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## Semantic and associative priming in picture naming

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We report four picture-naming experiments in which the pictures were preceded by visually presented word primes. The primes could either be semantically related to the picture (e.g., “boat” – TRAIN: co-ordinate pairs) or associatively related (e.g., “nest” – BIRD: associated pairs). Performance under these conditions was always compared to performance under unrelated conditions (e.g., “flower” – CAT). In order to distinguish clearly the first two kinds of prime, we chose our materials so that (a) the words in the co-ordinate pairs were not verbally associated, and (b) the associate pairs were not co-ordinates. Results show that the two related conditions behaved in different ways depending on the stimulus-onset asynchrony (SOA) separating word and picture appearance, but not on how long the primes were presented.

When presented with a brief SOA (114 ms, Experiment 1), the co-ordinate primes produced an interference effect, but the associated primes did not differ significantly from the unrelated primes. Conversely, with a longer SOA (234 ms, Experiment 2) the co-ordinate primes produced no effect, whereas a significant facilitation effect was observed for associated primes, independent of the duration of presentation of the primes. This difference is interpreted in the context of current models of speech production as an argument for the existence, at an automatic processing level, of two distinguishable kinds of meaning relatedness.

A central issue in theories of speech production concerns lexical selection: Given a situation and a communicative intention (e.g., if we have to name the picture of a cat), what mechanisms allow for the correct retrieval for production of a particular word (“cat”) among the 30,000 words that a speaker regularly uses (Levelt, 1992)? Most current models of speech production (Caramazza, 1997; Dell, 1986; Levelt, Roelofs, &

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Meyer, 1999) agree partly on the answer. They all propose an explanation based on the competition between several candidates activated by the conceptual information produced by a pre-verbal stage of message processing. A more controversial issue concerns the kind of representations that are involved in this competition. Some of the authors believe they must be lexical (so-called *lemmas*; see Dell, 1986; Levelt et al., 1999), others favour the hypothesis of form representations (Caramazza, 1997; Starreveld & La Heij, 1996b).

Still, whatever those representations might be, an important point is that despite the hypothesis of a competition among the candidates, lexical units (or, for that matter, form representations) have no explicitly described direct connections between them: They are only connected through the conceptual pre-verbal representations. Note, however, that in a previous version Levelt's model hypothesized the existence of "associative relations between entries [that] have no necessary basis in their semantic properties; rather, the basis lies in the frequent co-occurrence of the items in language use". He speculated that "though these connections are initially mediated by complex conceptual relations, they have become direct associations between lexical items" (Levelt, 1989, p. 184). This kind of hypothesis can in some way be linked to Collins and Loftus' (1975) original model of semantic memory. In this model, connections exist between *conceptual* units that, although being labelled *semantic* by the authors, are very often *associative*, at least in their examples (e.g., "house"–"fire", "street"–"vehicle", etc.). Therefore it can be argued that both models hypothesize the existence of associative relations, keeping in mind that this hypothesis is only implicit in the case of Collins and Loftus and only alluded to in the case of Levelt. But the locations of these links are different, being at the conceptual level in the former model and at the lexical level in the latter. Indeed, the theoretical status of those associative connections and their relation to semantic proximity is still not clear.

Recent research has addressed the question of the existence of a difference in the role of semantic and verbal association information during visual and auditory word recognition (Hino, Lupker, & Sears, 1997; Moss, McCormick, & Tyler, 1997; Perea & Gotor, 1997; Thompson-Schill, Kurtz, & Gabrieli, 1998; Williams, 1994; see also Lupker, 1984). These studies most often report associative facilitation effects that are usually interpreted as the consequence of associative links between formal or amodal lexical representations. The issue of semantic effects is less clear. They are not always observed, they seem to be task dependent to a certain degree, and their interpretation varies greatly across authors. Still, when they are observed they are always facilitative. As for speech production, the picture is not clear: There appear to be discrepancies between some of the reported observations. Moreover, very often there seems to be a confound between semantic and associative relatedness in the materials used. Nonetheless, putative associative effects in speech production can be expected to be facilitative if they are indeed due to activation links between representations, as is usually thought. Such a result would be in contrast with the semantic interference effects reported in the literature that lead to the notion of semantic competition (see later). Therefore, it seems that one can try to differentiate semantic and associative effects in order to ascertain their respective causes.

In this paper, we address the question of the possible implication of verbal association in the semantic competition mechanisms, and, more generally, we try to assess the relative status of semantic and associative proximity. We attempted to clarify these issues by using the classic paradigm of primed picture naming. Picture naming is indeed a widely used

and well-known technique to study language production (see Glaser, 1992, for a general review). As a first step, we now provide a brief presentation of the word–picture task that we have used as well as a short theoretical account of the mechanisms that it involves.

### Primed picture naming

In the word-primed picture-naming task, participants are presented successively with a word and a picture. Parameters associated with this paradigm are the modality of presentation of the prime, the time course of the events (e.g., the stimulus-onset asynchrony, SOA, or the duration of the prime), and the relation between prime and target. Usually variation of these parameters leads to variations of performance in the naming task, thus providing insights in the processes of speech production. For example, if a word that is semantically related to the picture is presented visually with a small SOA, naming times are usually longer than if the word is unrelated (e.g., Glaser & Dünghoff, 1984; see the following section for details on the experimental evidence available on this topic). As noted by Jescheniak and Schriefers (1998, p. 1260), “the observation that a . . . distractor effectively influences the picture naming process clearly indicates that these distractors make contact with the production system”.

The theoretical explanation of this kind of phenomenon relies on the assumption that when the word prime is processed, it activates its corresponding orthographic representations and then in turn its phonological and/or lexical (*lemmas*) representations in the production system (Roelofs, Meyer, & Levelt, 1996; Starreveld & La Heij, 1996a). If a picture is presented during the process of this activation—that is, shortly after the presentation of the prime—its naming will be influenced variably, depending on the nature and amount of representations shared with the prime. In this framework, the semantic effect just mentioned is explained by postulating a competition between the representation activated by the prime and that activated by the picture during the selection of the right name for the picture. Indeed, because both candidates are semantically related, semantic processing of the picture provides considerable “evidence” for both of them. Resolving this competition takes time. As there is no such proximity in the unrelated case, close competitors are less activated, hence the difference in the naming times between the two conditions. This competition mechanism is implemented in the WEAVER++ model (Levelt et al., 1999), which we examine further in the General Discussion. Before turning to our experiments, which use the word–picture task, we will begin by a review of experimental studies dealing with the role of semantic information and verbal association in picture naming.

### “Semantic” effects in picture naming

Among others, the question of semantic category versus associative effects in picture naming has already been highlighted by Lupker (1985) in a general comment on context effects influencing the picture-naming task. He noted that association strength was usually confounded with a semantic-category-based definition of relatedness. For example, pairs such as “chair”–“table” (strong associates and same semantic category) and “cow”–“horse” (weak associates and same semantic category) were indistinctly labelled as

*semantically related*. Careful consideration of these factors, he argued, is probably a necessary condition for establishing more clearly the nature of the mechanisms leading to the semantic effects.

