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Semantic Features and Semantic Categories: Differences in Rapid Activation of the Lexicon

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Robust priming was shown in a semantic categorization task for prime–target pairs which shared semantic features (e.g., *pumpkin–squash*). Priming facilitation for these pairs was demonstrated at extremely rapid prime exposures (28 and 43 ms) and increased with prime duration. The onset and amount of facilitation differed significantly for these semantic, nonassociative pairs and for associative-semantic prime–target pairs (e.g., *cow–bull*). The latter pairs produced facilitation, but later (at prime–target SOAs of 70 and 200 ms) and of lesser magnitude. These results are discussed in relation to three current models of semantic memory: spreading activation, compound cue, and distributed models.

Key Words: Semantic features; semantic categorization; associative relatedness.

Contrary to popular belief, semantic relations between words have not always proven to be effective in rapidly activating the mental lexicon. This issue has given rise to numerous studies aimed at determining whether semantic as opposed to associative relationships are the driving factor behind the facilitation observed in studies of word-priming (for recent discussions see Masson, 1995; McKoon & Ratcliff, 1992; McNamara, 1992; McRae & Boisvert, 1998; Shelton & Martin, 1992; Thompson-Schill, Kurtz, & Gabrieli, 1998). The present study sheds important light on this question and provides a clear test of current models of semantic memory.

In recent years, the widely accepted ''spreading activation'' model (Collins & Loftus, 1975; see Neely's 1991 review) has been challenged on various grounds. According to this model, lexical representations are stored in memory as discrete entries. The processing of a given lexical entry leads to its activation and, critically for the model, to the activation of other semantically and/or associatively related entries. Both of these assumptions are ques-

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tioned by distributed models of memory (Masson, 1995; McRae, de Sa, & Seidenberg, 1997). In distributed models, word meanings are represented as sets of features rather than as discrete ‘‘nodes.’’ The processing of a given word leads to a certain pattern of activation of the featural network or ‘‘semantic space.’’ Only one pattern is fully instantiated at any one time. The resettling of the network upon presentation of a subsequent word is accomplished faster if the latter is semantically similar to the first word, as the two have overlapping features and therefore similar representational patterns. Thus, shared semantic features between words facilitates processing, akin to what is proposed by spreading activation, but not via the ‘‘preactivation’’ of the lexicon, in contrast to what is proposed by the spreading activation model.

The assumption of a ‘‘preactivation’’ of the lexical system is also contested by advocates of the ‘‘compound cue’’ model (McKoon & Ratcliff, 1992). The latter model proposes an integrative account of processing, whereby two words presented in rapid succession are combined into a ‘‘compound cue’’ to be compared against stored relationships in memory. Provided a match, processing is facilitated in comparison to when no match is found for the retrieval cue. The model differs in its assumptions from the spreading activation model on several grounds. First, facilitation is the product of a relatively late process. Indeed, only after the processing of both the target and the prime can the compound cue be constructed. Second, no facilitation is predicted in the instance that the prime word cannot be identified, as this precludes the formation of a compound cue (Ratcliff & McKoon, 1988). Last, the model predicts facilitated processing only for pairs which have been stored together in memory, that is, which have associative value. The semantic nature of priming is not espoused by advocates of the compound cue model. In contrast, the spreading activation model predicts facilitation for word-pairs which enjoy either semantic overlap or an associative relationship, even under conditions which preclude prime identification. Distributed models clearly predict greater facilitation for semantic than associative relationships, although prime visibility is not necessarily a prerequisite.

These models were tested in four priming experiments. Unlike the majority of studies on this topic, we did not employ the lexical decision task. We chose, rather, a semantic categorization task in which participants made binary decisions to visually presented target words with respect to their membership in a semantic category. The choice of task was based on the results of a recent study (Grainger & Frenck-Mestre, in press) that demonstrated that early semantic processing can be detected far more reliably with a categorization task as opposed to a lexical decision task.

