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Accessing Different Types of Lexical Semantic Information: Evidence From Priming

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The types of semantic information that are automatically retrieved from the mental lexicon on hearing a word were investigated in 3 semantic priming experiments. The authors probed for activation of information about a word's category membership by using prime–target pairs that were members of a common semantic category (e.g., *pig–horse*) and 2 types of functional semantic properties: instrument relations (e.g., *broom–floor*) and script relations (e.g., *restaurant–wine*). The authors crossed type of semantic relation between prime and target with degree of normative association strength. In a paired and a single-word presentation version of an auditory lexical-decision priming task, the authors found significant priming for category and functionally related targets, both with and without an additional associative relation. In all cases there was a significant associative boost. However, in a visual version of the single-word lexical-decision paradigm, a different pattern of results was found for each type of semantic relation. Category coordinates primed only when they were normatively associated, instrument relations primed both with and without association, and script relations primed in neither condition.

The semantic priming paradigm introduced by Meyer and Schvaneveldt (1971) is one of the most widely used in psychological studies of memory and language. Many studies have demonstrated that participants' recognition of a target word, such as *nurse,* is facilitated when it is preceded by a related word like *doctor,* compared with a neutral or unrelated word (e.g., Antos, 1979; Becker, 1980; de Groot, 1984; McNamara, 1992a, 1992b; Neely, 1991; Seidenberg, Waters, Sanders, & Langer, 1984). The main concern of these studies has been to characterize the mechanisms by which the context provided by the prime influences processing of the target word. However, priming tasks can also be used to investigate a different kind of question: What types of semantic information are automatically accessed when a word is heard or read? For a prime word to facilitate recognition of a particular target, it is necessary that the semantic information underpinning that prime–target relationship be accessed when the prime is processed. For example, if *canary* primes *bird,* this suggests that when *canary* is heard, information about its superordinate category is accessed. If we find that *canary* also primes *small* and *yellow,* it suggests that certain perceptual properties are also made available; if *canary* primes *cage,* it suggests that the information accessed includes the situation in which canaries are typically encountered. Thus, researchers can investigate the nature of the semantic information accessed when a word is recognized by charting the range of prime–target relationships that support facilitatory priming of a reaction time response such as lexical decision.

The advantage of the priming task is that it can give a relatively transparent measure of the information that is normally made available to the comprehension system as a result of lexical access. This contrasts with off-line methods of probing meaning representations, such as asking participants to list or judge the importance of semantic properties of words (e.g., Ashcraft, 1978; Schoen, 1988). These explicit, metalinguistic tasks may tell researchers more about peoples' considered theories and beliefs about the meanings of words, and general knowledge of the world, than about their lexical semantic representations (Malt, 1990).

Using the semantic priming technique, we designed the three experiments reported in this article to probe the range of semantic information accessed for a given word. Specifically, we probed for activation of a word's category coordinates and different types of functional information. To determine the kinds of information that are reliably accessed in the absence of a supporting semantic–pragmatic context, we presented prime words in isolation rather than in sentential contexts. ~~If we can characterize the nature of the information that is activated whenever a word is heard, independently of context, this will help us to identify the most salient aspects of the underlying lexical semantic representation (cf. Neely, 1977)~~. In discussing the nature of a word's semantic representation, we make no distinction here between the meaning of a word and its corresponding concept. Although there has been much debate over the relation between meaning and concept (e.g., Murphy, 1991), we followed the "traditional stance" and equate the two (Komatsu, 1992). This framework is also consistent with accounts of semantic representation such as Jackendoff (1983) in which there is no clear cutoff point between meaning and conceptual or encyclopedic information.

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However, it is reasonable to assume that certain aspects of information within the semantic representation are more or less salient, and that it is the more salient aspects that will be automatically activated in the absence of supporting context (Barsalou, 1982). By developing an account of the semantic information that is automatically accessed when a word is processed in isolation, we can evaluate more clearly the results of studies investigating the influence of prior context on the lexical access process (e.g., Barsalou, 1982; Moss & Marslen-Wilson, 1993; Tabossi, 1988).

Although numerous semantic priming studies have been reported over the last 20 years, researchers still do not have a clear picture of the kinds of information automatically accessed. On the one hand, several studies seem to indicate that a wide range of information is automatically accessed and supports automatic priming (e.g., Fischler, 1977; Hodgson, 1991; Schreuder, Flores d'Arcais, & Glanzenborg, 1984), but other researchers have claimed that there is no such thing as automatic semantic priming at all (Lupker, 1984; Shelton & Martin, 1992). We have identified three main factors contributing to the continuing debate on this issue. First, normative association and semantic relations need to be distinguished and manipulated independently. Second, a narrow definition of what constitutes a semantic relation between two words may lead to invalid generalizations about semantic priming. Finally, it has not always been possible to distinguish priming on the basis of automatic activation of semantic representations from priming that may result from task-dependent strategies adopted by the participants. In previous priming studies, one or two of these issues have been identified and investigated. However, in no case have all three factors been considered together. We designed the current experiments to address this problem.

In the following two sections, we discuss the first two of these issues: semantic versus associative priming, and the range of semantic relations to be tested. Discussion of the third point—automatic and strategic priming—is postponed until after Experiment 1, as it provides the motivation for Experiments 2 and 3.

Associative and Semantic Priming

Many semantic priming studies have been reported, in both the visual (e.g., Antos, 1979; de Groot, 1984; Meyer & Schvaneveldt, 1971; see Neely, 1991, for a review) and auditory modalities (Radeau, 1983; Slowiaczek, 1994), which seems to suggest that an extensive range of semantic information is automatically accessed when a word is recognized. Priming has been found for category coordinates such as *cat–dog,* antonyms such as *hot–cold,* functional relations like *hammer–nail,* as well as many other kinds of relations. However, the primes and targets in these studies were normatively associated as well as semantically related in some way. By associated, we mean that a large percentage of people give the target as the first word they think of in response to the prime in free association norms (e.g., Postman & Keppel, 1970).

As first noted by Fischler (1977), priming for these items may be due to the associative strength between them rather than the various types of semantic relation that they share. If we assume that the mental lexicon includes a level of form representation, as well as a semantic level, as postulated in the Collins and Loftus (1975) network model (and in a number of more recent interactive activation models, for example, Dell, 1986), connections between associated words could exist between representations at this form level rather than (or in addition to) at the level of meaning. Such connections would be built up through repeated cooccurrence of two word forms. For example, if the words *cat* and *dog* are frequently processed together, then a facilitatory link will be formed between them. This link would represent only the fact that there is a high probability of the form *dog* occurring shortly after the form *cat,* and not encode anything about the meaning relation between them (Chiarello, Burgess, Richards, & Pollock, 1990; Fodor, 1983; Lupker, 1984; Moss & Marslen-Wilson, 1993; Shelton & Martin, 1992; Tanenhaus & Lucas, 1987). The distinction between associative priming, on the basis of cooccurrence, and semantic priming does not rely on a spreading-activation model of semantic memory. We have recently demonstrated that a similar distinction can be made in a distributed memory model of lexical representation without spreading activation (Moss, Hare, Day, & Tyler, 1994). However, we use the spreading-activation framework here for simplicity, as it is the most widely adopted in the priming literature.

The claim that there is a separate form-level associative priming mechanism rests on the assumption that a major determinant of the associative strength between two words is their common cooccurrence in the language. This assumption is supported by findings of correlations between associative strength and cooccurrence of words in large language corpora (Rapp & Wettler, 1991; Spence & Owens, 1990). However, it should be noted that there may also be some degree of cooccurrence for words that are not highly associated according to association norms. The studies mentioned above have not tested whether nonassociated, but semantically related, word pairs (e.g., *pig–horse*) also have a high cooccurrence probability. McKoon and Ratcliff (1992, Experiment 3) have recently demonstrated priming for pairs of words selected solely on the basis of their high cooccurrence values. These words were not associatively related, but it is not clear what kind of semantic relation they shared (if any).

Fischler (1977) established that not all supposed semantic priming is based on association by demonstrating significant priming for semantically related word pairs that do not share any association (e.g., *bread–cake* and *dance–skate*). This finding has been replicated in the auditory modality (Ostrin & Tyler, 1993) and extended in several subsequent visual priming studies (Chiarello et al., 1990; Chiarello & Richards, 1992; Fischler, 1977; Hines, Czerwinski, Sawyer, & Dwyer, 1986; Lupker, 1984; Schreuder et al., 1984). In the studies by Chiarello and colleagues, presentation of stimuli was lateralized to the left or right visual field such that the words would be processed selectively by the contralateral cerebral hemisphere. The results suggested that nonassociated category coordinate pairs were automatically activated and primed each other. When both prime and target were laterally presented, this effect was only found for the left visual field (right hemisphere). However, when primes were centrally presented, allowing interhemispheric sharing of information, the semantic priming effect was the same in the two hemispheres.

Because the normal conditions for language comprehension involve central presentation (i.e., to both visual fields or to both ears), we did not consider possible hemispheric asymmetries in semantic activation in our studies, although this is an important and intriguing issue.

Although the studies cited above have demonstrated the effect of semantic priming without association, they have only gone a little way toward determining which kinds of semantic information are accessed when the prime is heard. This is because the definition of semantically related materials has been very narrow, and normative association has still not completely been unconfounded with type of semantic relation. Thus, for many kinds of semantic relations, researchers still do not know whether priming is due to activation within the semantic system or is based on associative connections, a point we discuss further in the following section.

Types of Semantic Relation

Apart from distinguishing between associative and semantic relations between words, distinguishing between different types of semantic relation is also necessary. In previous studies "semantic relatedness" has most frequently been taken to refer to category membership only. For example, Lupker (1984), Hines et al. (1986), and Chiarello et al. (1990) all used the following three-way classification. A pair of words is semantically related only if their referents are category coordinates (e.g., *pig–horse*). The words are semantically and associatively related if their referents are category coordinates and the words are also normatively associated (e.g., *cat–dog*), and they are associatively related only if the words are normatively associated but their referents are related by some nontaxonomic relation (e.g., *hammer–nail* and *theater–play*). In the latter condition, the functional type of semantic relation (that the function of a *hammer* is to knock in nails and that a *theater* is a building designed to house plays) is treated as no semantic relation and confounded with normative association. In his review of the semantic priming literature, Neely (1991) also treated functional relations in this way; he classified pairs of words such as *rake–leaf* as merely associatively related.

However, there are grounds for arguing that functional information is a semantic component of many familiar words, particularly those referring to artifacts, such as *hammer* and *theater,* perhaps even constituting the very core of their meanings (e.g., Barton & Komatsu, 1989; Keil, 1986). The importance of this type of semantic information is demonstrated by the difficulty of trying to define the meanings of such words without appealing to the function of their referents (Miller & Johnson-Laird, 1976). The confound between a functional relationship and normative association is illustrated by considering examples that separate out the normative association and the functional semantic relation between the words. *Hammer–nail* are related through semantic properties to do with their functions (a hammer is a tool used to knock in nails) as well as being associatively related (36% of people give *nail* as the first word they think of in response to *hammer*). *Broom–floor* are related by the same kind of semantic link (a broom is a tool used to sweep floors) but are not associatively related (*floor* is hardly ever given as a response to *broom* or vice versa in an association norm test). In previous studies, pairs like *broom–floor* have not been studied. Thus, although there is some evidence for activation of nonassociated category coordinates, it is not possible to determine whether semantic information about the functional properties of a word's referent is automatically accessed in the absence of normative association. In general, the claims that have been made about purely semantic priming have been made on the basis of category coordinates only, and claims about associative priming have been made on the basis of materials in which normative association and functional relations are not distinguished.