The examples just cited are taken from Carr, McCauley, Sperber, and Parmelee's (1982) study, which showed reliable semantic facilitation effects in conditions where the pictures to be named were preceded by semantically related stimuli compared to unrelated primes. In some of their experiments, word primes were used, with mean exposure duration ranging from 65 to 100 ms and around 540 ms (primes were either undetectable or detectable by the participants). The facilitation effect was in fact significant for every prime duration. In another study, Sperber, McCauley, Ragain, and Weil (1979) showed that when participants had to name the prime (word) before the target (picture), and long interstimulus interval (ISI) of one second was used, the facilitation effect was smaller but still significant.

Glaser and Dungelhoff (1984) reported a systematic analysis of the time course of picture naming in a picture–word interference paradigm. In one of their experiments, the participants saw a word that they were asked to look at (without overt response) and a picture that they were asked to name. Two factors were crossed: SOA (the time elapsing between the onset of the word and the onset of the picture) and prime–target relatedness. SOA could be  $-400$ ,  $-300$ ,  $-200$ ,  $-100$  ms (word appearing before the picture), 0 ms (word and picture appearing simultaneously), or 100, 200, 300, 400 ms (word appearing after the picture). Word prime and picture could be unrelated, of the same semantic category, or identical. There was also a neutral condition in which the word was replaced by a row of Xs. For long negative SOAs ( $-400$  ms), pictures were named faster when preceded by a semantically related word than when preceded by an unrelated word.<sup>1</sup> For intermediate SOAs ( $-300$  and  $-200$  ms), there was no significant difference between the two priming conditions. For short SOAs ( $-100$  and 0 ms), the semantically related condition produced longer reaction times than the unrelated condition. This inhibition was still present for the 100-ms SOA condition, but disappeared if the word was presented later (SOAs 200, 300, 400 ms). This complex pattern of results (particularly the inhibition at short SOAs) somewhat contradicts the previously reported facilitation effects. The main difference between the two designs is the fact that the latter was an interference rather than a priming experiment, because the primes remained visible even after appearance of the target. However, it is not clear why this (small) difference between the paradigms should reverse the effects. In fact, the short SOA inhibition effect has been replicated by Starreveld and La Heij (1996b) in similar conditions (SOAs  $-100$  and 0 ms), and also by Schriefers, Meyer, and Levelt (1990) with a slightly different paradigm in which the participants heard (rather than saw) the prime word. Comparison of the semantically related and unrelated conditions<sup>2</sup> showed an inhibition effect for an SOA value of  $-150$  ms. For SOAs of 0 or 150 ms there was no significant difference between

<sup>1</sup> This difference was not significant. However, in an experiment not reported here, we observed a similar (significant) result with semantically related pairs when primes were presented with a comparable SOA of 600 ms.

<sup>2</sup> The results obtained in the phonologically related conditions of this study have been challenged recently by Jescheniak and Schriefers (1998), but the general pattern of the semantic condition observations was preserved.

these two conditions.<sup>3</sup> These authors also mention a similar experiment with an associatively related condition for which reaction times did not differ from the unrelated condition.

It is important to note yet another important factor in this kind of picture–word experiment. For instance, Roelofs (1992) showed that two conditions had to be met by the response set (the set of the names of the pictures used in the experiment) in order to observe inhibition. First, semantically related distractor words must be members of the response set (i.e., if there is a pair such as “pony”–HORSE<sup>4</sup> there should also be a pair such as “donkey”–PONY, etc.) and, second, there must be several members of a single category (e.g., there must be several pictures of *animals*). When the distractor co-ordinates were not in the response set, he observed semantic facilitation effects at SOA of –100 ms (Roelofs, 1993).

Moreover, another small modification of the picture–word paradigm that we have been describing can also lead to the observation of semantic facilitation effects. In the article mentioned before, Glaser and Döngelhoff (1984) observed a semantic facilitation if the task was not to name the picture but to give its superordinate category (e.g., say “animal” when faced with the picture of a DOG). That was true for the negative SOAs (word appearing first). Indeed, in that case the prime bears a different relation to the response than in the case of standard picture naming.

Note that in the preceding studies the authors did not give a fine-grained definition of the relation between the prime and the name of the corresponding picture. Wheeldon and Monsell (1994) proposed an interesting approach to the nature of semantic similarity by defining semantic relations as follows: Two words are semantically close if the objects they refer to share a “significant” number of properties, properties that can either be “functional” (based on uses, manner of use and, of course, category) or “structural” (based on features relevant to visual identification). Operationally, the measure of “semantic overlap” is made by asking neutral judges to rate on a numeric scale the functional or visual similarity of objects corresponding to pairs of words (see Wheeldon & Monsell, 1994, for details; Flores d’Arcais & Schreuder, 1987; Humphreys, Riddoch, & Quinlan, 1988, for a different analysis of the distinction between “functional” and “structural” as related to semantic categories). The two words of any of those pairs are named semantic competitors.

With these materials, they observed semantic inhibition in a different paradigm. In their experimental paradigm, participants were asked to respond alternatively to definitions, sentences to complete (both visually presented), or pictures to name. Consequently, they produced a word approximately every 4 s. Moreover, some of the words pronounced as responses to definitions or completions of sentences were implicit primes to the following picture or to a later one, by virtue of a semantic relation between the two (in

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<sup>3</sup> Small differences in the time course of visual interference (where, as observed by Glaser & Döngelhoff, 1984, the inhibition effect appears mainly for simultaneous presentation) can be explained by the particularities of the auditory modality. With auditory presentation, the whole word is not directly available as it is during visual presentation. The acquisition of interfering information from the word might take longer, thus needing a more negative SOA to be effective.

<sup>4</sup> Word contexts are denoted between quotes and picture targets in small upper-case letters.

this way prime and target are separated by at least a 4-s interval and by up to 4 min in certain conditions). The experiments yielded an important semantic effect: Significantly longer reaction times were observed for naming pictures for which a semantic competitor had been produced by the participants in the preceding trials than for pictures unrelated to the preceding answers. The amount of inhibition was relatively stable across SOA conditions, provided the number of trials separating prime and probe was not larger than two (approximately 12 s). The effect was also largely independent of structural similarity: Pairs that were both functionally and structurally similar yielded results comparable to those pairs that were only functionally similar. The authors concluded that inhibition is due to *competition* at a semantic level between prime and target during the process of finding the target, if activation of the “functionally overlapping” prime is still present.

