Journal of Experimental Psychology:
Learning, Memory, and Cognition
2007, Vol. 33, No. 3, 503–535

0278-7393/07/$12.00 DOI: 10.1037/0278-7393.33.3.503

Lexical Selection Is Not by Competition: A Reinterpretation of Semantic Interference and Facilitation Effects in the Picture–Word Interference Paradigm

Bradford Z. Mahon
Harvard University and University of Trento

Albert Costa
Parc Científic Universitat de Barcelona

Robin Peterson
University of Denver

Kimberly A. Vargas
Harvard University

Alfonso Caramazza
Harvard University and University of Trento

The dominant view in the field of lexical access in speech production maintains that selection of a word becomes more difficult as the levels of activation of nontarget words increase—selection by competition. The authors tested this prediction in two sets of experiments. First, the authors show that participants are faster to name pictures of objects (e.g., "bed") in the context of semantically related verb distractors (e.g., sleep) compared with unrelated verb distractors (e.g., shoot). In the second set of experiments, the authors show that target naming latencies (e.g., "horse") are, if anything, faster for within-category semantically close distractor words (e.g., zebra) than for within-category semantically far distractor words (e.g., whale). In the context of previous research, these data ground a new empirical generalization: As distractor words become semantically closer to the target concepts—all else being equal—target naming is facilitated. This fact means that lexical selection does not involve competition, and consequently, that the semantic interference effect does not reflect a lexical level process. This conclusion has important implications for models of lexical access and interpretations of Stroop-like interference effects.

Keywords: lexical access, competition, semantic interference, semantic facilitation, semantic distance

Supplemental material: http://dx.doi.org/10.1037/0278-7393.33.3.503.supp

There are two major approaches to modeling the dynamics of information retrieval from the mental lexicon (Levelt, 1999). One tradition, based primarily on analyses of naturally occurring (Dell, 1986; Stemberger, 1985) as well as aphasic (Caramazza, 1997; Rapp & Goldrick, 2000) speech errors, assumes that the level of activation of nontarget words does not affect the time required to select the target word. A second tradition, based on the patterns of chronometric effects observed in speech production experiments with normal participants, assumes that the time required to select the target word is affected by the levels of activation of nontarget words (La Heij, 1988; Levelt, Roelofs, & Meyer, 1999; Roelofs, 2003). This hypothesis is referred to as *lexical selection by competition*. The hypothesis of lexical selection by competition states that the time required to select the target word increases as the levels of activation of nontarget words increase (Belke, Meyer, & Damian, 2005; Bloem & La Heij, 2003; Bloem, van den Boogaard,

Bradford Z. Mahon and Alfonso Caramazza, Department of Psychology, Harvard University, and Center for Mind/Brain Sciences, University of Trento, Rovereto, Italy; Albert Costa, Grup de Recerca Neurociència Cognitiva, Parc Científic Universitat de Barcelona, Barcelona, Spain; Robin Peterson, Department of Psychology, University of Denver; Kimberly Vargas, Department of Psychology, Harvard University.

Experiments 1, 2b, 3, and 6c were previously reported as an abstract (Mahon, Costa, Shapiro, & Caramazza, 2002). Preparation of this article was supported in part by a Fulbright Grant from the Spanish and United States Governments and a National Science Foundation Graduate Research Fellowship to Bradford Z. Mahon as well as by National Institutes of Health Grant DC04542 to Alfonso Caramazza.

We would like to thank Mathew Finkbeiner for suggesting the post-hoc analyses reported on the data from Finkbeiner and Caramazza (2006b) as well as for making available the data. We are grateful to Xavier Alario, Jorge Almeida, David Caplan, Susan Carey, Mathew Finkbeiner, Chiara Finocchiaro, Niels Janssen, Eduardo Navarrete, Jesse Snedeker, and Yuhong Jiang for their comments throughout the course of this project. We would also like to thank the members of the Cognitive Neuropsychology Laboratory at Harvard University and the Grup de Recerca Neurociència Cognitiva of the University of Barcelona for their comments. Julia Mario, Stephanie Lawrence, and Coz assisted by running participants.

Correspondence concerning this article should be addressed to Bradford Z. Mahon, Department of Psychology, Harvard University, 33 Kirkland Street, Cambridge, MA 02138. E-mail: mahon@fas.harvard.edu

& La Heij, 2004; Caramazza & Costa, 2000; Costa, Miozzo, & Caramazza, 1999; Damian & Bowers, 2003; Damian & Martin, 1999; Damian, Vigliocco, & Levelt, 2001; Hantsch, Jescheniak, & Schriefers, 2005; Humphreys, Lloyd-Jones, & Fias, 1995; La Heij, 1988; Levelt et al., 1999; Roelofs, 1992, 1993, 2001, 2003; Santesteban, Costa, Pontin, & Navarrete, 2006; Schriefers, Meyer, & Levelt, 1990; Starreveld & La Heij, 1995, 1996; Vigliocco, Lauer, Damian, & Levelt, 2002; Vigliocco, Vinson, Damian, & Levelt, (2002); Vigliocco, Vinson, Lewis, & Garrett, 2004; Vitkovitch & Tyrrell, 1999).

The hypothesis of lexical selection by competition was initially adopted to explain an empirical observation: the semantic interference effect as observed in the picture–word interference paradigm. In the picture–word interference paradigm, participants name pictures of common objects as quickly and accurately as possible while ignoring distractor words that are embedded in the pictures (for a review, see MacLeod, 1991). The semantic interference effect refers to the observation that participants are slower to name pictures of objects (e.g., "horse") in the context of semantically related distractor words (e.g., whale) compared with unrelated distractor words (e.g., truck).[1] The interpretation of the semantic interference effect in terms of lexical selection by competition follows naturally from background assumptions generally shared by models of speech production. One important background assumption is that the amount of activation that spreads from the lexical-conceptual level to the lexical level is a function of the semantic similarity between activated concepts (e.g., Caramazza, 1997; Dell, 1986; Goldrick & Rapp, 2002; Levelt et al., 1999; Roelofs, 1992, 1993, 2003; Starreveld & La Heij, 1996; Stemberger, 1985; but see Bloem & La Heij, 2003; Bloem et al., 2004). It follows that, in the course of a given picture-naming event (e.g., "car"), lexical nodes corresponding to semantically related distractor words (e.g., *truck*) will be more highly activated than lexical nodes corresponding to unrelated distractor words (e.g., *hat*). This is because lexical nodes corresponding to semantically related distractor words will receive activation from two sources: (a) the written/aural presentation of the distractor word and (b) the target concept. In contrast, lexical nodes corresponding to unrelated distractor words will receive activation from only the written/aural presentation of the distractor word.

The more computationally explicit formulations of the hypothesis of lexical selection by competition have modeled the semantic interference effect in terms of the Luce choice ratio. The Luce ratio generates a probability as to whether the target lexical node will be selected at any given time step. The ratio that determines this probability is the level of activation of the target word divided by the levels of activation of all words in the system. In this way, the decision about which word is to be selected is stipulated prior to, and independently of, the determination of when that word is to be selected. This is a critical component of the theory, as it means that only the chronometric profiles of correct utterances are relevant to an evaluation of the hypothesis of lexical selection by competition. As Levelt et al. (1999) stated in their influential article:

> Rather than basing our theory on the evidence from speech errors, spontaneous or induced, we have developed and tested our notions almost exclusively by means of reaction time (RT) research. We believed this to be a necessary addition to existing methodology for a number of reasons. Models of lexical access have always been conceived as process models of normal speech production. Their ultimate test, we argued in Levelt (1991) and Meyer (1992), cannot lie in how they account for infrequent derailments of the process but rather must lie in how they deal with the normal process itself. RT studies, of object naming in particular, can bring us much closer to this ideal. (p. 2)

The hypothesis of lexical competition—unadorned and all else being equal—predicts that naming latencies of target pictures will increase as the levels of activation of lexical nodes corresponding to distractor words increase (e.g., Bloem & La Heij, 2003; Roelofs, 2003; Vigliocco et al., 2004). Thus, one way to evaluate the hypothesis of lexical selection by competition is to manipulate the relative levels of activation of lexical nodes corresponding to distractor words, independently of a semantic relationship between pictures and distractors. A means of doing this is to manipulate the frequency of unrelated distractor words. If lexical nodes corresponding to high-frequency words have higher resting levels than those corresponding to low-frequency words (McClelland & Rumelhart, 1981), participants should be slower to name target objects in the context of high-frequency distractor words compared with low-frequency distractor words. Contrary to this prediction, Miozzo and Caramazza (2003; see also Burt, 2002) observed that participants are slower to name pictures of objects in the context of low-frequency distractors compared with high-frequency distractors. The observation that naming latencies increase as the frequency of distractor words decreases means that the distractor frequency effect cannot be explained in terms of lexical selection by competition (Miozzo & Caramazza, 2003). In the context of the hypothesis of lexical selection by competition, the distractor frequency effect requires that further assumptions be made about the dynamics of information retrieval from the mental lexicon (e.g., Jescheniak & Levelt, 1994; Morton, 1969).

The most direct way to evaluate the hypothesis of lexical selection by competition is to consider the effect on object-naming latencies of decreasing the semantic distance between distractor words and target concepts. The semantic interference effect as observed in the picture–word interference paradigm constitutes one such manipulation of semantic distance. The interpretation of the semantic interference effect in terms of lexical selection by competition is based on the inference that lexical nodes corresponding to semantically related distractors are more highly activated than those corresponding to unrelated distractors. There are, however, equally compelling manipulations of semantic distance between distractor words and target pictures that yield semantic facilitation (e.g., Bloem & La Heij, 2003; Bloem et al., 2004; Caramazza & Costa, 2001; Costa, Alario, & Caramazza, 2005; Damian et al., 2001; Finkbeiner & Caramazza, 2006b; Kuipers, La Heij, & Costa, in press; Roelofs, 1992, 2003; Vitkovitch & Tyrrell, 1999). For instance, when participants name pictures of objects in their second language (L2; e.g., "coche" for a picture of a "car") distractor words corresponding to the first language (L1) translations of the responses (i.e., car) facilitate naming latencies compared with unrelated distractors (e.g., hat) (Costa & Caramazza,

[1] Following conventions in the literature, we use the following notations: picture names and participants' responses appear in quotes (e.g., "bed"), distractor words are underlined (e.g., table), lexical concepts are denoted by capital letters (e.g., BED), and lexical nodes are denoted by italics (e.g., *table*).

1999; Goodman, Haith, Guttentag, & Rao, 1985). As another example, participants are faster to name pictures of objects (e.g., "car") in the context of distractor words denoting (not-visible) parts of the target objects (e.g., engine) compared with unrelated distractor words (e.g., leaf; Costa et al., 2005).

The mere existence of semantic facilitation effects indicates that the experimental conditions that must be present in order to observe semantic interference are not reducible to a manipulation of semantic distance. The hypothesis of lexical selection by competition may be reconciled with such semantic facilitation effects by restricting the types of words that may enter into lexical competition for selection of the target response. This means that the hypothesis of lexical selection by competition must be supplemented with explicit stipulations about the experimental conditions that are expected to give rise to semantic interference. Do the stipulations with which the hypothesis of lexical selection must be supplemented follow naturally, or are they ad hoc? For instance, in order to explain why semantic facilitation is observed for distractor words in a part–whole relationship to the target pictures (Costa et al., 2005), the stipulation might be made that only words corresponding to semantic-category coordinates of the target concept may enter into competition with the target word. Such a stipulation lacks independent motivation and would thus be ad hoc. When in the course of accruing ad hoc assumptions a hypothesis becomes increasingly insulated from the empirical phenomenon that it was designed to explain, the question arises as to whether the hypothesis is worth its keep. Is the hypothesis of lexical selection by competition worth the explanatory burden it engenders with respect to semantic facilitation effects?

Reinterpretation of Semantic Interference and Facilitation Effects

There is a complex relationship between theories of lexical access and the patterns of semantic interference and facilitation observed in the picture–word interference paradigm. This is because, on the one hand, many different empirical phenomena have been reported, and on the other hand, important components of the hypothesis of lexical selection by competition have become background assumptions and, as such, are not usually considered open to revision. The hypothesis of lexical selection by competition consists of a conjunction of assumptions that may or may not be either individually or collectively valid. The project of this article is to make explicit the distinct assumptions that constitute the hypothesis of lexical selection by competition and to consider each assumption individually. In so doing, we offer a reassessment of the relative values of semantic interference and facilitation effects in informing a model of lexical selection in speech production. The standard position in the field of speech production is that semantic interference is the primary datum to be explained by a model of lexical selection. To anticipate our conclusion, we argue that the critical data that should inform models of lexical selection are semantic facilitation effects.

As noted above, models of lexical selection can be separated into two classes depending on whether they assume that the time required to select the target word is affected by the levels of activation of nontarget words. Regardless of which model of lexical selection is adopted, it is necessary to explain semantic interference and facilitation effects in terms of different processes or mechanisms. The hypothesis of lexical selection by competition naturally explains those empirical phenomena in which naming latencies increase as the semantic distance between distractor words and target concepts decreases. On the same hypothesis, however, semantic facilitation effects can be explained only by stipulating that certain types of experimental conditions must be present in order for lexical nodes corresponding to distractor words to compete for selection with the target response. In contrast, if a model of lexical selection is assumed in which the time required to select the target word is not affected by the levels of activation of nontarget words, then semantic facilitation effects fall out as a natural consequence. Such a model would predict that decreasing semantic distance between distractor words and target pictures should facilitate target picture-naming latencies, due to semantic priming. On the same hypothesis, observations of semantic interference must be explained in terms of a different process than that giving rise to semantic facilitation.

It is clear that, regardless of the model of lexical selection that is adopted, explicit assumptions are required about the experimental conditions that are assumed to give rise to semantic interference and facilitation. It is thus necessary to separate two levels of analysis in order to establish the relative values of semantic interference and facilitation effects in informing a model of lexical selection. The first level of analysis is purely descriptive and is concerned with characterizing the experimental conditions that must be present in order to observe either semantic interference or semantic facilitation. This level of analysis is concerned strictly with describing the boundaries of the empirical phenomena that are to be explained and is not committed to a particular theoretical view about the mechanisms that will ultimately explain semantic interference and facilitation effects. The second level of analysis is concerned with articulating a causal explanation of the observed semantic interference and facilitation effects. Thus, the two levels of analysis, although independent, are mutually constraining.

The descriptive and explanatory levels of analysis can be made concrete by considering the explanation of the semantic interference effect proposed by the hypothesis of lexical selection by competition. As has been discussed, the standard construal (i.e., descriptive analysis) of the experimental condition giving rise to semantic interference is that the phenomenon depends on a manipulation of the relative semantic distance between distractor words and target pictures. That description does not, in and of itself, constitute a causal explanation of semantic interference. Such an explanation is provided if it is independently assumed that the semantic interference effect arises at the level of lexical selection (e.g., Schriefers et al., 1990; see also Damian & Bowers, 2003), and a procedure is described according to which decreasing semantic distance between distractor words and target pictures makes selection of the target lexical node slower (i.e., harder; e.g., La Heij, 1988; Roelofs, 1992).

The hypothesis of lexical selection by competition thus consists of (a) a description of the experimental conditions that give rise to semantic interference (a manipulation of semantic distance) and (b) assumptions about the level of processing (lexical selection) at which, and the mechanism by which, semantic interference arises. Two implications follow from this. First, semantic interference effects are evidence for lexical selection by competition only in the measure to which it is true that decreasing semantic distance between distractor words and target pictures leads to longer target naming latencies. Second, the hypothesis of lexical selection by competition is only as strong as the demonstration that the semantic interference effect reflects lexical level processes. The argument of this article is accordingly divided into two parts. In the first part, we test the boundaries of the semantic interference effect, and in the second part we test whether the semantic interference effect reflects lexical selection by competition.