Two further studies have tested priming for words sharing semantic relations other than category coordination, and the results suggest a wider range of semantic priming without association. Hodgson (1991) found significant priming of lexical decisions for several types of semantic relation, including category coordinates, synonyms, conceptual relations (e.g., *election–vote*), as well as phrasal relations (e.g., *private–property*). However, the materials were not controlled for associative strength. Although associative strength did not correlate with priming in a post hoc analysis, the possibility of associative priming cannot completely be ruled out. Finally, Schreuder et al. (1984) studied priming for what they called *conceptual versus perceptual relations.* The conceptual relations were, in fact, all associated category coordinates. The perceptually related items were not associated but shared some perceptual property (e.g., *cherry* and *ball,* that share the property of being round). Schreuder et al. found priming for both types of relationship in slightly different priming procedures. The effect for nonassociated pairs such as *cherry–ball* suggests that the semantic information accessed for a word includes information about its appearance and that this type of information supports priming. Unfortunately there were a number of methodological problems with this study. Most important, items in the different conditions were not matched for frequency and were repeated within subjects. This renders the results suggestive rather than conclusive on this issue.

To summarize, the results of previous priming studies seem to suggest that a wide range of semantic information is accessed when a word is encountered. However, in most of these studies, prime–target materials were associatively related as well as semantically related, and so the priming could result from associative links rather than activation from within the semantic system. In the studies in which association and semantic relatedness have been separated out, only a very limited range of semantic information has been investigated, with reliable evidence for semantic priming without association confined essentially to category coordinates.

Therefore, we decided to investigate the issue further by systematically varying type of semantic relation between prime and target as well as their degree of associative strength. We focused on two main types of semantic relation: category coordinates and functionally related words. We included category coordinates for the purpose of comparison with results from earlier studies, along with two types of functional relationship, which have frequently been confounded with normative association strength in previous studies. In one set of conditions, there was no associative strength in either forward or backward direction. This allowed us to determine whether the default context-independent information accessed for the primes includes functional information of various kinds or whether it is limited to category information. If the claims of previous studies are correct, and functional relations are entirely associative rather than semantic in nature, we would not expect to see priming for functionally related pairs of words that are not associated (e.g., *broom–floor*). In the second set of conditions, word pairs were strongly associated. These conditions were included to investigate whether associative priming interacts with type of semantic relationship between prime and target or whether it has a consistent, additive effect on priming.

Experiment 1

In Experiment 1 we investigated access to different types of semantic information for prime words by measuring facilitation of lexical decision to semantically related target words. Unlike the great majority of previous priming studies, we presented materials in the auditory rather than in visual modality in our first two experiments. Our motivation for this is that, although speech is generally considered to be the primary medium of language, it has largely been neglected in the semantic priming literature (for exceptions, see Radeau, 1983, and Slowiaczek, 1994). There are no a priori reasons to suppose that the types of semantic information accessed when a word is heard are different to those accessed when the same word is read, and thus we have included discussion of visual priming studies as relevant to our investigation. However, although the basic patterns of priming may be similar for the auditory and visual domains (Holcomb & Neville, 1990), there may be important differences in the time course of projecting incoming auditory and visual information onto the mental lexicon (e.g., Marslen-Wilson & Tyler, 1980).

To reduce the contribution of possible strategic priming mechanisms, we used a short prime–target interstimulus interval (ISI) of 200 ms. Short prime–target delays have been found to reduce strategic effects, in the visual modality at least, as demonstrated by a pattern of facilitation without inhibition (de Groot, 1984; den Heyer, Briand, & Dannenbring, 1983; Lorch, Balota, & Stamm, 1986) and a reduction in the effect of the proportion of related items in the experimental list (de Groot, 1984; den Heyer, 1985; Tweedy, Lapinski, & Schvaneveldt, 1977). We considered the issue of automatic and strategic elements of the priming process in more detail in Experiment 2.

We probed access to two main kinds of semantic information: information about the taxonomic status of the prime word, as measured by facilitation of a category coordinate, and information about its functional properties, as probed by facilitation of a word, not in the same category but connected to the use or purpose of the prime's referent. The primes and targets were all concrete nouns (with one or two exceptions detailed below). This is because concrete nouns have been found to give robust priming effects in many previous studies, at least when normatively associated. The priming potential of other parts of speech has not been established to the same degree.

Category Coordinates

Most previous priming studies have treated category membership as the most typical, if not the only, semantic relationship that is mentally represented, whether it be a superordinate–exemplar relation (e.g., Becker, 1979, 1980; Neely, Keefe, & Ross, 1989) or one involving common coordinates (Chiarello et al., 1990; Chiarello & Richards, 1992; Hines et al., 1986; Lupker, 1984). We predicted priming for category coordinates on at least two different accounts of semantic memory. The first is that hierarchical taxonomic structure is a major organizing principle of semantic memory—a view independently supported by a variety of sources. Children learn about global categories (Mandler, Bauer, & McDonough, 1991; Markman & Hutchinson, 1984) and make inferences about category members on the basis of their superordinate properties (Gelman & Coley, 1990) by the age of two years: for example, to infer that animals have hearts. The ability to classify objects by conceptual category is often relatively preserved in aphasia when other semantic knowledge is disrupted (Goodglass & Baker, 1976; Hodges, Patterson, Funnell, & Oxbury, 1992; McCleary & Hirst, 1986; Warrington, 1975). On the second kind of account, priming between members of a common superordinate category is not due to the explicit representation of taxonomic structure in semantic memory but results from activation of units in semantic memory representing the many overlapping features of category coordinates (Masson, 1991; McRae, de Sa, & Seidenberg, 1993; Schreuder & Flores d'Arcais, 1989). Members of the same category often share a large number of perceptual and functional semantic properties: for example, *cats* and *dogs* are both four legged, have fur, two ears and eyes, a tail, are good pets, are playful, and so on. Similarly, *tables* and *chairs* both have four legs, are often made of wood, are found in kitchens, and so on.

Consistent with both of the accounts described above, previous priming studies have demonstrated robust priming effects for words that belong to the same semantic category. We have used common category coordinates as our first type of semantic relation, as a partial replication of previous studies and to act as a yardstick for measuring priming produced by other kinds of semantic relationship. Half of the category coordinate pairs were from artifact categories such as furniture and tools (e.g., *chair–table, spade-rake*) in order to probe further the role of taxonomic structure in the mental lexicon. The remaining pairs were taken from a range of other categories, mostly natural kinds such as animals and fruit (e.g., *dog–cat* and *plum–apricot*). We refer to these as the *natural* category condition. It has been suggested that category information may not be central for artifacts because artifact taxonomies are less stable than natural kinds, with the concepts organized around functional properties rather than category membership (Atran, 1989). If this is true, we might expect a less reliable priming effect for artifact category pairs than for other category pairs.

Functional Relations

In contrast to category coordinates, functional relations between (the referents of) two words have not widely been studied in priming experiments. As discussed above, they have sometimes been dismissed as nonsemantic relations and confounded with normative association. Does the semantic information accessed when a word is heard out of context include information about the use and purpose of its referent? If it does, we would expect pairs of words connected by a functional link to support priming, similar to that shown by category coordinates, even in the absence of normative association between them. If, however, functional information is a less central aspect of meaning representation than taxonomic structure, either because of a lack of explicit links between functionally related concepts or because they share fewer semantic features, then little or no priming is predicted.

All of the prime words in the functional condition come from *artifact* categories. This is because it is generally more straightforward to identify the functional properties of artifacts than other classes of noun, especially those from animate categories.[1] Two specific types of functional relations were included, which we refer to as *instrument and script relations.*[2] For the instrument relations, the intended function of the prime was to perform some action on the target. For example, *broom–floor,* in which a broom is used to sweep a floor, *hammer–nail,* in which a nail is used to knock in nails, and so on. Some authors have argued that function is a necessary property of an artifact noun, forming the core of its meaning representation (e.g., Barton & Komatsu, 1989; Keil, 1986). This claim is consistent with the earliness of acquisition of functional information, as evidenced, for example, by young children's definitions of nouns, which are often of the form "A chair is to sit" (e.g., Anglin, 1977; McGhee-Bidlack, 1991). However, this centrality of functional information, in the adult mental lexicon at least, has been subject to question (Malt & Johnson, 1992).

The second type of functionally related materials are the script relations. We selected prime words that refer to an event or place and so could evoke a script or schema (Rumelhart, Smolensky, McClelland, & Hinton, 1986; Schank & Abelson, 1977). For example, the *restaurant* schema may include sitting at a table, ordering food from a menu, waiters, drinking wine, and so forth. The targets we used refer to typical elements in the prime's script, for example, *restaurant–wine* and *orchard–apple.* As for the instrument relations above, there is evidence that script information is acquired early; it has been claimed that schematic (script-based) organization of the lexicon precedes taxonomic organization (Blewitt & Toppino, 1991; Nelson, 1979). However, once taxonomic structure has been developed, it is not clear what the status of script information is in the adult lexicon. A prevalent view is that script information is encyclopedic, general word knowledge, rather than part of a word's meaning (e.g., Bierwisch & Schreuder, 1992; MacNamara, 1984; Miller, 1978; see also Nelson, 1985). With this view it would be plausible to predict that script knowledge is not immediately activated whenever a word is heard but is only retrieved more slowly when required by a particular context. The presence or absence of priming for (nonassociated) pairs such as *restaurant–wine* will clarify whether the information accessed when a word is heard does include this kind of script knowledge.

Method

Participants

Participants were 29 members of the Birkbeck Speech and Language Centre participant pool. They were native speakers of British English between the ages of 18 and 40 years, most of whom were students at London University and who were paid for their participation.

Materials and Design

One hundred and twelve target words were each paired with a related prime and an unrelated control word to form the prime type variable. Half of the related primes were strongly normatively associated to their targets, and half had no associative strength. This variable of association was crossed with semantic type. Half of the related primes and targets were category coordinates, and half were functionally related. Under the semantic type variable was nested a further variable of semantic subtype. Half of the functionally related pairs were script related (e.g., *theater-play* and *restaurant–wine*), and half were instrument related (e.g., *hammer–nail* and *broom–floor*). For the category coordinates, half the items were artifacts (e.g., *dish–plate* and *airplane–train*), and half were natural kinds (*dog–cat* and *ruby–emerald*). There were 14 pairs in each Association × Semantic Type × Subtype condition.

An example stimulus set is given in Table 1, and all stimuli are listed in the Appendix. All words in the functionally related conditions, and most in the category coordinate conditions, were concrete nouns. In the category coordinate conditions, we also used a few familiar adjectives (such as *white–black*) and abstract nouns (such as *decade–century*). These were evenly distributed over associated and nonassociated conditions, and a post hoc examination of the results revealed that they behaved no differently from the concrete nouns.

Items in the associated condition were selected from several sets of association norms, including those published by Postman and Keppel (1970) as well as norms collected in our laboratory. These association norms were collected from a minimum of 40 participants from our participant pool who were asked to write the first word that they thought of when they heard each stimulus word played from tape or when they read it in a booklet (Moss & Older, in press). Overall, the mean associative strength in the associated condition was 38% (range 19%–77%). For the nonassociated condition, the target was never given to the prime in association norms (or hardly ever, that is, on fewer than 5% of occasions). In addition, to avoid possible backward associative priming effects (Koriat, 1981; Peterson & Simpson, 1989; Seidenberg, Waters, Sanders, & Langer, 1984), we ensured that the prime was very rarely given as a response to the target (less than 8% association strength).