EXPERIMENTS

All experiments were conducted in the French language using the same computerized task in all experiments. Participants began by encoding a category superordinate that was visually

TABLE 1
Facilitation of the Semantic Categorization of Targets Produced by Related Primes (Compared to Neutral Primes) as a Function of Prime–Target Relationship and Prime Duration

		Prime–target relationship		
Prime duration	(ms)	Associative-semantic	Identity	Semantic Nonassociative
Expt. 1	200	19 ms[b]	NA	57 ms[b,c]
Expt. 2	70	21 ms[b]	NA	25 ms[b]
Expt. 3	43	NA[d]	41 ms[b]	28 ms[b]
	28	NA[d]	29 ms[b]	22 ms[b]
Expt. 4	43	2 ms	29 ms[b,c]	NA[d]
	28	−1 ms	17 ms[b,c]	NA[d]

[a] Primes were backward masked for 14.2 ms.
[b] Significant by items and by subjects at $p < .05$ or better.
[c] Significantly different from the same row condition.
[d] NA = not applicable.

presented for an unlimited amount of time, but only once. Subsequently, a list of 20 target words (generally, high-frequency nouns) was presented one word at a time on a CRT screen. Ten different categories (lists) were presented. Participants were to categorize targets with respect to their membership in the prespecified category. Their manual response ended the presentation of one target and initiated that of the next. Targets were always preceded by a prime word, the prime itself being forward and backward masked. On critical trials, the targets were members of the prespecified category and required a positive response.[1]

The goal of these experiments was to examine the onset and evolution of priming facilitation, as produced by a ‘‘semantic nonassociative’’ relationship and by an ‘‘associative-semantic’’ relationship. Hence, both the duration of the prime and the type of prime–target relationship were varied across experiments. Three prime–target relationships were compared: *semantic nonassociative, associative-semantic,* and *identity.* The *semantic nonassociative* pairs ($n = 20$) were a subset, translated into French, of the materials developed in English by McRae and Boisvert (1998). The prime and target were members of the same semantic category and had overlapping ‘‘semantic features’’ without being associatively related (according to McRae & Boisvert’s pilot study) as illustrated by *rifle–pistol* and *whale–dolphin.* The *associative-semantic* pairs ($n = 20$) were created from our French pilot study. For these pairs, the target was the high ranking word given in a free-association test that was of the same semantic category as the prime, as illustrated by *cow–bull* and *shirt–pants.* No measure was taken to ensure featural overlap for these pairs. Nonetheless, as this factor was not controlled for, its possible role cannot be ruled out.[2] Identity pairs ($n = 40$) were made up of the above targets, with the prime being identical to the target.

In the first experiment, the *associative-semantic* and *semantic nonassociative pairs* were presented (in different categories, but within the same session). Primes were presented for 200 ms prior to target onset. The results are presented in Table 1. Targets were identified as

[1] The typicality of the targets and preceding primes was generally high, among the first 10 exemplars of a given category. This was not systematically, true, however, of the ‘‘semantic’’ pairs, translated from already-existing materials (McRae & Boisvert, 1998). On noncritical trials, the targets could be either members or nonmembers of the category. When members, the targets were in the same typicality range as critical targets.

[2] We are currently screening the materials, in a post-test, to examine this factor.

members of a semantic category significantly faster when preceded by *associative-semantic* primes. More importantly, priming was also found for the *semantic nonassociative* pairs, i.e., in the absence of a primary associative relationship between the prime and target. Facilitation for the *semantic, nonassociative* pairs was in fact statistically greater than that for the *associative-semantic* pairs.

In the second experiment, the same prime–target pairs were presented, but primes were shown for 70 ms prior to the target, thus reducing the possibility of strategic use of the prime. The pattern of results (cf. Table 1) closely paralleled that of the first experiment. Target words were categorized significantly faster when they shared semantic traits but not an associative link with the prime (*semantic nonassociative* pairs) as well as when they were associatively related to the prime and of the semantic category (*associative-semantic* pairs).

The effect of priming was examined independently for the *semantic nonassociative* pairs and the *associative-semantic* pairs in a third and fourth experiment, respectively. The amount of facilitation produced by each of these relationships was compared to that produced by identity-priming. Primes were presented at two exposures: 28 and 43 ms. Primes were forward and backward masked (for 500 and 14.2 ms, respectively). Prime availability was thus greatly reduced and primes could generally not be reported. The results (cf. Table 1) showed significant facilitation at both prime exposures for the *semantic nonassociative* pairs, which was not statistically different from that found for *identical* pairs. In contrast, the *associative-semantic* pairs did not produce facilitation at these rapid prime exposures, although significant identity-priming was observed.