Overview of the Argument

The principal task faced by participants in the picture–word interference paradigm is to name the target picture and ignore the distractor word. Printed (or aurally presented) distractor words have a privileged relationship with the articulators in a way that pictures do not. Thus, when participants are presented with a picture–word stimulus, the distractor word will have already engaged the articulators before the picture has engendered a motor relevant representation for articulation. In speech production, there is a necessary bottleneck, or "single-channel," at the level of the articulators. Thus, in order for a given picture to be named, it is first necessary to clear the path to the articulators. This means that representations within the language production system corresponding to distractor words must be excluded from production before the target picture name can be articulated. Naming latencies for target pictures are thus determined not only by properties of the target picture, its concept, and its name but also by the speed with which the system can exclude the distractor word as a potential response. In the measure to which representations corresponding to distractor words can be excluded from production relatively fast, target naming latencies will decrease. In the measure to which representations corresponding to distractor words take longer to exclude as potential responses, naming latencies for the target pictures will be slowed. Some effects in the picture–word interference paradigm fall within the scope of the framework just outlined—namely, those effects that are determined by a property of distractor words (e.g., the distractor frequency effect) or by a relation between distractor words and target pictures (e.g., the semantic interference effect).

In the context of the semantic interference effect, there are two ways in which one might describe the experimental conditions that make it more or less difficult for representations corresponding to distractor words to be excluded from production. The first way is in terms of semantic distance, which in the context of a model of lexical selection by competition is a proxy for a difference in activation levels of lexical nodes corresponding to distractor words. On this description, lexical nodes with higher levels of activation are more difficult to exclude from production. However, as noted above, observations of semantic facilitation indicate that a manipulation of semantic distance cannot, in and of itself, be the correct way to characterize the experimental conditions that give rise to semantic interference. An alternative way to describe the experimental conditions that must be present in order to observe semantic interference is in terms of what we will call *response-relevant criteria* (e.g., Glaser & Glaser, 1989; La Heij, 1988; Lupker, 1979; Lupker & Katz, 1981; Simon & Sudalaimuthu, 1979). The basic idea is that different types of distractor words will differ in the degree to which they satisfy general semantic constraints that must be met by an acceptable response to a target picture. For instance, Lupker (1979) argued that concrete noun distractors interfere more than abstract noun distractors because the former satisfy a response criterion demanded by the target pictures (i.e., "name an object"). With respect to the semantic interference effect, distractor words (e.g., whale) that are semantic-category coordinates of the target pictures (e.g., "horse") will meet broad semantic criteria that are demanded by the target pictures (e.g., "is an animal"; e.g., Lupker, 1979). Unrelated distractor words will not meet such criteria. This means that the manipulation of semantic distance inherent in the stimuli that generate the semantic interference effect is confounded with a difference in response-relevant criteria. It is important to note that the construal of the experimental conditions giving rise to semantic interference in terms of response-relevant criteria does not make reference to semantic distance. This alternative construal is formulated rather in the vocabulary of the general semantic constraints that are demanded of a valid response to a target picture, in the context of the task in which participants are engaged (e.g., Simon & Sudalaimuthu, 1979).

Any description of the experimental conditions that give rise to the semantic interference effect will, on pain of circularity, be agnostic as to the level of processing at which semantic interference is assumed to arise. It is known that semantic information of distractor words is processed, because as has been noted, a range of semantic effects (both interference and facilitation) has been documented. The fact that semantic variables can influence the time required to name target pictures in the context of distractor words does not mean that the variation in naming latencies that has been labeled the *semantic interference effect* arises at the semantic level. What this means is that the decision mechanism that excludes representations corresponding to distractor words is sensitive to semantic information (see, e.g., discussion of the Luce ratio above). We frame an account of semantic interference at a postlexical level in terms of a decision mechanism that operates over production-ready representations (for discussion, see Dyer, 1973; Finkbeiner & Caramazza, 2006b; Lupker, 1979; Miozzo & Caramazza, 2003; Morton, 1969). One way to flesh out this proposal is to note that coarse information about the provenance (picture or word) and the broad semantic category of the target picture will be available to the system relatively early in the naming process. Thus, the system may be able to use this information to decide relatively early on that unrelated distractors do not constitute potential responses to the target picture. On the other hand, this information would be less useful for excluding representations corresponding to distractor words that do satisfy such semantic constraints. Although this account is at present admittedly vague, we flesh it out in the General Discussion.

It is thus critical to empirically determine the boundaries of the semantic interference effect. This is important for two reasons. The first reason is that it is important to establish whether semantic interference is observed only when the semantic distance between distractor words and target pictures is manipulated along with a manipulation of response-relevant criteria. If these two dimensions—semantic distance and response-relevant criteria—were to be confounded whenever semantic interference is observed, then the original motivation for assuming lexical selection by competition would be, effectively, neutralized. The second reason why it is important to establish the boundaries of the semantic interference effect is because a proper description of the experimental conditions giving rise to the semantic interference effect determines the most direct way for testing the hypothesis of lexical selection by competition. In Experiments 1–4, we tested the boundaries of the semantic interference effect, and in Experiments 5–7, we directly tested the hypothesis of lexical selection by competition.

In Experiments 1 and 2, participants named pictures of objects (e.g., "bed") in the context of semantically related verb distractors (e.g., sleep) and unrelated verb distractors (e.g., shoot). According to lexical selection by competition, naming latencies should be longer in the semantically related condition than in the unrelated condition. This prediction follows because the lexical nodes corresponding to semantically related distractor words will be more highly activated than those corresponding to unrelated distractor words. In contrast, if the presence of semantic interference depends on a concurrent manipulation of response-relevant criteria, then either no effect or semantic facilitation is predicted. This is because in the course of naming concrete objects, neither the related nor the unrelated verb distractor words will satisfy the response criteria demanded by the target pictures (e.g., "name an object"). In Experiments 1 and 2, we observe that naming latencies are faster in the related verb distractor condition than in the unrelated verb distractor condition.

The hypothesis of lexical selection by competition may be reconciled with the data from Experiments 1 and 2 by stipulating ad hoc that verb distractors do not enter into competition when naming pictures of objects. In Experiment 3, we show that the amount of interference induced by unrelated noun distractors compared with unrelated verb distractors in object naming is determined by the degree to which the noun distractors satisfy response-relevant criteria demanded of the target objects. In Experiment 4, we take a different approach: We show that the semantic interference effect can be obtained while holding constant a graded measure of semantic distance. Participants named pictures of objects (e.g., "strawberry") in the context of distractor words that either were (e.g., lemon) or were not (lobster) semantic-category coordinates of the target pictures. Critically, according to a standard graded measure of semantic distance (Cree & McRae, 2003) the semantic similarity between STRAWBERRY and LEMON was equivalent to that between STRAWBERRY and LOBSTER. We observed a reliable semantic (category) interference effect. These data indicate that a manipulation of the semantic-category coordinate status of picture–word pairs is sufficient to produce the semantic interference effect.

In Experiments 5–7, we directly tested the hypothesis of lexical selection by competition. Participants named pictures of objects (e.g., "horse") in the context of semantically close within-category distractor words (e.g., zebra) and semantically far within-category distractor words (e.g., whale). The hypothesis of lexical selection by competition predicts that naming latencies will be longer in the within-category semantically close distractor condition than in the within-category semantically far distractor condition. Across three sets of materials, a replicable effect is observed in which decreasing within-category semantic distance between distractor words and target pictures leads to shorter naming latencies. These data indicate that the semantic interference effect does not reflect lexical selection by competition.

The findings that are reported and reviewed herein mean that we must reinterpret the inferences that may be drawn from semantic interference and facilitation effects to the dynamical principles that characterize speech production. We offer an alternative construal of the picture–word semantic interference effect. In the measure to which semantic interference can be explained at a postlexical locus, there is no empirical evidence for the hypothesis of lexical selection by competition. The range of semantic facilitation effects that we report and review collectively indicate that lexical selection is not by competition. These semantic facilitation effects can be explained only if it is assumed that the time required to select the target lexical node is not affected by the levels of activation of nontarget words.

Defining the Boundaries of Semantic Interference: Experiments 1–4

Experiment 1

In this experiment, participants named pictures of common objects (e.g., "bed") in the context of semantically related verb distractor words (e.g., sleep) and unrelated verb distractor words (e.g., shoot); the same set of pictures also appeared with noun distractor words that were either semantic-category coordinates (e.g., table) of, or unrelated to (e.g., rifle), the pictures. The hypothesis of lexical selection by competition predicts that naming latencies will be longer for semantically related verb distractor words compared with unrelated verb distractor words. However, if the semantic interference effect is due to a manipulation of response-relevant criteria, then naming latencies should be, if anything, faster for related compared with unrelated verbs. This is because neither related nor unrelated verbs will satisfy the response-relevant criterion of naming concrete objects, and so decreasing semantic distance between distractor words and target picture should facilitate target naming latencies. Thus, of particular interest will be whether there is an interaction between semantic relatedness and grammatical class.

Method

Participants. Twenty-nine native English speakers, students at Harvard University, were paid for their participation.

Materials. Thirty pictures of common objects were selected as target stimuli. Pictures were prepared in PhotoShop 5.5 and were scaled to an approximate width and height of 3.5 in. (8.89 cm). Each picture (e.g., "bed") was paired with four different distractor words: (a) a semantically related verb (e.g., sleep), (b) an unrelated verb (e.g., shoot), c) a semantic-category coordinate (e.g., table), and (d) an unrelated noun (e.g., rifle). Half of the verb distractors were pure verbs, and half were words for which the frequency values were (at least) twice as high for the verbal usage than for the nominal usage (average for verb usage = 135; average for noun usage = 13; Francis & Kucera, 1982). Each distractor appeared twice: once semantically related to a picture and once unrelated to another picture. In order to reduce the number of related stimuli, we presented the pictures along with a filler condition (a string of *XXX*s). See Appendix A for a list of the materials.

The distractor words appeared in capital letters (Geneva, bold, 22 points) around the fixation point, with a variation of 2 cm. Stimuli were presented in five blocks of 32 trials each (30 experimental and 2 warm-up), each picture appearing once in each block, and each block beginning with 2 warm-up trials. Trials with semantically related picture–word pairs thus comprised approximately 37.5% of all trials. Each condition appeared the same number of times in each block (6 times per block). Pictures and distractors that appeared in warm-up trials did not appear in any of the experimental trials, and distractors in warm-up trials were unrelated to their respective pictures. The order of block presentation to participants followed an incomplete Latin square design, and the order of the stimuli in the blocks was reversed, resulting in 10 different possible presentations.

Procedure. Participants were tested individually in a sound-attenuated room. They were instructed to name the pictures as quickly and as accurately as possible using a single word. Before the experiment proper, participants were presented with all of the target pictures and were asked to name them. When necessary, participants were asked to produce the word expected by the experimenter. In this phase, the pictures were presented without a distractor word. After the familiarization phase, there was a practice phase, consisting of 10 picture–distractor word pairs that were not related and that did not appear in any of the experimental trials. Participants were informed that they would see picture–word pairs and were asked to ignore the words. There was a small pause between the blocks during which participants could rest. A trial consisted of the following events: (a) a question mark appeared at fixation until the participant pushed the space bar; (b) a plus sign (fixation point) appeared for 500 ms; (c) the picture appeared along with the distractor word and remained until the participant responded or until 3,000 ms, whichever came first; (d) there was a 1,000-ms pause before the question mark appeared on the screen, signaling the beginning of the next trial. Response latencies were measured from the onset of the stimulus to the beginning of the naming response by means of a voice key. Stimulus presentation was controlled by the program PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993). The session lasted approximately 30 min.

Analyses. Four types of responses were scored as errors and excluded from the analyses of responses latencies: (a) production of names that differed from those designated by the experimenter, (b) verbal disfluencies (stuttering, utterance repairs, and production of nonverbal sounds that triggered the voice key), (c) recording failures, and (d) response times greater than 2,000 ms or less than 350 ms. Outliers (responses exceeding 2.5 standard deviations) were replaced with the 2.5 standard deviation cutoff, which was calculated for each participant on the basis of performance across all conditions. Separate analyses were conducted treating participants and items as random variables, yielding F_1/t_1 and F_2/t_2 statistics, respectively.

The XXX filler condition was excluded from the analyses reported below. Two bivalent variables were analyzed: grammatical class of the distractor word (noun vs. verb) and semantic relatedness (related vs. unrelated). Both variables were within-participant. Because the noun and verb distractors were not matched on relevant variables, we do not report statistical analyses on the main effect of grammatical class (but see Experiment 3 below). Table 1 shows the mean response latencies and error rates as a function of distractor type.

Results and Discussion

Erroneous responses were observed on 3.1% of the trials. In the error analysis, there was no main effect of semantic relatedness (both *F*s < 1) and a significant interaction between grammatical class and semantic relatedness, $F_1(1, 28) = 12.0$, $p < .003$, $\eta^2 = .3$; $F_2(1, 29) = 16.4$, $p < .001$, $\eta^2 = .36$. Planned *t* tests (two-tailed) showed that participants made fewer errors when the pictures appeared along with verb distractors that were semantically related than when they were unrelated, $t_1(28) = 2.6$, $p < .02$; $t_2(29) = 3.5$, $p < .002$. This tendency was inverted for the noun distractors: Participants made more errors in the semantically related than in the unrelated condition, $t_1(28) = 2.7$, $p < .02$; $t_2(29) = 2.3$, $p < .04$.

In the analysis of naming latencies, there was no main effect of semantic relatedness (both *F*s < 1), but there was a significant interaction between grammatical class and semantic relatedness, $F_1(1, 28) = 16.7$, $p < .001$, $\eta^2 = .37$; $F_2(1, 29) = 4.8$, $p < .04$, $\eta^2 = .14$. Planned *t* tests (two-tailed) showed that naming latencies were slower for semantically related nouns than for unrelated nouns, $t_1(28) = 2.8$, $p < .009$; this effect was not reliable in the item analysis, $t^2(29) = 1.6$, $p = .13$. In contrast, semantically related verbs interfered less than unrelated verbs; this difference

Table 1
Naming Latencies (in Milliseconds), Standard Deviations, and Error Rates (E%) by Type of Distractor in Experiments 1, 2, 2b, and 3

Experiment and picture–word relationship	Type of distractor word								
	Noun			Verb			XXX		
	M	*SD*	E%	*M*	*SD*	E%	*M*	*SD*	E%
Experiment 1									
Related	769	120	1.0	705	109	0.3			
Unrelated	752	112	0.6	723	116	0.7	684	88	0.5
Experiment 2									
Related	895	141	1.7	781	115	0.9			
Unrelated	838	114	1.1	802	123	0.9			
Experiment 2b									
Related				693	74	3.1			
Unrelated				716	84	2.0	671	76	1.7
Experiment 3									
Unrelated	653	81	3.4	645	81	3.8			

was significant by participants, $t_1(28) = 4.5$, $p < .001$, and was marginal by items, $t_2(29) = 1.8$, $p = .08$.

Experiment 2 sought to replicate the interaction between semantic relatedness and grammatical class observed in Experiment 1.

Experiment 2

Participants named pictures of objects in the context of four types of distractors: semantically related verbs versus unrelated verbs (e.g., picture "pencil": write vs. turn) and semantic-category coordinate noun distractors versus unrelated nouns (e.g., picture "ant": bee vs. pie). In order to ensure that any observed effect of related versus unrelated verb distractors could not be attributed to the behavior of a particular unrelated baseline, we paired three unrelated verb distractors with each related verb distractor. A given participant saw only one of the unrelated verb distractors, and all unrelated verb distractors appeared equally often across all participants.

Method

Participants. Sixty native English speakers, students at Harvard University, were paid or received course credit for their participation.