Potential test pairs conforming to each semantic type were selected according to the judgments of the experimenters. These judgments were then confirmed as follows.

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[1] This is a further reason for dividing the category coordinates into natural and artifact subtypes. To avoid a confound between type of semantic relationship between prime and target (category coordinate vs. functional relationship) and semantic domain of the prime (artifact vs. natural kind), we can separately compare priming for the artifact category coordinates with the functional conditions (which are all artifacts).

[2] Our instrument and script relations correspond quite closely to the functional–associate and functional–context relations described by Goodglass and Baker (1976). To avoid further confusions over the use of *associate,* we have adopted different terms.

Table 1
Example Stimulus Set With Mean Association Strength and Median Target Frequency per Million Words for Each Condition

Semantic type and condition	Associated: Related prime	Target	AS (%)	TF	Nonassociated: Prime	Related target	AS (%)	TF
Category coordinate								
Natural	Dog	CAT	43	35	Pig	HORSE	1	27
Artifact	Dish	PLATE	34	20	Spade	RAKE	0	21
Functionally related								
Script	Theater	PLAY	36	44	Restaurant	WINE	1	36
Instrument	Hammer	NAIL	39	26	Broom	FLOOR	1	20

Note. Each target word is also paired with an unrelated control prime. Median rather than mean frequencies are given, as means can be inflated by a few very high-frequency targets. AS = association strength; TF = target frequency.

Category coordinates. Word pairs were selected that were clearly members of the same superordinate category. We checked rank typicality in the Battig and Montague (1969) norms to ensure that pairs in the associated and nonassociated category conditions, and in the artifact and natural kind subtypes, were equally typical of their category. We did this because it has been claimed that highly typical prime words facilitate category coordinate targets more strongly than less typical primes (Hines et al., 1986). (Mean rankings: associated natural, 9; associated artifact, 11; nonassociated natural, 7; and nonassociated artifact, 6.)[3]

Instrument-related pairs. Word pairs were selected if it was true (according to the judgments of the four experimenters) that "you use an x to do y" where *x* is the prime and *y* is the target (e.g., "you use a broom to sweep the floor" and "you use shampoo to wash hair").

Script-related pairs. Word pairs were selected if it was true that "at *x* you (verb) *y* ," where *x* is the prime and *y* is the target. The verb here is usually *see* (e.g., "at the zoo you see penguins") and "at a theater you see plays") but may also be some other appropriate verb (e.g., "at an interview you wear a suit" and "at a party you hear music"). In each case, the target was judged to be a typical element of the situation described by the prime.

The degree of semantic relatedness between primes and targets in the instrument and script conditions was then checked by carrying out a relatedness judgment pretest. Fourteen participants were given a booklet containing all of the potential functionally related test pairs, as well as filler pairs of varying semantic relatedness (from highly related synonyms to semantically unrelated rhyme pairs). Participants were asked to indicate on a scale ranging from 1 (*very unrelated*) to 9 (*very related*) how related in meaning they thought each pair of words were. Although synonyms received a mean rating of 8, and rhyme pairs a mean rating of 1, the mean for the functionally related items was 7.25. This indicates that the functionally related pairs were considered to be highly related by our participant population in an off-line task (mean ratings: associated script, 8; associated instrument, 8; nonassociated script, 7; and nonassociated instrument, 6).

Finally, targets in the associated and nonassociated conditions were matched for frequency of occurrence (Hofland & Johansson, 1982) for all semantic types (median frequencies: associated 31 per million and nonassociated 26 per million). See Table 1 for the median target frequency in each subtype condition.

Each target was paired with an unrelated prime to act as a baseline for lexical decision. Unrelated primes were generated by reassigning each target to another prime in the set. These were semantically and phonologically unrelated to the targets. To avoid repetition within subjects, we split materials into two versions presented to separate groups of participants. A target appeared only once in each list: with its related prime in one version, and its unrelated control in the other. The number of trials in each condition was fully counterbalanced across versions.

Fillers. Two hundred and twenty-four filler trials were added to each version. One hundred and sixty-eight word–nonword trials were added to give 50% of trials on which participants should make a negative lexical decision to the target. All nonword targets were phonologically permissible strings in English and were matched for length in syllables to the real-word targets in the list. An additional 56 fillers were unrelated word pairs to reduce the proportion of trials on which the target was related to the prime. In total, 17% of all trials were related word–word pairs (i.e., 33% of real-word trials). A low relatedness proportion reduced the contribution of strategic priming effects (de Groot, 1984; den Heyer, 1985; Neely, 1991; Tweedy et al., 1977). The nonword ratio (Neely et al., 1989) was 0.6. Fillers and test items were evenly distributed throughout the test lists. To start each block of the test list, we also constructed a set of 36 practice trials and 8 dummy trials.

Procedure

All materials were recorded by a female native speaker of British English in a sound-attenuated booth and then digitized at a sampling rate of 20 kHz. The experiment was controlled by a computer that played out speech directly from a hard disk and recorded participants' responses.

Participants were tested in groups of up to 4 at a time, with speech presented over closed ear headphones. Each trial consisted of a word–word or word–nonword pair separated by an ISI of 200 ms. Participants made a lexical decision to the second (target) item only. Lexical-decision responses were made by pressing a button marked *yes* or *no* on a box placed in front of the participant. The dominant hand was always used for a positive response. Reaction times were measured from the onset of the target to a time-out of 3 s. After all participants had responded or timed out, a delay of 1.5 s preceded the following trial. The test session lasted approximately 50 min.

Results

Eight of the 112 test items were removed from the data set because the target received more than 50% incorrect re-

[3] Not all of the categories we used were represented in the Battig and Montague (1969) norms. The means given here are based on 78 words out of our total of 112. The categories not included are equally distributed over the various conditions.

Table 2
Mean Reaction Times (in Milliseconds) and Error Rates (%) in Each Condition in Experiment 1

Semantic type and condition	Associated R M	Associated R ER (%)	Associated U M	Associated U ER (%)	Associated Priming: U − R	Nonassociated R M	Nonassociated R ER (%)	Nonassociated U M	Nonassociated U ER (%)	Nonassociated Priming: U − R
Category coordinate	664	1.0	772	8.0	108	713	2.8	801	3.5	88
Natural	660	1.2	782	9.7	122	704	3.8	792	0.6	88
Artifact	667	0.7	762	6.2	95	721	1.8	809	6.3	88
Functionally related	648	2.5	755	3.9	107	731	2.8	796	6.2	65
Script	649	2.7	760	3.4	111	714	1.2	790	6.0	76
Instrument	647	2.3	752	4.2	105	749	4.6	803	6.4	54

Note. R = related prime; U = unrelated control prime; ER = error rate.

sponses (these were evenly distributed over conditions). Four participants were rejected because they had a high error rate (more than 10%), and 1 was rejected because the mean reaction time was more than two standard deviations above the version mean. This left 12 good participants in each version of the experiment. Once bad items and participants were removed, 4% of responses were incorrect lexical decisions. No values were cut off by the 3-s time-out. Following the recent recommendations of Ulrich and Miller (1994), we did not trim the data set to remove outlying values. This was to avoid possible distortions arising from inappropriate truncation of the distribution of reaction times.[4]

Reaction Times

In the first analysis, we examined the effects of prime type (related vs. unrelated), association (associated vs. nonassociated), and semantic type (category coordinate vs. functionally related), collapsing over the nested subtypes (natural and artifact category coordinates, and script and instrument functionally related items). We looked at subtype effects in a second analysis presented below. Mean reaction times were entered into four-way analyses of variance (ANOVA; Version × Association × Semantic Type × Prime Type) with both participants (F_1) and items (F_2) as random variables. Version was included as a dummy variable in all analyses to stabilize variance because of the rotation of items and participants over the two test lists. Mean reaction times in each condition are given in Table 2.

There was a significant overall priming effect. Reaction times to targets in the related condition were 92 ms faster than in the unrelated control condition, $F_1(1, 22) = 17.40$, $MSE = 21{,}246.93$, $p < .001$; $F_2(1, 96) = 141.11$, $MSE = 3{,}118.03$, $p < .001$. Responses were also 51 ms faster overall in the associated than the nonassociated condition, $F_1(1, 22) = 73.92$, $MSE = 1{,}691.40$, $p < .001$; $F_2(1, 96) = 10.42$, $MSE = 12{,}769.83$, $p < .01$. Finally, the priming effect for the associated condition (109 ms) was larger than for the nonassociated condition (76 ms), giving a significant interaction between association and prime type, $F_1(1, 22) = 6.56$, $MSE = 1{,}557.48$, $p < .05$; $F_2(1, 96) = 3.95$, $MSE = 3{,}118.03$, $p < .05$. To investigate this interaction, we carried out ANOVAs on associated and nonassociated items separately. The priming effect was significant both for the associated condition, $F_1(1, 22) = 20.64$, $MSE = 12{,}184.62$, $p < .001$; $F_2(1, 47) = 80.17$, $MSE = 3{,}716.30$, $p < .001$, and for the nonassociated condition, $F_1(1, 22) = 12.09$, $MSE = 10{,}619.79$, $p < .001$; $F_2(1, 49) = 60.94$, $MSE = 2{,}544.17$, $p < .001$.

In contrast to the effects of association strength, the type of semantic relation between prime and target had no effect on participants' responses. There was no significant difference between amount of priming for category coordinates (98 ms) and functionally related items (86 ms); the interaction between prime type and semantic type did not approach significance, $F_1(1, 22) = 1.86$, $MSE = 669.81$, $p > .1$; $F_2 < 1$. Nor was there a difference in the overall reaction times to category coordinates and functionally related items (F_1 and $F_2 < 1$). Finally, both category coordinates and functionally related items showed the same increase in priming for the associated over the nonassociated condition; there was no three-way interaction between prime type, association, and semantic type, $F_1(1, 22) = 1.60$, $p > .2$; $F_2 < 1$.

Error Rates

Error proportions were calculated over items and arcsine transformed to stabilize variances (Winer, 1971). They were then entered into a Version × Association × Semantic Type × Prime Type ANOVA. There was a significant main effect of prime type, $F_2(1, 96) = 13.61$, $MSE = .0036 p < .01$, with fewer errors in the related condition (2%) than the control unrelated condition (5%). Every Association × Semantic Type condition showed this reduction in errors by the related prime. However, there was a three-way interaction, $F_2(1, 96) = 6.49$, $MSE = .0036$, $p < .05$. For the category coordinates, the error rate was reduced more for associated than nonassociated items, whereas for functionally related items, the related prime reduced the error rate more for nonassociated than associated items. Thus the pattern of the error data supports that of the reaction times, with facilitatory priming for all types of semantic relation.

[4] The lack of trimming introduces the possibility that any effects found may entirely be located within the extended right-hand tail typically found in the distribution of reaction time responses (Ratcliff, 1993). This is not the case for our studies. All analyses reported here have also been carried out by using midmeans. The midmean is the mean of the central 50% of the data distribution and is therefore not influenced by the longest reaction times. In all cases, we found the same pattern of results.

Subtypes

Category coordinates and functionally related prime–target pairs showed the same pattern of priming effects. However, it is possible that there may be some differences if the more fine-grained *subtype* divisions are looked at. That is, there may be a difference between artifact coordinates such as *spade–rake* and natural co-ordinates such as *lettuce–cabbage,* or between the functional script relations such as *theater–play* and the instrument relations such as *broom–floor.* Subtype was not added into the main analyses reported above as it is nested under semantic type, having different levels for the category coordinates and functionally related items. Therefore, we investigated it by entering the category coordinates and the functionally related items into two separate sets of Version × Association × Subtype × Prime Type analyses.

