Response Latency (in Milliseconds) and Percentage of Errors (Experiment 1)

	Strong (First Associate)		Weak (First Associate)		Weak (Fourth Associate)	
	M	*SE*	*M*	*SE*	*M*	*SE*
Response Latency						
Related	586	13	583	14	598	17
Unrelated	617	15	612	15	592	14
Priming effect	+31	11	+29	11	−6	9
Percentage of Errors						
Related	1.00	.004	1.39	.005	1.98	.007
Unrelated	2.18	.006	2.78	.009	2.98	.007
Priming effect	+1.18	.007	+1.39	.010	+1.00	.010

Note—Priming effect = unrelated − related.

mantic relationships are found in the present set of critical items, such as category coordinates (e.g., *peach–plum*), similarity (e.g., *pride–arrogance*), concept–feature (e.g., *oil–black*), feature–concept (e.g., *yellow–banana),* meronymy (e.g., *elephant–trunk*), exemplar–category (e.g., *parachutist–soldier*), collocations (e.g., *air–mail*), verb–noun (e.g., *kindle–light*), script (e.g., *menu–restaurant*), and functional relations (e.g., *ladle–soup*). Some studies suggest, although not conclusively, that certain types of semantic relations differ in the scope of their automatic semantic priming. For example, Moss, Ostrin, Tyler, and Marslen-Wilson (1995) have shown that under conditions that encourage automatic processing no priming is obtained for script-related pairs, whereas it is observed for functionally related pairs. Thus, it could be claimed that specific semantic types, which yield more automatic semantic priming, typify the pairs of the primary associate groups (strong and weak), whereas other types of semantic relations, those that do not yield priming, typify the pairs that comprise the nonprimary associate group. In other words, the distribution of the various semantic types will vary across the three critical groups. However, an examination of the distribution of the different semantic classes among the three experimental conditions revealed no difference [$\chi^2(18) = 18.04, p > .45$].[3] In addition, we probed whether the different semantic types in the present experiment yielded divergent priming effects, as suggested by the alternative account. An ANOVA performed on the mean priming scores of the different semantic types across the three experimental conditions was not significant. Hence, the type of the semantic relationship does not seem to explain the present results for two main reasons. First, the different semantic classes are equally distributed in the three experimental groups. Second, no indication was found in the present experiment for the dependency of the priming magnitude on specific semantic relations.

Another possible interpretation is that although the pairs in the three conditions did not differ in their semantic classification, the strength of the semantic relations between the critical pairs may have varied. McRae and Boisvert (1998) have found that strong semantically related targets are facilitated under conditions that encourage automatic processing while weak related pairs are not. If primary and nonprimary associated pairs differed in their semantic strength, then the pattern of results obtained in Experiment 1 could be easily explained as an outcome of the differences in semantic strength.

In order to investigate this option we asked a group of 14 participants, who had not taken part in Experiment 1, to rate the relatedness strength of the critical prime–target pairs on a 7-point scale (1 = *not related at all*, 7 = *highly related*). Before beginning the rating procedure, the participants were informed that several types of semantic relationships might be found in the pairs. The various types were described and specific examples (different from the critical pairs) were given. The ratings were as follows: primary strong associates, $M = 5.32$, $SE = .15$; primary weak associates, $M = 4.72$, $SE = .15$; nonprimary weak associates, $M = 4.85$, $SE = .17$. There was a significant main effect of the three types of associate conditions [$F(2,69) = 3.79$, $MS_e = 0.62$, $p < .05$]. Planned comparisons showed that primary strong associates were more semantically related than both weak primary associates and nonprimary associates [$F(1,69) = 6.79$, $MS_e = 0.62$, $p < .01$, and $F(1,69) = 4.28$, $MS_e = 0.62$, $p < .05$, respectively]. The weak associates ratings did not differ from each other.