Note that in this case the association strength was not controlled in the definition of the prime–target pairs, therefore it did vary between the pairs. Other studies, however, have more directly attempted to disentangle these two characteristics. Actually, in Lupker’s picture-naming studies, associative strength (as measured by verbal association norms) was usually controlled when dealing with semantic coordinates (Lupker, 1979, 1988). In the first of these two studies (Lupker, 1979), the author showed the existence of a semantic inhibition effect, which was independent of association strength. Specifically, he compared naming times for pictures (e.g., MOUSE) with a superimposed word (i.e., at SOA = 0 ms). The word could be of the same semantic category as the object depicted by the pictures (“dog”), a close associate not from the same category (“cheese”), or an unrelated word (“hand”). Prime and picture from the same semantic category produced longer reaction times than did the two other conditions, which produced equivalent reaction times. Moreover, in a second experiment prime and target were semantic coordinates *and* verbal associates (pairs such as “cat”–MOUSE instead of “dog”–MOUSE used previously). An inhibition was observed once again: If the prime and the picture were verbal associates taken from the same semantic category, naming times were longer than if they were unrelated. Interestingly, in the other study (Lupker, 1988, Experiment 3), the priming of a target picture by another picture or by a word produced a reliable facilitation effect for associated primes and targets, independent of the semantic category relationship. (Note, however, that in this paradigm participants were asked to name the prime before naming the target, and that 250 ms separated the end of the response to the prime and the onset of the target. Therefore the SOA was at least 750 ms.) This result is consistent with that of Irwin and Lupker (1983) who observed that, with long SOAs, semantic category did not produce priming effects on naming pictures in the absence of associative relatedness, but it contradicts the study by Sperber et al. (1979) in which facilitation was observed in the semantically related condition.

La Heij, Dirx, and Kramer (1990) also reported interesting results, comparing several semantic priming conditions. In their Experiments 2 and 3, pictures to be named could alternatively be primed by a categorically related–highly associated word, by a categorically related–low-associated word, or by an unrelated word. SOAs were –400, 0, 75, and 150 ms. For a –400-ms SOA, shorter naming times were observed in the categorically related–highly associated priming condition than in the unrelated condition. There was no such difference for the categorically related–low-associated condition (contrary to

what could be expected after the  $-400$ -ms SOA condition in Glaser & Dungelhoff's, [1984] study). These results, then, support the view of an associative origin of facilitative effects when long SOAs are used, in agreement with Lupker's observations. For the  $0$ -ms SOA, there was a slowing of the naming times in the categorically related–low-associated condition. This effect is comparable to most of the other observations for semantic primes presented at short SOAs, if its origin is to be found in the categorical relation between prime and picture. However, in order to explain the absence of effect in the categorically related–highly associated condition, the authors postulated that the inhibition effect might have been compensated by the existence of an associative facilitation effect, that could also be present for the  $0$ -ms SOA condition. The reliability of this postulate is difficult to evaluate: No direct evidence is available for a short-SOA associative effect, and Lupker's results seem to show (indirectly) that associative relation had no effect in addition to the semantic relation in this experimental paradigm.

Thus, a temporary conclusion from this review could be that, for short SOAs, there is a trend for the existence of semantic inhibition (provided that the response set meets the requirements pointed out by Roelofs, 1992, 1993: i.e., presence of several members of each category and of distractors in the response set) and an indeterminacy for the role of verbal association. This inhibition is explained by positing a competition between several semantically related candidates (see WEAVER++ model, Levelt et al., 1999). Note that if the explanation of semantic effects in terms of a competition between candidates is correct, inhibition should not be expected when the primes are associatively related to the pictures. Indeed, associative relation per se does not imply that the objects denoted by the two words are similar (with similarity defined, e.g., in the way that Wheeldon & Monsell, 1994, define it: sharing of a significant number of semantic features). That is, there are pairs such as “nest”–“bird”. Therefore, if a purely associative relation was tested, a facilitation (due to possible associative links) or a null effect should be observed. However, even in the studies that acknowledged the distinction, semantic and associative factors were not completely dissociated and this (partial) confound does not allow us to draw clear conclusions on the role of associates during lexical selection. Moreover, although Roelof's (1992) modelling proposal simulated the absence of verbal association effects observed by Lupker, there is no explicit attention given to verbal association in the last version of the WEAVER++ model (Levelt et al., 1999). The model might certainly account easily for possible association effects by reconsidering the existence of associative links.

For longer SOAs, facilitation seems to be the rule (with the main exception of the results of Wheeldon & Monsell, 1994), but its origin, either semantic (Carr et al., 1982; Sperber et al., 1979) or associative (Irwin & Lupker, 1983; Lupker, 1988), is controversial. A possible explanation for these differences could be that participants might sometimes use controlled strategies, which are more prone to variability than automatic processes. This remark applies mainly to facilitation effects observed in the experimental conditions involving the longer SOAs (Carr et al., 1982; Irwin & Lupker, 1983; Lupker, 1988; Sperber et al., 1979). Indeed, semantic and associative relations are quite easy to detect and could have been exploited by the participants. Clearly, if a procedure allows participants to use strategies, it is not certain that automatic lexical selection is the process being tested.



Further evidence for the existence of a significant difference between semantic and associative properties can be found in neuropsychological data. Coltheart (1980; see also Nickels, 1997, for a recent review) reports a classification of the relationships between stimulus and semantically erroneous responses given by deep dyslexic patients in a word-reading task. The errors can either be due to “shared features”, when the stimulus and the response have an important number of common semantic properties (which entails almost always belonging to the same semantic category; e.g., *tulip* read as “crocus”); or be “associative”, when the stimulus and the response are verbally associated (e.g., *postage* read as “stamps”). Indeed, Coltheart’s discussion of possible theoretical explanations of this distinction shows the difficulty of accounting for both kinds of error in a simple manner. But, as Nickels argues, this difficulty should not blur the importance of the distinction, as it might be the basis for a further analysis of the “semantic” impairment in aphasia.

Indeed, the experimental evidence available does not provide a clear picture for assessing the role of verbal association in the production lexicon and, more specifically, its involvement in the lexical selection processes. To clarify this issue, we conducted four experiments. In particular, we attempted to separate semantic and associative effects in the picture-naming task, using a priming paradigm in which automatic processing of the stimuli was hypothesized. This goal required a careful selection of the materials, described in the following section. Also, we tried to ascertain whether time parameters were responsible for the difference between the results of the Carr et al. (1982) study and those of the others.

### Tentative dissociation of semantic relation and verbal association

Unfortunately, there is no indisputable definition of semantic similarity that can be used when selecting word–picture pairs for semantically related experimental conditions. Semantically related pairs can be defined as those that pertain to a same (intuitive) semantic field, this being either explicit (such as *animals*) or covert (such as *the set of devices for telling the time*, see Cruse, 1986). Semantic fields seem to have a psychological reality: A number of neuropsychological data have been interpreted as evidence for a semantic-categories-based organization of the lexicon (e.g., Caramazza & Shelton, 1998). Attention can also be given to the structure of the taxonomy from which the instances are selected; this might allow one to ascertain, among others, hierarchical levels (e.g., to differentiate between subordinate–superordinate pairs and same-level pairs: i.e., dog–animal versus dog–horse), typicality of members (e.g., an apple is usually considered as a better instance of fruit than a hazelnut), etc. (see Cruse, 1986, for a linguistic description of lexical configurations). Sharpening the criteria, an evaluation of the relative similarity between pairs chosen at a given level of taxonomy can provide a normalization of pairs that can otherwise refer to either very close (e.g., ox–bull), or quite distant (e.g., cat–elephant) objects. A first method for evaluating similarity is to have subjects produce judgements of similarity for different pairs. As was mentioned before, Wheeldon and Monsell (1994) asked different subjects to rate pairs of items for “functional” or “structural” similarity. Although it provides a rough classification of the pairs, the task is not

without problems, given its sensitivity to contextual and interpretative factors (see Medin, Goldstone, & Gentner, 1993, or Tversky, 1977, for attempts to clarify this issue). Otherwise, subjects can be asked to produce features associated with a concept; co-occurrence and/or correlations among features are then evaluated, and a measure of proximity between items can be deduced (McRae, de Sa, & Seidenberg, 1997).