Materials. Sixty pictures of common objects were selected as target stimuli. These pictures were divided into three sets of twenty. For one set of twenty pictures (Set I), each picture was paired with a semantically related verb (for example, the picture "pencil" was paired with the related verb write). Three different unrelated baselines (arbitrarily labeled A, B, and C in Appendix B) were selected. Related and unrelated verb distractors were matched pairwise on frequency (mean for related: 120; unrelated Set A: 120; Set B: 113; Set C: 118; CELEX database), length in letters (for related, $M = 4.6$; unrelated Set A, $M = 4.6$; unrelated Set B, $M = 4.7$; unrelated Set C, $M = 4.7$), length in syllables (for related, unrelated Sets A, B, and C, $M = 1.2$), and imageability (for related, $M = 5.3$; unrelated Set A, $M = 5.0$; unrelated Set B, $M = 5.1$; unrelated Set C, $M = 5.3$), all Fs < 1. Imageability ratings were obtained by having 10 native English speakers, none of whom participated in the experiments, rate the words on a scale of 1–7 according to "how easy it is to make a picture of the referent of the word in your head." Approximately one quarter of the distractors were pure verbs; the rest had a verb frequency that was at least three times as large as the noun frequency (frequency as a noun for related verb distractors = 6.8; unrelated Set A = 13; unrelated Set B = 7.40; unrelated Set C = 18.4). Semantic similarity ratings (see Table 2) confirmed that semantically related verbs were more semantically similar to the target pictures than were the unrelated verb distractors.

Each picture (e.g., "ant") of the second set of twenty pictures (Set II) was paired with two different noun distractors—a semantic-category coordinate (e.g., bee) and a semantically unrelated noun (e.g., pie). The related and unrelated distractors were matched on frequency (related = 10.5; unrelated = 10.6), length in letters (related = 5.6; unrelated = 5.3), length in syllables (related = 1.5; unrelated = 1.6), and imageability (related = 6.4; unrelated = 6.3), all Fs < 1. The third set of twenty pictures (Set III) was paired with semantically and phonologically unrelated words in order to reduce the number of related trials in the experiment. Each picture of this set was paired with two words,

Table 2
Semantic Similarity Ratings for the Stimuli Used in Experiments 2 and 4–7

Type of distractor word and statistical analysis	Experiment 2	Experiment 4	Experiment 5	Experiment 6	Experiment 7
Verb					
Related	5.9				
Unrelated					
A	1.2				
B	1.3				
C	1.3				
Related vs. unrelated	$t(19) = 32.0$				
Noun					
Coordinates		4.6			
Noncoordinates		1.9			
Coordinate vs. noncoordinate		$t(13) = 14.2$			
Within category					
Close			5.3	5.6	5.3
Far			3.9	3.8	3.3
Unrelated			1.3	—	1.3
Close vs. far			$t(19) = 7.3$	$t(21) = 11.12$	$t(35) = 13.1$
Close vs. unrelated			$t(19) = 38.8$		$t(35) = 36.2$
Far vs. unrelated			$t(19) = 16.5$		$t(35) = 18.0$

Note. Native English speakers rated word pairs corresponding to picture–word stimuli on how "related are the two concepts denoted by the words" (1 = not related; 7 = very related). All stimuli were presented as printed word pairs in a different random order to each participant. One group of participants ($n = 10$) rated stimuli from Experiments 2 and 5–7 while another group ($n = 14$) rated the stimuli from Experiment 4 (all t values are significant at $p < .001$, two-tailed).

one of which had a higher frequency as a noun and the other of which had a higher frequency as a verb. Thus the occurrence of verb-like and noun-like distractors was balanced throughout the experiment.

Design. Stimuli were presented in two blocks of 62 trials (60 experimental and 2 warm-up), each picture appearing once in each block, and each block beginning with two warm-up trials. Trials with semantically related picture–word pairs thus comprised approximately 32% of all trials. The order of block presentation to participants followed a Latin square design, and the order of the stimuli in the blocks was reversed, resulting in four different possible presentations. Everything else regarding procedure was the same as in the previous experiment.

Analyses. The data were analyzed in the same way as in Experiment 1, with the exception that grammatical class was a between-items variable in the F_2 analysis. The mean naming latencies and error rates by distractor condition are reported in Table 1.

Results and Discussion

Erroneous responses were observed on 6.0% of the trials. In the error analysis, there was a main effect of semantic relatedness, $F_1(1, 59) = 4.5$, $p < .04$, $\eta^2 = .07$; $F_2(1, 38) = 4.1$, $p = .05$, $\eta^2 = .10$, and a significant interaction between semantic relatedness and grammatical class, $F_1(1, 59) = 6.7$, $p < .02$, $\eta^2 = .10$; $F_2(1, 38) = 5.0$, $p < .04$, $\eta^2 = .12$. A repeated measures analysis of variance (ANOVA) with two levels (related vs. unrelated) indicated no difference in error rates between related verb distractors and unrelated verb distractors (Fs < 1) but more errors for related noun distractors than unrelated noun distractors, $F_1(1, 59) = 8.52$, $p < .006$, $\eta^2 = .13$; $F_2(1, 19) = 6.72$, $p < .02$, $\eta^2 = .26$.

In the analysis of naming latencies, there was a main effect of semantic relatedness, $F_1(1, 59) = 13.08$, $p < .002$, $\eta^2 = .18$; $F_2(1, 38) = 7.0$, $p < .02$, $\eta^2 = .16$, indicating that overall naming latencies were slower for related distractors than for unrelated distractors. There was also a significant interaction between grammatical class and semantic relatedness, $F_1(1, 59) = 56.9$, $p < .001$, $\eta^2 = .49$; $F_2(1, 38) = 28.9$, $p < .001$, $\eta^2 = .43$. A repeated measures ANOVA with two levels (related vs. unrelated) revealed that semantically related verb distractors interfered less than unrelated verb distractors, $F_1(1, 59) = 12.72$, $p < .002$, $\eta^2 = .18$; $F_2(1, 19) = 5.26$, $p < .04$, $\eta^2 = .22$, and for noun distractors, a reliable semantic interference effect was observed, $F_1(1, 59) = 50.44$, $p < .001$, $\eta^2 = .46$; $F_2(1, 19) = 24.90$, $p < .001$, $\eta^2 = .57$.

The results of Experiment 2 establish the reliability of the interaction between semantic relatedness and grammatical class. Furthermore, whereas semantic interference was observed for noun distractors, semantically related verb distractors facilitated basic-level object naming compared with unrelated verb distractors. In a separate experiment (Experiment 2b) with a different group of participants and a different set of materials from those that were used in Experiments 1 and 2, the same pattern of shorter naming latencies to target objects in the context of semantically related verbs compared with unrelated verbs was replicated, $t_1(22) = 3.3$, $p < .004$; $t_2(24) = 3.0$, $p < .007$; see Table 1 and supplemental online materials for details).

One dimension that likely correlates with our manipulation of semantic distance in Experiments 1 and 2 is the degree to which there is an associative relationship between distractor words and target pictures in the semantically related and unrelated verb distractor conditions. The available evidence regarding associative relationships between distractor words and target pictures suggests that there is no effect of this dimension on response times, at least within the range of stimulus onset asynchrony (SOA) used in Experiments 1 and 2 above (i.e., SOA = 0) (Alario, Segui, & Ferrand, 2000; Lupker, 1979; Schriefers et al., 1990). In the Discussion section following Experiment 6 below, we return to this issue and show empirically that associative relationships cannot explain the semantic facilitation effect observed in Experiments 1 and 2.

As noted in the introduction, the hypothesis of lexical selection by competition— unadorned and all being else equal—predicts that decreasing semantic distance between distractor words and target concepts will lead to longer target naming latencies. The pattern of shorter naming latencies in the semantically related (verb) distractor condition compared with the unrelated (verb) distractor condition is contrary to this prediction. This is because on all models of lexical access, the lexical nodes corresponding to semantically related verbs will have higher levels of activation than those corresponding to unrelated verbs. These data indicate that decreasing semantic distance between distractor words and target pictures does not uniformly lead to semantic interference. This in turn means that a manipulation of semantic distance is not the correct way to describe the experimental condition that gives rise to the semantic interference effect.

One way in which the hypothesis of lexical selection by competition might be reconciled with the data from Experiments 1–2 would be to stipulate that there are grammatical class constraints on lexical selection, so that lexical nodes corresponding to verb distractors do not enter into competition with the names of the target objects (for discussion and relevant empirical work, see Pechmann, Garrett, & Zerbst, 2004; Pechmann & Zerbst, 2002; Vigliocco, Vinson, & Siri, 2005). An alternative way to describe the experimental conditions present in Experiments 1–2 is that neither the related nor unrelated verb distractors satisfy the task-determined response-relevant criteria demanded by the target pictures (i.e., "name an object"). Both descriptions are consistent with the observation that, in Experiments 1 and 2, noun distractors interfered more than verb distractors in object naming (see Table 1). One way to distinguish between these two construals is to ask whether a difference between noun and verb distractors would be observed when relatively abstract noun and verb distractors are compared. According to the description in terms of grammatical class constraints at lexical selection, the difference between noun and verb distractor conditions (in an object-naming task) should not vary as a function of the imageability of the distractor words. In contrast, according to the construal in terms of response-relevant criteria, neither abstract nouns nor abstract verbs will satisfy the general semantic constraints demanded by the target pictures (i.e., "name an object"). Thus the description in terms of response-relevant criteria, but not the description in terms of grammatical class constraints, predicts that the degree to which noun distractor words will interfere compared with verb distractor words will increase as the imageability of the distractor words increases. This is because relatively more imageable nouns will satisfy the response-relevant criterion of naming a depictable thing. We tested this prediction in Experiment 3.

Experiment 3

Method

Participants. Thirty native English speakers, students at Harvard University, participated in the experiment.

Materials. Forty pictures of common objects were selected as target stimuli, and 120 pure nouns and 120 pure verbs were selected as distractors. None of the distractors appeared as targets, and none of the targets appeared as distractors. Each picture was paired with three semantically and phonologically unrelated noun–verb distractor pairs. The noun and verb distractors were matched pairwise for frequency (Francis & Kucera, 1982; F&K: nouns = 41.1, verbs = 41.5; Usenet frequency: nouns = 3.7, verbs = 3.7) and number of letters (nouns = 4.8, verbs = 4.8). The verb distractors were, if anything, slightly more imageable than the noun distractors (mean verb imageability = 4.11, $SE = 0.09$; mean noun imageability = 4.08, $SE = 0.09$), $t(29) = 2.53$, $p < .02$ (paired, two-tailed). This difference in imageability goes against the expectation of observing longer naming latencies for noun distractors than verb distractors. Usenet frequency values and all imageability values for Experiment 3 were obtained from the norms provided in Chiarello, Shears, and Lund (1999). See Appendix C for a complete list of the materials.

Design. Stimuli were presented in six blocks such that each picture appeared once in each block. Stimuli were randomized within blocks according to the following criteria: (a) Stimuli on adjacent trials (either pictures or distractors) were never semantically or phonologically related, and (b) no more than two successive trials contained distractors of the same grammatical class. Stimuli from the two different conditions (noun or verb distractors) appeared the same number of times in each block (20). Each block began with two warm-up trials, which did not contain experimental stimuli. The order of blocks was determined by an incomplete Latin square design.

Procedure. The experiment began with a familiarization phase. In this phase the pictures were presented without a distractor word. After the familiarization phase, there was a practice block of twelve trials. Targets and distractors in the practice block did not appear in any of the experimental trials, and the practice distractors were unrelated to their target stimuli. Stimulus presentation was controlled by the program PsyScope (Cohen et al., 1993). The session lasted approximately 40 min.

Analyses. In the analyses, we assessed the main effect of the variable grammatical class (noun vs. verb), collapsing across the three picture repetitions. The mean naming latencies and error rates by distractor condition are reported in Table 1. We then assessed the magnitude of the main effect of grammatical class by binning picture-naming latencies according to the imageability of the pairwise matched noun–verb distractor pairs (Figure 1).

Results and Discussion

Following the error criteria, 7.2% of the data points were excluded from the analysis. An error analysis did not reveal a significant difference in error rates between the noun and verb distractor word conditions (Fs < 1). We observed that pure noun distractors reliably slowed object-naming latencies (653 ms) compared with pure verb distractors (645 ms) $t_1(29) = 3.4$, $p < .003$; $t_2(119) = 2.8$, $p < .007$ (paired, two-tailed). Furthermore, as depicted in Figure 1, the magnitude of the difference between the noun and verb distractor conditions was modulated by the imageability of the distractor words. The difference between the noun and verb distractors (noun > verb) increased as the imageability of the distractor words increased. These data suggest that response-relevant criteria, and not grammatical class constraints at lexical selection, are implicated by the semantic facilitation effect observed in Experiments 1–2. By extension, this means that response-relevant criteria are important in determining the polarity of semantic interference and facilitation effects in the picture–word interference paradigm.

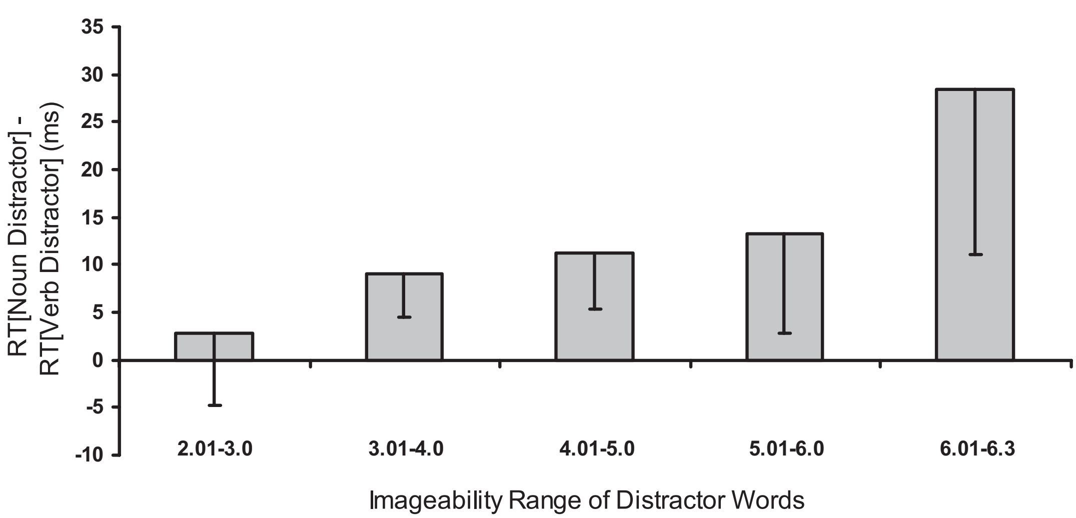

Figure 1. The difference (noun − verb) between the noun and verb distractor conditions for an object-naming task (Experiment 3) is plotted against the imageability of the same noun–verb distractor pairs. Error bars represent standard error of the mean of the difference scores. There is a modulation of the effect, with a larger difference between noun and verb distractors as the imageability of the distractor pairs increases. RT = response time.

The Relation Between Response-Relevant Criteria and Semantic Distance

Another way to evaluate whether response-relevant criteria determine the polarity of semantic effects in the picture–word interference paradigm is to consider whether there is independent evidence for the assumption that the semantic interference effect is due to a manipulation of semantic distance. The experimental manipulation giving rise to semantic interference confounds a manipulation of semantic distance with a difference in response-relevant criteria. It is therefore important to consider whether there are compelling empirical arguments for effects of semantic distance that do not conflate semantic distance with response-relevant criteria.

A principal argument for the claim that the semantic interference effect reflects lexical selection by competition has been the existence of so-called "graded" semantic distance effects. Klein (1964) was the first to report a "semantic gradient" in the Stroop task. Klein observed, using the standard color–word Stroop task, that if the task is to name the ink color "red," the distractor blue (in the response set) interferes more than gray (not in the response set), which in turn interferes more than sky (related to blue; see also Dalrymple-Alford, 1972; Glaser & Glaser, 1989, Experiment 5). The standard interpretation of the "semantic gradient" construes the phenomenon as arising because of a manipulation of the relative semantic distances between the target concepts and the distractor words. For instance, Fox, Shor, and Steinman (1971) wrote, "The results of Klein's study suggest that the degree of interference caused by irrelevant nonpictorial information follows a gradient that is a function of the strength of the semantic relation between the irrelevant information and the names of the colors" (quoted in La Heij, Van der Heijden, & Schreuder, 1985, p. 62). Similarly, Roelofs (2003) restated MacLeod's (1991) conclusion as "Interference in color naming decreases with increasing semantic distance" (p. 90; see also Glaser & Düngelhoff, 1984). We quote these construals of the semantic gradient in order to underline the consensus view currently found in the literature that Stroop-like semantic interference effects are due to the sensitivity of a decision process (e.g., lexical selection by competition) to the continuous dimension of semantic distance.