The relatedness ratings obtained for the different associate groups show that the differences in the priming effects could not be explained in terms of semantic strength. Indeed, primary strong associates are more related than nonprimary weak associates, and this could account for the differences in the priming effect. Yet, these associates are also more related than primary weak associates are, and greater priming effects would have been expected if semantic strength was the underlying factor. Moreover, because primary and nonprimary associates did not differ in their similarity ratings, equivalent priming effects are hypothesized to be obtained. In conclusion, a semantic strength interpretation of the results can provide a satisfactory account for only a fraction of the present results.

The measures adopted in Experiment 1, such as short SOA (200 msec) and low RP (0.33), were intended to minimize strategic processing in an attempt to uncover the structure of the mental lexicon and the organizing principles underlying it. Nevertheless, the possibility that nonautomatic processes did occur cannot be completely ruled out. Priming effects, according to some theories, can arise from the participants' controlled strategies. The two prominent types of strategic explanations are *prospective expectancy models* (Becker, 1980; Posner & Snyder, 1975) and *retrospective semantic matching* (de Groot, 1984; den Heyer, Briand, & Dannenbring, 1983; Neely & Keefe, 1989; Neely, Keefe, & Ross, 1989; Seidenberg, Waters, Sanders, & Langer, 1984). According to the former account, participants use the prime to generate a set of expected targets that are related to the prime. If the actual target is indeed part of the set, its recognition is facilitated. The latter account emphasizes the postlexical locus of the priming effect: Once the target has been accessed the participants utilize the relationship between the prime and the target to determine their lexical decision response. Specifically, participants are biased to respond *word* if the prime and target are related, because the target is most likely to be a word if it is related to the prime. Conversely, the participants are inclined to provide a *nonword* response if the pair is not related. As a result, additional time is required to overcome this bias and provide the correct *word* response to the unrelated word target.

The short SOA and low RP adopted in Experiment 1 are considered useful methods in minimizing the prospective expectancy generating strategies. A short SOA presumably prevents participants from developing an expectancy set, due to insufficient time (de Groot, 1984; den Heyer et al., 1983; Neely, 1977; Stolz & Neely, 1995). Similarly, a low proportion of related targets is claimed to discourage participants from generating potential related targets (e.g., Chiarello, Richards, & Pollock, 1992). Low RP is also considered useful in reducing retrospective semantic matching (Neely, 1991; Neely et al., 1989) for the following reason: If the relatedness proportion is low, participants have less incentive to examine the relationship between the prime and the target in order to bias their response. In addition, Neely and Keefe (1989) asserted that short SOA deters participants from semantic matching, since the short prime–target interval does not allow the participants to access the prime's meaning before the target appears. In spite of these arguments, a general concern could be voiced that strategic processing might still be operating in this procedure, at least by participants who notice the existence of relationship between several pairs. Although this perception may not lead to expectancy generation, due to the short SOA, some postlexical semantic matching might be performed (de Groot, 1985).

Recently, a modified version of the priming paradigm has been introduced aiming to reduce the influence of strategic processes (McNamara & Altarriba, 1988; McRae & Boisvert, 1998; Shelton & Martin, 1992). In this version of the priming paradigm, stimuli are presented individually and participants perform a lexical decision task for both the prime and the target. This method is considered an improved procedure for obtaining automatic semantic priming effects because participants are less aware of the prime–target pairing than in the paired presentation priming technique. Thus, it is less plausible that participants would initiate a semantic matching strategy that would bias their lexical decision responses.

Empirical support for the nonstrategic nature of the priming effect with the single presentation lexical decision task was provided by Shelton and Martin (1992, Experiment 1), who obtained mediated priming with this modified procedure. The existence of mediated priming, in which prime and target are connected by a mediated association (e.g., priming of *tiger* by *mane* mediated through *lion*), is an indicator of automatic priming because participants cannot anticipate the target on the basis of the prime. Nor can they find, after the lexical access of the target, any relation between it and the prime. In addition, Shelton and Martin (1992, Experiment 2) have demonstrated that no backward priming (e.g., priming the target *crew* by the prime *cut*) is obtained in the single presentation compared with the paired presentation procedure. The lack of backward priming is an additional sign of the involvement of automatic spreading activation in the single presentation procedure because this type of priming can be attributed mainly to a postlexical checking strategy (Seidenberg et al., 1984; but see Kahan, Neely, & Forsythe, 1999).