For category coordinates there was no main effect of subtype, F_1 and $F_2 < 1$, nor any interaction of subtype with either prime type, F_1 and $F_2 < 1$, or association, $F_1(1, 22) = 2.56, MSE = 1{,}780.49, p > .1; F_2 < 1$. Both natural and artifact category coordinates conditions showed equal facilitation by the related prime, whether associated or nonassociated. A similar picture emerges for the functionally related condition, with no main effect of subtype (script or instrument), $F_1(1, 22) = 1.79, p > .1; F_2 < 1$, and no significant interaction between subtype and either prime type, F_1 and $F_2 < 1$, or association, $F_1(1, 22) = 2.94, MSE = 3{,}176.54, p > .1; F_2 < 1$.

Discussion

The results of Experiment 1 indicate that functional semantic properties, as well as information connecting members of a common semantic category, are rapidly accessed when a word is heard in isolation. Targets related to functional properties of primes, both instrument and script information, were facilitated as much as targets related by membership of a common artifact or natural category. The contrast between category and functional relation had little influence on priming, but the presence or absence of association had a highly significant effect, with the associated conditions showing larger priming effects than the nonassociated across the board. We defer discussion of the effect of association until after Experiment 2.

However, a potential explanation of the priming effects in Experiment 1 is that they were based on strategic rather than on automatic processes. If this is the case, the results would not be a true reflection of the automatic access to semantic information when a word is heard. By automatic access we mean that the information is made available whenever a word is heard, as a result of lexical access, rather than being retrieved under voluntary control in an explicit manner to comply with the demands of a particular task or as a result of interaction with information from the utterance context. We used the priming task to probe this access process because of its on-line characteristics. However, over the years, a variety of nonautomatic components of the priming procedure have been identified, including generation of expectancy sets (Becker, 1979, 1980; Neely, 1991; Neely et al., 1989) and postlexical congruency checking (or semantic matching), (e.g., Colombo & Williams, 1990; den Heyer et al., 1983; Neely, 1977, 1991; Neely et al., 1989). To the extent that these are operative, priming in Experiment 1 may not be a transparent reflection of automatic access to the meaning of the prime.

The issue of automatic versus strategic priming is especially important, given that several researchers have claimed that although associative priming may be automatic, all purely semantic priming is based entirely on strategic processes and, as such, cannot inform us about automatic lexical semantic access (Lupker, 1984; Shelton & Martin, 1992). Lupker's argument was based on his finding of priming for nonassociated category coordinates in a lexical-decision task, but not in a naming task—a task generally considered to be less susceptible to strategic priming effects (e.g., Balota & Chumbley, 1984; Balota & Lorch, 1986; Seidenberg et al., 1984). However, other studies have found purely semantic priming in a naming task (Chiarello et al., 1990; Chiarello & Richards, 1992; Hines et al., 1986; Schreuder et al., 1984). Shelton and Martin (1992) found priming for associated but not for nonassociated category coordinates in a single-word continuous presentation lexical-decision task, again thought to minimize strategic priming (McNamara & Altaribba, 1988). The nature of the single-word presentation task is discussed in more detail below, as it is the procedure adopted in Experiments 2 and 3.

Because we used a paired presentation lexical-decision task in Experiment 1, it is possible that the priming for some or all of the conditions was based on strategic rather than on automatic processes, in spite of the short ISI and a fairly low proportion of related prime–target pairs (16% real-word trials were related). It is, therefore, necessary to consider in some detail what implications strategic priming may have for our interpretation of semantic priming, and how it can be further reduced in Experiments 2 and 3.

The debate over automatic–strategic components of the priming task has been framed in terms of the way in which the prime influences recognition of the target. The automatic component is traditionally explained as activation of the prime automatically spreading to the target representation, with the result that less activation from the subsequent sensory input is required to bring it to response threshold (Collins & Loftus, 1975). Two major strategic components have been posited. The first is that on hearing the prime, participants generate a set of related words that they think will include the target (Becker, 1979, 1980). When the target is presented, the expectancy set is searched before the lexicon as a whole, and so if the target is a member, it will be recognized more quickly. The content of the expectancy set will be determined by the experimental list. If it contains many prime–target pairs of a given kind, participants will notice and use this information to construct the set. For example, if the list contains entirely coordinate pairs, the expectancy set will consist of coordinates of the prime, and these will be facilitated. If this is the source of priming in Experiment 1, it would undermine our claim that we are probing the semantic information that is automatically accessed when a word is heard, as the prime–target relationships that support priming would vary from experiment to experiment, depending on the makeup of the test list. However, expectancy generation would not be an efficient strategy in our experiment, as the wide range of different kinds of semantic relation between primes and targets would necessitate the generation of a very long list of expected targets for each prime, and this list would then have to be consulted on each trial. Also, if participants were generating expectancy sets, we would expect priming to increase throughout the duration of the test list, as their expectancies were developed. However, we found no correlation between magnitude of priming and position in the test list, $r(88) = -.11, p > .1$.

The second kind of strategic priming mechanism put forward is that participants check the meaning of the target against that of the prime to ascertain whether they are related (Colombo & Williams, 1990; den Heyer et al., 1983; Neely, 1991; Neely et al., 1989). This is a postlexical mechanism as it operates after lexical access of the target. This kind of meaning check can facilitate lexical decision because, if a semantic match is found, the target must be a real word, as nonwords have no meaning. Although this is usually considered a strategic effect, Hodgson (1991) has argued that meaning integration is automatic in the sense that it is what the comprehension system aims to do whenever words are presented; that is, to integrate new words into the existing context to produce a coherent interpretation of the input. Either way, a postlexical meaning check does not necessarily argue against our claims that Experiment 1 reflects automatic access to the prime's meaning. Even if participants are trying to integrate the meanings of prime and target in some controlled, task-dependent manner, as long as they can only match the target against the semantic information that has already been accessed for the prime—that is, the kind of rapidly accessed semantic information we aimed to probe in Experiment 1—our interpretation stands. What would be more problematic is if participants are able to use the target as a context for interpreting the prime itself, in a form of backward priming (Koriat, 1981; Peterson & Simpson, 1989; Seidenberg et al., 1984). If this were the case, it could be argued that semantic information that is not normally accessed for the prime is being retrieved as a result of contextual information supplied by the target. For example, participants may not normally access the information "used to sweep floors" when they hear *broom,* but when it is shortly followed by *floor,* this acts as a context encouraging participants to retrieve additional information relevant to the relation between them. This would, in turn, facilitate continued processing of the target, and so lead to the priming effect observed for the lexical-decision response (this is closely related to Koriat's 1981 backward priming account of the priming effect for multiple meanings of a homophonous prime). Although we ruled out backward associative strength between our nonassociated prime–target pairs, the backward semantic relation alone may be enough to influence the priming effect.

Experiment 2

We conducted Experiment 2 with the aim of ruling out strategic processes in priming for different kinds of semantic relationship, particularly the kind of backward priming effect just outlined. Although it is often argued that a naming task reflects automatic priming to a greater extent than lexical decision (Balota & Chumbley, 1985; Balota & Lorch, 1986; Seidenberg et al., 1984), recent studies have suggested that it may be susceptible to some of the same strategic influences (Keefe & Neely, 1990). Instead, we decided to stick with the lexical-decision task, although we used a single-word presentation procedure, rather than the standard method, in which each prime and target is presented as a distinct pair. This is in response to recent claims that it is the explicit pairing of primes and targets, rather than the nature of the reaction time task, that renders priming susceptible to postlexical effects (McNamara & Altarriba, 1988; Shelton & Martin, 1992). McNamara and Altaribba found that mediated priming (the facilitation of a target by a shared associate, for example, *lion–(tiger)–stripes*) did not obtain in lexical decision when the prime and target words were presented as pairs. However, when the prime and target words were presented as single words in a list, in which each word was separated by a constant ISI, then mediated priming was found. Priming between *lion* and *stripes* cannot be due to postlexical meaning integration, as there is no direct relation in meaning. Priming must be due to spreading activation from *lion* to *tiger* to *stripes.*[5] This suggests that postlexical meaning integration may contribute to lexical-decision priming when primes and targets are explicitly paired (overshadowing any automatic prelexical component), but not when all of the items are individually presented with a constant ISI.

If we find the same priming results as we found in Experiment 1 in the single-word paradigm, this would reinforce our claim that the semantic relations that support priming reflect the type of information automatically activated when the prime is heard, rather than resulting from some kind of postlexical strategic process, such as the use of the target as a context for interpreting the prime. However, on the basis of Shelton and Martin's (1992) results from a visual version of this paradigm, we did not expect to find semantic priming without association; they demonstrated priming for associated category coordinates such as *cat–dog,* but they found no priming for nonassociated category coordinates such as *pig–horse.* However, as in many other studies, only category coordinates were tested, and thus we cannot determine whether there is automatic semantic priming for other kinds of semantic relation. We presented a subset of the items from each condition in Experiment 1, thus testing for automatic priming for both category and functional semantic relations, with and without additional normative association.

Method

Participants

Participants were 24 members of the Birkbeck Speech and Language Centre participant pool. They were native speakers of British English between the age of 18 and 40 years, most of whom were

[5] The claim that mediated priming is based on two-step spread of activation has been disputed by proponents of the compound-cue theory of priming (e.g., McKoon & Ratcliff, 1992) and a distributed memory model of priming (e.g., Masson, 1991). However, in spite of other attractions of these alternative accounts, neither has a plausible explanation of mediated priming. Both rely on the argument that mediated priming must result from weak but direct relations between prime and target (e.g., between *lion* and *stripes*). However, this does not seem to be a plausible account of the mediated priming results, and, therefore, we have explained mediated priming here in terms of spreading activation.

Table 3
Mean Reaction Times (in Milliseconds) and Error Rates (%) in Each Condition in Experiment 2

Semantic type and condition	Associated					Nonassociated				
	R		U		Priming: U − R	R		U		Priming: U − R
	M	ER (%)	*M*	ER (%)		*M*	ER (%)	*M*	ER (%)	
Category coordinate	697	0	791	5.5	94	724	1.2	760	3.3	36
Natural	695	0	804	1.7	109	698	0.8	755	0.8	57
Artifact	699	0	777	9.3	78	750	1.7	766	5.9	16
Functionally related	688	0	759	1.7	71	742	1.2	783	2.9	41
Script	682	0	762	1.7	80	749	0.8	780	1.7	31
Instrument	695	0	755	1.8	60	735	1.7	785	4.2	50

Note. R = related prime; U = unrelated control prime; ER = error rate.

students at London University and who were paid for their participation. None of the participants had taken part in Experiment 1.

Materials and Design

We used the same design in Experiment 2 as we used in Experiment 1, with the fully crossed variables of prime type (related vs. unrelated), association (associated vs. nonassociated), and semantic type (category coordinates vs. functionally related) and the nested variable of subtype (natural and artifact category coordinates vs. script and instrument functionally related pairs). Ten of the 14 pairs in each condition in Experiment 1 were selected. The reduction in item numbers was necessary to keep the experiment to a reasonable length, given the additional filler items required for the single-word presentation paradigm. Stimuli used in Experiment 2, as well as Experiment 1, are shown in the Appendix.

In the single-word presentation paradigm, participants make a lexical decision to every word, both primes and targets, presented sequentially in a list. This means that the proportion of nonword targets has to be calculated over the whole set of words, rather than just over targets. We therefore removed all of the real-word filler primes that had been paired with nonword targets in Experiment 1. This gave an overall nonword proportion of 43%. We then added an additional 40 real-word–nonword pairs. This broke up the regular pattern of real words always occurring in pairs, without changing the nonword proportion.