Note that the different definitions overlap, and their relative merits are yet to be clarified. To date, there is no clear evidence for a featural representation of concepts (although some arguments have been provided by McRae & Boisvert, 1997, or McRae et al., 1997), nor for the role played by typicality of items in their class (see Hines, Czerwinski, Sawyer, & Dwyer, 1986, for a study of this factor in visual word recognition). Therefore, to select a group of semantically related pairs, we chose a group of 66 pairs of members of (intuitive) semantic categories and asked 9 subjects to judge the similarity of the members of each pair *among the members of their category* (participants were instructed in French: "You are going to see pairs of words designating objects of a single semantic category, e.g., two animals: horse and donkey. For each of these pairs of words, evaluate the similarity of the two objects to which they refer, as compared to other members of the category to which they belong."). All the pairs were formed by members of a single category, and participants were asked to make their judgements inside each category, in order to compare pairs that were always relatively similar so as to minimize the variability inherent in the interpretation of the task. Subjects answered using a 5-point scale (1 = not very similar, to 5 = very similar indeed). A crucial point is that the pairs we chose were not associatively related, according to the criteria described later (Ferrand & Alario's, 1998, French norms).<sup>5</sup> Considering constraints of picturability and name agreement (Alario & Ferrand, 1999), we kept 22 of these pairs among those that were judged more similar; the difference between the ratings for those 22 pairs and the others was significant,  $t(64) = 2.69, p = .01$ . These pairs were called "co-ordinate pairs" (e.g., boat-train). Similarly defined pairs were named "competitor pairs" by Wheeldon and Monsell (1994). Such a name acknowledges that the objects designated by the two words were very similar (they have a "substantial semantic overlap").

Alternatively, association norms (counts of frequency of response to a stimulus word: Ferrand & Alario, 1998; Moss & Older, 1996; Postman & Keppel, 1970) possibly provide a different approach to relations between lexical items. Indeed, verbal associations are very often based on the meaning of the stimuli (e.g., "nest"-"bird") as opposed to phonological or other form-based relations (as could be the unobserved rhyming pair "hat"-"cat"). Clark (1970) classified the most common kinds of response in this task. Also, he proposed an explanation of their appearance based on hypothesized syntactic and semantic features of the stimulus. A response in a verbal association task, he argued, will generally be the result of a minimal change made on the features of the stimulus word. For example, participants will respond "boy" to "girl" as a result of a switch of the value of the semantic feature "sex" that is part of the representation of the meaning of "girl". He specified furthermore a series of rules that describe the possible kinds of change that participants will apply as well as their probability of use. No direct evidence is available for this proposal, however.

<sup>5</sup> One of the material pairs (dog-cat) happened to be associatively related.

Another approach to explain verbal association is to relate it to co-occurrences in language use. Spence and Owens (1990) argue that two words will be associated by subjects if they appear often as close neighbours in written text (see also Church & Hanks, 1990). However, it is not clear whether co-occurrences reflect mainly associative or, rather, semantic relations (see Lund & Burgess, 1996; Lund, Burgess, & Audet, 1996). Therefore, and disregarding the issue of the primal origin of verbal associations, we relied on the classic task of free association to select the materials for the verbal associates condition. We selected verbal associate pairs among those that had the most frequent associates in Ferrand and Alario (1998) French norms. These norms were collected for 366 words from a group of 89 participants, who were undergraduate students in psychology, like the participants of the experiments reported in this paper. Importantly, we selected pairs for which the two words were not members of a single (intuitive) semantic category (see previous definition of co-ordinate pairs). An additional constraint was that verbal associates had to be unambiguously picturable. Finally, 20 pairs were selected (e.g., nest–bird, ashtray–cigarette). They had a mean association frequency of 46% (range 18% to 84%); selected associates were all “first associates”). We did not explicitly rate semantic similarity between the members of these pairs, but, as they were never from a common semantic category, they could not designate similar objects in the way that was defined previously (see examples given earlier).

As a final result of the various constraints that had to be satisfied in the selection of the materials for both conditions, two non-overlapping groups of pictures were produced. Therefore, we decided to treat the co-ordinate condition and the associated condition separately.

### Time parameters

Because we wanted to test the role of verbal associates lexical competition in the naming task, we chose a short SOA between prime and target. Indeed, according to most of the studies reviewed earlier, semantic interference produced by a visually presented word is maximal (and more probably observed) if the word is presented shortly before the picture. Moreover, according to Neely and Keefe’s (1989) review, a prime presented with a short SOA elicits automatic processing by the participants.<sup>6</sup> Therefore, a short SOA is taken to tap automatic priming processes and to reveal lexical competition processes. We chose an SOA of about 100 ms (114 ms). Semantic effects in the word–picture task are maximal around this SOA.

On the other hand, and as noted earlier, Carr and colleagues (Carr et al., 1982) did not report a semantic interference effect but rather semantic facilitation. In their study, primes were presented with short or very short SOA and also with a short prime duration (the prime always disappeared before the onset of the picture). Note also that the facilitation was present with both masked and unmasked primes. To ascertain if variations of prime presentation duration produced the difference between this study and most of the

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<sup>6</sup> They proposed 250 ms as the upper limit after which participants’ strategies might come into play. Actually, this criterion referred to semantic priming in the lexical decision task but, provided it refers mainly to the processing of the prime, it should be readily exportable to a picture-naming paradigm.

other reports, we chose a short prime duration as well. However, in order to render our experiments comparable to those of Carr et al. and the others, we chose not to mask the primes.<sup>7</sup> We used a prime duration of 100 ms.

In sum, in our first experiment, participants saw the word prime for 100 ms, then the screen was blank during 14 ms (one screen-refreshing cycle), and finally the picture was presented. We expected to observe an inhibition for the co-ordinate (semantic) condition, similar to that reported in most of the word–picture studies that we have reviewed. The verbal association condition, on the other hand, was expected to produce a facilitatory effect or no effect.

## EXPERIMENT 1

### Method

#### Participants

There were 40 participants, 20 in Experiment 1a and 20 in Experiment 1b. All were students at René Descartes University (Paris) and participated in the experiments for course credit. They were all native speakers of French and reported normal or corrected-to-normal vision.

#### Materials

Pairs of semantically or associatively related words were selected according to the criteria described in the previous section. From these pairs we selected 42 simple black and white line drawings of common objects as experimental pictures: 22 in Experiment 1a (co-ordinate priming) and 20 in Experiment 1b (associative priming). The line drawings corresponded to one of the two words of each of the co-ordinate pairs and to the associated (response) word in the verbally associated pairs. All but two of the drawings were taken from the French norms developed by Alario and Ferrand (1999). The added pictures (“SPEAR” in Experiment 1a and “BABY” in Experiment 1b) were not available in the norms, but were drawn in the same fashion as the others. In both Experiment 1a and Experiment 1b, the objects could be approximately classified as belonging to 8 “intuitive semantic categories”. The mean name agreement for the pictures used in Experiment 1a was 93%, and for Experiment 1b it was 90%. In addition to the experimental stimuli, five training picture pairs were selected for both experiments. The pictures were taken from the same source as those described previously. Each drawing appeared in black on a white square of  $245 \times 245$  pixels in the centre of the computer screen. Participants were seated about 60 cm from the screen so that the visual angle occupied by the stimuli was approximately  $6.25^\circ \times 6.25^\circ$ . The complete list of the stimuli is given in the Appendix.