In summary, the use of the more stringent automatic priming procedure, namely the single presentation lexical decision task, may corroborate the results obtained in Experiment 1. If comparable priming effects are obtained for primary strong and weak associates, while differential priming is found between weak primary and weak nonprimary associates, the claim that the association hierarchy plays a key role in obtaining the strength effect will be further substantiated.

EXPERIMENT 2

In Experiment 2 we aimed to explore automatic processes by using the single presentation priming procedure, first used by McNamara and Altarriba (1988). Due to the fact that a lexical decision response is required for both prime and target, participants are presumably unaware of the prime–target pairing. Consequently, the participants are not likely to be engaged in strategic processing underlying expectancy or semantic matching while performing the lexical decision task.

Method

Participants. Thirty undergraduate students at Ben-Gurion University of the Negev participated in the experiment in exchange for course credit. All were native Hebrew speakers with normal or corrected-to-normal vision.

Materials and Procedure. The stimuli and procedure were identical to those of Experiment 1 with the exception that participants performed a lexical decision task for every letter string. A letter string appeared on the screen until the participant responded. The next letter string followed immediately after the response. Prime and target pairs were presented successively but participants were not informed of this pairing design.

Results and Discussion

A trimming procedure, identical to the one carried out in Experiment 1, was performed, resulting in the discarding of 2.5% of the trials. The mean RT and error rate as a function of condition are presented in Table 3. As in Experiment 1 an ANOVA was performed on participants' (F_1) and items' (F_2) mean priming scores (unrelated target − related target) in the different associative strength conditions. A significant effect was obtained, indicating differences in the priming effects between the three conditions [$F_1(2,58) = 5.25, MS_e = 2,660, p < .01$, $F_2(2,69) = 3.58, MS_e = 2,773, p < .05$]. Planned comparisons revealed that both primary strong and weak associates yielded greater priming than the nonprimary weak associates [primary strong associates vs. nonprimary weak associates, $F_1(1,29) = 11.43, MS_e = 2,336$, $p < .005$, $F_2(1,69) = 6.41, MS_e = 2,773, p < .01$; primary weak associates vs. nonprimary weak associates, $F_1(1,29) = 4.04, MS_e = 3,098, p = .05, F_2(1,69) = 4.06$, $MS_e = 2,773, p < .05$]. The priming effects of primary strong and weak associates did not differ.[4] The priming effects of the two primary groups were significant and differed from zero [primary strong associate: $t_1(29) = 4.51, SE = 9.57, p < .001, t_2(23) = 3.36, SE = 11.54$, $p < .005$; primary weak associates: $t_1(29) = 2.19, SE = 13.61, p < .05, t_2(23) = 3.02, SE = 10.26, p < .01$]. No reliable effects were found in the non-primary weak associate group.

Table 3
Mean Response Latency (in Milliseconds) and Percentage of Errors (Experiment 2)

	Strong (First Associate)		Weak (First Associate)		Weak (Fourth Associate)	
	M	*SE*	*M*	*SE*	*M*	*SE*
Response Latency						
Related	535	18	545	18	560	19
Unrelated	578	19	575	19	562	20
Priming effect	+43	9	+30	13	+2	12
Percentage of Errors						
Related	1.40	.006	.00	.000	.30	.003
Unrelated	.60	.004	.30	.003	.80	.004
Priming effect	−.80	.008	+.30	.003	+.50	.006

Note—Priming effect = unrelated − related.

Analyses of the error rate did not reveal significant differences between the three associative strength conditions. In addition, no significant priming effects were observed when each group was analyzed separately.