An alternative interpretation of the semantic gradient reported by Klein (1964) can be described in terms of different levels of response-relevant criteria that are confounded with semantic distance. Consider first the contrast between distractor words denoting colors that appear as targets in the experiment versus distractor words denoting colors that do not appear as targets in the experiment. A number of authors (e.g., Caramazza & Costa, 2000, 2001; Glaser & Glaser, 1989; La Heij, 1988; Roelofs, 1992, 2001) have documented that distractor words corresponding to actual responses in the experiment tend to interfere more than distractor words that are not in the set of actual responses. Klein also observed that color words, not in the response set, interfere more than noncolor words. This manipulation of semantic distance is also confounded with a manipulation of a response-relevant criterion: In the context of a task in which participants are naming ink colors, noncolor words will not satisfy the response criterion of being a possible response in the experiment. In this way, the semantic gradient discovered by Klein can be explained in terms of response-relevant criteria: The semantic gradient is due not to a manipulation of semantic distance but rather to a manipulation of response-relevant criteria. This means that the (so-called) semantic gradient does not constitute support for the assumption of lexical selection by competition.

The notion of response-relevant criteria, as it is deployed in this article, is to be understood as a discrete variable. By *discrete*, we do not mean all or none; the behavior of any given experimental condition must be interpreted with respect to the appropriate baseline. By *discrete* we mean that either a given response-relevant criterion is satisfied by a distractor word or it is not. So, for instance, with respect to Klein's (1964) study, either a distractor word names a color that also appears as a target, or it names a color that does not appear as a target in the experiment. Similarly, either the distractor word names something that could plausibly be presented within the current task (e.g., a color) or it names something that could not plausibly be presented within the current task (e.g., sky). With respect to the semantic interference effect, either the distractor names an item that shares a critical feature with the target or it does not. It is important in this regard to stress that the effect of any given manipulation of any given response-relevant criterion must be interpreted with respect to the appropriate baseline condition. There are, in principle an indefinite number of response-relevant criteria, because such criteria are, in part, a product of task constraints decided by the experimenter.

Another demonstration of graded semantic distance effects comes from the picture–word interference paradigm (Vigliocco et al., 2004). Vigliocco et al. observed a linear trend when comparing naming latencies to target objects (e.g., "axe") in four distractor conditions, listed here in the order of increasing interference: (a) far (e.g., ceiling; mean response time [RT] = 642 ms, *SE* = 8.0 ms), (b) medium (e.g., pencil; mean RT = 648 ms, *SE* = 7.9 ms), (c) close (e.g., spanner; mean RT = 657 ms, *SE* = 8.2 ms), and (d) very close (e.g., hammer; mean RT = 671 ms, *SE* = 8.8). The linear function was estimated on the basis of an independent measure of semantic similarity, which was derived from a feature generation task (for discussion of the database used to derive the semantic similarity values, see Vinson & Vigliocco, 2002; Vinson, Vigliocco, Cappa, & Siri, 2003). In a post-hoc analysis, Vigliocco et al. (2004) separated the items in the medium condition into those that were either within the same semantic category as the target picture (n = 6 of 24) or were not in the same semantic category as the target picture (n = 18 of 24). There was no reliable difference between the two groups of items in terms of the amount of interference produced in picture naming. The authors concluded that "there was no additional benefit of category membership beyond our measure of semantic distance for these items" (p. 458).[2]

[2] In another demonstration of graded semantic distance effects, Vigliocco, Vinson, et al. (2002) found that participants were slower to name pictures blocked by two different but semantically close categories (e.g., clothing and body parts) compared with two different and semantically far categories (e.g., body parts and vehicles). As the authors described in their study, visual similarity correlated with semantic similarity. Relevant to the potential effects of visual similarity, Lotto, Job, and Rumiati (1999; see also Job, Rumiati, & Lotto, 1992; Snodgrass & McCullough, 1986) demonstrated that participants were slower to categorize pictures (by means of a push button response) when the pictures within a block were high in visual similarity compared with when the pictures were low in visual similarity. This finding was observed when semantic distance was held constant between the visually similar and dissimilar blocks of pictures. Furthermore, Lotto et al. (1999) used an experimental design that was identical, in the relevant respects, to that used by Vigliocco, Vinson, et al.

An alternative interpretation of the graded semantic distance effect reported by Vigliocco et al. (2004) may be formulated in terms of the proportion of items within each distractor condition that satisfy the response-relevant criterion demanded by the target pictures. Because all of the items in their close distractor condition were category coordinates of the target pictures, whereas none of the items in the far condition were coordinates of the target pictures, the 15-ms difference between these two conditions likely reflects a small semantic (category) interference effect. The behavior of the medium (or mixed related and unrelated) condition can be explained in terms of a subset of the picture–word pairs in this condition satisfying the response-relevant criterion demanded by the target pictures. In Experiments 5–7, we study the parametric contrast between the very close (i.e., within-category semantically close) and the close (i.e., within-category semantically far) conditions.

What, however, is to be made of the claim that there is no additional effect of semantic category over and above a graded measure of semantic distance? One possibility is that the post hoc statistical test carried out by Vigliocco et al. (2004) on the items from the medium condition did not have enough power to detect an effect (i.e., the comparison of 6 out of 24 vs. 18 out of 24 is too weak to detect an effect). If this surmise were to be correct, then it should be possible to demonstrate empirically that semantic (category) interference can be observed while holding constant a graded measure of semantic distance. This was the goal of Experiment 4. In this experiment, instead of manipulating both semantic-category coordinate relationships and a graded measure of semantic similarity (and thus confounding them) we sought to hold-constant a graded measure of semantic similarity while manipulating semantic-category coordinate relationships.

Experiment 4

The purpose of this experiment was to test for the presence of a semantic interference effect, while holding constant the semantic similarity between distractor words and target pictures, as measured through a feature generation task. Participants named pictures of objects (e.g., "strawberry") in the context of semantic-category coordinate distractor words (e.g., lemon) and distractor words corresponding to items from a different superordinate category (e.g., lobster). Critically, the semantic similarity between STRAWBERRY and LEMON was equivalent to that between STRAWBERRY and LOBSTER. If semantic interference arises because of a manipulation of response-relevant criteria, then semantic interference should be observed with these materials. If however, semantic-category coordinate relationships between target pictures and distractor words do not add anything over and above a graded measure of semantic similarity (e.g., Vigliocco et al., 2004), then no semantic interference should be observed in this experiment.

Method

Participants. Twenty-four native English speakers, students at Harvard University, were paid or received course credit for their participation.

Materials. Fourteen pictures of common objects were selected as target stimuli. Fourteen distractors were chosen that were semantic-category coordinates of the target pictures; these distractor words were then re-paired with the target pictures to form the noncoordinate condition. Distractor words and target pictures were chosen such that, according to the norms of semantic similarity of Cree and McRae (2003), the average similarity between the pictures and their semantic-category coordinate distractors (.16) was the same as that between the noncoordinate picture–distractor pairs (.17), $t(13) < 1$. Because of the constraints of using a within-items design, it was not possible to select more than 14 items. Fourteen additional pictures and distractor words were chosen for filler trials; the assignment of distractors to the filler pictures followed the same design as for the critical items, except that all filler picture–word pairs were semantically unrelated. In order to overcome possible limitations of power associated with a relatively low experimental sample size, the entire stimulus set was repeated three times within participants. See Appendix D for all stimuli.

Design. Stimuli were presented in six blocks of 30 trials (14 experimental, 14 filler, and 2 warm-up), each picture appearing once in each block, and each block beginning with two warm-up trials. Picture–word pairs that were in a semantic-category coordinate relationship composed approximately 23% of all trials in the experiment. Each pair of two blocks (Blocks 1 and 2, 3 and 4, 5 and 6) contained the entire set of stimuli, both critical items and fillers. The order of stimuli within blocks was randomly determined for each participant, with the constraint that no more than two trials in a row contained items from the same condition. Stimulus presentation was controlled by the program DMDX (Forster & Forster, 2003). Everything else regarding procedure was the same as in the previous experiments.

Analyses. Two factors were analyzed: repetition (with three levels) and semantic-category coordinate status of distractors (with two levels). F_2 analyses were not conducted. In place of F_2 analyses on response times, the actual number of items (out of 14) that showed semantic (category) interference (i.e., semantic-category coordinate distractors > noncoordinate distractors) is reported.

Results and Discussion

Erroneous responses were observed on 5.0% of the trials (semantic-category coordinate distractor condition = 2.8%, unrelated condition = 2.2%). In the error analysis, there was no main effect of repetition ($F < 1$), no main effect of semantic-category coordinate status of distractors ($F < 1$), and no interaction between repetition and semantic-category coordinate status of distractors, $F_1(2, 46) = 1.4$, $p = .25$, $\eta^2 = .06$. In the RT analysis, there was a main effect of repetition, $F_1(2, 46) = 3.1$, $p = .055$, $\eta^2 = .12$, indicating shorter naming latencies with repetition (mean RT for first repetition = 747 ms, second repetition = 740 ms, third repetition = 723 ms). There was a main effect of semantic-category coordinate status of distractors, $F_1(1, 23) = 4.5$, $p < .05$, $\eta^2 = .16$, indicating longer naming latencies in the semantic-category coordinate distractor condition (M = 745 ms, SD = 110 ms) compared with the noncoordinate condition (M = 728, SD = 96). There was no interaction between repetition and semantic-category coordinate status ($F < 1$). Inspection of the effect of semantic-category coordinate status of distractors by items revealed that for 11 out of 14 items, naming latencies were longer in the semantic-category coordinate condition compared with the noncoordinate condition. These data undermine the claim (Vigliocco et al., 2004) that there is no additional benefit of the semantic-category coordinate status of picture–word pairs over and above a graded measure of semantic distance.

One objection that may be raised against our Experiment 4 is that in order to select semantic-category coordinate and noncoordinate distractors that are equivalently similar to the target pictures, one necessarily ends up selecting idiosyncratic items. For instance, the reason why STRAWBERRY and LOBSTER are as similar as STRAWBERRY and LEMON is due to the preponderance of participants who produce the feature "is red" to both LOBSTER and STRAWBERRY. Not surprisingly, semantic similarity ratings ($n = 14$) demonstrated that participants judged the coordinate picture–word pairs to be more similar than the noncoordinate picture–word pairs (see Table 2). This discrepancy between graded semantic similarity measures (e.g., Vigliocco et al., 2004) and the intuitions of native speakers is, however, precisely why the results of Experiment 4 are informative. Vigliocco et al. (2004) used the same type of graded semantic similarity measures to choose items for an experiment in which the authors found a graded semantic distance effect. Thus, the objections that may be raised against our Experiment 4 apply equally to the study of Vigliocco et al. The implication is that the results of our Experiment 4 undermine claims that graded semantic distance effects constitute support for the assumption of lexical selection by competition.

The results of Experiments 1–4 shift the burden of argument: There is more reason to believe that the semantic interference effect arises because of a manipulation of response-relevant criteria than there is reason to believe that the semantic interference effect is due to a manipulation of semantic distance. To summarize our argument, first, the experimental manipulation giving rise to the semantic interference effect confounds a manipulation of semantic distance with a manipulation of response-relevant criteria. Second, when a difference in response-relevant criteria is not confounded with a manipulation of semantic distance (Experiments 1 and 2), decreasing semantic distance between distractor words and target pictures produces semantic facilitation. Third, extant arguments for graded response time effects as a function of graded measures of semantic distance confound different levels of response-relevant criteria. Fourth, holding constant a graded measure of semantic distance, while manipulating response-relevant criteria, produces semantic interference (Experiment 4). Therefore, the burden of argument lies with the hypothesis that semantic interference is due to a manipulation of semantic distance and not to a manipulation of response-relevant criteria. We now apply this line of argument to a broader range of semantic interference and facilitation effects.

Review of Semantic Interference and Facilitation Effects

We first present a summary of the principal ways in which semantic interference and semantic facilitation have been observed in the picture–word interference paradigm, as well as in related paradigms. The studies referenced in Tables 3 and 4 are not intended to be an exhaustive listing of all observations of each phenomenon. Rather, we aim to capture the range of different semantic interference and facilitation effects that have been observed. We then unpack in more detail the role of response-

Table 3
Observations of Semantic Interference

Target response	Task	Related condition	Unrelated condition	Examples of observations
car$_{\text{(picture)}}$	Basic-level naming	truck$_{\text{(word)}}$	> hat$_{\text{(word)}}$	Rosinski (1977); Lupker (1979)
car$_{\text{(picture)}}$	Basic-level naming	truck$_{\text{(picture)}}$	> hat$_{\text{(picture)}}$	Glaser & Glaser (1989)
Mini$_{\text{(picture)}}$	Subordinate-level naming	Porsche$_{\text{(word)}}$	> daisy$_{\text{(word)}}$	Vitkovitch & Tyrrell (1999)
Mini$_{\text{(picture)}}$	Subordinate-level naming	glider$_{\text{(word)}}$	> daisy$_{\text{(word)}}$	Vitkovitch & Tyrrell (1999)
car$_{\text{(picture)}}$	Basic-level naming	Blocked by semantic category	> Not blocked by semantic category	Kroll and Stewart (1994)
coche$_{\text{(picture of car)}}$	Basic-level naming in L2	truck$_{\text{(word in L1)}}$	> hat$_{\text{(word in L1)}}$	Costa et al. (1999)
car$_{\text{(picture)}}$	Postcue basic-level naming	truck$_{\text{(picture)}}$	> hat$_{\text{(picture)}}$	Humphreys et al. (1995)
car$_{\text{(picture)}}$	Postcue basic-level naming	truck$_{\text{(word)}}$	> hat$_{\text{(word)}}$	Humphreys et al. (1995)
car$_{\text{(word)}}$	Postcue word reading	truck$_{\text{(picture)}}$	> hat$_{\text{(picture)}}$	Humphreys et al. (1995)
de kerk$_{\text{(bare noun, in Dutch, i.e., 'kerk')}}$	Reading with determiner production	Blocked by semantic category	> Not blocked by semantic category	Damian et al. (2001)
car$_{\text{(word in L2, i.e., 'coche')}}$	Translation (L2→L1)	Blocked by semantic category	> Not blocked by semantic category	Kroll & Stewart (1994)
car$_{\text{(word in L2, i.e., 'coche')}}$	Translation (L2→L1)	truck$_{\text{(word in L1)}}$	> hat$_{\text{(word in L1)}}$	Bloem & La Heij (2003)
car$_{\text{(word in L2, i.e., 'coche')}}$	Translation (L2→L1)	vehicle$_{\text{(word in L1)}}$	> animal$_{\text{(word in L1)}}$	Bloem & La Heij (2003)
car$_{\text{(definition of 'car')}}$	Definition naming	truck$_{\text{(word)}}$	> hat$_{\text{(word)}}$	La Heij et al. (1993)
car$_{\text{(picture)}}$	Picture naming after definition naming	Definition of semantic category coordinate	> Definition of unrelated item	Wheeldon & Monsell (1994)
Mini$_{\text{(picture of a 'Mini')}}$	Subordinate-level naming	car$_{\text{(word)}}$	> hat$_{\text{(word)}}$	Hantsch et al. (2005)
car$_{\text{(picture of a 'Mini')}}$	Basic-level naming	Mini$_{\text{(word)}}$	> daisy$_{\text{(word)}}$	Hantsch et al. (2005)
car$_{\text{(picture of a 'car')}}$	Basic-level naming	vehicle$_{\text{(word)}}$	> animal$_{\text{(word)}}$	Kuipers et al. (in press)

Note. Subscript parenthetical terms and phrases indicate the format of the stimulus. Examples of stimuli do not reflect actual items from the cited studies. For studies using bilingual populations, we have normalized examples to facilitate exposition: L1 is English, and L2 is Spanish.