#### Design

In both experiments, the prime–target relation was treated as a within-participants factor with two levels: related (co-ordinate related in Experiment 1a and associatively related in Experiment 1b) and unrelated. For Experiment 1a, prime–target pairs were rotated across the two priming relations across two groups of participants such that no participant saw any single word prime or target picture

<sup>7</sup> This also avoids raising the difficult question of the effects produced by a “consciously/unconsciously” identified prime (see Holender, 1986, for a discussion of the complexity of this question).

more than once, but each participant received both experimental conditions. Therefore, every participant saw 22 word prime–picture target pairs, 11 from each condition. To achieve this, the word–picture pairs were divided into two groups of 11 pairs each. List 1 was created by keeping the pairs in the first group and re-pairing randomly the pairs in the second group, thus creating unrelated pairs for half of the pictures. List 2 was created by a symmetric procedure. Participants were assigned one of the two lists, alternately, in their order of appearance in the laboratory.

The same manipulations were applied to the materials of Experiment 1b.

### Apparatus and procedure

Participants were tested individually. Before starting the experiment itself, they were given a booklet including all drawings and their names (following Ferrand, Grainger, & Segui, 1994, and Schriefers et al., 1990). They were asked to examine all the drawings and to use only the proposed name. During the experiment, word primes and target pictures were presented on the centre of the screen of a personal computer with a 70-Hz refresh rate. Every trial consisted of the following sequence of four stimuli: (1) A white rectangle ( $240 \times 50$  pixels) was presented for approximately 14 ms; (2) the prime appeared in black upper-case letters on the rectangle for 100 ms; (3) the word prime disappeared subsequently: the rectangle was maintained for 14 ms; (4) the picture to be named replaced the rectangle and remained on the screen until the participant responded. The next sequence followed after a 2-s delay. The experiment began with the presentation of five training trials (with the same order for all participants). Then a break followed to provide participants with feedback on their use of the voice-key. Then the probe trials came (with a different randomized order for each participant).

Participants were asked to concentrate on the middle of the screen (location of all stimuli) and to name as rapidly and as accurately as possible the depicted object when it appeared. The computer recorded the naming times, measured from the target onset to the triggering of the voice key by the participant's response (Sennheiser MD211N microphone). The experimenter sat in the same room as the participant in order to check and note the responses of the participant.

## Results

### Experiment 1a

Trials for which the voice key was triggered by noise or when it did not detect the participant's response were regarded as technical errors and were excluded from the analysis (19 errors: 4.3% of the total data). Trials on which participants named the picture incorrectly (particularly if they did not use the name that was proposed), hesitated noisily, stuttered, or failed to answer were regarded as participants' errors (24 errors: 5.5% of the data). Items that produced more than 25% of errors were excluded from the analysis (there were two such items: SPEAR and DART). Note that, because of the design we chose, exclusion of an item affects the two priming conditions equally. Among the 20 remaining items, errors amounted to only 7.3% of the data (4.0% technical errors and 3.3% participant errors). In order to normalize the data, latencies of more than two standard deviations from the mean of each participant were considered as outliers and were also excluded from the reaction time analysis (18 measures: 4.5% of the remaining data).

Mean naming latencies and error rates by prime relation are given in Table 1. Matched pairs *t* tests on the mean reaction time data showed that the  $-33$ -ms effect of prime

TABLE 1  
Mean naming latencies (M)<sup>a</sup> and error rates (ER)<sup>b</sup> for each priming condition in Experiment 1<sup>c</sup>

Exp.	Prime relation							
	Co-ordinates		Associated		Unrelated		Priming effect	
	M	ER	M	ER	M	ER	M	ER
1a	719	2.9			687	3.7	-33	+0.9
1b			656	2.0	659	3.5	+3	+1.5

Note: Examples of prime-target pairs: *co-ordinate* "boat"-TRAIN; *associated* "nest"-BIRD. Original stimuli in French.

<sup>a</sup>In ms. <sup>b</sup>In percentages. <sup>c</sup>SOA: 114 ms; prime duration: 100 ms.

relation was significant for both participants,  $t_1(19) = 2.06$ ,  $p = .05$ , and items,  $t_2(19) = 2.27$ ,  $p = .03$ , analyses. The difference in the error rates was not significant (both  $t < 1$ ).

### Experiment 1b

The same treatment was used for the data of Experiment 1b. Technical errors amounted to 3.8% of the data (15 measures), and participants' errors amounted to 2.8% of the data (11 measures). No item produced more than 25% of errors so they were all kept for further analysis. Outliers represented 5.5% of the data (22 measures). Mean naming latencies and error rates by prime relation are given in Table 1. Matched pairs  $t$  tests on mean reaction time data showed that the 3-ms difference between the two prime relations was not significant (both  $t < 1$ ), nor was the +1.5% difference in the error rates (both  $t < 1$ ).

### Discussion

The results obtained in Experiments 1a and 1b can be summarized as follows: When word primes are presented briefly (100 ms) before a picture to be named, close semantic coordination between prime and target slows naming, whereas a strong verbal association between prime and target has no influence, both priming conditions being compared to an unrelated condition baseline.

The semantic effect fits partly with the aforementioned observations. In particular, it is inconsistent with Carr et al.'s (1982) observation of facilitation effects, but it is comparable to the inhibition effects observed by Glaser and Dünghoff (1984, Experiment 1, SOAs -100 and 0 ms), La Heij et al. (1990, Experiments 2 and 3, SOAs 0 and 75 ms), Lupker (1979), Starreveld and La Heij (1996b), and also Schriefers et al. (1990, Experiment 2, SOA -150 ms). However, it is important to remember that Carr et al. (1982) did not isolate the semantic (as opposed to associative) component of meaning proximity between pairs of stimuli. This could be a possible explanation for the differences between the results of their study and those of ours (although the fact that we do not observe any effect for associated primes makes it difficult to argue that associative relatedness did have

an effect in their study). One can also attempt a “practice account” of the facilitation effects observed by Carr and colleagues. In their study, threshold durations were determined for the (only) 12 prime–target pairs during a (long) 1¼-hr session. Then, the day after, the same subjects participated in the experiment itself, with several (eight) repetitions of the same 12 pairs in different conditions. Such a long practice with a small set of materials might induce the influence of much more episodic representations than would our procedure, and thus a different outcome. Finally, the small set of items used in the study could be responsible by itself for the absence of semantic inhibition. As argued by Roelofs (1993), semantic inhibition will be observed in this paradigm only when there are several targets from a single category (e.g., several animals). This was not the case in Carr and colleagues’ material.