The results of the present experiment basically replicate those obtained in Experiment 1: Priming effects were observed with the strong primary pairs but not the nonprimary weak pairs. Moreover, when primary strong and weak associates were contrasted, a comparable effect was obtained. Thus, the results are commensurate with past studies in which these two patterns of results were demonstrated. However, in contrast to the initial view regarding these results as incompatible, the present interpretation finds no contradiction between past studies. Because of the importance of the associate's rank, differences in priming effects are expected to occur between strong and weak associates only if the weak associate is not a primary response.

Aside from clarifying an empirical difficulty, some theoretical implications can be drawn from these results. Traditional network models of memory (Anderson, 1983; Collins & Loftus, 1975) envisage memory as a network of interconnected nodes, each representing a concept. When a concept is activated its activation spreads throughout the network and temporarily increases the activation of nearby concepts. The amount of activation given to neighboring nodes is negatively correlated with (1) the distance between the concepts and the source node, and/or (2) the strength of the pathways between them. A powerful tool in examining the nature of this network is the discrete free-word association norms (Clark, 1970; de Groot, 1989; Szalay & Deese, 1978). More specifically, the strength of the links that connect a concept node to other nodes is indicated by the association proportion or frequency. Weak links will be characterized with low-association frequency whereas high-association frequency will typify strong links.

According to this theoretical approach, the association frequency is an important factor determining the magnitude of the priming effect. Thus, a low-frequency associate reflecting a weak relation to the stimulus concept would yield less priming than a high-frequency associate. The present results clearly indicate that this is not the case. The priming of weak primary associates was not significantly different from that of strong primary associates, whereas the lack of priming of the nonprimary weak associates did differ from the effects of both strong *and* weak primary associates.

One interpretation that can be advanced in order to account for the present results is that some concepts may have several strongly related concepts situated equidistant from the source node. Because in discrete free-word association norms only one response is permitted, the responder will name the associate that first completes the association retrieval process. However, because the retrieval probability is approximately the same for all the strongly related concepts, on some occasions one concept will be retrieved first and consequently named, whereas on other occasions another concept will be given as a response. As a result, the association frequency of the primary response will be low, but this low frequency will not be an indication of weak relationship between the prime and the associate. Rather, it would suggest that the prime word is related to several strong associates. Because the discrete word association norms procedure allows only one response by participants, the frequency of the primary response is not expected to be high given that the other strong associates are mentioned as well by other participants. Thus, the association frequency in the discrete word association norms does not genuinely reflect the strength of the relationship between the prime and the primary associate. The actual strength of the primary weak associate is revealed only in the priming effect.

According to this hypothesis the structure of the conceptual network of primes with primary weak and strong associates is different. The former type of network consists of several strong associates (as well as weak associates), whereas the latter type consists mainly of one strong associate and several weak associates. The frequency reported in word association norms, therefore, does not necessarily index the strength of links between connected nodes. Both primary strong and weak associates have strong relationships to the prime, as revealed by the comparable priming effect.

One measure that can validate our suggestion to view the ranking of an associate in the discrete word association norms as a viable indicator of relationship strength is its ranking obtained in a continuous free-word association task. In this task participants generate as many associates to a stimulus word as possible in a prespecified amount of time (de Groot, 1989; Noble, 1952). The data collected with this procedure enable not only the measurement of the proportion of participants who responded with this associate but also the mean ranking of each associate, across all participants. With this approach it can be determined whether the serial order of associates obtained in the discrete word association norms does in fact mirror the actual ranking of related concepts in the lexicon. Thus, if our suggestion to view the associate's rank in discrete word association norms as valid indicator of association strength is correct, we would expect to find differences between the average ranking of primary and nonprimary weak associates in a continuous free-word association norms.