We divided materials into two versions, as was done in Experiment 1, with each target following the related prime in one version and the unrelated control in the other. Test pairs were evenly distributed throughout the list, and we ensured that there was no regularity in the occurrence of words and nonwords. There were 488 items in each version, of which 280 were real words. Only 8% of all potential sequential pairings were semantically, associatively or both related.[6] Thus, the relatedness proportion was very low. There was a practice block of 36 words, and eight dummy trials preceded the test list and followed the halfway break.

Procedure

The experiment was computer controlled, as it was for Experiment 1. Each word was played out to participants with a constant interval of 1,000 ms from the acoustic offset of one word to the onset of the next word. Participants made a lexical decision to every word. We established in a pilot study that the ISI of 1,000 ms was the shortest at which participants could perform the task successfully. This is because they were making a lexical decision, with a reaction time of around 750 ms to each word (timed from word onset). At shorter ISIs, responses were often not complete before the next word was heard, resulting in very high error rates. Reaction times were measured from the onset of each word to a time-out of 1350 ms. The test session lasted approximately 15 min. Otherwise, the procedure was the same as that for Experiment 1.

Results

One of the 80 test items was removed because the target received more than 50% incorrect responses. No participants were rejected. A total of 6% of the responses were incorrect lexical decisions to either a target or its prime. These were removed and not replaced. Only six target responses (0.3%) were cut off by the time-out of 1,350 ms. These were removed and not replaced. Means were then calculated over participants and items in each condition.

Reaction Times

As for Experiment 1, we first examined the effects of prime type, association, and semantic type, collapsing over the nested subtypes. We looked at subtype effects in a second analysis presented below. Mean reaction times were entered into four-way ANOVAs (Version × Association × Semantic Type × Prime Type) with both participants and items as random variables. Mean reaction times in each condition are given in Table 3.

The results were almost identical to those of Experiment 1. Reaction times in the related condition were 60 ms faster than in the unrelated control condition, $F_1(1, 22) = 79.18$, $MSE = 2.105.52$, $p < .001$; $F_2(1, 71) = 64.54$, $MSE = 2,216.96$, $p < .001$. Responses to associated targets were 18 ms faster than to nonassociated targets, $F_1(1, 22) = 12.03$, $p < .01$, $MSE = 1,399.19$, $F_2(1, 71) = 1.25$, $MSE = 10,687.30$, $p > .2$. There was a significant interaction between priming and association, with a greater priming effect for associated items (82 ms) than nonassociated items (38 ms), $F_1(1, 22) = 25.62$, $MSE = 804.96$, $p < .001$; $F_2(1, 71) = 8.47$, $MSE = 2,216.96$, $p < .01$. To investigate this interaction, we carried out ANOVAs on associated and nonassociated items separately. The priming effect was significant both for the associated condition, $F_1(1, 22) = 125.16$, $MSE = 1,217.08$, $p < .001$; $F_2(1, 35) = 38.54$, $MSE = 3,429.22$, $p < .001$, and for the nonassociated condi-

[6] The list for each version (including dummy items) consisted of approximately 32% word–word transitions, 25% word–nonword, 25% nonword–word, and 18% nonword–nonword.

tion, $F_1(1, 22) = 20.69$, $MSE = 1{,}695.38$, $p < .001$; $F_2(1, 36) = 28.70$, $MSE = 1{,}038.38$, $p < .001$.

As was the case in Experiment 1, the type of semantic relation between prime and target had no effect. There was no overall difference in reaction times to category coordinates and functionally related items ($F_1 < 1$ and $F_2 < 1$). These two types of items showed equal facilitation in the related over the control condition, with no interaction with prime type, $F_1(1, 22) = 1.31$, $MSE = 1{,}354.87$, $p > .2$; $F_2 < 1$, and no reliable interaction with association, $F_1(1, 22) = 17.23$, $MSE = 1{,}059.28$, $p < .01$; but $F_2(1, 71) = 1.51$, $MSE = 10{,}687.30$, $p > .1$. Finally, category coordinates and functionally related words showed the same priming advantage for associated over nonassociated words, with no three-way interaction between semantic type, prime type, and association, $F_1(1, 22) = 1.35$, $MSE = 1{,}026.56$, $p > .1$; $F_2 < 1$.

Error Rates

Item error data (arcsine transformed) were entered into a four-way (Version × Association × Semantic Type × Prime Type) analysis, with items as a random variable. This revealed a main effect of prime type, $F_2(1, 71) = 13.38$, $MSE = 0.159$, $p < .001$, with fewer errors on related (0.6%) than on unrelated (4%) targets. There were no other main effects or interactions.

Subtypes

As in Experiment 1, we then looked at category coordinates and functionally related items separately to see whether the more fine-grained division of semantic type into subtypes had any effect on priming. For the category coordinates there was no reliable main effect of subtype, $F_1(1, 22) = 6.82$, $MSE = 741.70$, $p < .05$; $F_2 < 1$, and no reliable interaction of subtype with association, $F_1(1, 22) = 5.60$, $MSE = 4270.12$, $p < .05$; $F_2 < 1$. However, subtype did interact with prime type, $F_1(1, 22) = 5.12$, $MSE = 2{,}626.00$, $p < .05$; $F_2(1, 32) = 4.52$, $MSE = 1{,}399.77$, $p < .05$. This was due to the fact that there was an 82 ms priming effect for the natural subtype, but only 47 ms effect for the artifact subtype. The associated conditions primed more strongly than the nonassociated for both subtypes (109 ms vs. 57 ms for the natural subtype, and 78 ms vs. 16 ms for the artifact subtype), with no three-way interaction of association, subtype, and prime type (F_1 and $F_2 < 1$).

To follow up on the significant interaction between subtype and priming, we entered the data for the natural and artifact conditions into a further set of separate analyses. These showed that the priming effect was significant for both subtypes: natural subtype, $F_1(1, 22) = 61.98$, $MSE = 2{,}605.33$, $p < .001$; $F_2(1, 16) = 40.14$, $MSE = 1{,}704.00$, $p < .001$; artifact subtype, $F_1(1, 22) = 16.78$, $MSE = 3{,}371.03$, $p < .001$; $F_2(1, 16) = 20.28$, $p < .001$. $MSE = 1{,}095.53$, $p < .001$. A final set of analyses was carried out to determine whether the priming effect was significant for each subtype both with and without association. The effects were significant for the natural category subtype with association, $F_1(1, 22) = 74.24$, $MSE = 1{,}853.36$, $p < .001$; $F_2(1, 8) = 21.6$, $MSE = 2{,}730.55$, $p < .01$, and without association, $F_1(1, 22) = 20.91$, $MSE = 1{,}862.62$, $p < .001$; $F_2(1, 8) = 23.78$, $MSE = 667.46$, $p < .01$. However, for the artifact subtype, the priming effect was significant in the associated condition only, $F_1(1, 22) = 28.35$, $MSE = 2{,}376.63$, $p < .001$; $F_2(1, 8) = 25.24$, $MSE = 1{,}212.12$, $p < .01$. The 16-ms effect for the nonassociated artifact condition did not reach significance, $F_1(1, 22) = 1.70$, $MSE = 3{,}462.85$, $p > .2$; $F_2(1, 8) = 1.32$, $MSE = 978.94$, $p > .2$.

For the functionally related condition there was no main effect of subtype (script and instrument) (F_1 and $F_2 < 1$) and no significant interaction between subtype, and any of the other variables; Subtype × Prime Type F_1 and $F_2 < 1$; Subtype × Association F_1 and $F_2 < 1$. There was a 52-ms priming effect for the script subtype and 53-ms effect for the instrument subtype. Association increased the priming effect equally for both subtypes (80 ms against 31 ms for scripts and 60 ms against 50 ms for instruments) and there was no three-way interaction between association, subtype, and prime type, $F_1(1, 22) = 3.04$, $MSE = 970.87$, $p = .095$; $F_2 < 1$.

Despite the fact that there was no interaction of subtype with the other variables, we carried out further analyses for each subtype separately, for the purposes of comparison with the category coordinate subtypes. These analyses confirmed that both subtypes produced significant priming effects: scripts, $F_1(1, 22) = 16.93$, $MSE = 3{,}534.61$, $p < .001$; $F_2(1, 16) = 21.20$, $MSE = 1{,}475.22$, $p < .001$; instruments, $F_1(1, 22) = 33.81$, $MSE = 1{,}918.63$, $p < .001$; $F_2(1, 16) = 5.57$, $MSE = 5{,}102.83$, $p < .05$. The final set of analyses for associated and nonassociated items in each subtype showed that although the script pairs primed reliably when associated, $F_1(1, 22) = 29.94$, $MSE = 2{,}123.41$, $p < .001$; $F_2(1, 8) = 18.15$, $MSE = 1{,}771.27$, $p < .01$, the 31-ms effect in the nonassociated condition was only marginally significant, $F_1(1, 22) = 3.14$, $MSE = 2{,}800.73$, $p = .09$; $F_2(1, 8) = 4.25$, $MSE = 1{,}179.18$, $p = .07$. For the instrument subtype, the 60-ms priming effect for the associated condition was significant by participants, $F_1(1, 22) = 31.30$, $MSE = 1{,}341.45$, $p < .001$, but not by items, $F_2(1, 7) = 1.69$, $MSE = 9{,}618.93$, $p > .2$.[7] The 50-ms priming effect for nonassociated instruments was significant, $F_1(1, 22) = 11.71$, $MSE = 2{,}059.64$, $p < .01$; $F_2(1, 8) = 10.81$, $MSE = 1{,}151.24$, $p < .05$.

Discussion

In Experiments 1 and 2 we have demonstrated significant priming effects for both category coordinates and functionally related targets, both with and without normative association. This was the case even when we used the single-word presentation paradigm to minimize the possible contribution of nonautomatic priming effects, especially backward priming. It would seem, therefore, that when a word is heard in isolation, semantic information concerning the function and situation of its referent is rapidly and automatically accessed, along with

[7] Inspection of the data indicated that this lack of significance in the items analysis was due to a very fast mean reaction time in the unrelated condition for one item (almost 200 ms faster than any other reaction time in the condition), which greatly increased the variance in the comparison. When we removed this item, the resulting 90-ms priming effect was significant, $F_2(1, 6) = 6.5$, $p < .05$, $MSE = 5{,}030.60$.

information about the superordinate category to which it belongs. Because these priming effects were obtained with no wider contextual support, and were consistent over two different priming procedures with different groups of participants, it is plausible that this information constitutes some of the most salient properties of the underlying lexical semantic representations.

However, although there was an overall significant priming effect for category coordinates and functionally related targets in Experiment 2, in the absence of associative strength, closer inspection revealed some interesting differences in the strength of priming for the various subtypes of information. Specifically, priming was weak for the artifact category coordinates, such as *spade–rake* and *violin–guitar*. As we discussed in the materials section, it has been claimed that category membership may be less important for human-made objects than for natural kinds (Atran, 1989). This is consistent with our results because category coordinates from natural-kind categories primed much more strongly (e.g., *pig–horse* and *plum–apricot*). Further evidence for the hypothesis that functional properties are more important than category relations for artifacts is provided by the robust priming for the instrument relations such as *broom–floor* and *knife–bread*. All of the prime words in this condition came from categories of human-made objects such as tools, weapons, and so on. We also found that priming in the script subtype was rather weak when the primes and targets were not associated. So, for example, priming effects for pairs like *restaurant–wine* and *zoo–penguin* were only marginally significant in both participants and items analyses. This is also consistent with the idea that activation of this kind of schema-based information may be less central to the meaning of a word than other kinds of information. However, the difference in priming for script and instrument subtypes was not sufficient to give rise to a statistically significant interaction between subtype and priming, so it is not yet clear how marked the difference is between the two kinds of relationship.

