SEMANTIC AND ASSOCIATIVE PRIMING IN THE MENTAL LEXICON

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Abstract

This chapter investigates one of the most studied effect in psycholinguistics: the so-called "semantic priming effect". After a brief survey of the literature, a lexical decision experiment is presented and investigates two types of "semantic priming" : (1) purely semantic priming without association, and (2) purely associative priming without semantic similarity. Three prime duration were tested in the reported experiment (100, 250, and 500 msec). The results demonstrate the existence of automatic semantic similarity priming in the absence of normative association (for pairs such as "dolphin-WHALE"), and also the existence of automatic associative priming in the absence of semantic similarity (for pairs such as "spider-WEB"). These separate effects of priming (semantic and associative) are interpreted within the framework of the spreading-activation theory (Collins & Loftus, 1975), the distributed model of semantic memory (Plaut, 1995; Plaut & Booth, 2000) and the Interactive Activation model including semantics (McClelland, 1987; Stolz & Besner, 1996).

One of the most studied effect in psycholinguistics is the so-called "semantic priming effect" (see Neely, 1991; Lucas, 2000; Hutchison, 2003, for reviews). Early studies of semantic priming (e.g., Meyer & Schvaneveldt, 1971) actually investigated "associative priming" rather than "semantic priming" since prime-target pairs were taken from norms of word association: a word such as "BUTTER" (the target) was recognized significantly faster (in a lexical decision task) when it was preceded by a related word (the prime, such as "bread") than when it was preceded by an unrelated word (such as "doctor"). Whether this priming is in fact associative or semantic has since become the subject of some debate (Hutchison, 2003; Lucas, 2000; McRae & Boisvert, 1998; Perea & Rosa, 2002; Shelton & Martin, 1992; Thompson-Schill, Kurtz, & Gabrieli, 1998).

In particular, one can distinguish an associative relation among words from a purely semantic relation. Semantic relatedness reflects the similarity in meaning or the overlap in featural description of two words (e.g., “whale-dolphin”). On the other hand, associative relatedness is a normative description of the probability that one word will call to mind a second word (e.g., “spider-web”; Postman & Keppel, 1970). Associative relations are assumed to reflect word use rather than word meaning. Although the degree of semantic relatedness and associative relatedness between two words often vary together, it is possible for words to be either weakly associated yet semantically similar (e.g., “radish-beet”) or highly associated yet semantically dissimilar (e.g., “coat-rack”). Clearly, an issue of interest is whether a prime and target that are semantically related but not associatively related will yield a facilitatory priming effect, and also whether a prime and target that are associatively related but not semantically related will also yield a facilitatory effect. This issue is important because these priming effects can help us to better understand the structure and the processes of semantic memory.

Associative versus semantic priming

A number of studies have investigated priming among words that are semantically but not associatively related. Fischler (1977) was the first to disentangle semantic and associative relationships, by looking at priming for both associative pairs (e.g., cat-dog) and pairs that were semantically related but not associated (e.g., table-stool). Although he found constructing such stimuli difficult, Fischler (1977) showed a pure semantic priming effect and an associative priming effect using simultaneously presented stimulus pairs in a double lexical decision task (i.e., are both letter strings words?). Fischler (1977) concluded that semantic priming results not only from word associations, but from the semantic relations among words as well. However, these results were difficult to replicate (e.g., Lupker, 1984; Shelton & Martin, 1992). This might be attributed to Fischler's task that was a simultaneous lexical decision task, rather than the standard sequential lexical decision task used by Lupker (1984) and Shelton and Martin (1992). In particular, Shelton and Martin (1992) suggested that Fischler's priming for semantically related but unassociated word pairs reflected controlled rather than automatic processing. Taken at face value, this finding supports priming theories based on associative relatedness. Indeed, Shelton and Martin (1992) concluded that “words that are very similar in meaning or sharing many features will not show automatic semantic priming if they are not also associated” (p. 1204). In their analyses of the literature, Lucas (2000) and Hutchison (2003) nevertheless conclude that it is possible to obtain a “pure semantic” priming effect when great care is taken to select semantically related but unassociated stimuli (see also McRae & Boisvert, 1998; Moss, Ostrin, Tyler, & Marslen-

Wilson, 1995; Perea & Gotor, 1997; Perea & Rosa, 2002; Seidenberg, Waters, Sanders, & Langer, 1984; Thompson-Schill et al., 1998; Williams, 1996).