This norming procedure was performed recently in our laboratory (Rubenstein et al., 2003; see the Appendix for description of the norming procedure) and the mean rankings of all the associates in the present study were measured. The following results were found: The mean rankings of the weak nonprimary, weak primary, and strong primary associates were 4.94, 3.64, and 2.19, respectively [$F(2,69) = 11.53$, $MS_e = 1.69$, $p < .001$]. All groups differed significantly from one another [primary strong associates vs. nonprimary weak associates, $F(1,69) = 23.02$, $MS_e = 1.69$, $p < .001$; primary weak associates vs. non primary weak associates, $F(1,69) = 5.14$, $MS_e = 1.69$, $p < .05$; primary strong associates vs. primary weak associates, $F(1,69) = 6.4$, $MS_e = 1.69$, $p < .05$]. Thus, associates ranked in fourth position in the discrete word association norms were ranked lower in the continuous word association norms than associates ranked in first position. These results substantiate the suggestion that information concerning the structure of the network can be elicited from the discrete word association norms and specifically from the serial position of the associates.

One seemingly conflicting result that merits discussion is the different ranking scores of the primary strong and weak associates. Primary strong associates appeared, on average, earlier in the participants' reported list of associates than primary weak associates. How can this finding be reconciled with the comparable priming effects obtained in our study and with the fact that both types of associates were ranked in the discrete word association norms as the primary response? We suggest that this result is not surprising in light of our claim that the targets in the primary weak associate condition are characterized as being part of a set with several strong associates. These associates might sometimes precede the primary weak associate in the continuous free-word association task. Therefore, on average, the primary weak associate will be ranked by participants *later* than the primary strong associates in the continuous free-word association task, although it will be ranked *before* the nonprimary weak associate.

The lack of any priming effects for the weak nonprimary pairs in the two experiments is consistent with de Groot et al.'s (1982) findings, which showed comparable response latencies for targets following weakly related primes and neutral (the word *blank*) primes. Cañas (1990), on the other hand, found a 17-msec priming effect for weakly related targets. However, this effect was collapsed over several SOA and RP conditions. An examination of the short SOA (200 msec) and low RP (.17) condition in Cañas's study, which is the most similar to the present study, reveals −18 msec of priming. Thus, the strength effect obtained under conditions encouraging automatic processing is usually characterized by the lack of priming for the weakly related nonprimary associates.

GENERAL DISCUSSION

The experiments reported herein were designed to settle conflicting results found in the literature concerning the effects of associative strength on automatic priming. Several studies have shown a strength effect in which priming for strong associates was larger than for weak associates (e.g., Cañas, 1990; de Groot et al., 1982; Warren, 1974). In contrast, other studies have failed to show differential priming for the two types of associates (e.g., Fischler, 1977; Koriat, 1981; Warren, 1977). The conjecture advanced in the present study was that some of the discrepancies are due to the different types of weak associates used in prior studies. In studies in which the weak associates were the primary responses, no strength effect was revealed. However, in studies comparing nonprimary weak associates with primary strong associates, the strength effect was obtained. Indeed, the present investigation demonstrates that the strength effect is dependent on whether the weak associate is the most frequent response or not. This dependency was obtained both with paired presentation (Experiment 1) and single presentation (Experiment 2) priming procedures.

As noted earlier, these results are not consistent with spreading activation theories, which assert that the activation of a target is proportional to the strength of the connections between the target and the prime nodes in the lexical network (e.g., Collins & Loftus, 1975). As a result, these theories predict an enhancement of the priming effect of strongly related concepts relative to weakly related ones. If measures of association frequencies, obtained in discrete word association norms, are valid estimates of relationship strength (de Groot, 1989), then priming effects should interact with association frequency. Our results do not support this prediction. Taken as a whole, the present findings rather point to the importance of hierarchical position of associate in the response set rather than to its association frequency per se. Primary associates, regardless of their association frequency, will elicit greater priming than nonprimary associates.