Table 4
Observations of Semantic Facilitation

Target response	Task	Related condition	Unrelated condition	Examples of observations
car$_{\text{(picture)}}$	Basic-level naming	engine$_{\text{(word)}}$	$<$ tongue$_{\text{(word)}}$	Costa et al. (2005)
car$_{\text{(picture)}}$	Basic-level naming	/#truck#/$_{\text{(masked word)}}$	$<$ #/hat#/$_{\text{(masked word)}}$	Finkbeiner & Caramazza (2006b)
car$_{\text{(picture 300-ms presentation)}}$	Basic-level naming	truck$_{\text{(picture presented for 50 ms)}}$	$<$ hat$_{\text{(picture presented for 50 ms)}}$	La Heij et al. (2003)
Mini$_{\text{(picture)}}$	Subordinate-level naming	car$_{\text{(word)}}$	$<$ hat$_{\text{(word)}}$	Vitkovitch & Tyrrell (1999)
coche$_{\text{(picture of car)}}$	Basic-level naming in L2	car$_{\text{(word in L1)}}$	$<$ hat$_{\text{(word in L1)}}$	Costa & Caramazza (1999)
car$_{\text{(word in L2, i.e., ‘coche’)}}$	Translation (L2→L1)	truck$_{\text{(picture)}}$	$<$ hat$_{\text{(picture)}}$	Bloem & La Heij (2003)
vehicle$_{\text{(picture of car)}}$	Superordinate-level naming	truck$_{\text{(word)}}$	$<$ hat$_{\text{(word)}}$	Costa et al. (2003)
vehicle$_{\text{(word ‘car’)}}$	Superordinate-level naming	truck$_{\text{(word)}}$	$<$ hat$_{\text{(word)}}$	Glaser & Glaser (1989)
vehicle$_{\text{(picture of car)}}$	Superordinate-level naming	truck$_{\text{(picture)}}$	$<$ hat$_{\text{(picture)}}$	Glaser & Glaser (1989)
vehicle$_{\text{(word ‘car’)}}$	Superordinate-level naming	truck$_{\text{(picture)}}$	$<$ hat$_{\text{(picture)}}$	Glaser & Düngelhoff (1984)
de kerk$_{\text{(bare noun, in Dutch, i.e., ‘kerk’)}}$	Reading with determiner production	house$_{\text{(picture)}}$	$<$ hat$_{\text{(picture)}}$	Roelofs (2003)
car$_{\text{(picture)}}$	Basic-level naming	truck$_{\text{(masked picture presented for 17 ms)}}$	$<$ hat$_{\text{(masked picture presented for 17 ms)}}$	Dell’Acqua & Grainger (1999)
car$_{\text{(word)}}$	Word reading	Blocked by semantic category	$<$ Not blocked by semantic category	Damian et al. (2001)
car$_{\text{(word ‘Mini’)}}$	Basic-level word naming	Porsche$_{\text{(word)}}$	$<$ daisy$_{\text{(word)}}$	Kuipers et al. (in press)
vehicle$_{\text{(word in L2, i.e., ‘coche’)}}$	Produce superordinate name in L1 given L2 basic-level name	car$_{\text{(word presented in L1)}}$	$<$ hat$_{\text{(word presented in L1)}}$	Kuipers et al. (in press)
vehicle$_{\text{(word in L2, i.e., ‘coche’)}}$	Produce superordinate name in L1 given L2 basic-level name	bus$_{\text{(word presented in L1)}}$	$<$ hat$_{\text{(word presented in L1)}}$	Kuipers et al. (in press)
car$_{\text{(picture)}}$	Basic-level naming	drive$_{\text{(word)}}$	$<$ sleep$_{\text{(word)}}$	Experiments 1–2 (current study)

Note. Subscript parenthetical terms and phrases indicate the format of the stimulus. Examples of stimuli do not reflect actual items from the cited studies. For studies using bilingual populations, we have normalized examples to facilitate exposition: L1 is English, and L2 is Spanish.

relevant criteria in determining the polarity of semantic effects in the picture–word interference paradigm. This section concludes with a strong empirical prediction that is tested in Experiments 5–7.

Table 3 summarizes the results of studies demonstrating semantic interference across a number of paradigms. For instance, Bloem and La Heij (2003) reported that participants were slower to translate words from English (L2) into Dutch (L1) in the context of semantic-category coordinate distractor words (presented in L1) compared with unrelated distractor words. Another important observation of semantic interference is that participants are slower to perform naming tasks over stimuli that are blocked by semantic category compared with a mixed (related and unrelated) context. This semantic context effect has been observed in word translation (e.g., Kroll & Stewart, 1994; Vigliocco, Lauer, et al., 2002), picture naming (e.g., Belke et al., 2005; Kroll & Stewart, 1994; Santesteban et al., 2006; Vigliocco, Vinson, et al., 2002), and word reading with determiner production (Damian et al., 2001). Semantic interference has also been observed in the postcue paradigm (e.g., Humphreys et al., 1995; see also Dean, Bub, & Masson, 2001). In this paradigm, participants are presented with two pictures on every trial, one colored red and the other colored green, and are instructed to prepare responses to both potential targets. After a short interval, the pictures are replaced with a cue, either the word *GREEN* or the word *RED*, and participants' task is to produce the name of the picture corresponding to the cued color. Humphreys et al. (1995) found that participants were slower to produce the name of a picture (e.g., "car") when that picture had been prepared along with a picture depicting a semantic-category coordinate (e.g., "truck") compared with an unrelated picture (e.g., "hat"; see Table 3 for other demonstrations of semantic interference).

Table 4 summarizes those studies in which participants are producing object names (to either picture or word stimuli) in the context of distracting stimuli (pictures or words) and in which naming latencies are facilitated by decreasing semantic distance between the target and distracting stimuli. Included in Table 4 is the semantic facilitation effect reported in Experiments 1 and 2. Other demonstrations of decreasing target naming latencies as the semantic distance between distractors and targets decreases have been observed using noun distractor words. For instance, semantic-category coordinate distractors (e.g., dog) facilitate superordinate level picture naming (e.g., "horse" → "animal"; e.g., Glaser and Düngelhoff, 1984), whereas basic-level picture naming (e.g., "car") is facilitated by distractor words that are in a part–whole relation to the target concept (e.g., engine; Costa et al., 2005). Another striking demonstration of semantic facilitation is the observation of faster naming latencies when participants must translate words from their L2 to their L1 (e.g., "coche" → "car") in the context of pictures denoting semantic-category coordinates (e.g., "truck") compared with unrelated pictures (e.g., "hat"; Bloem & La Heij, 2003; Bloem et al., 2004). As a final example, participants are faster to name target objects (e.g., "coche" [i.e., "car"]) in their L2 while ignoring distractor words in their L1 that are either translations of the target (i.e., car) or unrelated (e.g., hat; see Table 4 for other demonstrations of semantic facilitation).

There is one important discrepancy in results that is represented in Tables 3 and 4.[3] Vitkovitch and Tyrrell (1999) found that subordinate-level naming latencies (e.g., "Mini") are facilitated by congruent basic-level distractors (e.g., car) compared with unrelated basic-level distractors (e.g., hat). In contrast, Hantsch et al. (2005) observed exactly the opposite result: subordinate-level naming latencies were longer in the context of congruent basic-level distractor words compared with unrelated basic distractor words. As discussed by Hantsch et al., it is not clear why the two studies observed opposite patterns. Interestingly, using the same target pictures, Hantsch et al. observed that basic-level naming latencies (e.g., "car") were slowed by correct subordinate-level distractors (Mini) compared with unrelated distractors (e.g., daisy). The pattern of results obtained by Hantsch et al. is what would be expected if semantic interference arises because distractor words from the semantically related condition satisfy a response criterion demanded by the target pictures. In other words, when naming a picture of a Mini, "car" is an appropriate response, whereas "hat" is not; similarly, when naming a picture of a Mini as "car", the distractor Mini is appropriate, whereas the distractor daisy is not. The same situation arises when basic-level names are produced in the context of superordinate-level distractor words; when naming a picture of a dog, "animal" is an appropriate response, whereas "vehicle" is not (Kuipers et al., in press). The observation that semantic interference is observed across levels of categorization (Hantsch et al., 2005; Kuipers et al., in press) reinforces the conclusion that semantic interference is observed when semantically related distractor words satisfy response-relevant criteria demanded by the target pictures that are not satisfied by unrelated distractor words.

Common to the semantic interference effects listed in Table 3 is the experimental situation in which (a) participants must make a naming response in the context of a prepotent distracting stimulus, and (b) semantic distance is manipulated in such a way that the semantically closer item satisfies response-relevant criteria that are not satisfied by the unrelated baseline. For instance, the observation that participants are slower to name stimuli that are blocked by semantic category, compared with a mixed context (e.g., Damian et al., 2001; Kroll & Stewart, 1994), falls under the above description, even though there are no explicit distracting stimuli in that paradigm. Previously named pictures will be available as potential responses. Consistent with this analysis, Belke et al. (2005) demonstrated that the semantic blocking effect arises only after participants have already named all of the items in the set.

As noted above, response-relevant criteria are determined, in part, by the task in which participants are engaged and the nature of the computations that are being carried out on the target stim-

[3] It is also important to note that studies using an action-naming task (e.g., Vigliocco et al., 2004, 2005) have observed diverging results from the results observed in object naming. Vigliocco et al. (2005) found that action-naming latencies were slowed by semantically related noun distractors compared with unrelated noun distractors. These data may demonstrate an important asymmetry between object and action naming (cf. Experiments 1 and 2 herein). One possible reason for this asymmetry is that in order to have participants name most actions, objects must be included in the displays (e.g., "shaving"). The factors underlying the asymmetry between object and action naming merit further study. However, as the focus of our investigation and review is restricted to those experimental situations in which the hypothesis of lexical selection by competition was developed (e.g., see Levelt et al., 1999), we do not cover in this article the experimental situation of action naming.

ulus (e.g., Glaser & Glaser, 1989; Simon & Sudalaimuthu, 1979). Consistent with this construal, it is clear through comparison of Tables 3 and 4 that a mere change in task instructions can reverse the polarity of the distractor effect from semantic interference to semantic facilitation. In other words, the same materials that produce semantic interference under one set of task instructions produce semantic facilitation under a different set of task instructions.

The organization of semantic interference and facilitation effects that we have proposed according to response-relevant criteria generates two empirical predictions. These two predictions correspond to two ways in which pure effects of semantic distance may be studied. Common to both ways of observing pure effects of semantic distance is the experimental situation in which response-relevant criteria are held constant between the semantically closer and the semantically more distant distractor word conditions.

The first way in which pure effects of semantic distance may be observed is represented by those experimental situations in which both the semantically closer and the semantically more distant distractor word conditions are equivalently irrelevant to the task in which participants are engaged. In other words, both the semantically close and the semantically more distant distractor word conditions do not satisfy response-relevant criteria demanded by the targets. These experimental conditions are present in Experiments 1 and 2 above: Participants named target objects in the context of semantically related or unrelated verb distractors. In this situation, neither verb distractor condition contains a distractor word that could be a potential response to naming a target object. It was found that naming latencies were faster for semantically closer distractor words than semantically more distant distractor words. Exactly parallel to the results of Experiments 1 and 2, Dalrymple-Alford (1972; see also Glaser & Glaser, 1989, Experiment 4) found that naming latencies to the target ink color "red" are shorter in the context of the (semantically closer) distractor word blood than in the context of the (semantically more distant) distractor word sky. As with our observation of a facilitatory effect on object naming of semantically related verbs, this facilitatory effect of decreasing semantic distance was observed when neither the semantically closer nor the semantically more distant distractor word were potential responses to the targets.

The second way in which pure effects of semantic distance may be observed is represented by those experimental situations in which both the semantically closer and the semantically more distant distractor word conditions meet the same response-relevant criterion with respect to the task in which participants are engaged. One elegant demonstration of such an experimental situation is the observation by Ischebeck (2003) that participants are faster to name target Arabic digits (e.g., "8") in the context of written number word distractors that are numerically close (e.g., seven) compared with number words that are numerically far (e.g., three). In this experimental situation, both the semantically closer and the semantically more distant distractor conditions are equally relevant to the task of naming numbers. The observation that naming latencies decrease with decreasing numerical distance between the distractor (number) words and the target numbers indicates that response-relevant criteria must be construed as a discrete constraint.

This line of reasoning generates a clear prediction for the picture–word interference paradigm. If participants name pictures of objects (e.g., "horse") in the context of within-category semantically close distractors (e.g., zebra) and within-category semantically far distractors (e.g., whale), the two distractor conditions will be equivalent with respect to response-relevant criteria (e.g., "name an animal"). Of course, this would be the case only in the measure to which response-relevant criteria are construed as discrete variables—in other words, in the measure to which response-relevant criteria are the same between the within-category semantically close and within-category semantically far distractor conditions. If one adopted this framework in order to account for the existence of the semantic interference effect, there would then be no need to assume that lexical selection is by competition. If a model of lexical selection were assumed in which the time required to select the target node is not affected by the levels of activation of nontarget words, then the following prediction would follow for our parametric manipulation of within-category semantic distance. In the measure to which there is any effect of varying the within-category semantic distance between distractor words and target pictures, naming latencies should be faster for within-category semantically close distractors compared with within-category semantically far distractors. This is because there will be greater distractor-to-target priming as the within-category semantic distance between the distractor words and the target pictures decreases.

Alternatively, if the semantic interference effect is assumed to be due to lexical selection by competition, and not a manipulation of response-relevant criteria, then the opposite prediction follows. The hypothesis of lexical selection by competition predicts that naming latencies will be longer in the within-category semantically close distractor condition than in the within-category semantically far distractor condition.

The Dynamics of Lexical Selection: Experiments 5–7

Experiment 5

The purpose of this experiment was to test the central prediction made by the interpretation of the semantic interference effect in terms of lexical selection by competition: Participants will be slower to name pictures (e.g., "horse") in the context of within-category semantically close distractors (e.g., zebra) than in the context of within-category semantically far distractors (e.g., whale). Pictures and distractors were re-paired in such a way as to create the within-category semantically close and within-category semantically far conditions with the same distractors and the same pictures. This design allows a direct comparison of the within-category semantically close and within-category semantically far distractor conditions.

Method

Participants. Twenty native English speakers from the same population participated in the experiment.

Materials. Twenty pictures of common objects were selected as target stimuli. Within-category semantic distance was manipulated within pictures and within distractors. As an illustration of the design, a given picture (e.g., "horse") was paired with one within-category semantically close distractor (e.g., zebra) and one within-category semantically far distractor (e.g., whale). Another picture (e.g., "dolphin") then appeared with the same two distractors but with the relative semantic distances reversed (e.g., whale is close to "dolphin," whereas zebra is far from "dolphin"). An unrelated baseline condition was created by re-pairing the related distractors with the pictures twice; the two presentations with unrelated distractors for a given picture were collapsed to form a single data point. Thus, the same set of pictures and distractors was used to make all three conditions (within-category semantically close, within-category semantically far, and unrelated; see Appendix E for materials). Semantic similarity ratings (see Table 2) indicated that the manipulation of within-category semantic distance was salient to participants.

Analyses. The same criteria for treating errors and outliers were applied as in previous experiments. A repeated measures ANOVA with three levels was used to test for a main effect of distractor condition (within-category semantically close, within-category semantically far, and unrelated). Subsequent planned *t* tests (two-tailed) then directly contrasted the within-category semantically close and within-category semantically far distractor conditions, as well as each semantically related condition with the unrelated baseline. The mean naming latencies and error rates are reported in Table 5.

Results and Discussion

Erroneous responses were observed on 4.9% of trials. In the error analysis, a repeated measures ANOVA with three levels (within-category semantically close, within-category semantically far, and unrelated) revealed a marginally significant main effect of distractor condition by participants, $F_1(2, 38) = 3.1$, $p = .058$, $\eta^2 = .14$, but not by items, $F_2(2, 38) = 1.4$, $p = .27$. Planned *t* tests (two tailed) indicated more errors in the within-category semantically close condition than in the unrelated baseline, $t_1(19) = 2.51$, $p < .03$; $t_2(19) = 1.6$, $p = .12$, as well as more errors in the within-category semantically far condition than in the unrelated baseline, $t_1(19) = 2.1$, $p = .052$; $t_2(19) = 1.7$, $p = .11$. There was no difference in error rates between the within-category semantically close and within-category semantically far distractor conditions (*t*s < 1).