For instance, Thompson-Schill et al. (1998) tested forward and backward priming effects using word pairs that shared semantic features, but were asymmetrically associated according to word association norms. The conditions of priming were designed to be primarily automatic, with the use of a low proportion of related primes and a short SOA with a lexical decision task and a naming task. The results obtained showed comparable priming effects in both directions for semantically related pairs. However, priming was not obtained in either direction when pairs were associated but not semantically similar in a naming task. These results seem to indicate that semantic similarity is sufficient to produce priming whereas associative relatedness is not (but see Hutchison, 2003, for a criticism). One of the most convincing demonstration of a "pure semantic" priming effect has been provided by McRae and Boisvert (1998). In their lexical decision and semantic decision experiments, McRae and Boisvert (1998) obtained robust automatic semantic similarity priming with highly similar prime-target pairs that were unassociated (such as “whale-dolphin”, “missile-bomb”). Furthermore, McRae et Boisvert (1998) showed that Shelton and Martin’s (1992) null effect resulted from a confluence of factors; they used moderately similar prime-target pairs and targets that were both relatively short and frequent (such as “duck-cow”, “knife-hammer”, “nose-hand”). In a final lexical decision experiment, McRae and Boisvert (1998) tested triplets in which a target (e.g., jar) was paired with both a highly similar prime (e.g., bottle) and a less similar prime (e.g., plate). The less similar primes were chosen so that rated prime-target similarity would be in the same range as Shelton and Martin’s (1992) items, with the targets being longer and less frequent. Priming was found for highly similar items at both SOAs (250 and 750 msec), but for less similar items only at the long SOA. The authors concluded that the priming for highly similar items is indeed automatic. Overall therefore, the results of this study firmly establish the existence of automatic semantic similarity priming in the absence of normative association. Furthermore, this study explains the empirical inconsistency between the present results and previous ones (e.g., Shelton & Martin, 1992) in terms of the degree of semantic similarity between lexical concepts. More recently, Perea and Rosa (2002) also reported reliable priming effects for pairs that were highly semantically related but associatively unrelated (such as synonyms, antonyms and coordinates) in a masked priming experiment combined with the lexical decision task using different SOAs (83 msec, 100 msec, 116 msec and 166 msec). They did not test, however, pairs that were associatively but not semantically related.

In her meta-analysis of the literature, Lucas (2000) examined semantic priming across different tasks (such as naming, paired lexical decision, lexical decision with a mask, and serial or continuous lexical decision). For the majorities of the studies, she showed that the effects were similar across tasks (a conclusion also shared by Hutchison, 2003). Only naming showed a smaller priming effect. This is not surprising, because naming effects are usually smaller than lexical decision effects (Hodgson, 1991; Neely, 1991).

Concerning “pure associative” priming (i.e., priming for associatively related stimuli that are yet semantically unrelated), very few studies have been conducted (see Lucas, 2000, and Hutchison, 2003, for reviews). For instance, Hodgson (1991) and Williams (1996) have examined priming for phrasal associates, words that tend to co-occur in common phrases (e.g., help-wanted). These items are supposed to share very little semantic overlap; thus, any priming from these items is supposedly due to association strength or lexical co-occurrence frequency. These two studies reported robust effects of pure associative priming in lexical decision and naming tasks. However, Lucas (2000) underlined methodological problems in Hodgson’s (1991) experiments; and an examination of Williams’s (1996) stimuli reveals many semantic relations.

None of the studies discussed previously tested both pure semantic and associative priming *within* the same experiment. This point is addressed explicitly in a study presented in this chapter. In search for "purity" in our experimental stimuli (see Hutchison, 2003), we controlled both association values (in terms of strength of verbal association) and semantic similarity of the pairs (in terms of shared features) for both "pure semantic pairs" (non-associative) and "pure associative pairs" (non-semantic). Indeed, it is difficult to separate association strength from semantic overlap. It is because highly-associated items tend to share semantic relations as well. In order to circumvent this problem, we combined association values with rated semantic similarity for all stimuli (see McRae & Boisvert, 1998, for such a procedure).

Theoretical accounts of semantic and associative priming

According to the spreading-activation theory of Collins and Loftus (1975), one of the most popular theories of lexical processing, semantic memory consists of a network of interconnected nodes and activation spreads along the connections in this network. Information about words and their meaning is stored in separate networks. One network is purely lexical and contains only phonological and orthographic information about words. The other network is purely semantic and contains all concepts, including those linked to word forms in the lexical network. In the lexical network, nodes are connected to each other on the basis of phonological and orthographic similarity. In the semantic network, nodes are connected to each other on the basis of semantic similarity. Furthermore, the semantic network is connected with the lexical network. Within this framework, connections between associated words would exist between representations at the lexical level rather than at the semantic level. Such connections would be built through repeated occurrence of two word forms. If the words "spider" and "web" are frequently processed together, then a facilitatory link will be formed between them. This link represents only the fact that there is a high probability of the form “spider” occurring shortly after the form “web”. It does not code anything about the meaning relation between the two forms. On the other hand, connections between semantically similar words would exist at the semantic level rather than at the lexical level. Such connections are built on the basis of semantic similarity, in terms of shared features for instance.

According to the distributed semantic network of Plaut (1995; Plaut & Booth, 2000), concepts are represented by distributed patterns of activity over a large number of interconnected processing units, such that the related concepts are represented by similar patterns. Semantic priming arises because, in processing the target, the network starts from the pattern produced by the prime, which is more similar to the representation of the target for a related prime compared to an unrelated prime. In this model, semantic relatedness among words is encoded by the degree of feature overlap in their semantic representations, whereas associative relatedness is encoded by the frequency with which one word followed another during training. Semantic priming should occur because a related prime activates features that overlap with those of the target. On the other hand, associative priming would be due to the increased frequency with which targets are preceded by associated versus non-associated primes during training. Associative priming thus arrives because the network has learned to derive the representation of a target word more frequently, when starting from an associated prime word compared with a non-associated prime. Plaut (1995) presents simulations of his model comparing two types of relationships: an associative relationship (e.g., bread-BUTTER) and a semantic relationship (e.g., bread-CAKE). He also tested eight different prime duration (however, it is not possible to approximate the actual duration of the primes since the absolute time scale of the network is arbitrary; in other words, direct comparisons with empirical results might be difficult because the manipulation of prime duration was intended primarily to illustrate effects in network). His simulation results suggest an early priming effect for the semantic relationship which decreased as prime duration increased. In particular, semantic priming peaks at very short prime duration then gradually declines as the prime is processed more fully. In contrast, for associative pairs, the priming effect increases with prime duration and reaches an asymptote threshold when the effect with semantic pairs decreases. However, these simulations are of limited interest since the stimuli were not previously tested with real subjects.