One potential modification that can be adopted in order to reconcile spreading activation theory with our results is to consider the rank of the associate in the set of responses when determining the strength of association. We suggested above that the rank of the associate might be a better indicator than association frequency and that the strength of connections should be perceived in terms of the position of the associate in the response hierarchy. The interpretation that we advanced in order to account for the existence of primary associates with low association frequency was that some concepts are characterized by having several strong associates. Because the discrete word association norms limit the participants to one response, these strong associates will appear in the response set but each one will have low association frequency. Thus, a low association frequency of the primary associate should not be conceived in this case as a sign of weak relationship between prime and target but rather as pointing to the existence of several strong associates.

It should be also noted that according to this interpretation associations that are ranked as the primary response should be regarded as strongly related to the prime stimulus regardless of their association frequency. However, not all associates that are ranked as nonprimary should be automatically classified as weakly related. Some of them could potentially be strong associates whose association frequency differs only slightly from that of the primary response. In order to define correctly the nature of the associate, the formation of the response set should be determined. One approach would be a measure of a ratio score of the mean association frequency between the primary associate and the specific nonprimary associate. For example, an associate ranked in the fourth position with a frequency of 10% should be conceived as strongly related if the frequency of the primary response is 12% (yielding a ratio score of 1.2), and conversely, as weakly related if the frequency of the primary response is 25% (yielding a ratio score of 2.5).

We now turn to consider the implication of the present results on other accounts of automatic priming effects. Compound cue theories (Dosher & Rosedale, 1989; McKoon & Ratcliff, 1992; Ratcliff & McKoon, 1988) suggest a different mechanism according to which prime and target are combined by participants in short-term memory and used as a cue to access long-term memory. The familiarity of the compound is determined by the strength of associations between the items in long-term memory. If the items are strongly associated, either by co-occurrence or semantic relationships, the familiarity value will be high, and vice versa when the items are weakly associated. The familiarity value of the compound is used by participants in making their lexical decision response. Thus, if the familiarity value is high, as in associated pairs, the *word* response is facilitated. If, however, the familiarity value is low, as in unassociated pairs, additional processing time is needed to supply the correct response.

Are the present results problematic to compound cue theories? It is important to remember that the present study voices the concern that association frequencies obtained in discrete word association norms cannot be perceived as direct predictors of the magnitude of the priming effect. However, this criticism has already been advanced by proponents of the compound cue theory (McKoon & Ratcliff, 1992). Specifically, McKoon and Ratcliff have shown that weakly related targets (e.g., *grain)* that are not associates of the prime (*deer*) according to word association norms, by neither direct nor mediated links, are still facilitated. Their conclusion was that word association frequencies cannot be accepted as an infallible index to associative links in memory and as a valid predictor of the priming effects. As an alternative they recommend more reliable indices such as frequency co-occurrence in large corpora of spoken language or semantic similarity measures. Thus, the present results that point to the problematic use of word association norms as a predictor of the priming effect size do not seem to place any difficulty on compound cue theorists, who would prefer to abandon it completely.

An alternative view of automatic priming effects has been developed in connectionist modeling (Kawamoto, 1993; Masson, 1991, 1995; McRae, de Sa, & Seidenberg, 1997; Plaut, 1995; Sharkey & Sharkey, 1992). Masson's (1991, 1995) *distributed memory model* is based on a Hopfield net (Hopfield, 1982) and consists of perceptual input and conceptual output units. According to this model, semantically related words are similar in their pattern of activation, and consequently fewer cycles are needed to reach a stable state when a related target is presented. In contrast, when an unrelated target is presented a completely new set of updates should be reconstructed in order to reach a stable pattern of activation.

According to Masson's (1991, 1995) model, the meaning of a concept is determined by the context in which it occurs. Similar concepts frequently co-occur and as a result share many features of the mutual context. Thus, if discrete word association norms reflect frequency co-occurrence of associated pairs (Spence & Owens, 1990), then different pairs with identical association frequency should also be similar in their semantic features overlap. Consequently, the pairs would not differ in their pattern activation and would yield equal priming effects. The present results evidently do not support these conjectures because (1) different priming effects were found for weak primary and nonprimary associates, and (2) similar priming effects were found for strong and weak primary associates.