Thus, the pattern of priming across the different kinds of semantic relationship in Experiment 2 is consistent with the differences in salience of different types of semantic information that have been suggested in the literature. However, it remains the case that for at least two kinds of semantic information—category relations for natural kinds and instrument relations for artifacts—we have demonstrated robust semantic priming without association in a single-word lexical-decision task. This was in spite of the fact that the overall magnitude of priming effects was significantly reduced from Experiment 1 to Experiment 2, $F_2(1, 74) = 6.37$, $p < .01$, $MSE = 22{,}205.60$. The additional priming in Experiment 1 may well have been due to strategic priming processes operating in paired lexical decision over and above the automatic effect that was revealed in the single-word presentation task of Experiment 2. Such strategies may have obscured the differences in the strength of automatic priming effects for the different kinds of semantic relationships that showed up in Experiment 2.

In both experiments, the addition of normative association strength to all types of semantic relation resulted in an additional priming effect. This associative boost is consistent with the view that there is a separate associative priming mechanism, over and above priming on the basis of relations within the semantic system. The claim that associative priming is a distinct form-based mechanism is supported by several other lines of evidence. First, associative priming appears to be impervious to the biases of sentential context constraints, whereas nonassociative semantic priming is weaker and context dependent (Moss & Marslen-Wilson, 1993; Tanenhaus & Lucas, 1987). Second, the boost in priming for associated over nonassociated semantically related items is diminished when prime and target words are presented in different modalities, presumably disrupting the form-based spread of activation (Moss, Ostrin, Tyler, & Marslen-Wilson, 1992). Finally, we have found that semantic and associative priming are differentially affected in a number of aphasic patients (Moss & Tyler, 1993). A similar result has been reported for patients with dementia of the Alzheimer type (Glosser & Friedman, 1991).

Our finding of semantic priming without association in the single-word lexical-decision task conflicts with the view that purely semantic priming is a strategic rather than an automatic process (Lupker, 1984; Shelton & Martin, 1992). In particular, our results are not compatible with those of Shelton and Martin who found no purely semantic priming for category coordinates in the same single-word presentation paradigm. The main difference between the two studies is that Shelton and Martin presented materials visually, whereas our experiment was auditory. As explained in the *Method* section of Experiment 2, the use of spoken materials necessitated a longer interval between primes and targets than was the case in Shelton and Martin's study (1,000 ms vs. 500 ms). It is possible that our longer ISI meant that postlexical priming effects were not entirely eliminated, accounting for the purely semantic priming effect. However, it is important to note that the time course of projection of information onto the lexicon differs for auditory and visual inputs, with the spoken word taking time to unfold, whereas the written word is available all at once (Marslen-Wilson & Tyler, 1980). Therefore, a 500-ms difference in the absolute duration of the ISI in the auditory and visual domains may represent little difference in terms of the interval between the point at which participants have sufficient information to make their lexical-decision response and the onset of the subsequent word. As a further test of whether our priming results reflect automatic activation of semantic information, we carried out Experiment 3. We used the single-word presentation lexical-decision task with visual presentation of primes and targets—that is, exactly the same as the procedure used by Shelton and Martin (1992). To give a direct comparison of priming effects in the auditory and visual modality, we used the same materials as in Experiment 2. If the priming effects in Experiment 2 are automatic, we would expect to find priming for both associated and nonassociated pairs of each semantic type. If Shelton and Martin's interpretation is correct, however, there should be no priming for any of the nonassociated pairs. The Shelton and Martin study examined only one type of semantic relationship: category coordinates. Our category coordinate conditions thus provide a close replication of their study over a new set of items. Our functionally related conditions expand the study to examine a new set of semantic relations not previously included.

Experiment 3

Method

Participants

Participants were 27 members of the Birkbeck Speech and Language Centre participant pool. They were native speakers of British English between the ages of 18 and 40 years, most of whom were students at London University and who were paid for their participation.

Materials and Design

The materials and design were identical to those of Experiment 2.

Procedure

The procedure was the same as that reported by Shelton and Martin (1992), Experiment 3. Participants were seated in front of a computer monitor. Each word was presented in uppercase in the center of the screen. The display was terminated at the point that participants made a lexical-decision response by pressing the yes or no button on the box in front of them (timed individually for each participant) to a time-out of 2 s. An interval of 500 ms then followed before the next word was displayed. Participants made a lexical decision to every word presented. The session lasted approximately 15 min and included three short breaks to reduce fatigue.

Results

No participants or items needed to be removed from the data set, as error rates were uniformly low. There were 14 participants in Version 1, and 13 in Version 2. A total of 6% of the responses were incorrect lexical decisions to either a target or its prime. These were removed and not replaced. Only one data point was cut off by the 2-s time-out. This was removed and replaced.

Reaction Times

The overall mean reaction time was 495 ms. This is similar to the mean reported in the Shelton and Martin (1992) study (approximately 535 ms). As response time determined display duration, this shows that this variable did not differ greatly between the two studies.

As for the previous experiments, we first examined the effects of prime type, association, and semantic type, collapsing over the nested subtypes, and then looked at subtype effects in a further set of analyses. Mean reaction times were entered into four-way ANOVAs (Version × Association × Semantic Type × Prime Type), with both participants and items as random variables. Mean reaction times in each condition are shown in Table 4.

Overall, reaction times in the related conditions were 9 ms faster than in the unrelated conditions, giving only a marginally significant main effect of prime type, $F_1(1, 25) = 3.82$, $MSE = 1206.45$, $p = .06$; $F_2(1, 72) = 3.44$, $MSE = 1{,}013.13$, $p = .06$. There was no difference in reaction times to associated and nonassociated targets, $F_1(1, 25) = 2.68$, $MSE = 1{,}095.71$, $p > .5$; $F_2 < 1$, or in reaction times to category and functional items, $F_1(1, 25) = 1.44$, $MSE = 867.23$, $p > .2$; $F_2 < 1$. There were no interactions between these variables, although that between prime type and association was marginally significant, $F_1(1, 25) = 4.21$, $MSE = 1{,}458.83$, $p < .05$; $F_2(1, 72) = 3.43$, $MSE = 1{,}013.13$, $p = .06$. This was due to a greater priming effect for associated items (19 ms) than for nonassociated items (0 ms).

Following this overall analysis we then looked at category coordinates and functionally related pairs separately. This was done in order to compare the pattern of results for the kind of materials used in the Shelton and Martin (1992) study (i.e., category coordinates) with the functionally related items that have not previously been tested, and also so that we could examine any differences among the nested subtype conditions.

Category Coordinates

Data for the category coordinates were entered into ANOVAs, including the factor of subtype (natural and artifact). The priming effect for category coordinates was not significant: 11 ms, $F_1(1, 25) = 1.86$, $MSE = 2{,}833.13$, $p > .1$, $F_2(1, 32) = 3.03$, $MSE = 820.73$, $p = .09$. Associated category coordinates produced a 27-ms priming effect, whereas nonassociated category coordinates showed a −4-ms effect, giving rise to a significant interaction between priming and association, $F_1(1, 25) = 10.76$, $MSE = 1{,}486.13$, $p < .01$, $F_2(1, 32) = 5.70$, $MSE = 820.73$, $p < .05$. This difference is clearly the pattern predicted by Shelton and Martin (1992), with significant priming only for associated items. This pattern held for both the natural and artifact subtypes; for the natural category coordinates, there was a 36-ms priming effect for the associated condition and a −9-ms effect for the nonassociated,

Table 4
Mean Reaction Times (in Milliseconds) and Error Rates (%) in Each Condition in Experiment 3

Semantic type and condition	Associated R *M*	Associated R ER (%)	Associated U *M*	Associated U ER (%)	Associated Priming: U − R	Nonassociated R *M*	Nonassociated R ER (%)	Nonassociated U *M*	Nonassociated U ER (%)	Nonassociated Priming: U − R
Category coordinate	473	1.2	500	3.5	27	501	1.2	497	1.9	−4
Natural	472	0	508	4.6	36	506	1.5	497	3.9	−9
Artifact	475	2.3	491	2.3	16	496	0.8	498	0	2
Functionally related	491	3.1	503	4.7	12	493	1.5	498	4.6	5
Script	504	3.9	497	6.2	−7	505	0	488	4.6	−17
Instrument	479	2.3	509	3.1	30	482	3.1	508	4.6	26

Note. R = related prime; U = unrelated control prime; ER = error rate.

whereas for the artifact coordinates there was a 16-ms effect for the associated condition and 2 ms for the nonassociated. Although the distinction was more marked for the natural than the artifact subtype, this was not a significant difference, with no interaction between subtype and priming (F_1 and $F_2 < 1$) and no three-way interaction between subtype, association, and priming, $F_1(1, 25) = 1.99$, $MSE = 1{,}578.23$, $p > .1$, $F_2(1, 32) = 1.43$, $MSE = 820.73$, $p > .1$.

Functionally Related Items

Data for functionally related items were entered into ANOVAs, which included the subtype variable (script and instrument relations). There was no overall priming effect for functionally related items (8 ms), $F_1 < 1$, $F_2(1, 32) = 1.15$, $MSE = 1{,}127.09$, $p > .1$, nor any interaction between priming and association, F_1 and $F_2 < 1$. However, there was a significant interaction between priming and subtype, $F_1(1, 25) = 12.81$, $MSE = 3{,}184.53$, $p < .01$, $F_2(1, 32) = 6.96$, $MSE = 1{,}127.09$, $p < .05$. This interaction was due to the fact that instrument pairs showed a priming effect of 28 ms, whereas script pairs showed no priming at all (−11 ms). This difference in priming for the script and instrument pairs did not interact with association strength (F_1 and $F_2 < 1$); the instrument pairs showed 30 and 26 ms in the associated and nonassociated conditions respectively, whereas the script pairs showed −7 and −17 ms. An analysis of the data for the instrument subtype confirmed that the 30-ms priming effect in the associated condition was significant by participants and marginally significant by items, $F_1(1, 25) = 4.49$, $MSE = 3{,}344.47$, $p < .05$, $F_2(1, 8) = 4.13$, $MSE = 1{,}066.98$, $p = .08$, and that the 26-ms priming effect for the instruments in the nonassociated condition was reliable over participants and items, $F_1(1, 25) = 4.39$, $MSE = 2{,}557.81$, $p < .05$; $F_2(1, 8) = 5.95$, $MSE = 568.15$, $p < .05$.

Because the priming effect for the nonassociated instrument subtype provides the crucial evidence for purely semantic priming in the visual continuous lexical decision paradigm, we carried out a further analysis to establish the reliability of the result. In the original analysis, no long reaction times were excluded as potential outliers. It might be argued that the small but significant priming effect could be entirely due to a few extreme values in the control condition. Ratcliff (1993) has shown how different procedures for trimming data can affect the power of the analysis, depending on whether long values are part of the distribution of reaction times for the process of interest or whether they are true outliers. Therefore, in a subsequent analysis, a cutoff point of 1,000 ms was imposed (based on visual inspection of the frequency distribution). Thirty data points fell above this cutoff (1.5%), and these were removed and not replaced. Following this procedure, means were recalculated over participants and items. The priming effect for the nonassociated instrument condition remains significant: 32 ms, $F_1(1, 25) = 4.90$, $MSE = 2{,}454.03$, $p < .05$; $F_2(1, 8) = 7.10$, $MSE = 700.76$, $p < .05$. The size of this effect compares well with that for the associated natural category coordinates: 38 ms, $F_1(1, 25) = 18.66$, $MSE = 1{,}242.28$, $p < .01$; $F_2(1, 8) = 7.21$, $MSE = 1{,}004.77$, $p < .05$. This demonstrates that the nonassociated instrument priming is a robust effect, which is not dependent on only the slow tail of the distribution.