We now discuss how the Interactive Activation (IA) framework (McClelland, 1987; McClelland & Rumelhart, 1981) would account for associative and semantic priming. Although a semantic level is included in this model, the authors do not specify the characteristics of this level in much detail. It is often assumed that the Interactive Activation approach can not accommodate semantic/associative priming. However, Stolz and Besner (1996; see also Balota, 1990) have proposed a conceptualization of how this semantic level might operate given the constraints laid out by McClelland (1987). The IA framework proposed by McClelland (1987) and used by Stolz and Besner (1996) is presented in Figure 1.

<Insert Figure 1 about here>

This model contains three levels: a letter level, a word level, and a semantic level.. According to McClelland (1987), between-level connections are excitatory and within-level connections are competitive, *even at the semantic level*. In other words, the model denies within-level excitatory activation. This leads to a conceptualization of activation within semantic level that differs from the view commonly expressed in the literature. The absence of facilitatory connections within the semantic level and the word level precludes the standard notion of spreading activation. How, then the IA model will explain associative and semantic priming? Stolz and Besner (1996, p. 1168) suggest that “in addition to activation being fed forward from a word-level representation to its corresponding representation at the semantic level, activation also spreads from the word-level representation to the representations of associates at the semantic level". The authors assume a word-level-to-semantic-level activation for related concepts to accommodate semantic priming. On Figure 2, we illustrate how the IA model could account for semantic and associative priming.

<Insert Figure 2 about here>

Consider "spider" and "web" as associates, whereas "spider" and "ant" are semantically related only. Presentation of the visual prime "spider" will activate its corresponding letters at the letter level which in turn will send activation to the word level. Within-level competition should result in "spider" being the most active candidate at the word level. Activation will also feed forward from the word level to the semantic level to activate the semantic representation for [SPIDER] and for associates (such as [WEB]) and for semantically related words (such as [ANT]). (note 1). Within-level competition should result in activation for [SPIDER] being higher than for all other candidates. However, it is assumed that this within-level inhibition only reduces and not eliminates the activation of [WEB] and [ANT] relative to [SPIDER]. Therefore, subsequent presentation of an associated target (such as [WEB]) or of a semantically related target (such as [ANT]) will require less bottom-up activation for recognition at the semantic level (provided that the lexical decision task is semantic-sensitive; see De Groot, 1990), resulting in a benefit of processing.

Stolz and Besner (1996) suggest the existence of a second locus for semantic/associative priming effects (see Figure 2, lower panel).This locus would result from semantic-level activation feeding back to the word-level. For instance, when [SPIDER] and associates (such as [WEB]) and semantically related words (such as [ANT]) become active at the semantic level, top-down activation will activate SPIDER, WEB and ANT at the word level. If WEB or ANT is presented as a target, its preactivated word level representation will require less activation to become fully activated relative to an unprimed target. However, according to Stolz and Besner (1996; see also Stolz & Neely, 1995), the feedback from the semantic level to the word level does not appear under automatic condition.

The present study: Dissociating semantic and associative priming

The experiment reported in the present chapter focused on (1) semantic similarity in the absence of normative association, and (2) on associative relationship in the absence of semantic similarity (see Alario, Segui & Ferrand, 2000, for a similar approach applied to picture naming). In particular, we tested two types of prime-target relationships: (1) semantically related but not verbally associated pairs, and (2) verbally associated but not semantically related pairs. For the semantically related pairs, we started from a set of 78 pairs of members of (intuitive) semantic categories. Following Shelton and Martin (1992), and McRae and Boisvert (1998), these 78 pairs were tested by 40 participants in a semantic similarity rating task : participants were instructed to rate the pairs on how similar in meaning the two words were. Participants answered using a 7-point scale (1 = not at all similar, 7 = highly similar). A crucial point is that the pairs we chose were not associatively related (or very weakly), according to the French norms of Ferrand and Alario (1998). We kept 44 of these pairs among those that were judged more semantically similar. As shown on Table 1, mean semantic similarity was 5.0 and mean associative strength was 4.5%. The stimuli are presented in Table 2. Of course, it could be argued that one can not be sure that there are no associative relationships between semantically related words that do not occur in association norms. However, as Perea and Rosa (2002) put it "[…] it is obvious that there must be a clear difference in associative strength between pairs that appear in published association norms relative to those pairs that do not appear in these norms".

<Insert Table 1 about here>

The verbally associated pairs were selected among those that had the most frequent associates in Ferrand and Alario (1998) French norms. We started from 71 pairs that were not (intuitively) members of semantic categories. We asked the same 40 participants to judge the semantic similarity of these pairs on the same 7-point scale. Importantly, we selected pairs for which the two words were not members of a single (intuitive) category and therefore had very low semantic overlap. We kept 44 of these pairs among those that were judged not semantically similar. As shown on Table 1, mean semantic similarity was 1.58 and associative strength was 52%. The full set of these stimuli is presented in Table 2.