Otherwise, the fact that we do not observe any associative facilitation argues against the explanation given by La Heij et al. (1990) of the absence of a semantic effect in their semantically related–highly associated condition at short SOAs (remember that these authors posited an associative effect at the 0-ms SOA that could compensate for semantic inhibition). Also, it seems to indicate that associative relatedness does not play a major role in the processes of speech production revealed by this procedure. Therefore, we can take these results, and the general tendency observed in the other studies, as strong arguments for a rather pure semantic origin of the inhibition effect observed in Experiment 1a. This inhibition effect can be explained by postulating a competition among different candidates for the selection of a name for the picture, as was described in the Introduction. Details of this mechanism are provided in the General Discussion.

It could be argued that the null effect in the associate condition of Experiment 1b is due to a lack of strength in the relations between prime–target pairs (in spite of the careful procedure used to select them). Also, temporal parameters (SOA or prime presentation duration) have been shown to modulate priming effects, as we discussed earlier. It might be that the 114-ms SOA and 100-ms prime duration that we chose did not allow enough time for associative effects to develop. Therefore we decided to conduct a second experiment with the same materials but with the prime presentation conditions changed to allow a longer (and, it was hoped, deeper) processing of the prime. There are two ways to achieve this goal: increasing SOA or increasing prime presentation duration. SOA is the variable most often used in this kind of study but prime presentation duration is sometimes manipulated. Especially, it was the variable manipulated in the Carr et al. (1982) study. In order to explore further the status of verbal associates and to ascertain clearly the influence of time parameters we decided to vary prime presentation duration while using a longer SOA.

Experiment 2 was conducted with a new SOA of 234 ms, which was significantly longer than 100 ms but still short enough to elicit automatic processing.<sup>8</sup> Prime presentation duration was introduced as a factor with two levels: 100 ms (similar to Experiments 1a and 1b) and 220 ms. Experiment 2a was conducted with the semantic pairs, and Experiment 2b was conducted with the associated pairs.

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<sup>8</sup> According to the 250-ms criterion discussed earlier.

## EXPERIMENT 2

### Method

#### Participants

There were 80 participants: 40 for Experiment 2a and 40 for Experiment 2b. All were students at René Descartes University (Paris) and participated in the experiments for course credit. They were all native speakers of French and reported normal or corrected-to-normal vision. None of them had participated in Experiments 1a or 1b.

#### Materials and procedure

The materials and procedure were similar to those of Experiments 1a and 1b, except that the word primes were now presented with an SOA of 234 ms and two possible prime durations (100 or 220 ms). Therefore the sequence of events seen by the subjects on each trial was: (1) a white rectangle ( $250 \times 50$  pixels) presented for approximately 14 ms; (2) the prime written in black upper-case letters on the rectangle for 100 ms (or 220 ms); (3) disappearance of the prime; the rectangle was maintained for 134 ms (or 14 ms); (4) the picture to be named, which remained on the screen until the participant responded.

#### Design

The design of Experiment 2 was similar to that of Experiment 1. In both Experiments 2a and 2b the prime–target relation was treated as a within-participants factor with two levels: related (co-ordinate related in Experiment 2a and associatively related in Experiment 2b) and unrelated. Prime presentation duration was a between-participants factor (in each experiment, half of the participants saw the prime for 100 ms and the other half saw it for 220 ms). SOA was held constant (234 ms).

As the materials were the same as those in Experiment 1, similar list manipulations were applied.

### Results

#### Experiment 2a

The data were treated in the same way as those of Experiments 1a and 1b. In this experiment, 3.4% of the data were considered as technical errors (30 measures) and 6.1% were participants' errors (54 measures). One item produced more than 25% of errors and was therefore excluded from further analysis (SPEAR). Among the 21 remaining items, there were 8.6% of errors (technical 3.1%, 26 measures; participants' 5.5%, 46 measures). For each subject, latencies distant of more than two standard deviations from the mean were considered as outliers and were excluded from further treatment (5.1% of the data, 43 measures).

Mean naming latencies and error rates for each priming condition are given in Table 2. We analysed the reaction time data by conducting two analyses of variance (ANOVA). First, in a  $2 \times 2$  by participants ANOVA ( $F_1$ ), prime relation (co-ordinate vs. unrelated) was a within-participants factor, and prime presentation duration (100 ms vs. 220 ms) was a between-participants factors. In a second  $2 \times 2$  by items ANOVA ( $F_2$ ), both prime relation and prime presentation duration were within-items factors. The 3-ms difference



TABLE 2  
 Mean naming latencies (M)<sup>a</sup> and error rates (ER)<sup>b</sup> for each prime relation and prime duration in Experiment 2<sup>c</sup>

Exp.	Prime presentation duration	Prime relation							
		Co-ordinates		Associated		Unrelated		Priming effect	
		M	ER	M	ER	M	ER	M	ER
2a	100 ms	682	5.8			680	7.1	-2	+1.3
	220 ms	641	3.8			649	5.4	+8	+1.6
2b	100 ms			565	1.5	593	2.5	+28	+1.0
	220 ms			601	1.0	642	1.5	+41	+0.5

Note: Examples of prime–target pairs: *co-ordinate* “boat”–TRAIN; *associated* “nest”–BIRD. Original stimuli in French.

<sup>a</sup>In ms. <sup>b</sup>In percentages. <sup>c</sup>SOA: 234 ms.

between the two prime relation conditions (coordinate: 661 ms; unrelated: 664 ms) was not significant (both  $F_s < 1$ ). There was a trend for an effect of prime presentation duration, only significant by items,  $F_1(1, 38) = 2.2, p = .15$ ;  $F_2(1, 20) = 16.3, p < .01$ . Importantly, the two factors did not interact (both  $F_s < 1$ ).

The error rates were submitted to a similar analysis, but no main effect or interaction reached significance (all  $F_s < 1.4$ ).

### Experiment 2b

Errors amounted to 4.5% of the data (technical 2.9%, 23 measures; participants' 1.6%, 13 measures). No item produced more than 25% of errors so they were all kept for the analysis. Outliers (defined in the same way as before) amounted to 4.4% (35).

Mean naming latencies and error rates for each priming condition are also given in Table 2. Similar analyses to those conducted for Experiment 2a were conducted here. We observed a clear priming condition effect: associates: 583 ms; unrelated: 618 ms; difference: 35 ms;  $F_1(1, 38) = 6.6, p = .01$ ;  $F_2(1, 19) = 15.4, p < .01$ . There was a trend for a prime duration effect,  $F_1(1, 38) = 3.1, p = .09$ ;  $F_2(1, 19) = 28.4, p < .01$ . Importantly, the interaction between the two factors was not significant (both  $F_s < 1$ ).

The error rates were submitted to a similar analysis, but no main effect or interaction reached significance (all  $F_s < 1$ ).

### Discussion

Using a longer SOA, the semantic competition effect observed in Experiment 1a was not present in Experiment 2b, but, interestingly, an associative facilitation effect clearly emerged. As shown by the absence of interaction between the two factors, this association effect is independent of prime presentation duration, at least for the two values that we compared.

The emergence of an effect in the associated condition is important: It shows that association strength between our stimulus pairs is sufficient to produce priming effects, but that those are only possible for certain SOAs. The fact that this effect is facilitative clearly dissociates it from the inhibition observed for semantic pairs in the 114-ms SOA condition, especially because there was no semantic effect in Experiment 2a. Indeed, we believe that different mechanisms were at work to produce the two effects.