DISCUSSION

The results of these four experiments show robust effects of priming, in a semantic categorization task, for prime–target pairs which were created on the basis of their ‘‘featural overlap.’’ The priming facilitation for these pairs began extremely early, following 28 ms of prime exposure (plus 14.2 ms of backward masking), and increased with prime duration. These results extend those of previous studies, showing priming for this type of relationship at much longer prime exposures (McRae & Boisvert, 1998; Thompson-Schill et al., 1998). They are in line with results reported by Grainger and Frenck-Mestre (1998), showing an extremely rapid onset of priming facilitation provided that the task involves semantic processing and that the prime and target word have high semantic overlap. With respect to the latter criterion, common membership in a semantic category is not sufficient to ensure high semantic similarity. The rapid onset of priming observed for pairs sharing featural overlap and category membership (i.e., *pumpkin–squash*) was not found for pairs that shared category membership but were created on the basis of an associative relationship rather than featural overlap (i.e., *cow–bull*). This strongly suggests that priming facilitation for category coordinates, at least under conditions of extremely short prime exposure, is not produced via the activation of a common ‘‘category node.’’

At longer prime durations (70 and 200 ms), the semantic categorization of targets was facilitated for a larger range of prime–target relationships. Both semantic nonassociative pairs (i.e., *pumpkin–squash*) and associative-semantic pairs (i.e., *cow–bull*) were effective. While further research is warranted to determine the linguistic difference behind these two types of pairs, the present results suggest, in line with the proposals of recent distributed models (Masson, 1995; McRae et al., 1997), that the greatest and earliest effects of priming are observed for words which enjoy a high degree of semantic similarity or featural overlap. Thompson-Schill et al. (1998) have also shown that semantic relationships (i.e., *lizard–snake*) produce priming more reliably than associative relationships (e.g., *fruit–fly*). These results constrain models based on spreading activation, which assume that associative relationships should be effective in producing facilitation. While our results show this to be true, and prior research has shown that even indirect associations such as *cat–bone* can produce priming facilitation (Balota & Lorch, 1986; McNamara & Altarriba, 1988; Shelton & Martin, 1992), they also demonstrate that the presence of an associative relationship does not guarantee rapid priming, nor is it indeed necessary.

Our findings are problematic for the compound cue model (McKoon & Ratcliff, 1992), which postulates that word-priming should only be observed for words sharing an associative relationship and only when the prime can be identified. Concerning prime identification, an independent post-test revealed less than 30% correct report when participants were instructed to ignore targets and to report primes (presented for 43 ms and backward masked). Given such, the briefly presented primes were undoubtedly not consciously identified on the majority of trials in the semantic categorization task. Neither the spreading activation model nor the distributed models make specific claims about prime identification.

Further research is warranted concerning the specificity of our results to the task we employed. With regard to this, McRae and Boisvert (1998) reported facilitation at an SOA of 250 ms, with virtually the same ‘‘semantic nonassociative’’ pairs as in the present experiment (but in English), where the task was to decide if the target word was animate or inanimate rather than if it belonged to a specific category. This suggests that our results are linked to the nature of the task—one that requires the retrieval of semantic information—rather than to the particular task (see also Monsell, Doyle, & Haggard, 1989). Indeed, previous failures to obtain priming facilitation for ‘‘semantically similar’’ pairs (Lupker, 1984; Shelton & Martin, 1992) may be partially explained by the use of tasks which do not sufficiently tap semantic processing (cf. Grainger & Frenck-Mestre, 1998). Last, the extremely rapid onset of priming we observed for the ‘‘semantic, nonassociative’’ prime–target pairs may have been aided by the presence of identical prime–target pairs, the latter serving to create a stronger priming context. Note, however, that this priming context did not produce significant priming for the ‘‘associative-semantic’’ pairs. Future investigations should clarify the exact nature of the lexical relationship as well as the conditions necessary to produce rapid priming between word-pairs. Our results are a significant step in this direction.

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