Error Rates

Arcsine transformed error data were entered into ANOVAs with items as a random variable, parallel to those for reaction times. For the category coordinates, there were no reliable main effects or interactions. However, the pattern of error rates mirrored that of the reaction times, with a reduction in errors from 4% to 1% by the related prime in the associated condition, but an increase of from 1% to 1.9% in the nonassociated condition. For the functionally related items, there was an overall priming effect, with an error rate of 5% in the unrelated condition and 2% in the related condition: $F_2(1, 32) = 4.40$, $MSE = .0025$, $p < .05$. This did not interact with either subtype or association strength (both Fs < 1). For associated items, the related prime reduced the error rate from 5% to 3%; for the nonassociated items, it reduced the error rate from 5% to 2%.

Discussion

It is clear that the pattern of results in Experiment 3 differs markedly from that found in the first two experiments. Instead of priming for all kinds of semantic relationship, with a consistent boost for associated items, the visual single-word presentation paradigm produced different patterns of priming for the different kinds of semantic relationship. Category coordinate pairs primed when they were strongly associated but not when they were only semantically related. This was most striking for the natural-kind subtype—thus *cat–dog* primed strongly, whereas *pig–horse* did not prime at all. The effect was not quite as clear for the artifact condition, with a smaller priming effect in the associated condition. However, the pattern was the same as for the natural subtype and did not differ significantly from it. Taken alone, these results replicate Shelton and Martin's (1992) findings for category coordinates (in which no distinction was drawn between natural and artifact coordinates, and the materials included a mixture of the two). On the basis of this pattern of results, Shelton and Martin argued that associative priming is an automatic effect, whereas purely semantic priming is strategic.

However, when we looked at a wider range of semantic relations, this interpretation is no longer supported. Instrument relations primed significantly and equally, both when associated (e.g., *hammer–nail*) and when nonassociated (e.g., *broom–floor*). In contrast, script relations showed no priming, either with association (e.g., *theater–play*) or without (*restaurant–wine*), at least as far as reaction times were concerned. There was some evidence that error rates were reduced by the related prime in the script condition, indicating that some small priming effect may have been operating. The reduction in errors by the related prime in the script condition, from 5% to 0%, was marginally significant over both participants and items, $F_1(1, 25) = 3.60$, $p = .071$, $MSE = 0.009$; $F_2(1, 16) = 3.70$, $p = .073$, $MSE = 0.42$. There was no interaction with association, suggesting that this reduction in errors was present for both associated and nonassociated items. Thus, the results for functionally related items suggest, first, that there is automatic purely semantic priming for at least one type of relation and, second, that associative priming is not necessarily automatic.

General Discussion

The results from our three priming experiments raise a number of questions concerning the automatic activation of a word's semantic information. In the first experiment, with auditory presentation of materials and paired lexical decision, we found priming for a wide range of semantic information, including conditions in which associative relations had been ruled out. However, when we used a continuous presentation paradigm in the second experiment, there was a reduction in overall priming effects from Experiment 1 to Experiment 2, suggesting that the paired lexical-decision procedure may have given rise to an additional component of strategic priming. In addition, we found that priming for some types of information was not reliable when such strategic effects were eliminated. Specifically, there was little evidence of priming between members of artifact categories, and priming between script-related words was only marginally significant. Nevertheless, priming effects were obtained in Experiment 2 for natural category coordinates and for instrument relations. Moreover, the results of the first two experiments were very similar in another way; there was a consistent increase in the priming effect for all conditions when normative association was added to the semantic relationship between prime and target—an effect we have termed the *associative boost.*

In contrast, the visual single-word presentation procedure of Experiment 3 showed different patterns of priming for different types of semantic relation, none of which was the same as in the first two experiments. Category coordinate information primed only when associated, script targets did not prime at all, and instrument targets primed whether associated or not. This pattern seems to suggest that the range of semantic information automatically activated when a word is read in isolation is very limited. How can this difference be interpreted between the visual and auditory domain and between different kinds of semantic information?

In the remainder of this article, we discuss a number of potential interpretations of the data. The first is that the visual version of the single-word lexical-decision paradigm is the true measure of automatic priming (as argued by Shelton & Martin, 1992), on which account there is automatic semantic priming only for instrument related pairs. In discussing this interpretation we also examine the possibility that priming for the nonassociated instrument pairs in Experiment 3 was due to mediated associative priming rather than to semantic activation processes. We then consider the possibility that the visual single-word lexical-decision task does not simply eliminate strategic priming effects but rather is a somewhat unreliable and insensitive measure of priming effects in general. Finally, we put forward an alternative account of the pattern of results in terms of differences in the time course of activation of different types of semantic information.

The first potential account of our data rests on accepting the claim that the visual single-word presentation procedure used in Experiment 3 is the best available measure of automatic activation untainted by strategic priming effects. With this interpretation, the differences in results between the auditory priming tasks used in Experiments 1 and 2, and the visual single-word technique of Experiment 3, are attributable to the involvement of strategic mechanisms such as postlexical semantic matching in the first two experiments. In the case of Experiment 2, the auditory single-word presentation task, this difference may have been because the longer prime–target interval allowed participants to become aware of semantic relations between consecutive items, in spite of there being no explicit pairing of the words.

If Experiment 3 is the best diagnostic of automatic priming, the following conclusions can be drawn. First, the range of semantic information automatically activated and able to support priming is more restricted than we suggested, on the basis of Experiments 1 and 2 and as indicated by previous priming studies. Automatically activated information includes neither common category coordinates nor script-type information. The lack of automatic priming for script-type information such as *restaurant–wine* is perhaps not unexpected, as such information is more appropriate in some contexts than in others, and may only be retrieved when it is highlighted by prior semantic–pragmatic context. Moreover, the results for the script condition are not completely at odds in our auditory and visual continuous presentation experiments. In Experiment 2, priming for the nonassociated scripts was only marginally significant. Also, in spite of the lack of reaction time effects for script relations in Experiment 3, there was a clear reduction in the error rate to the related targets, both in the associated and nonassociated condition. This suggests that priming for script relations may not have entirely been absent in the visual experiment. There may be a very small but consistent priming effect for script relations that shows up in both the visual and auditory continuous presentation paradigms.

It is more surprising that (natural) category coordinates do not support automatic priming unless associated, as these are strongly linked on several different models of semantic memory, whether through explicitly encoded taxonomic structure or through their many overlapping semantic features. The natural category coordinate conditions also showed very robust priming effects in the absence of association in the first two experiments. Nevertheless, for category coordinates, at least, our results are consistent with those of Shelton and Martin (1992).

With the assumption that Experiment 3 reflects automatic priming only, our results do not, however, support the general claim made by Shelton and Martin (1992) and by Lupker (1984) that there is no such thing as automatic semantic priming. In contrast to the other types of semantic relation tested, we found significant priming for instrument related words in the absence of any normative association in either forward or backward direction. The size of this priming effect was no smaller than when association was present. This indicates that information about the use and purpose of an object in relation to other objects is immediately and automatically activated when a word is heard in the absence of supporting context. Examples of this kind of information are that a broom is used to sweep floors and that a spoon is used to eat dessert. Thus, if we accept that the paradigm used in Experiment 3 produces automatic priming, we have demonstrated automatic semantic priming for at least one type of semantic relation.

A possible defense of the claim that there is no such thing as automatic semantic priming could be that the facilitation we observed for the nonassociated instrument-related pairs was not due to the semantic relation between the prime and target but rather to mediated associative priming. Perhaps, for example, *broom* primes *floor* because there is a mediating word such as *sweep,* to which both are associated. Mediated associative priming has been shown to operate in visual single-word lexical decision (McNamara & Altaribba, 1988; Shelton & Martin, 1992). As we did not select our materials explicitly to rule out the possibility of mediated priming, perhaps a large proportion of our nonassociated items happened to share a mediating associate, which could give rise to the priming effect we observed.

To address this question, we collected further sets of association norms. The materials entered into the new norms were all of the associates of the primes in the nonassociated conditions of Experiments 1–3. This included any word that had an association strength of 5% or more to any of the primes. Forty participants were asked to write down the first word that came to mind in response to these words. We then determined whether any of the nonassociated targets were given as responses. Any prime–target pair that had a mediating associate (with an associative strength of 5% at any point in the chain) was counted as a potential mediated pair. On this basis, only 6 of the 40 nonassociated prime–target pairs in Experiment 3 had a mediating associate, of which just 2 were in the nonassociated instrument condition.[8] When we removed these 2 pairs and retested the by-item ANOVA for the instrument condition, we found that it made no difference to the priming effect, $F_2(1, 14) = 7.30, p < .05, MSE = 864$, with a 22-ms priming effect for the nonassociated instrument pairs and a 30-ms effect for the associated pairs. Similar analyses revealed that the priming effects for all conditions in Experiment 2 are also unaffected by removing the 6 mediated items.

These analyses indicate that the priming for semantically related words was not due to the presence of mediating associates. Furthermore, all previous demonstrations of mediated priming have found facilitatory effects considerably smaller than those for direct associative priming; whereas in our experiment, the magnitude of the priming effect is equal for associated and nonassociated instrument-related pairs. It should also be noted that any account in terms of mediated priming would have to apply to the category coordinate conditions as well as to the instrument condition. If *broom* can prime *floor* in Experiment 3, by a possible mediator such as *sweep,* then we would have to say that *pig* could prime *horse* or that *plum* could prime *apricot* through category mediators such as *animal* or *fruit* (indeed, the superordinate would seem to be a very likely candidate for a mediating associate). However, there is no sign of priming in the nonassociated category conditions. Thus, although in principle it may be possible to identify very weak mediating associates (e.g., by collecting association norms in which participants give multiple responses), such an account would have to explain both how the nonassociated instrument items produce a priming effect much larger than that usually observed for mediated priming and why such mediators support priming in the instrument condition but not in the category condition in which they would be much more likely to exist. We cannot completely rule out the mediated priming account, but it seems very implausible in this case.

There is another very different possible account of the priming for nonassociated instruments in Experiment 3, which would also deny that it is based on automatic semantic priming as such. This is derived from the compound-cue model of priming (McKoon & Ratcliff, 1992; Ratcliff & McKoon, 1988). With this account, priming is a function of the familiarity of prime and target as a compound cue for accessing semantic memory. Recently McKoon and Ratcliff have suggested that cue familiarity can directly be measured by the probability of cooccurrence of the prime and target in the language. They showed that cooccurrence (as measured in a large language corpus) predicted priming in a visual single-word lexical-decision experiment. The important point about this was that the pairs with high cooccurrence were not highly normatively associated (although it has often been assumed that association strength and cooccurrence are correlated). This finding suggests the possibility that the pattern of priming in Experiment 3 was determined not by the nature of the semantic relation between prime and target but by their cooccurrence probabilities. Specifically, it may be that the instrument-related pairs have high cooccurrence probabilities, as do associated category coordinates, whereas nonassociated category coordinates and script-related pairs do not. Our materials were not selected on the basis of cooccurrence data, therefore, we do not address this possibility. However, evidence that cooccurrence may not be the sole basis of automatic priming comes from a study by Williams (1994), who used a masked priming paradigm, which is believed to be sensitive to automatic rather than to strategic priming. Williams found that words that shared a high degree of semantic overlap primed (regardless of cooccurrence), whereas those that had a high cooccurrence frequency, but which were not semantically similar, did not support priming. Thus, although we cannot rule out cooccurrence as an explanation of the semantic priming effect in Experiment 3, it does not seem to be a likely explanation. Nevertheless, it will be an interesting issue in future research for researchers to establish whether there are, in fact, differences in the cooccurrence probabilities of different kinds of semantic relationship and how this relates to associative strength.