## GENERAL DISCUSSION

In order to provide a more comprehensive view of the results that we obtained, we now take a slightly different perspective. We begin by a discussion of the time parameters affecting priming in picture naming. Then we discuss the semantic inhibition effect and the associative facilitation effect. Final thoughts about their relationship are then sketched.

### Time parameters

In the experiments that we report, different patterns of priming were obtained for different SOAs. With the short SOA, there was a semantic interference effect but no associative effect. By contrast, with the long SOA, there was no semantic effect but an associative facilitatory effect, independent of the prime presentation duration.

Indeed, SOA has already been shown to be an important factor influencing priming in the picture-naming task (see, e.g., Glaser & Dünghoff, 1984). Prime duration, on the other hand, was the variable manipulated by Carr et al. (1982) in the study in which they observed semantic facilitation with a priming paradigm. Note, however, that because their primes were always presented before the onset of the picture, their manipulation confounded prime duration and SOA (a prime presented for a longer time was also presented earlier). Our results, in particular the absence of any interaction in Experiments 2a and 2b, indicate that priming effects are, at least to a certain degree, independent of prime duration. This is not surprising: In the short prime duration condition of Experiment 2, the prime was presented long enough to be identified by the participants. Arguably, in that case all the information that the visual stimuli can provide is made available to the subject, and the processing produced during the remaining 134 ms before picture onset seems to take place independently of the presence of the prime in the subject's visual field. As could be expected in the visual modality, for the range of time parameters we studied "depth of processing" is linked to SOA rather than to stimulus presentation duration. We therefore refer to SOA as the important variable in the remainder of the paper.

Finally, both Experiment 2a and Experiment 2b show trends for an effect of prime presentation duration as a main factor. However, these two tendencies differ in their direction (slower naming times for short prime duration in Experiment 2a and the contrary in Experiment 2b). As this factor has been manipulated between subjects, the differences could be explained by the presence of slower or faster groups of subjects.

## Semantic inhibition

The inhibition observed at short prime duration is somehow surprising in a priming paradigm of the kind we used (where the prime words disappear before the onset of the picture). Indeed, facilitation has previously been observed (Carr et al., 1982). As noted earlier, we have only a tentative explanation for this difference. Especially, an explanation in terms of variable associative strength between the items does not seem to be satisfactory, but an explanation in terms of participants' practice or a limited set of stimuli appears more attractive. However, the reported interference effect, which to our knowledge is observed for the first time in French, is reliable and is comparable with the effects observed using other languages in picture–word interference designs (in which the word prime is still on the screen when the picture appears). This is an argument in favour of the reliability of the observed phenomenon. Moreover, it seems to indicate that the presence or absence of the word on the screen during picture processing does not make much difference (just as the prime duration per se does not have a major influence in the range of values we manipulated). The theoretical account of the effect runs along the lines sketched in the Introduction (Levelt et al., 1999; Roelofs et al., 1996; Starreveld & La Heij, 1995, 1996a, b; Wheeldon & Monsell, 1994). When the word prime is processed (e.g., “boat”), it activates its corresponding phonological and/or lexical representations. When the picture of a TRAIN is presented during the process of this activation, that is, shortly after the presentation of the prime, its processing will produce the activation of semantic information associated with it. Because boats and trains share a “substantial semantic overlap”, considerable evidence for both candidates will be available. Moreover, the prior activation of boat makes it a good available candidate to name the picture. The system will have to select among these two possibilities, and maybe some others. As a consequence it takes more time to select the right candidate than when the picture is shortly preceded by an unrelated word, which does not induce conflicting activation that influences lexical selection. (See Roelofs et al., 1996; Starreveld & La Heij, 1995, 1996a, b for a detailed discussion of the interaction between the processing of the prime and the processing of the picture. See Levelt et al., 1999, for an implementation of this mechanism in the general framework of the WEAVER++ speech production model.)

Note that further support for the semantic competition view comes from the absence of any interference effect with the same stimuli when the prime is presented with an SOA of 234 ms (the disappearance of the inhibition at longer SOAs is predicted by WEAVER++). Indeed, it is possible to imagine that when enough time is left for processing the word prime (whether or not it is present on the participants' visual field), the lexical access process produced by the prime is completed when the picture appears; the identification of the prime is effective, and its representations are already on their way to their rest state. Their activation decreases and, consequently, the activation produced by the processing of the word prime will not influence in any significant manner the naming of the picture.

Importantly, the competition process seems to happen strictly between semantically related candidates, whereas verbal associates of a possible candidate do not have any significant role to play, as shown by the null effect in Experiment 1b. Indeed, as was noted earlier, associative relation per se does not mean that the objects denoted by both words have similar referents or a substantial overlap of semantic features (e.g., nest–bird).

Therefore, associates of the name of a picture are not to be expected among the cohort of co-ordinates produced during initial semantic processing of the picture.

Other accounts of the semantic interference effect can of course be imagined. In particular, a version of Berg and Schade's (1992) interpretation of Schriefers et al.'s (1990) results could be applied to explain successfully the particular inhibition effect that we observed. These authors postulate the existence of lateral inhibition between representational units at any given level, and particularly at the lemma level. According to their interpretation, when a lemma begins to be activated (for example, by the presentation of the word prime) it sends inhibition automatically to its semantic neighbours (co-ordinates). Therefore, if a picture representing one of these neighbours is presented shortly after a word prime, its corresponding lemma will suffer from an initial activation handicap. Naming of the picture is thus slowed in comparison to a situation in which an unrelated word is presented as a prime. This account is certainly attractive, particularly because lateral inhibition can be functionally justified by the need to discriminate between two very close responses (the two semantic neighbours). An inhibition that takes advantage of the existence of a small feature difference might be very effective and accurate while selecting the correct answer among possible candidates.

However, even if this explanation seems appealing, it is somewhat ad hoc. For example, Roelof's modelling proposal (Roelofs, 1992; see also WEAVER++ model in Levelt et al., 1999) accounts for inhibition effects without the need to postulate lateral inhibition at the lexical level. Furthermore, some predictions of Berg and Schade's (1992) explanation seem to contradict results obtained in the word naming task, where brief presentation of a semantically related word before the target word often facilitated naming (see the references cited in the Introduction; see also Neely's, 1991, review but note that in the studies he described, short SOAs are always around 200 ms, a little more than the values for which we found inhibition in our experiment). The initial inhibition account cannot explain such a facilitation.

The semantic competition explanation, however, is neutral with regard to the semantic facilitation effect in word naming. Importantly, the reading of a word is not initially driven by its semantic properties, as is the naming of a picture. It is rather based on the analysis of an orthographic pattern (at least in alphabetical writing systems). Therefore, reading a word does not, in principle, engage the activation of several semantically related candidates among which the system selects the correct one. As a consequence, the activation produced by processing a co-ordinate prime will not, in principle, interfere with a selection based on graphemic criteria. Moreover, the facilitation effect that is sometimes observed could still be explained by a spread of activation through the conceptual semantic units that the prime and the target have in common.