In the analysis of naming latencies, a repeated measures ANOVA with three levels (within-category semantically close, within-category semantically far, and unrelated) revealed a main effect of distractor condition, $F_1(2, 38) = 17.7$, $p < .001$, $\eta^2 = .48$; $F_2(2, 38) = 13.2$, $p < .001$, $\eta^2 = .41$. Planned *t* tests (two-tailed) indicated naming latencies were reliably shorter in the within-category semantically close condition compared with the within-category semantically far condition, $t_1(19) = 5.5$, $p < .001$; $t_2(19) = 4.9$, $p < .001$. There was no difference between the within-category semantically close condition and the unrelated baseline (*t*s < 1), but there was reliable semantic interference for the within-category semantically far condition compared with the unrelated baseline, $t_1(19) = 4.2$, $p < .002$; $t_2(19) = 4.4$, $p < .001$.

The results of Experiment 5 demonstrate a facilitatory effect on naming latencies of decreasing within-category semantic distance between distractor words and target pictures. With a different group of participants ($n = 32$) and largely the same set of materials ($n = 24$), we replicated this facilitatory effect on naming latencies of decreasing within-category semantic distance between distractor words and target pictures, Experiment 5b, $t_1(31) = 3.0$, $p < .006$; $t_2(23) = 2.4$, $p < .03$ (see Table 5 and supplementary online materials for details). In that replication, there was a trend for higher error rates in the within-category semantically close than in the within-category semantically far condition, $t_1(31) = 1.72$, $p = .095$; $t_2(23) = 2.12$, $p < .05$, (overall error rate = 6.0%). The trend toward more errors in the within-category semantically close than the within-category semantically far condition may be interesting in its own right, as it may constitute a phenomenon distinct from the effect on naming latencies of manipulating within-category semantic distance. Of course, before reaching this conclusion, the possibility must first be raised that a speed–accuracy trade-off could carry the response time difference between the within-category semantically close and within-category semantically far conditions. This possibility can be dismissed for two reasons.

The first reason is empirical. The results of Experiment 5, in which a reliable difference in response times between the within-category semantically close and within-category semantically far conditions was observed, but no difference in error rates was observed, indicate that the two dependent measures dissociate (see also Experiments 6 and 7 below for further demonstrations).

The second reason is theoretical. The concern that a speed–accuracy trade-off may cause a difference in response times between two conditions in an experiment is relevant for those experimental situations in which such a strategy on the part of participants could be conceivably useful. For instance, in an experiment with a two-alternative forced-choice design, there is the possibility to make fast but error-prone responses. In the case of picture naming, and in particular in a picture-naming experiment with a large number of target pictures (e.g., ≥ 20), it is not clear that participants would have at their disposal a strategy of sacrificing accuracy for speed. We return to discuss this issue in the discussion section of Experiment 7.

Table 5
Naming Latencies (in Milliseconds), Standard Deviations, and Error Rates (E%) by Type of Distractor in Experiments 5, 5b, and 6

	Type of picture–word relationship		
	Within category		
Experiment and statistic	Semantically close	Semantically far	Unrelated
Experiment 5			
M	724	765	728
SD	76	95	82
E%	1.9	1.8	1.2
Experiment 5b			
M	726	746	709
SD	49	56	46
E%	2.4	2.0	1.6
Experiment 6			
Picture naming			
M	798	814	
SD	106	108	
E%	3.6	2.9	
Same–different judgments			
M	758	659	
SD	194	141	
E%	3.3	0.2	

In Experiment 6 we sought to replicate, using different materials, the difference in response times between the within-category semantically close and within-category semantically far distractor word conditions.

Experiment 6

The present experiment tested only for the direction of an effect of manipulating within-category semantic distance between distractor words and pictures, and so no unrelated baseline was included in the design. In order to obtain independent empirical confirmation of the manipulation of within-category semantic distance deployed in the materials, we had a different group of participants make same–different judgments over the same picture–word stimuli presented in the naming experiment. Participants' task was simply to decide whether a given word matched a given picture for every picture–word stimulus. In the same–different task, the expectation is that naming latencies will be longer for deciding different in the within-category semantically close than in the within-category semantically far condition.

Method

Participants. Forty-two participants participated in this Experiment; 32 participated in the naming experiment, and 10 participated in the same–different judgment task.

Materials. Twenty-four new pictures were chosen; some pictures corresponded to distractors from Experiment 5, but the pictures used in this experiment were not pictures in Experiment 5, nor were the distractors in the present experiment distractors in Experiment 5. The same within-item design was used to test for an effect of varying within-category semantic distance. One picture ("elephant") was excluded from all analyses because a distractor paired with this picture was misspelled (mastodon); this required excluding from the analyses the companion picture to elephant ("lion") which also appeared with the distractor mastodon. Semantic similarity ratings (see Table 2) demonstrated that our manipulation of within-category semantic distance was salient to participants (see Appendix F for materials).

Thirty-six pictures were chosen as filler items; each filler picture was paired with two distractors. None of the pictures or distractors that appeared as fillers appeared in the critical trials, and none of the picture–word pairs corresponding to fillers were semantically or phonologically related. Stimuli were presented in two blocks of 62 trials each: 24 experimental, 36 filler, and 2 warm-up trials. Thus, trials consisting of semantically related picture–word pairs constituted approximately 39% of all trials in the experiment.

For the same–different task, the same materials were used as in the naming experiment. These picture–word pairs constituted the different trials. An equal number of same trials were included by writing the picture names inside the pictures. Participants responded with a push-button response: right button for same, and left button for different.

Everything else regarding procedure, method, and analyses was the same as in the previous experiments. Mean naming latencies and error rates are reported in Table 5.

Results and Discussion

In the picture-naming experiment, erroneous responses were observed on 6.5% of trials. In the error analysis, there was no difference in error rates between the within-category semantically close and within-category semantically far conditions, $F_1(1, 31) = 1.1$, $p = .31$; $F_2(1, 21) = 1.1$, $p = .32$. The analysis of naming latencies revealed that naming latencies were shorter in the within-category semantically close than in the within-category semantically far condition. This effect was reliable by participants, $F_1(1, 31) = 5.5$, $p < .03$, $\eta^2 = .15$, but not by items, $F_2(1, 21) = 2.7$, $p = .11$, $\eta^2 = .12$.

In the analysis of the same–different judgment task, erroneous responses were observed on 3.5% of trials. There were more errors in the within-category semantically close condition than in the within-category semantically far condition, $F_1(1, 9) = 10.9$, $p < .01$, $\eta^2 = .55$; $F_2(1, 23) = 11.0$, $p < .004$, $\eta^2 = .32$. Participants were slower to decide "no" in the within-category semantically close condition than in the within-category semantically far condition, $F_1(1, 9) = 25.1$, $p < .002$, $\eta^2 = .74$; $F_2(1, 23) = 41.4$, $p < .001$, $\eta^2 = .64$.

The results of Experiment 6 demonstrate a replicable difference in naming latencies between the within-category semantically close and within-category semantically far distractor conditions: Naming latencies are faster for within-category semantically close distractors than within-category semantically far distractors. Furthermore, the interaction between task (naming vs. same–different) and within-category semantic distance (close vs. far) was robust in an F_2 analysis, $F_2(1, 42) = 37.0$, $p < .001$, $\eta^2 = .47$.

As discussed above (see *The relation between response-relevant criteria and semantic distance*), Vigliocco et al. (2004) reported that naming latencies were 14 ms slower in their very close (i.e., within-category semantically close) condition compared with their close (i.e., within-category semantically far condition). Although it is not reported whether this difference was statistically reliable, it remains that the direction of the reported difference contrasts with the consistent pattern that emerges from Experiments 5, 5b, and 6 herein. The divergence in results may be due to differences in experimental design. In Experiments 5 and 6 above, we used within-item designs, such that any response time difference between the within-category semantically close and within-category semantically far conditions cannot be attributed to intrinsic properties of the stimuli. Vigliocco et al. used different sets of distractor words for the various experimental conditions. Although the stimulus properties of those words were carefully controlled, a nonoptimal design was employed. Distractor words were re-paired with different pictures within the same condition, and the number of repetitions of the same distractor words differed across conditions. Another potentially important difference between the experimental design used herein and that used by Vigliocco et al., is that whereas we used an SOA of 0 (i.e., the target picture and the distractor word appeared at the same time) Vigliocco et al. used an SOA of −150 ms (the distractor words preceded the onset of the target pictures by 150 ms). However, as will be shown in Experiment 7 below, using a similar SOA (−160 ms), we again observe faster naming latencies in the within-category semantically close condition than in the within-category semantically far condition. Thus, ultimately, it cannot be known from our perspective why Vigliocco et al. observed a difference in the opposite direction as that which is reported herein, and so we will not discuss the discrepancy further.

The Role of Visual Similarity and Associative Relatedness

Any manipulation of within-category semantic distance will likely confound other dimensions, such as the visual similarity and the strength of associative relationships between distractor words and target pictures. Furthermore, the manipulation of semantic distance in Experiments 1 and 2 will likely be confounded with a manipulation of associative relatedness.

The available evidence indicates that increasing visual similarity between the referents of distractor words and target pictures will, if anything, slow down naming latencies (e.g., Klopfer, 1996; see also Neumann & Kautz, 1982, discussed in La Heij, 1988). As noted above (see the *Results and Discussion* section of Experiment 2), there is no effect on response times of associative relationships between distractor words and target pictures, at least within the SOA range used in Experiments 1–2 and 5–6 above (i.e., SOA = 0) (Alario et al., 2000; Lupker, 1979; Schriefers et al., 1990). Nevertheless, in order to directly address the potential contributions of these dimensions, we conducted two control experiments.

In the first control experiment, Experiment 6b, target pictures ($n = 20$; e.g., "orange") were selected along with distractor words denoting objects visually similar to the targets (e.g., ball; see supplementary online materials for details). These distractors were re-paired with the target pictures to form the unrelated condition. There was no difference in error rates between the visually similar and the unrelated conditions (both Fs < 1). In the analysis of response times, there was a trend for longer reaction times in the visually similar condition ($M = 737$ ms; $SD = 55$ ms) than in the visually dissimilar condition ($M = 725$; $SD = 53$ ms), $F_1\,(1, 15) = 3.8$, $p = .069$; $\eta^2 = .20$; $F_2\,(1, 19) = 1.0$, $p = .32$; $\eta^2 = .05$. The results of this control experiment indicate that the dimension of visual similarity cannot account for the observation (Experiments 5 and 6) that participants were faster to name pictures in the context of within-category semantically close distractors compared with within-category semantically far distractors.

In a second control experiment, Experiment 6c, target pictures ($n = 20$; e.g., "rake") were paired with noun distractors that were (e.g., leaf) or were not (e.g., pond) associatively related to the pictures' names. Associative relationships were quantified with a word association test administered to 20 participants, none of whom participated in this experiment (see the supplemental online materials for details). In order to assess the sensitivity of the experiment, we included two additional distractor manipulations: semantic-category coordinate distractors (e.g., shovel) and their respective baseline (e.g., cherry) and phonologically related distractors (e.g., cake) and their respective baseline (e.g., acid; see the supplementary online materials for details). The results of this experiment indicated that picture-naming latencies do not depend on whether the picture name is an associate of the distractor word (mean for associatively related = 654 ms, $SD = 64$ ms; mean for unrelated = 652 ms, $SD = 71$ ms; Fs < 1). However, with the same target objects reliable semantic interference (mean for semantically related = 673 ms, $SD = 68$ ms; mean for unrelated = 653 ms, $SD = 61$ ms), $F_1(1, 14) = 7.9$, $p < .02$, $\eta^2 = .36$; $F_2(1, 19) = 6.1$, $p < .03$, $\eta^2 = .24$, as well as phonological facilitation (mean for phonologically related = 615 ms, $SD = 73$ ms; mean for unrelated = 655 ms, $SD = 63$ ms), $F_1(1, 14) = 22.0$, $p < .001$, $\eta^2 = .61$; $F_2(1, 19) = 17.0$, $p < .002$, $\eta^2 = .47$, effects were observed. These data rule out an associative relationship as the relevant variable underlying the pattern of effects observed in Experiments 1–2 and 5–6.

This conclusion is further confirmed by the results of analyses of covariance conducted on the data from Experiments 2 and 5, the two experiments in which we observed the strongest effects of each type of semantic distance. If the facilitatory effects of decreasing semantic distance between distractor words and target pictures in Experiments 2 and 5 are not reducible to associative relationships, then these semantic facilitatory effects should remain after associative strengths are covaried out. To address this question, we conducted repeated measures analyses of covariance on the item effects in Experiments 2 and 5, entering the difference in associative strength between the related/semantically close and the unrelated/semantically far conditions and the target picture names as a covariate. Preliminary analyses evaluating the homogeneity of slopes assumption indicated that the relationship between the covariate and the dependent variable did not differ as a function of the independent variable in either analysis; for Experiment 2, $F < 1$; for Experiment 5, $F_2(1, 18) = 2.1$, $p = .16$. After associative strengths were covaried out, there remained significant effects of related compared with unrelated verbs, Experiment 2, $F_2(1, 18) = 4.5$, $p < .05$, $\eta^2 = .20$, as well as within-category semantically close versus within-category semantically far noun distractors, Experiment 5, $F_2(1, 18) = 10.3$, $p < .006$, $\eta^2 = .36$. These analyses indicate that associative relationships cannot explain the semantic facilitatory effects that we have reported.

The inability of an associative relationship to explain the pattern of findings reported herein is important, because La Heij, Dirkx, and Kramer (1990) reported that, at SOA = 0, distractors that were both semantic-category coordinates and highly associated to the picture names did not produce semantic interference relative to an unrelated baseline. In contrast, distractors that were semantic-category coordinates of the target pictures but not highly associated with the picture names did produce semantic interference. Given that associative relationships cannot explain the effect of decreasing response times as within-category semantic distance decreases between distractor words and target pictures, it is possible that La Heij et al. may have (inadvertently) observed an effect of within-category semantic distance. Consistent with this conjecture, semantic distance ratings on the English translations of La Heij et al.'s stimuli demonstrated that the distractor words that generated less semantic interference were rated as being more similar to the target concepts than the distractor words that generated more semantic interference (high-associated $M = 6.4$; low-associated $M = 5.1$), $t_1(9) = 6.63$, $p < .001$ (see also Starreveld & La Heij, 1995, Experiment 2).

In summary, we have demonstrated that neither visual similarity nor associative relationships are able to account for the observation that decreasing within-category semantic distance between distractor words and target pictures facilitates target naming. Because of the theoretical importance of this effect, Experiment 7 again tested, using different materials, for the effect on target naming latencies of manipulating within-category semantic distance between distractor words and target pictures.

Experiment 7

Experiment 7 was a further attempt to empirically characterize the effect of parametrically varying the within-category semantic distance between distractor words and target pictures. Two independent measures were used in order to select items for this experiment. First, items were selected such that there was a large manipulation of semantic similarity according to the feature generation norms of Cree and McRae (2003). Second, semantic similarity ratings for all picture–word pairs were obtained from a group of native English speakers (see Table 2).

In an effort to more fully describe the effect of decreasing within-category semantic distance on naming latencies, we manipulated SOA between participants. Within the context of the hypothesis of lexical selection by competition, it is generally agreed (e.g., Schriefers et al., 1990) that competition for selection of the target picture's name is (assumed to be) greatest at short negative SOAs and at an SOA of 0. Thus, three levels of SOA were deployed: −160 ms (distractor precedes picture), 0 ms (distractor and picture presented concurrently), and +160 ms (picture precedes distractor word). In order to increase the power to detect any effects, all stimuli were repeated three times at each SOA within participants.

Method

Participants. Forty-eight native English speakers from the same population participated for course credit or money. Sixteen participants were run at each level of SOA.