<Insert Table 2 about here>

A lexical decision task with three prime duration (100, 250, and 500 msec) and a low proportion of related primes (25%) was used to study the automaticity of semantic and associative priming. It could be argued that a naming task is less sensitive to strategic processes. However, priming effects are typically smaller in naming than in lexical decision (e.g., Hodgson, 1991; Neely, 1991; Lucas, 2000; Hutchison, 2003) and we decided to use the lexical decision task to give the maximum chance to observe separate effects of semantic and associative priming. Furthermore, the lexical decision task was used because it is the most common task in the literature, thus allowing direct comparisons to previously published studies. According to the spreading-activation theory of Collins and Loftus (1975), there should be both a pure semantic priming effect and a pure associative effect. Priming within the lexical network of phonological and orthographic information would be based on associative links which connect words that are often contiguous (e.g., “spider-web”) and that may not share semantic features. Priming within the conceptual network would be based on semantic similarity (e.g., category coordinates that share features, such as “radish-beet”). Plaut’s (1995) model also predicts a semantic and an associative priming effect. Simulations based on the model even suggest a different time-course for these effects (note though, that

Plaut did not simulate empirical data). His simulations suggest an early priming effect for semantic pairs which should decrease as prime duration increased, and for associative pairs, a late priming effect increasing with prime duration. According to the IA model including semantics (McClelland, 1987; Stolz & Besner, 1996), there should be both a pure semantic priming effect and a pure associative priming effect. These priming effects would be due either to word-level-to-semantic-level activation or to semantic-level-to-word-level activation for semantically related and/or associated words.

An empirical demonstration of "pure" associative and "pure" semantic priming

Method

Participants. One hundred and twelve psychology students at René Descartes University, Paris, and Ecole de Psychologues Praticiens, Paris, served as participants for course credit. 40 received the pre-test on semantic similarity and the remaining 72 participated at the experiment proper, with 24 participants in each of the three prime duration conditions (100, 250, and 500 msec). All were native speakers of French, with normal or corrected-to-normal vision.

Stimuli and Design. The experimental stimuli consisted of 88 French pairs (see Table 2 for the complete list). Two different types of French word pairs (semantically or associatively related words) were selected according to the following criteria. Different targets had to be used because it was not possible to use the same targets for the two types of relationships (i.e., purely associative and purely semantic). The purely semantic pairs (non-associative) and the purely associative pairs (non-semantic) were presented within the same experiment. For the first type of pairs (semantic but non-associative pairs), each target word was preceded by two types of prime: (1) semantically similar but non-associative word primes (such as “dauphin-BALEINE” [dolphin-WHALE]); (2) word primes that were totally (orthographically, phonologically, associatively, and semantically) unrelated to the target (such as “complot-BALEINE”). For the second type of pairs (associative but non-semantic pairs), each target word was preceded by two types of prime: (1) strongly associative but semantically dissimilar word primes (such as “araignée-TOILE” [spider-WEB]); (2) word primes that were totally (orthographically, phonologically, associatively, and semantically) unrelated to the target (such as “monument-TOILE”).

Word association norms (taken from Ferrand & Alario, 1998) were used to rule out prime-target associations for the first category of stimuli (purely semantically related pairs). The same norms were used to select the strongest prime-target associates in the forward direction for the second category of stimuli (purely associated pairs). These norms were collected for 366 words from a group of 89 participants, who were undergraduate students in psychology, like the participants of the experiment reported in this article.

In the pilot study, 40 psychology students rated the semantic similarity of prime-target pairs on a 7-point scale (1 = not at all similar, 7 = highly similar). We started from 71 associated pairs and 78 semantically similar pairs. We kept 44 stimuli in each category. The ratings are presented in Table 1. Target length was equated (for semantic targets: M = 6.0, SD = 1.52, range = 3-10 ; for associative targets: M = 5.6, SD = 1.56, range = 3-9) but it was not possible to equate target frequency due to the constraints of our stimuli (for semantic targets: M = 16.3 occurrences/million, SD = 27.3; for associative targets: M = 98.37, SD = 110.1; printed frequency is taken from the French database "Lexique" developed by New, Pallier, Ferrand, & Matos, 2001). Associative targets were more frequent than semantic targets; it not surprising given that it is more likely to give a high-frequency word than a low-frequency word in response to the prime in a free association task (Spence & Owen, 1990).

Two lists were created so that participants saw no prime or target more than one time. For each list and each category, 22 targets were paired with related primes, and 22 with unrelated primes. 88 filler trials of unrelated pairs were added in order to have 25% of related pairs only.

Three prime duration were used: 100, 250, and 500 msec. Priming condition was crossed with prime duration as a between-subject factor. Prime-target pairs were rotated across the priming conditions across two groups of participants (for each prime duration) such that no subject saw any single prime or target more than once, but each subject received all priming conditions. Every subject saw 88 prime-word target pairs, 22 from each condition, and 88 prime-nonword target pairs. The participants were presented with 20 practice trials before the experiment proper. These consisted of 10 words and 10 nonwords.

Procedure. The participants were tested individually. Prime and target stimuli were presented with DMDX (Forster & Forster, 2003) in the center of the screen of a personal computer with a 70-Hz refresh rate. Each trial consisted of the following sequence of three stimuli presented on the same screen location. First a fixation point (a cross "+") was presented for 500 ms. This was immediately followed by presentation of the prime for 100 msec, 250 msec, or 500 msec, which was followed immediately by the presentation of the target word in the same screen location as the prime. The targets remained on the screen until the participants responded. Primes were always presented in lowercase letters and targets in uppercase letters. The participants were instructed to focus on the fixation point and to read the first letter string in lowercase and respond only to the second letter string in uppercase. The next trial sequence followed after a 1-sec delay. Stimulus presentation was randomized, with a different order for each subject. Participants were asked to judge as fast and accurately as possible whether the letter string in uppercase was a French word or not.