### Associative facilitation

Both experiments show that the association strength between stimulus pairs is sufficient to produce priming effects, but priming occurs only at certain SOAs. This associative effect is very different from the semantic inhibition that we have just discussed: It is observed for a different SOA (234 ms vs. 114 ms), and it is different in nature (facilitation vs. inhibition).

These effects are not predicted in a strict sense by explicitly implemented models of speech production (WEAVER++ model, or Dell, 1986). However, the existence of a facilitation effect when the picture to be named is preceded by an associated word could be taken naturally as an argument for the existence, in the speech production system, of direct associative links between representations of the kind that were discussed in the Introduction. Whether the representations are conceptual (Collins & Loftus, 1975), lexical (Levelt, 1989), or phonological is an issue in itself. If one posits the existence of these associative links, a spreading activation account for the effect could go as follows: In the course of an experimental trial, the activation of a certain unit by the word prime (e.g., "nest") will in turn spread towards, among others, the units to which it is associatively linked (e.g., bird). Therefore, when the picture is presented, the associates of the prime benefit from an activation advantage, as compared to the situation in which the prime and target are unrelated. This activation advantage allows a faster selection, and thus a facilitation effect arises. Moreover, our results give an idea of the time course of this process. Indeed, the fact that we do not observe any effect of associate primes for the short-SOA condition (114 ms) suggests that it takes a certain amount of time for the spread of activation to reach the associates of the prime in a significant manner. If the prime presentation is brief, the prime has not received very much processing by the time the picture is presented. The amount of activation that has reached the primes' associates is either zero or insufficient to produce any observable effect. On the other hand, if enough time is left for the processing of the prime (234 ms or so, according to our study), the spread of activation reaching the associates of the primes will be effective.

Still, one question remains: Why should the spread of activation be so slow? Indeed, there have been arguments indicating that this process can sometimes have very fast or even instantaneous consequences (see, e.g., Ratcliff & McKoon, 1981).<sup>9</sup> There are at least two explanations.

The first one is based on the level of processing where associated representations are linked. Note that processing of the word prime starts with the activation of letter feature representations, then letter representations, and so on, until it reaches some kind of meaning representations (Balota, 1994). Without any modularity hypothesis, one can nonetheless reasonably suppose that the representations at the different levels are activated gradually, not all at once. Because verbal association acts only when the prime is presented early enough before the picture, it can be argued that the associative connections that we hypothesized do not link representations activated at the first stages of word processing (form representations). Associative connections should rather be found at "late" stages of processing: between lexical or conceptual representations. Indeed such an explanation lacks empirical support. To be fully reliable, it probably demands a better understanding of the interactions between the comprehension and production systems.

The second explanation for the delay characterizing verbal association effects in our study has to do with the use of language in normal situations. Although it is a point of discussion, there is some evidence that verbal association is somehow linked to co-occurrences in language use (Church & Hanks, 1990; Spence & Owens, 1990). If this is

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<sup>9</sup> Note, however, that this study was conducted in a very specific situation in which participants had to read and comprehend a text.

true, it might be functionally profitable that when a word is produced (e.g., “nest”) its verbal associates are also activated (“bird”). Indeed, they have a relatively high probability to be used in close proximity. However, to be fully reliable, this spread of activation should not go too fast, in order to avoid the associates participating in the lexical competition described earlier. Remember that lexical selection takes place among the most activated candidates.

## CONCLUSION

The two picture-naming experiments that we have reported show that a careful selection of the materials can lead to the dissociation of two relations often confounded in the production literature: semantic proximity and verbal association. Indeed, prime–target pairs related in these two ways produced very different patterns of priming effects. This difference was modulated by SOA, but not by prime duration. Differences between these two relations are by no means a novelty, but they are shown here in the case of language production by normal subjects.

We favour the view that semantic inhibition and associative facilitation are subserved by rather distinct processes: A lexical selection by competition of several candidates in the first case and probably associative links in the production lexicon for the latter. If this view is correct, then the naming of a picture is achieved by a selection of the right name among several semantic co-ordinates activated by the early processing of the picture. There are no verbal associates among these candidates. Later, activation links between verbal associates might come into play. Our data indicate that processing of a word can produce this spread of activation.

Therefore, keeping in mind the peculiarities of the procedure and the task we used, we interpret our results as evidence for the existence, at an automatic level of processing, of a “dissociation” between semantic and associative relatedness. Both kinds of relation seem to have different roles to play in the speech production processes.

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## APPENDIX

Materials used in the experiments, with their corresponding English translation

	<i>Prime</i>		<i>Target</i>	
<i>Co-ordinate pairs</i>	fil	(thread)	CORDE	(ROPE)
	chien	(dog)	CHAT	(CAT)
	bateau	(boat)	TRAIN	(TRAIN)
	fleur	(flower)	ARBRE	(TREE)
	école	(school)	EGLISE	(CHURCH)
	cheveu	(hair)	NEZ	(NOSE)
	éléphant	(elephant)	RHINOCEROS	(RHINOCEROS)
	voiture	(car)	AVION	(AIRPLANE)
	mer	(sea)	MONTAGNE	(MOUNTAIN)
	photo	(photography)	TABLEAU	(PAINTING)
	clou	(nail)	VIS	(SCREW)
	flèche	(arrow)	LANCE	(SPEAR)
	dentifrice	(toothpaste)	ROUGEALÈVRES	(LIPSTICK)
	cheval	(horse)	ZEBRE	(ZEBRA)
	cou	(neck)	PIED	(FOOT)
	poisson	(fish)	DINOSAURE	(DINOSAUR)
	porte	(door)	FENÊTRE	(WINDOW)
	ballon	(ball)	FLECHETTE	(DART)
	marteau	(hammer)	SCIE	(SAW)
	abeille	(bee)	MOUCHE	(FLY)
	oiseau	(bird)	CHAUVE SOURIS	(BAT)
	vis	(screw)	AIGUILLE	(NEEDLE)
	<i>Associated pairs<sup>a</sup></i>	gant	(glove)	MAIN
carotte		(carrot)	LAPIN	(RABBIT)
os		(bone)	CHIEN	(DOG)
chèvre		(goat)	FROMAGE	(CHEESE)
clou		(nail)	MARTEAU	(HAMMER)
cendrier		(ashtray)	CIGARETTE	(CIGARETTE)
peigne		(comb)	CHEVEUX	(HAIR)
vase		(vase)	FLEUR	(FLOWER)
nid		(nest)	OISEAU	(BIRD)
ruche		(hive)	ABEILLE	(BEE)
bouton		(button)	CHEMISE	(SHIRT)
écureuil		(squirrel)	ARBRE	(TREE)
oeuf		(egg)	POULE	(HEN)
cloche		(bell)	EGLISE	(CHURCH)
ancre		(anchor)	BATEAU	(BOAT)
poignée		(handle)	PORTE	(DOOR)
pneu		(tire)	VOITURE	(CAR)
berceau		(cradle)	BEBE	(BABY)
serrure		(lock)	CLEF	(KEY)
aquarium		(aquarium)	POISSON	(FISH)

<sup>a</sup> From Ferrand and Alario's 1998 French association norms.