The model advanced by Plaut (1995) differs from Masson's (1991, 1995) model in several ways. From the present viewpoint the major divergence is expressed in the distinction made between semantic and associative relations: Semantic relations are encoded, as in the previous model, by the degree of overlap of the activated semantic units. Associative relations, however, are encoded by the probability that one word would follow the other during training. An associated target follows a prime more frequently than an unassociated target, making the network more capable of shifting from the prime pattern of activation to the target pattern of activation.

Plaut (1995) did not manipulate and test different co-occurrence probabilities, so it is hard to speculate whether the model predicts that the network responds to the absolute value of the probability of co-occurrence or to the relative value of the probability. If the latter option is correct, it is possible to deduce that any two primary associates will not differ in the number of cycles required to obtain a stable pattern, because the network corresponds maximally to the most frequent shift of pattern activation.

In conclusion, beyond the partial settlement of past controversies concerning the strength effect, the present results raise some theoretical issues pertaining to the mechanism of the spreading activation process and the structure of the mental lexicon. The main issue is probably the difficulty that confronts spreading activation theories in predicting priming effects on the basis of discrete word association norms (see also McKoon & Ratcliff, 1992). One possibility is to abandon the notion of discrete word association norms as reflecting strength of relationship in the lexicon and as predicting priming effects. One potential substitute might be latent semantic analysis (LSA; Landauer & Dumais, 1997; Landauer, Foltz, & Laham, 1998), which is a statistical/mathematical technique that analyzes a large corpus of natural text and generates a representation from which similarity measures between words can be computed. One of the salient characteristics of this technique is its ability to infer "deeper" relationships between words that are not tapped by more traditional frequency co-occurrence counts. Thus, the LSA could accommodate the present results effortlessly. However, before discarding the discrete word association norms we strongly recommend another possibility, namely its exploitation in a more sophisticated manner, as detailed here. By that we will ensure its future application as a useful tool in mirroring accurately lexical representations in memory and in predicting reliably semantic priming effects.

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NOTES

1. Our failure to detect a significant difference in the priming effects of strong and weak primary responses was not due to low statistical power. If the true difference in priming was the same magnitude as the one between strong primary and weak nonprimary associates—that is, a Cohen's d of .54 (Cohen, 1988)—our power to detect it (with a one-tailed $p < .05$) was greater than .91 (Erdfelder, Faul, & Buchner, 1996). Even if the true effect size was much smaller (a Cohen's d of 0.35), our power to detect it (with a one-tailed $p < .10$) would be greater than 0.83.

2. In order to further substantiate this conclusion we conducted a simultaneous multiple regression analysis to identify the factors contributing to the priming effects. Two independent variables were entered into the analysis: association frequency of the 72 critical items and their rank in the response set, which we treated as a continuous variable. If, indeed, the position of the associate in the response set is critical, then it will account for most of the explained variance of the dependent variable, namely the magnitude of the priming effects. The results of the analysis yielded a significant multiple R of .28 [$F(2,69) = 3.06$, $MS_e = 4{,}262$, $p < .05$]. More importantly, the only predictor of this variance was the rank of the associate [$\beta = -.26$, semipartial $r = -.22$, $t(69) = -1.93$, $p < .05$]. The association frequency did not explain a unique portion of the total variance. These results are, therefore, consistent with our ANOVA results, emphasizing the importance of the ranking of the associate rather than its association frequency per se.

3. In chi-square tests for association a minimum expected frequency of 5 in each cell is required for tables with more than one degree of freedom. Due to the wide range of semantic classes found in the stimuli and the limited amount of pairs in each condition, it was hard to meet this standard. However, some statisticians (Hays, 1997; Siegel & Castellan, 1988) view this rule as highly conservative and maintain that when the number of degrees of freedom is high, the minimum expected frequency could be as small as 1, as long as this frequency is found in less than 20% of cells. In our contingency table only 6 out of 30 cells had an expected frequency of 1, enabling the performance of the chi-square test.