Results

Mean lexical decision latencies and percentage of errors are given in Table 3 for each prime duration. An ANOVA was run with Type of Target (semantic vs. associative), Type of Prime (related vs. unrelated), and Prime Duration (100, 250, and 500 msec) entered as main factors. F values are reported by participants (F1) and items (F2).

<Insert Table 3 about here>

Decision latencies. There were significant main effects of Type of Target [F1(1,69)=118.37, p<.001 and F2(1,86)=15.87, p<.001], Type of Prime [F1(1,69)=99.25, p<.001 and F2(1,86)=47.96, p<.001], and Prime Duration [F1(2,69)=3.58, p<.05 and F2(2,172)=34.41, p<.001]. Type of Target interacted significantly with Type of Prime [F1(1,69)=6.52, p<.05 and F2(1,86)=2.62], but not with Prime Duration [F1(2,69)=1.22 and F2(2,172)<1]. Type of Prime did not interact with Prime Duration [F1(2,69)=1.28 and F2(2,172)<1]. The three-way interaction was not significant [F1(2,69)<1 and F2(2,172)<1].

We conducted independent analyses for the two types of prime-target relationship (semantic vs. associative). For the pure semantics, planned comparisons showed a significant semantic facilitation effect at 100 msec [d=+41 msec; F1(1,23)=30.62, p<.001 and F2(1,43)=30.07, p<.001], 250 msec [d=+32 msec; F1(1,23)=22.86, p<.001 and F2(1,43)=7.36, p<.01] and 500 msec [d=+31 msec; F(1,23)=12.27, p<.01 and F2(1,43)=9.82, p<.005]. For the pure associated words, planned comparisons showed a significant associative facilitation effect at all duration: 100 msec [F1(1,23)=19.53, p<.001 and F2(1,43)=6.03, p<.05], 250 msec [F1(1,23)=4.94, p<.05 and F2(1,43)=4.87, p<.05] and 500 msec [F1(1,23)=3.61, p=.067 and F2(1,43)=9.95, p<.005].

Errors. There were significant main effects of Type of Target [F1(1,69)=22.15, p<.001 and F2(1,86)=6.91, p<.01], Type of Prime [F1(1,69)=4.22, p<.05 and F2(1,86)=3.46, p=.063], and Prime Duration [F1(2,69)=13.64, p<.001 and F2(2,172)=15.05, p<.001]. None of the interaction were significant [all Fs<1]. The only significant planned comparison was the associative priming effect at 250 msec [F1(1,23)=4.28, p<.05 and F2(1,43)=4.98, p<.05].

GENERAL DISCUSSION

The experiment described in this chapter was designed to examine semantic memory by focusing on two types of "semantic" relatedness, associative relatedness and semantic similarity. The present lexical decision experiment demonstrates (1) the existence of automatic semantic similarity priming in the absence of normative association (for pairs such as "dolphin-WHALE"), thus replicating some previous studies (McRae & Boisvert, 1998; Thompson-Schill et al., 1998), and (2) the existence of automatic associative priming in the absence of semantic similarity (for pairs such as "spider-WEB"), contrary to what Thompson-Schill et al. (1998) found, but in accordance with Hodgson (1991) and Williams (1996). Thompson-Schill et al. (1998) presented evidence that associatively related pairs in and of themselves do not automatically prime unless they are also semantically related, contrary to what we found in our present study. However, they used a naming task, which, as well known, is going to produce, at best, a small priming effect. In addition, the targets they used were very high in frequency (250 occurrences per million according to the Kucera and Francis database). This might have also drove down the priming effect. As such, the demonstration of a null priming effect in these circumstances is far from compelling.

Our results also show that these semantic and associative priming effects are significant at the three prime duration tested (100, 250 and 500 msec) with target length equated. However, on average, the size of the priming effect was larger for semantic pairs (d=+34.5msec) than for associative pairs (d=+18.5 msec). It can easily be explained by the fact that semantic targets had a lower printed frequency (M = 16.3 occurrences/million) than associative targets (M = 98.3 occurrences/million). Previous studies obtained larger priming effects for low- compared to high-frequency targets (e.g., Becker, 1979; Borowsky & Besner, 1993). The finding of an interaction of target frequency and priming context (i.e., larger priming effects for low- compared to high-frequency targets) is traditionally interpreted within the spreading-activation model of Collins and Loftus (1975) as the fact that the resting activation level of a word unit is further from threshold for low-frequency words than for high frequency words, resulting in a larger effect of priming context on the former than on the latter (but see Plaut & Booth, 2000, for a different explanation).

The present results only partly follow the simulation-based results of Plaut (1995). Plaut compared two types of relationships: an associative relationship (e.g. “bread-BUTTER”) and a semantic relationship (e.g., “bread-CAKE”). His simulation results showed an early priming effect for the semantic relationship which decreased as prime duration increased. Conversely, with associated pairs, the priming effect increased with prime duration. In our study, there was no point in time where our semantically related pairs began to produce a priming effect earlier than associated pairs. As a matter of fact, both types of pairs produced a priming effect at 100 msec, 250 msec, and 500 msec. However, the effect with semantic pairs did (slightly) decrease with time as predicted by Plaut’s model, suggesting that 500 msec is sufficient to produce a dissimilarity between the pattern of the prime word and the pattern of the target word. Concerning associated pairs, the results did not follow Plaut’s predictions, since the priming effect appeared at the shortest duration and slightly decreased with longer duration. According to Plaut (1995), the priming effect obtained with associated words was supposed to reach an asymptote threshold when the effect with semantically related words decreased.