Materials. Thirty-six pictures were selected together with thirty-six within-category semantically close distractors and thirty-six within-category semantically far distractors. The same within-item experimental design was used to test for an effect of within-category semantic distance (see Appendix G for the materials). The length, frequency, and familiarity of the two distractors (within-category semantically close and within-category semantically far) that appeared with a given picture were equivalent. This allowed for selection of a different set of distractors ($n = 18$), each of which was pairwise matched to both the semantically close and within-category semantically far distractors on length in letters (related = 5.4, unrelated = 5.5; $t < 1$), frequency (related = 10.4, unrelated = 11.2; $t < 1$), and familiarity (related = 5.6, unrelated = 5.3; $t < 1$). Each unrelated distractor appeared with two pictures (the two with which the corresponding related distractors appeared). In order to reduce the number of related trials in the experiment to approximately 50%, we paired each target picture with another unrelated distractor word that did not correspond to any other item in the experiment. The data from this filler condition were excluded from all analyses.

According to the semantic similarity measures available in the norms compiled by Cree and McRae (2003), the mean similarity between the pictures and the within-category semantically close distractors was .54, whereas that between the pictures and the within-category semantically far distractors was .16; this difference was consistent for all stimuli, $t(35) = 12.0$, $p < .001$. The mean semantic similarity between the unrelated distractors and their respective target pictures was .01; this difference was reliably smaller than that corresponding to the semantically close condition, $t(35) = 20.1$, $p < .001$ and the semantically far condition, $t(35) = 7.1$, $p < .001$. Semantic similarity ratings (see Table 2) further confirmed that these estimates of semantic similarity were salient to participants.

Procedure. After the familiarization phase, participants practiced naming all pictures in the experiment once in a random order; in this practice phase, the pictures appeared with phonologically and semantically unrelated pure noun distractors that did not appear elsewhere in the experiment. The experimental stimuli were presented in 12 blocks; contiguous groups of four blocks contained all stimuli in the experiment, and every picture appeared once per block. The order of the four blocks within each repetition followed a Latin square, and this was counterbalanced across participants. Stimuli within a given block were randomized with the restriction that no more than two adjacent trials were from the same experimental condition. Approximately 50% of trials were semantically related. Stimulus presentation was controlled by the program DMDX (Forster & Forster, 2003). The experiment lasted approximately 45 min. Everything else regarding procedure and analysis was the same as in previous experiments.

Analyses. We present three levels of analyses. In the first level analysis, we conducted omnibus analyses on response times and errors rates, with SOA (between-participants, 3 levels), repetition (within-participants, 3 levels), and condition (within-participants, 3 levels). The main effect of SOA is not interpretable and is not discussed further; similarly, with regard to interactions, of concern are only the potential interactions between condition and repetition, and condition and SOA. All other interactions are not reported.

Because condition was reliable in the first level analysis for both response times and errors, in a second level analysis, we compared the three experimental conditions of interest against one another (within-category semantically close vs. unrelated, within-category semantically far vs. unrelated, within-category semantically close vs. within-category semantically far). We do not report main effects of repetition in this second level analysis or the interaction between repetition and condition; we do report whether condition interacted with SOA.

Finally, because in the omnibus analysis of response times, but not in the error analysis, there were interactions between condition and SOA, we report a third level of analysis studying the three parametric comparisons of interest at each level of SOA for response times. Mean naming latencies and error rates are reported in Table 6 for all distractor conditions at all levels of SOA, collapsing across repetition. To facilitate the exposition of the analyses within each level of SOA, we report only p values and effect sizes (η^2), with p_1 and p_2 referring to analyses by participants and items, respectively; all other statistical details of these analyses can be found in Table S1 of the supplementary online materials. For all analyses, alpha levels and degrees of freedom were corrected with Greenhouse–Geisser correction where the assumption of sphericity was violated.

Results and Discussion

First-level analysis. In the analysis of response times, there was a main effect of condition, $F_1(2, 90) = 20.2$, $p < .001$, $\eta^2 = .31$; $F_2(2, 210) = 10.3$, $p < .001$; $\eta^2 = .09$, and a main effect of repetition, $F_1(1.6, 72.4) = 4.49$, $p < .022$, $\eta^2 = .09$; $F_2(2, 210) = 17.2$, $p < .001$; $\eta^2 = .14$. The interaction between condition and SOA was reliable in the participants analysis but not by items, $F_1(4, 90) = 2.89$, $p < .03$, $\eta^2 = .11$; $F_2(4, 210) = 1.7$, $p = .15$,

Table 6
Naming Latencies (in Milliseconds), Standard Deviations, and Error Rates (E%) by Type of Distractor in Experiments 7 and 7b

Experiment and Statistic	Within category: Semantically close	Within category: Semantically far	Unrelated
Experiment 7			
SOA −160 ms			
M	730	746	717
SD	103	97	95
E%	2.1	1.5	1.1
SOA 0 ms			
M	752	748	732
SD	63	57	64
E%	2.7	2.1	2.0
SOA +160 ms			
M	698	708	695
SD	91	91	83
E%	2.0	1.4	1.4
Experiment 7b			
M	773	773	755
SD	89	90	80
E%	1.1	1.1	1.0

$\eta^2 = .03$. The interaction between condition and repetition was not significant (*F*s < 1).

In the analysis of errors, there was a main effect of condition, $F_1(2, 90) = 15.6$, $p < .001$, $\eta^2 = .26$; $F_2(2, 210) = 11.94$, $p < .001$, $\eta^2 = .10$, and no main effect of repetition, $F_1 < 1$; $F_2(2, 210) = 2.17$, $p = .12$, $\eta^2 = .02$. Condition did not interact with SOA (*F*s < 1) or repetition, $F_1(3.3, 146.7) = 1.6$, $p = .18$, $\eta^2 = .04$; $F_2(4, 420) = 1.9$, $p = .10$, $\eta^2 = .02$.

Second-level analysis. Naming latencies were reliably shorter in the within-category semantically close condition than in the within-category semantically far condition in the analysis by participants, $F_1(1, 45) = 4.9$, $p < .032$, $\eta^2 = .099$; $F_2(1, 105) = 2.5$, $p = .12$, $\eta^2 = 02$. There was a trend toward an interaction between this main effect and SOA in the participants analysis but not in the analysis by items, $F_1(2, 45) = 2.1$, $p = .066$, $\eta^2 = .11$; $F_2(2, 105) = 2.1$, $p = .12$; $\eta^2 = .04$. Reliable semantic interference was observed for the within-category semantically close condition, $F_1(1, 45) = 13.7$, $p < .002$, $\eta^2 = .23$; $F_2(1, 105) = 9.0$, $p < .004$; $\eta^2 = .08$, and the within-category semantically far condition, $F_1(1, 45) = 57.3$, $p < .001$, $\eta^2 = .56$; $F_2(1, 105) = 19.2$, $p < .001$, $\eta^2 = .16$. The observed semantic interference effect for within-category semantically close distractors did not interact with SOA, $F_1(2, 45) = 2.1$, $p = .14$, $\eta^2 = .08$; $F_2(2, 105) = 1.3$, $p = .28$, $\eta^2 = .02$. The semantic interference effect for within-category semantically far distractors interacted with SOA in the participants analysis, $F_1(2, 45) = 4.2$, $p < .023$, $\eta^2 = .16$; $F_2(2, 105) = 1.7$, $p = .19$, $\eta^2 = .03$.

There were reliably more errors in the within-category semantically close condition than in the within-category semantically far condition, $F_1(1, 45) = 13.8$, $p < .002$, $\eta^2 = .23$; $F_2(1, 105) = 12.2$, $p < .002$, $\eta^2 = .10$. There were also reliably more errors in the within-category semantically close condition than in the unrelated baseline, $F_1(1, 45) = 38.6$, $p < .001$, $\eta^2 = .46$; $F_2(1, 105) = 21.2$, $p < .001$, $\eta^2 = .17$. There was no difference in errors rates between the within-category semantically far condition and the unrelated baseline, $F_1(1, 45) = 1.6$, $p = .22$, $\eta^2 = .03$; $F_2(1, 105) = 1.4$, $p = .25$, $\eta^2 = .01$.

Third-level analysis. Naming latencies were reliably shorter in the within-category semantically close condition than in the within-category semantically far condition at SOA −160 ($p_1 < .02$, $\eta^2 = .34$; $p_2 < .03$, $\eta^2 = .13$). At SOA 0 there was no difference between the two conditions (*F*s < 1), whereas at SOA +160 there was some suggestion of shorter naming latencies in the within-category semantically close condition compared with the within-category semantically far condition ($p_1 = .14$, $\eta^2 = .14$; $p_2 = .20$, $\eta^2 = .05$). Reliable semantic interference for within-category semantically close distractors was observed at SOAs −160 ($p_1 < .02$, $\eta^2 = .32$; $p_2 = .052$, $\eta^2 = .10$) and 0 ($p_1 < .02$, $\eta^2 = .35$; $p_2 < .03$, $\eta^2 = .13$), but there was no effect at SOA +160 (*F*s < 1). Semantic interference for within-category semantically far distractors was observed at SOA −160 ($p_1 < .001$, $\eta^2 = .76$; $p_2 < .001$, $\eta^2 = .37$), SOA 0 by participants ($p_1 < .003$, $\eta^2 = .47$; $p_2 = .12$, $\eta^2 = .07$), and SOA +160 ($p_1 < .02$, $\eta^2 = .33$; $p_2 < .04$, $\eta^2 = .12$).

In Experiment 7, collapsing across SOA, naming latencies were reliably shorter in the within-category semantically close distractor condition compared with the within-category semantically far distractor condition. A closer look at the effect of within-category semantic distance at each level of SOA revealed a robust effect at SOA −160 but no difference between the two within-category distractor conditions at SOA 0. The lack of an effect of within-category semantic distance at SOA 0 cannot be due to the materials used in Experiment 7 because of the reliable effect observed at SOA −160. In an effort to address this issue, we reran the SOA 0 condition with a new group of participants (*n* = 36); in this replication (Experiment 7b), the number of related trials in the experiment was reduced to approximately 36%, and all stimuli were presented once to participants. The results of Experiment 7b replicated the pattern observed in Experiment 7 at SOA 0: Naming latencies were the same in the within-category semantically close condition (773 ms) and in the within-category semantically far condition (773 ms; see Table 6). Semantic interference was observed for each condition compared with the unrelated baseline, within-category semantically close vs. unrelated, $t_1(35) = 3.3$, $p < .003$; $t_2(35) = 2.5$, $p < .02$; within-category semantically far vs. unrelated, $t_1(35) = 3.8$, $p < .001$; $t_2(35) = 2.0$, $p = .059$.

The pattern of findings observed in Experiments 5–7 suggests that multiple factors may contribute to the observed response time effects of manipulating within-category semantic distance between distractor words and target pictures. In particular, the results of Experiment 6b above (see also Klopfer, 1996; Neumann & Kautz, 1982, discussed in La Heij, 1988) suggest that the confounded dimension of visual similarity may push response times in the opposite direction of the manipulation of within-category semantic distance. Another observation is that there is a tendency for higher error rates in the within-category semantically close distractor condition than in the within-category semantically far distractor condition (see also Vigliocco et al., 2004). This trend in the error analysis is independent of the effect in the response time analysis. For instance, in Experiment 7, although naming latencies were reliably shorter in the within-category semantically close condition compared with the within-category semantically far condition only at SOA −160, there were reliable differences in error rates at all

SOAs (the effect of higher error rates in the within-category semantically close condition than in the within-category semantically far condition did not interact with SOA; $Fs < 1$). As noted in the introduction, this effect on error rates does not fall within the scope of the hypothesis of lexical selection by competition (e.g., Levelt et al., 1999). However, this error effect can be explained by the class of models designed to explain how the system determines which lexical node is to be selected (e.g., Caramazza, 1997; Dell, 1986; Rapp & Goldrick, 2000). On that class of models, the lexical node with the highest level of activation is selected for production. Thus, there would be a higher probability of (mis)selecting the lexical node corresponding to the distractor word in the within-category semantically close condition than in the within-category semantically far condition.

The critical empirical fact that emerges from Experiments 5–7 concerns the vast majority of trials on which the system does in fact select the correct lexical node. We have observed a consistent pattern in which naming latencies are shorter in the within-category semantically close condition than in the within-category semantically far condition. These data indicate that the semantic interference effect does not reflect lexical selection by competition.

General Discussion

In this article, we have undertaken an analysis of the hypothesis of lexical selection by competition. In the introduction, we noted that the semantic interference effect is confounded with a manipulation of response-relevant criteria: Semantic-category coordinate and unrelated distractor words differ in whether they satisfy task-determined semantic constraints demanded by the target pictures. In Experiments 1 and 2, we manipulated semantic distance while holding response-relevant criteria constant between the semantically close and the semantically more distant distractor word conditions. Participants named objects (e.g., "bed") in the context of semantically related verb distractors (e.g., <u>sleep</u>) and unrelated verb distractors (e.g., <u>shoot</u>). We found that naming latencies decrease as the semantic distance between verb distractors and target pictures decreases. The data from Experiments 1 and 2, when added to the ledger of known semantic facilitation effects (see Table 4), indicate that the semantic interference effect cannot be due solely to a manipulation of semantic distance. In Experiment 3, we showed that response-relevant criteria, rather than grammatical class constraints at lexical selection, can most readily account for the observation that unrelated noun distractors interfere more than unrelated verb distractors in object naming. In Experiment 4, we showed that a manipulation of the semantic coordinate status of distractor words in relation to the target pictures is sufficient to produce semantic interference. Participants named pictures of objects (e.g., "strawberry") in the context of distractor words denoting semantic-category coordinates (e.g., <u>lemon</u>) and distractor words denoting items from a different superordinate semantic category (e.g., <u>lobster</u>). Critically, using a graded measure of semantic similarity (Cree & McRae, 2003), we held constant the semantic similarity between the target pictures and the distractor words that were, and were not, in a semantic-category coordinate relationship. The data from Experiment 4 undermine the claim that there is no additional effect of semantic category coordinate relationships over and above graded effects of semantic distance.

An important implication of the results from Experiments 1–4, in the context of known semantic interference and facilitation effects, is that pure effects of semantic distance are detectable only when the semantically close and the semantically more distant distractor word conditions are equivalent with regard to the response-relevant criteria demanded by the target pictures. This construal determines the appropriate ground for testing the hypothesis of lexical selection by competition. The explanation of the semantic interference effect in terms of lexical selection by competition predicts that naming latencies will increase as the within-category semantic distance between distractor words and target pictures decreases. In Experiments 5–7 we found that decreasing within-category semantic distance between distractor words and target pictures, if anything, facilitates naming latencies. The findings from Experiments 5–7 mean that the semantic interference effect does not constitute support for the hypothesis of lexical selection by competition. Given that other observations of semantic interference (see Table 3) confound a manipulation of semantic distance with a manipulation of response-relevant criteria, we conclude that there is no empirical evidence in support of the hypothesis that lexical selection is by competition.

In the remaining discussion, we consider two questions: (a) Can an alternative causal explanation of the semantic interference effect be formulated? (b) What implications does this alternative account have more generally for a theory of lexical access in speech production?

The Response Exclusion Hypothesis: An Alternative Explanation of the Semantic Interference Effect

To this point, we have developed an alternative construal of the picture–word semantic interference effect in terms of response-relevant criteria. This framework, as noted in the introduction, is not committed to a particular theoretical view about the mechanism by which, or the level of processing at which, the semantic interference effect is assumed to arise. The critical component of this framework is that semantic-category coordinate and unrelated distractor words differ in whether they satisfy general semantic constraints demanded by the target pictures. In order for this descriptive analysis to be translated into a causal explanation of semantic interference, it is necessary to specify the nature of the decision mechanism that uses response-relevant criteria to exclude from production representations corresponding to distractor words. Here, we argue that the semantic interference effect arises at a postlexical level of processing and reflects the speed with which production-ready representations can be excluded as potential responses to the target picture (see also Dyer, 1973; Klein, 1964; Morton, 1969; for discussion see Glaser & Düngelhoff, 1984; Lupker & Katz, 1981; MacLeod, 1991). Specifically, production-ready representations corresponding to unrelated distractor words can be excluded faster than representations corresponding to distractors that satisfy a response criterion demanded by the target pictures. We refer to this hypothesis as the *response exclusion hypothesis* (for discussions of an earlier version of this hypothesis, see Finkbeiner & Caramazza, 2006b; Finkbeiner, Gollan, & Caramazza, 2006; Miozzo & Caramazza, 2003).