4. Here again the failure to detect a significant difference between the two primary conditions was not because of low statistical power. If the true difference in priming had been of the same magnitude as the one between strong primary and weak nonprimary associates (a Cohen's d of .68), the power to detect it (with a one-tailed $p < .05$) would have been greater than .98. Even for a smaller effect size ($d = 0.35$), the power of detection would still have remained high (above 0.73 with a one-tailed $p < .10$).

In addition, as in Experiment 1, we conducted a simultaneous multiple regression analysis into which we entered the rank of the associate and its association frequency. The results of the analysis yielded results similar to those obtained in Experiment 1, though they were only marginally significant: The multiple R was .26 [$F(2,69) = 2.53$, $MS_e = 3{,}267$, $p = .08$]. The rank of the associate predicted all this variance ($\beta = -.24$, semipartial $r = -.21$, $t(69) = -1.81$, $p = .06$].

(*Continued on next page*)

APPENDIX
Critical Stimuli of Experiments 1–2

Strong (First Associate)		Weak (First Associate)		Weak (Fourth Associate)	
Prime	Target	Prime	Target	Prime	Target
body	man	missile	arrow	ears	lobe
destiny	cruel	duck	lake	armchair	sofa
linen	cloth	horse	stable	mail	air
jest	joke	tropical	climate	kindle	light
screwdriver	screw	chest	cupboard	handkerchief	cry
Snow-White	dwarves	housing	home	yellow	banana
vein	blood	meadow	grass	fry	onion
elephant	trunk	experience	success	tank	huge
slavery	freedom	wolf	animal	clock	sand
glazier	window	bewitched	fable	parachutist	soldier
frog	green	pride	arrogance	add	arithmetic
country	Israel	red	greenness	ornament	expensive
sidewalk	road	unemployed	money	policeman	hat
pleasure	fun	violin	music	bat	night
hot dog	bun	fork	hoe	hoe	rake
apron	kitchen	skin	coat	wash	clean
menu	restaurant	bus	passengers	hashish	cigarette
ladle	soup	stand	newspaper	throw	stone
sailing-boat	boat	television	radio	sooty	smoke
officer	army	notebook	register	sickle	hammer
cherry	frosting	trumpet	noise	pool	summer
tennis	table	oil	black	bathtub	foam
distinction	difference	band	song	carpet	floor
turmeric	spice	excited	happy	peach	plum

Administration of the Discrete and Continuous Word Association Norms

The Hebrew discrete word association norms were administered in a manner similar to the procedure described in de Groot (1989, Experiment 1). The stimuli consisted of 800 nonambiguous words (588 nouns, 121 verbs, and 91 adjectives). Two hundred and four participants participated in the norming procedure; each participant was presented with a set of 400 words. Words were presented randomly on a computer screen (the width and height of each letter was approximately 3 and 7 mm, respectively), and participants were asked to pronounce as rapidly as possible the first word that came to mind when reading the stimulus word. The participants' oral response RTs were registered by a microphone that activated a voice-operated switch. An experimenter typed the participants' responses and marked the occasions in which the voice-operated microphone was triggered prematurely or when no response was given after 5 sec.

The continuous association norming procedure was also similar to the one described in de Groot (1989, Experiment 3). Sixty participants were each given eight booklets containing 50 pages. On the top of each page appeared 1 of the 800 stimulus words that were used in the discrete word association norms. Participants were asked to write down all the words that came to their mind while reading the stimulus word. They were given 60 sec to perform this task for each stimulus word and were asked to refrain from producing "association chains" (i.e., an association to an association rather than to the stimulus word). The 800 words were divided into two lists, and each participant completed the task on 400 words only.

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