The present results are consistent with the predictions of the spreading-activation theory. Collins and Loftus (1975) explicitly stated that one dimension along which the human semantic network is organized is featural similarity. The automatic semantic priming would result from spreading activation between semantic representations. On the other hand, the automatic associative priming would result from spreading activation between (non-semantic) lexical representations. In addition to the semantic network, the Collins and Loftus (1975) model assumed a lexical network consisting of phonological and orthographic representations of words, each of which was connected to a node in the conceptual network. Although Collins and Loftus assumed that activation in the lexical network spread on the basis of phonological/orthographic similarity, it is also conceivable that activation in the lexical network could spread by co-occurrence frequency. Words that often occurred together in text or speech would be close together (or strongly linked) in the lexical network. Pure associative priming would reflect the activation that spreads through the (non-semantic) lexical network. In other words, pure associative priming would result from connections between lexical representations that have developed on the basis of co-occurrence of frequency, rather than from connections at the meaning level. On the contrary, pure semantic priming would reflect the activation that spreads through the semantic network. This leads to predict an “associative boost”, i.e., priming should be greater for word pairs that are both associatively and semantically related, than for word pairs that are only semantically related. Current work is under way to test this hypothesis.

Our results are also consistent with the Interactive Activation model including semantics (McClelland, 1987; Stolz & Besner, 1996). It is often assumed that the interactive approach can not accommodate semantic and associative priming. We showed on the contrary that an IA model including semantics can perfectly well explain these effects (see Figures 1 and 2). Visual presentation of a semantic prime or an associative prime will activate its corresponding letters at the letter level which in turn will send activation to the word level. Activation will also feed forward from the word level to the semantic level to activate the semantic representations for semantics and associates. Therefore, subsequent presentation of a semantically related target or of an associated target will require less bottom-up activation and will result in facilitation of target processing (compared to presentation of unrelated primes). These semantic and associative priming effects could also result from semantic-level activation feeding back to the word-level. Preactivated word level representations will require less activation to become fully activated relative to unprimed targets. Therefore, these effects would be due to feedback from the semantic level to the word level. The preference for one locus (feedforward facilitation from the word-level to the semantic-level) or another (feedback facilitation from the semantic-level to the word-level) remains an empirical question and our results can not favor one or another locus.

The present findings suggest that semantic relatedness on one hand, and associative relatedness on the other, are sufficient to produce priming under automatic conditions. The spreading-activation model (Collins & Loftus, 1975) and the distributed model of semantic memory (Plaut, 1995) can both account for the existence of a semantic priming effect without association and an associative priming effect without semantic relatedness. More interestingly, we showed that the IA model including semantics (McClelland, 1987; Stolz & Besner, 1996) can also account for both semantic and associative priming. This is unexpected because it is traditionally assumed in the literature (see Neely, 1991; Lucas, 2000; Hutchison, 2003) that such a model was not able to do so.

In conclusion, the finding of a pure associative priming effect independently of a pure semantic priming effect is an important one since Lucas (2000) concluded in her recent meta-analysis that while there is strong evidence for an overall pure semantic priming effect, yet no evidence for priming based purely on association. Overall, the current results demonstrate that automatic priming appears to be due to both association strength and semantic relationship.

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TABLE 1

Characteristics of the Stimuli Used in the Lexical Decision Task

Type of Pairs	Semantic Similarity[a]			Associative Strength[b]		
	M	SD	Range	M	SD	Range
Semantic pairs (non-associative)	5.0	0.79	3.7-6.5	4.5%	4.31	0-12
Associative pairs (non-semantic)	1.58	0.24	1.25-2.37	52%	16.29	30.3-92.1

Note. a: means on a 7-point scale (1 = not at all similar, 7 = highly similar); b: percentages taken from Ferrand and Alario (1998).

TABLE 2

Stimuli Used in the Lexical Decision Task (primes are in lowercase and targets in uppercase)

Semantic pairs (non-associative)

allumette-BRIQUET	match-LIGHTER
betterave-RADIS	beet-RADISH
bombe-MISSILE	bomb-MISSILE
bouteille-GOURDE	bottle-GOURD
canot-BARQUE	fishing boat-SMALL BOAT
chardon-CACTUS	thistle-CACTUS
clarinette-FLUTE	clarinet-FLUTE
coffret-BOITE	casket-BOX
courgette-CITROUILLE	zucchini-PUMPKIN
dauphin-BALEINE	dolphin-WHALE
dinde-OIE	turkey-GOOSE
fauteuil-CHAISE	armchair-CHAIR
guêpe-MOUCHE	wasp-FLY
guitare-VIOLON	guitar-VIOLIN
homard-CRABE	lobster-CRAB
crêpe-GAUFRE	pancake-WAFFLE
lance-EPEE	spear-SWORD
métro-TRAIN	subway-TRAIN
montre-REVEIL	watch-ALARM
moto-VELO	motorbike-CYCLE
moule-HUITRE	mussel-OYSTER
oreiller-COUSSIN	pillow-CUSHION
orgue-PIANO	organ-PIANO
palais-CHATEAU	palace-CASTLE
panier-SAC	basket-BAG
pichet-CARAFE	pitcher-CARAFE
pierre-BRIQUE	stone-BRICK
pipe-CIGARE	pipe-CIGAR
pistolet-CARABINE	pistol-RIGLE
placard-ARMOIRE	cupboard-WARDROBE
pneu-ROUE	tire-WHEEL
poulet-CANARD	chicken-DUCK
radeau-CANOE	raft-CANOE
râteau-BECHE	rake-SPADE
renard-LOUP	fox-WOLF
rideau-STORE	curtain-BLIND
scie-HACHE	saw-AXE
sécateur-CISEAUX	secateurs-SCISSORS
stylo-CRAYON	pen-PENCIL
tapis-MOQUETTE	rug-CARPET
torrent-RUISSEAU	torrent-STREAM
trapèze-BALANCOIRE	trapeze-SWING
voilier-PENICHE	sailing boat-BARGE