We turn now to the second major implication of our results, still assuming that only Experiment 3 reflects automatic priming; that priming between normatively associated words is not necessarily automatic. In the script-related condition, we found no priming for any pairs, even when they were strongly associated, as in *theater–play* and *farm–animal* (although as mentioned above, there were effects for the error rates, if not for reaction times). This result conflicts with the view that

[8] These were *broom–floor* (*broom–sweep,* 21% and *sweep–floor,* 8%) and *mallet–peg* (*mallet–tent,* 7% and *tent–peg,* 21%).

associative priming is based on an automatic spread of activation between frequently cooccurring form representations. It also contrasts with our earlier experiments in which we found a constant associative boost in priming, irrespective of the type of semantic relation to which associative strength was added. In Experiment 3, the effect of association varied for different types of semantic relation. One possibility is that although associative strength as measured in normative studies is usually based on cooccurrence of the words in the language, this is not always the case. When participants give script-type associations such as *play* to *theater,* perhaps this response is not based on cooccurrence, but on some other grounds that do not support automatic priming. Numerous possible bases for associative strength have been suggested, as discussed, for example, by Clifton (1967). Both the general issue of associative connections and the specific question about how associated script pairs might differ from other kinds of relation warrant further investigation.

Having discussed the interpretation that would follow if we accept that Experiment 3 reflects automatic priming, we now address the question of whether this assumption is fully justified and consider an alternative account. Although Shelton and Martin (1992) and McNamara and Altaribba (1988) presented convincing evidence that the visual single-word presentation procedure produces mediated priming, and it is difficult to account for this as anything other than an automatic spread of activation (although see McKoon & Ratcliff, 1992), it seems premature to conclude either that the visual single-word presentation paradigm always and only taps into automatic priming processes or that any task that shows a different pattern of results necessarily reflects only strategic priming. One reason to suspend judgment on this issue is that mediated priming is not found in a masked priming paradigm (de Groot, 1983). Masked priming is also thought to give a pure measure of automatic priming because participants are not consciously aware of the primes and would not be able to generate expectancy sets or carry out postlexical semantic coherence checks. It is not clear, then, that any priming task that does not support mediated priming necessarily involves strategic processes.

A second problem is that the visual single-word presentation task seems to produce small and variable priming results. Although our results for the category coordinates in Experiment 3 replicate those found by Shelton and Martin (1992), other researchers have reported a different pattern of results by using the identical stimulus set to that of Shelton and Martin (McKoon & Ratcliff, 1992; footnote 2). We have also found different patterns of results by using a visual single-word presentation task with only a minor methodological difference. When we conducted an experiment that was identical in every way to Experiment 3, except that items were displayed on the computer screen for a constant 500 ms rather than until the participant made a response (with a mean reaction time of 495 ms), we found no priming in any condition, except for a marginal effect for the associated natural category coordinate subtype. We have also tested a different set of items in the continuous presentation procedure with a constant target duration and found no priming for strongly phrase-associated pairs such as *elbow–grease* and only marginal priming for synonym pairs, whether associated or not. It is not clear why this minor change in presentation timing in the visual domain should have such an effect, but it suggests that the task is susceptible to more than automatic priming and that in some cases, it is insensitive to priming effects for even the most strongly related prime–target pairs, whether associated or semantically related or both.

Given these problems, we cannot be sure that a lack of priming for a particular type of semantic relation in the visual single-word paradigm necessarily means that there is no automatic activation of the corresponding semantic activation information. Even more debatable is the idea that any facilitation in a different variant of the priming paradigm must necessarily be strategic if it does not also hold up in the visual single-word task. In particular, we cannot dismiss the priming in the auditory single-word task of Experiment 2 for a wide range of semantic relations as being strategic simply on the basis that they did not also support priming in Experiment 3.

In addition to these doubts about the visual single-word presentation task, an alternative interpretation of our data is also possible, which does not rely on the distinction between automatic and strategic priming. It may be that the differences in priming between the auditory and visual modalities (between Experiments 2 and 3) reflect differences in the time course of activation for various kinds of semantic information rather than an automatic–strategic distinction between them. Specifically, instrument information may be accessed very quickly, thereby producing priming at the short delays of the visual paradigm, whereas category information becomes available more slowly. This would mean that category information is activated by the time the target is encountered in the auditory experiment (1,000-ms postoffset) but not in the 500-ms interval of the visual experiment. If direct word–word associations exist between members of a category, these will quickly be activated enough for visual priming too.

The account here is similar to previous claims that differential priming effects for naming and lexical-decision tasks may be due to the typically slower time course of lexical decision than naming rather than to differences in automatic and strategic contributions to priming (Chiarello et al., 1990; Schreuder et al., 1984). This kind of interpretation does not rule out the possibility that there may be varying degrees of postlexical matching strategies contributing to the total priming effect, but it does suggest that the slower time course alone does not necessarily mean that it is not possible to tap automatic priming effects in the auditory modality.

In summary, we have suggested two possible interpretations of our data. The first is that priming in the visual single-word presentation task (Experiment 3) is a good reflection of automatic priming and, as such, shows purely semantic priming for instrument relations, but not for category coordinates or script relations. With this account, the range of semantic information activated, when associative priming is prevented, is very restricted and does not include many of the kinds of information indicated by our first two experiments and by previous priming studies. However, our data from this task do not support the view that there is no such thing as automatic semantic priming. We have demonstrated that this claim rests on generalizing from only one type of semantic relation—

category coordination—to all semantic information. However, because of reservations about the visual single-word presentation task as the true diagnostic of automatic priming, we have offered an alternative interpretation: We suggest that different types of semantic information are activated with different time courses and that these lead to different patterns of facilitation, depending on the prime–target delay in each experiment. Given our results, it would seem that instrument relations have a faster activation time than either script or category relations, whereas associative priming is always rapid, except perhaps in the case of script relations.

The results of our priming experiments point toward further work that must be carried out to distinguish whether Experiment 3 does show the true extent of automatic priming or whether differences in time course of access determine facilitation. This will involve varying the ISIs of primes and targets in both visual and auditory versions of the single-word presentation tasks and by further exploring the nature of automatic priming for different semantic relations, perhaps by using procedures such as masked priming. On the basis of the current results we can, however, conclude the following: (a) there is automatic activation of at least some types of semantic information; (b) claims about semantic priming as a whole cannot be made on the basis of just one type of semantic relation; (c) our data are consistent with a separate associative mechanism that gives a priming boost in the auditory experiments; (d) functional relations are not purely associative, as nonassociated functional relations support priming; and (e) one particular type of functional relation, the instrument relation between words like *broom–floor,* may be particularly central to the semantic representations of artifact nouns.

This fifth point is based on the following grounds: Whether the time course account or the automatic–strategic account turns out to be the correct interpretation of the data, it remains the case that instrument relations support priming over a wider range of tasks than any of the other relations tested. Whether this is due to faster activation or to automatic activation of this kind of information, it would seem that instrument relations have a particularly important role in lexical semantic access. This is consistent with the view that functional information is central to the meanings of nouns that refer to artifact objects (e.g., Barton & Komatsu, 1989; Keil, 1986). It remains an open question whether the same result would be found for nouns from the natural-kind domain. The centrality of functional information is also widely supported by the developmental literature, in which functional aspects of word meanings are reported to be acquired at a very early stage (e.g., Anglin, 1977; Blewitt & Toppino, 1991; Nelson, 1979, 1985). Nevertheless, it is generally thought that the initial functional organization is superseded by a hierarchical taxonomic structure (Nelson, 1979), and we might expect this to be reflected in more robust category-based priming for adults. The primacy of category structure in the adult lexicon is also assumed in studies of semantic impairment after brain damage. It has frequently been claimed that category information is preserved in many cases in which other semantic properties—including functional information—are lost (e.g., Warrington, 1975). However, this is not always the case. We have found selective preservation of functional knowledge, of the types tested in our experiments in the face of impaired category knowledge, in a patient with profound semantic dementia (Moss, Tyler, Hodges, & Patterson, 1995). However, the developmental evidence and the neuropsychological evidence, which we have referred to in this article, apply to both instrument and script relations, making no distinction between them. In contrast, the priming results in Experiment 3 suggest that it is only one specific subset of functional information that is rapidly or automatically accessed: instrument information. Script information does not enjoy this status and, in fact, tends to support the least robust priming effects across our three experiments. It seems, then, that the account of access to different types of semantic information will involve more than a simple category–functional distinction. What is clear, nevertheless, is that functional semantic information differs in important ways from category information and that it should not be dismissed as "merely associative," as has been the case in previous priming experiments.

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Appendix

Stimuli Used in Experiments 1–3

Materials

All items were used in Experiment 1. The first 10 items of each condition were also used in Experiments 2 and 3.

Category Coordinates

Associated Natural		*Associated Artifact*		*Nonassociated Natural*		*Nonassociated Artifact*	
thunder	lightning	bat	ball	aunt	nephew	aeroplane	train
white	black	boat	ship	cow	goat	kite	balloon
brother	sister	coat	hat	green	pink	bed	desk
square	circle	comb	brush	lake	mountain	book	magazine
dog	cat	dish	plate	nose	head	dagger	spear
gold	silver	cup	saucer	onion	garlic	blouse	dress
king	queen	hatchet	axe	pig	horse	jumper	skirt
latin	greek	record	tape	plum	apricot	tent	cabin
lettuce	cabbage	table	chair	prince	duke	lorry	bike
soldier	sailor	trumpet	horn	ruby	emerald	violin	guitar
measles	mumps	flannel	towel	decade	century	doll	puppet
month	year	shirt	tie	spanish	english	piano	harp
moon	stars	pencil	pen	lieutenant	sergeant	roof	wall
salt	pepper	cutlass	sword	copper	tin	spade	rake

Functionally Related

Associated Scripts		*Associated Instruments*		*Nonassociated Scripts*		*Nonassociated Instruments*	
beach	sand	belt	trousers	castle	dungeon	broom	floor
butcher	meat	bow	arrow	restaurant	wine	button	collar
canal	barge	grill	toast	college	teacher	oven	potato
farm	animal	hammer	nail	hospital	doctor	knife	bread
gallery	art	kettle	tea	market	vegetables	mallet	peg
kitchen	sink	needle	thread	lounge	sofa	trap	bear
orchard	apple	net	fish	circus	lion	spoon	dessert
pub	beer	pram	baby	bingo	prize	string	parcel
theater	play	shampoo	hair	war	army	drill	teeth
wedding	bells	umbrella	rain	station	guard	fridge	cheese
christmas	tree	bandage	wound	zoo	penguin	antidote	venom
dairy	milk	pump	water	hotel	foyer	saucepan	custard
hurricane	wind	harpoon	whale	interview	suit	furnace	steel
estate	house	gun	bullet	party	music	razor	leg

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