volcan-MONTAGNE	volcano-MOUNTAIN

Associative pairs (non-semantic)

aiguille-FIL	needle-THREAD
album-PHOTO	album-PHOTO
ampoule-LUMIERE	bulb-LIGHT
ancre-BATEAU	anchor-BOAT
aquarium-POISSON	aquarium-FISH
araignée-TOILE	spider-WEB
astronaute-ESPACE	astronaut-SPACE
berceau-BEBE	cradle-BABY
bouée-SAUVETAGE	buoy-RESCUE
brouette-JARDIN	wheelbarrow-GARDEN
bureau-TRAVAIL	office-WORK
caméra-FILM	camera-MOVIE
canon-GUERRE	gun-WAR
cartable-ECOLE	schoolbag-SCHOOL
cassette-VIDEO	tape-VIDEO
cendrier-CIGARETTE	ashtray-CIGARETTE
cheminée-FEU	chimney-FIRE
clou-MARTEAU	nail-HAMMER
coquillage-MER	shellfish-SEA
cor-CHASSE	horn-HUNTING
frigo-FROID	fridge-COLD
gâteau-CHOCOLAT	cake-CHOCOLATE
girafe-COU	giraffe-NECK
grenouille-VERTE	frog-GREEN
hibou-NUIT	owl-NIGHT
luge-NEIGE	sled-SNOW
lunettes-SOLEIL	glasses-SUN
nid-OISEAU	nest-BIRD
perceuse-TROU	drill-HOLE
poignée-PORTE	handle-DOOR
raquette-TENNIS	racket-TENNIS
rhinocéros-CORNE	rhinoceros-HORN
robinet-EAU	faucet-WATER
ruche-ABEILLE	hive-BEE
sapin-NOEL	fir-CHRISTMAS
serrure-CLEF	lock-KEY
tasse-CAFE	cup-COFFEE
tente-CAMPING	tent-CAMPING
timbre-POSTE	stamp-POST
tomate-ROUGE	tomato-RED
tonneau-VIN	barrel-WINE
vache-LAIT	cow-MILK
valise-VOYAGE	suitcase-TRIP
zèbre-RAYURES	zebra-STRIPES

Note. Approximate English translation are presented in the right column.

TABLE 3

Mean Lexical Decision Latencies (RT in Milliseconds), Standard Deviations (into brackets) and Percentage of Errors (PE) to Targets Preceded by Related and Unrelated Primes Throughout the Three Prime Duration

Prime Duration	Related		Unrelated		Net Priming	
	RT	PE	RT	PE	RT	PE
	Pure semantic relationship (e.g., “dauphin-BALEINE” [dolphin-WHALE])					
100	562 (62)	0.85	603 (66)	2.80	+41*	+1.95*
250	522 (59)	6.47	554 (75)	7.40	+32*	+0.93^{ns}
500	558 (55)	3.10	589 (74)	3.95	+31*	+0.85^{ns}
	Pure associative relationship (e.g., “araignée-TOILE” [spider-WEB])					
100	537 (55)	1.15	561 (60)	0.56	+24*	-0.59^{ns}
250	501 (62)	2.05	515 (60)	4.32	+14*	+2.27*
500	523 (60)	0.56	540 (50)	1.41	+17*	+0.85^{ns}

Note: * significant effect; ns: effect not significant.

FOOTNOTE

Footnote 1. The representation of the word “spider” could be local, the concept being represented by a node, or distributed, the concept being represented as a pattern of activation across nodes. Also, the concept [SPIDER] can be considered as an entire concept or as composed of a set of semantic features. This issue of the nature of semantic representations, although very important, is not critical here because both types of representation can produce priming.

FIGURE LEGENDS

Figure 1. An Interactive Activation model of visual word recognition including semantics (McClelland, 1987; Stolz & Besner, 1996). Within-level connections are purely inhibitory (at all levels) and between-level connection are mainly excitatory (for simplicity, the featural level is not included). Pathways A and B feed activation from lower to higher levels. Pathways C and D feedback activation from higher to lower levels to provide a top-down support for the activation being fed bottom up.

Figure 2. Semantic and associative priming effects accounted by an interactive activation model of visual word recognition including semantics. In this example, “spider-WEB” are considered as purely associates, whereas “spider-ANT” are considered as purely semantics. Two possible loci of the semantic and the associative priming effects are proposed in this figure.

FIGURE 1

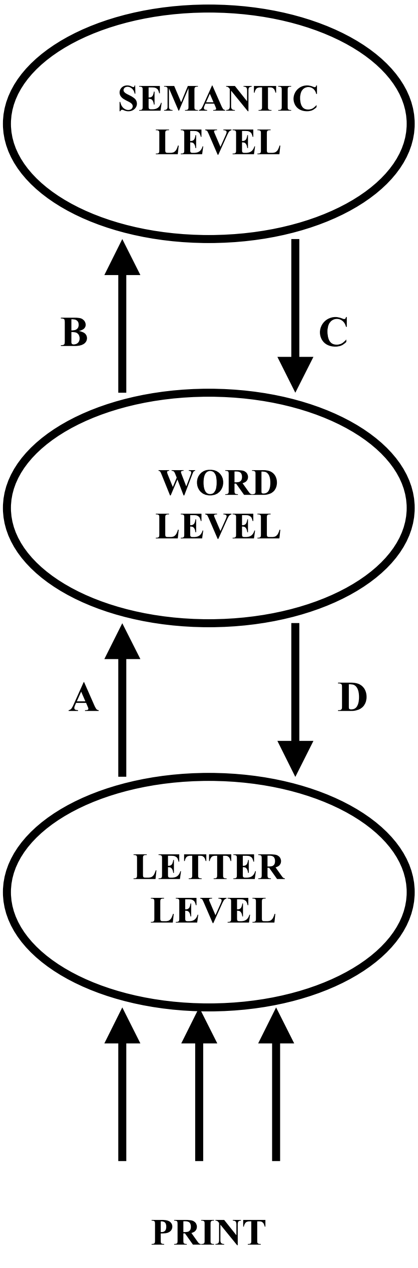
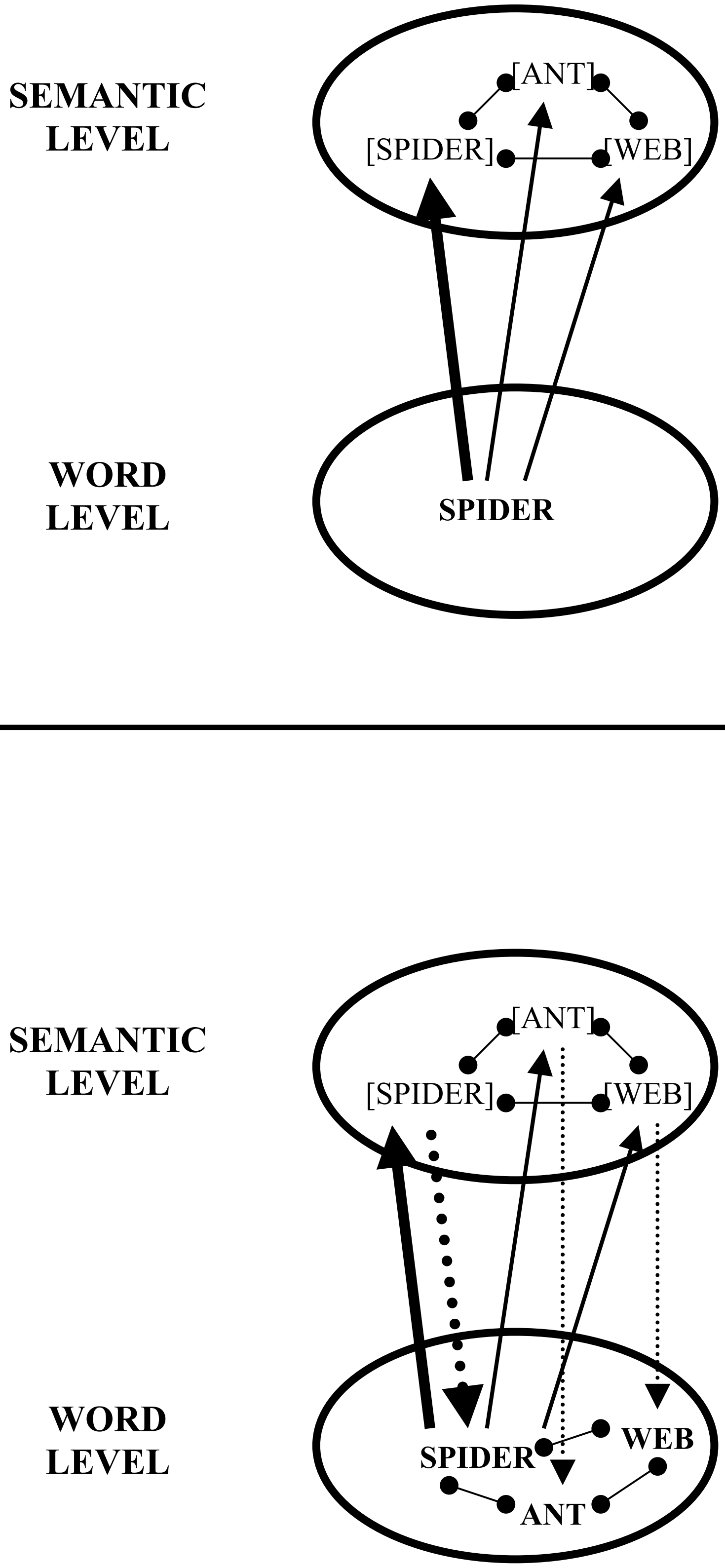


FIGURE 2


SEMANTIC LEVEL
[ANT]
[SPIDER]
[WEB]
WORD LEVEL
SPIDER
SEMANTIC LEVEL
[ANT]
[SPIDER]
[WEB]
WORD LEVEL
SPIDER
WEB
ANT