Following previous theorists, we assume that different pathways from perception to action are differentially privileged (McLeod & Posner, 1984; Glaser & Glaser, 1989). In the case of the Stroop and picture–word interference tasks, printed words, compared with colors or pictures, have privileged access to the articulators. By "privileged relationship," we do not imply that there is a shorter route (e.g., fewer connections) between a printed word and the articulators compared with a picture stimulus and the articulators (e.g., Roelofs, 1992). Rather, we suggest that word reading benefits from the quasi rule-like relationship between orthography and phonology (for a different implementation of this privileged relationship, see Roelofs, 2003, Figure 7, route b). The strongest version of the response exclusion hypothesis would locate the semantic interference effect at a bottleneck at the level of motor-relevant, or production-ready, representations. On this account, the target response (the picture or color name) can be produced only if the single-channel output buffer is not occupied by a representation corresponding to the distractor word. Another way to state this is that in order for the name of the target picture to be produced, motor relevant representations controlling the articulators must be disengaged from the distractor word.

The critical assumption made by the response exclusion hypothesis is that the decision mechanism that clears the output buffer of nontarget words is sensitive to the provenance of the representations over which it operates. The claim is not that semantic information is duplicated at a postlexical (i.e., response) level; rather, response level representations can index general properties of their corresponding concepts (e.g., semantic category) as well as their source (picture or word).[4] Stated differently, task constraints determine certain parameters that are used to filter out production ready representations that do not correspond to the target. The efficacy with which the system can exclude such representations affects the time required to name the target pictures.

Independent empirical evidence that converges with this argument is provided by the distractor frequency effect reported by Miozzo and Caramazza (2003). As discussed in the introduction, those authors observed that low-frequency distractor words interfere more in object naming than high-frequency distractor words. This otherwise counterintuitive effect is naturally explained by the response exclusion hypothesis. There is no difference in response-relevant criteria between the high- and low-frequency distractor words. Thus, the difference in target naming latencies directly reflects the speed with which production-ready representations corresponding to high- and low-frequency distractor words are available for exclusion (for further discussion, see Miozzo & Caramazza, 2003).

The assumption that information from a higher cognitive level is available to decision mechanisms that operate over representations at a lower level is an old idea; in fact, all accounts of Stroop-like interference effects must specify how participants produce the correct response (i.e., that corresponding to the target; e.g., see La Heij, 1988; Levelt et al., 1999; Lupker, 1979; Roelofs, 2003). For instance, in the model of Roelofs (1992), information about the provenance (e.g., picture vs. word) of representations is stipulated at the (lemma) lexical level, or the level at which only grammatical properties of words are represented.

The Semantic Interference Effect as a Postlexical Phenomenon

There is already some evidence that is consistent with the view that semantic interference arises at a stage of processing subsequent to lexical selection. As discussed above (see the *Review of semantic interference and facilitation effects* section), Humphreys et al. (1995) observed semantic interference in the postcue paradigm. In this paradigm, participants are presented with two pictures on every trial, one colored red and the other colored green. After an interval, the pictures are replaced with a cue, either the word *GREEN* or the word *RED*, and the participants' task is to produce the name of the picture corresponding to the cued color. Humphreys et al. (1995) found that participants were slower to produce the name of a picture (e.g., "car") when that target picture had appeared with a semantically related picture (e.g., "truck") compared with an unrelated picture (e.g., "hat"). The observation of semantic interference in a paradigm in which participants must prepare the name of the target (as well as that of the distractor) suggests that semantic interference arises at a bottleneck subsequent to the stage of name retrieval (i.e., subsequent to lexical selection). Of course, this inference is indirect, as without the proper experiment-internal controls it cannot be known at what level of processing participants prepared the two potential responses.[5] However, it is relevant in this context to note that Humphreys et al. also observed semantic interference when participants produced a target name that had been presented as a word stimulus in the context of a distracting picture stimulus. These data again suggest, but do not demonstrate unequivocally, that the semantic interference effect arises at a level of processing subsequent to lexical selection.

A similar study by Dean et al. (2001) replicated Humphreys et al.'s (1995) observation of semantic interference in the postcue paradigm. However, Dean et al. reasoned that if the observed semantic interference effect is due to greater competition for selection of the cued picture's name in the related compared with

[4] This proposal has certain surface similarities to what has been termed a *monitor* in models of speech production (e.g., Hartsuiker & Kolk, 2001; Levelt, 1989; Postma, 2000). However, the term *monitor* might imply a more active process than what we have in mind. In particular, we assume that task constraints as well as general information about the current target set parameters on the types of information that can be filtered out, or which do not meet response-relevant criteria.

[5] Janssen, Schirm, Mahon, and Caramazza (2007) had participants delay their naming responses to target objects for 1,000 ms until a cue was presented. The cue consisted of a distractor word that was presented either in blue or in red ink. If the distractor word was presented in blue ink, participants were to produce the prepared picture name. If the distractor word was presented in red ink, participants were to disregard the prepared picture name and to read the word as quickly as possible. Distractor words (i.e., cues) could be either semantic-category coordinates of the target pictures or unrelated. A separate group of participants received the same task but with no delay (i.e., picture and cue presented concurrently). The critical observation was that although semantic interference was observed under both delayed and immediate naming conditions, an effect of the pictures' frequency was observed only under immediate naming conditions. These data indicate that semantic interference may be observed in a delayed naming task, and critically, under conditions in which no effect of the target pictures' frequency is observed.

the unrelated condition, then the interference effect should be eliminated when participants are not required to produce the name of the picture. To this end, Dean et al. cued participants to report the color of one of the presented pictures. So for instance, participants might see the pictures "car" (colored green) and "truck" (colored red) and then at cue receive a picture depicting a "car" from a different viewpoint. It was observed that participants were slower to report the color of a postcued picture (by means of a button press) when that picture had appeared with a semantically related picture (e.g., "truck") than when it had appeared with an unrelated picture (e.g., "hat"). We suggest that the common factor uniting the studies of Humphreys et al. and Dean et al. is the task constraint of producing a response in the context of a prepotent alternative response that either satisfies response-relevant criteria or does not.

Another line of convergent support for the response exclusion hypothesis comes from research on semantic context effects on the online repair of speech errors. In the study reported by Hartsuiker, Pickering, and de Jong (2005) participants' task was to name pictures of objects that were presented for 500 ms; on a small proportion of trials (13.6%), however, the initially presented picture (hereafter, context picture; e.g., "strawberry") was presented for only 300 ms and was then replaced by a second picture (hereafter, target picture; e.g., "grape"). The target picture then remained on the screen for 500 ms. On such change trials, participants' task was to abandon their initial naming response to the context picture and name the target picture as quickly as possible. The context and target pictures could be semantic-category coordinates or unrelated (see Experiment 1). Trials were separated into those in which participants interrupted their naming response to the context picture (e.g., e.g., "straw . . . grape") and those in which participants articulated the full name of the context picture before naming the target picture ("strawberry . . . grape"). These two trial types can be conceived, in the context of the response exclusion hypothesis, as a manipulation of whether motor relevant information (corresponding to the context picture's name) remains in the output buffer. For trials in which participants interrupted their naming response to the context picture, such information would have to be excluded from the buffer before the target picture could be named.

The response exclusion hypothesis generates two expectations for the experimental paradigm used by Hartsuiker et al. (2005). The first expectation follows from the view that the semantic interference effect as observed in the picture–word interference paradigm arises because production-ready representations corresponding to unrelated distractors can be excluded sooner than those corresponding to semantic-category coordinate distractors. If this is the case, then in Hartsuiker et al.'s paradigm, it should be observed that participants find it easier to interrupt naming of the context picture when it is followed by an unrelated target picture than when it is followed by a target picture depicting a semantic-category coordinate of the context picture. Consistent with this expectation, Hartsuiker et al. found that participants interrupted naming of context pictures reliably more often when those pictures preceded an unrelated target picture than when they preceded a semantically related target picture.

The second expectation generated by the response exclusion hypothesis concerns the potential effects of semantic interference and facilitation on target picture-naming latencies in Hartsuiker et al.'s (2005) study.[6] One of the dependent measures used by Hartsuiker et al. was the time between the onset of the target picture and the beginning of the target naming response. For those trials in which participants have interrupted their naming response to the context picture (e.g., "straw . . . grape"), we might assume that information remains in the output buffer that must first be cleared before articulation of the target picture name can occur. For such trials, the response exclusion hypothesis predicts that semantic interference will be observed. In contrast, for those trials in which participants completed articulation of the context picture (e.g., "strawberry . . . grape"), it can be assumed that there is no information that remains in the output buffer that must first be cleared before the target can be named. Therefore, if any effect were to be observed, the response exclusion hypothesis would predict semantic facilitation. Hartsuiker et al. observed the pattern of results that would be expected by the response exclusion hypothesis: semantic interference for trials in which the naming response to the context picture was interrupted and semantic facilitation when the context pictures were fully named.

Privileged Relationships Between Perception and Action Versus Speed of Processing

Early so-called "horse-race" or "response competition" models (e.g., Dyer, 1973; Warren, 1972, 1974) assumed that Stroop-like semantic interference effects arise because the faster dimension (i.e., the distractor word) gains access to the articulators sooner than the slower dimension (i.e., the picture or the ink color name; see also Stroop, 1935). As Warren (1974) argued, "Interference in the color-naming task can occur only when a motor program other than that for the color name is loaded in the buffer first" (p. 157). In contrast, the response exclusion hypothesis is based on the notion that printed words, compared with colors or pictures, have a privileged relationship to the articulators. The notion of privileged access is an important departure from models based on speed of processing. The latter class of models lost favor (e.g., Glaser & Düngelhoff, 1984) when it became clear that speed of processing was not in itself sufficient to account for those situations in which Stroop-like semantic interference was or was not observed. In particular, accounts based on speed of processing predict that reverse Stroop effects (interference of a distracting color patch while reading a word) should be observed if the slower dimension (e.g., the ink color or picture name) could be sped up relative to the faster dimension (the distractor word). Although there have been observations of reverse Stroop effects (e.g., Glaser & Glaser, 1989, Experiment 1; Humphreys et al., 1995, Experiment 5; Dunbar & Macleod, 1984), it is generally agreed that reverse Stroop effects are not observed simply by manipulating the SOA between target and distractor or by degrading the target stimulus so as to slow down its processing (for review, see MacLeod, 1991; Roelofs, 2003). The fact that reverse Stroop effects cannot be induced by manipulating the relative times at which the target and distracting information arrive to output processes suggests that speed of processing per se is not the relevant variable explaining Stroop-like semantic interference. Of course, this does not mean that the semantic interference effect does not arise at a postlexical level of processing.

[6] We thank Rob Hartsuiker for raising this interpretation of the data from Hartsuiker et al. (2005).

A related issue is whether Stroop-like interference effects can be observed with modally pure stimuli and, in particular, stimuli consisting of a target word that must be read and a distractor word that must be ignored. Glaser and Glaser (1989) observed Stroop interference using modally pure color–color (Experiment 2) and word–word stimuli (Experiments 2 and 3), as well as semantic interference using picture–picture stimuli (Experiment 6). However, these observations of Stroop-like semantic interference were observed with a paradigm in which participants were required to make fine grained temporal discriminations as to which element of the display was the target and which was to be ignored. In another study, La Heij, Happel, and Mulder (1990, Experiment 1) observed a trend, $F(1, 15) = 4.5$, $p < .06$, toward longer naming latencies for reading target words (e.g., "pear") in the context of semantic-category coordinate distractor words (e.g., cherry) compared with unrelated words (e.g., nose) but then failed to replicate the effect in subsequent experiments. More generally, there seems to be consensus (e.g., see Damian & Bowers, 2003; La Heij, Happel, & Mulder, 1990; Navarrete & Costa, 2005) that semantic interference is not observed with modally pure picture–picture or word–word stimuli in experimental situations in which there is no task uncertainty as to which element is the target and which is the distractor.

The empirical fact that semantic interference is not observed with modally pure picture–picture stimuli (Damian & Bowers, 2003; Navarrete & Costa, 2005) cannot be explained by assuming that the lexical node corresponding to a distractor picture is not activated. This is because Morsella and Miozzo (2002; see also Navarrete & Costa, 2005) observed phonological facilitation when a distractor picture was phonologically related to the target picture. The lack of semantic interference with modally pure picture–picture stimuli falls out as a natural consequence of the response exclusion hypothesis, as there is no prepotent response engendered by the distracting stimulus when the distracting stimulus is a picture. In other words, when the distracting stimulus is a picture, the distractor does not have a privileged relationship to articulatory processes. Thus, according to the response exclusion hypothesis, the relevant question is not, why is there no semantic interference with modally pure picture–picture stimuli? Rather, the question is, why is there no semantic facilitation with modally pure picture–picture stimuli? In fact, there is already some indication (La Heij, Heikoop, Akerboom, & Bloem, 2003) that semantic facilitation can be observed using picture–picture stimuli by manipulating the relative durations of presentation of the target and distractor pictures (see also Bloem & La Heij, 2003, for an important observation of semantic facilitation induced by distractor pictures).

The notion of privileged access also accounts for the lack of semantic interference for modally pure word–word stimuli. If there is no task uncertainty as to which element of the display is the target word and which is the distractor word, then the target word will gain direct access to the articulators. The result is that the bottleneck on the output will already be occupied by the target, and there will thus be no representation that must be excluded or blocked in order for articulation of the target to proceed. This interpretation, while speculative, generates an otherwise counter-intuitive prediction: If a semantic interference effect were to be observed at all using modally pure word–word stimuli, then according to the response exclusion hypothesis, such an effect might be observed when the distractor word is presented after the target (i.e., at positive SOAs).[7]

Implications for Models of Lexical Access in Speech Production

The implication of adopting the response exclusion hypothesis is that the semantic interference effect does not support inferences about the dynamical properties of lexical selection. This conclusion has broad implications for the field of lexical access, because semantic interference has become nearly synonymous with lexical competition.

Rather than semantic interference, effects of semantic facilitation, as observed in the picture–word interference paradigm, are more informative of the dynamical principles that characterize lexical selection. These semantic facilitation effects can be explained in terms of greater distractor-to-target priming as the semantic distance between distractors and targets decreases. Obviously, this interpretation goes through only if it is assumed that the time required to select the target lexical node does not depend on the levels of activation of nontarget nodes. Therefore, we conclude that the time required to select the target node is not affected by the levels of activation of nontarget nodes (e.g., Caramazza, 1997; Dell, 1986; Rapp & Goldrick, 2000).

Independent support for this line of reasoning is provided by the study of Finkbeiner and Caramazza (2006b; for discussion, see Finkbeiner & Caramazza, 2006a; La Heij, Kuipers & Starreveld, in press). Finkbeiner and Caramazza (2006b) had participants name pictures of objects in the context of semantic-category coordinate distractors and unrelated distractors. The critical manipulation was whether the distractor words were forward and backward masked such that participants were not aware that a distractor word had been presented. Under conditions of forward and backward masking, it may be argued that the distractor word does not engender a production-ready representation; thus, there is nothing to be excluded, and only the effects of distractor-to-target priming will be observed. Consistent with this analysis, although reliable semantic interference was observed for unmasked distractors, a semantic facilitation effect emerged under conditions of forward and backward masking.

The response exclusion hypothesis, in the context of a model of lexical selection in which the time required to select the target node is not affected by the levels of activation of nontarget nodes, generates a unique prediction about the relationship between item-specific-priming and item-specific-interference effects that should be observed within the same participants. The prediction is made that the more priming a given distractor-target pair produces under masked conditions, the less interference the same pair should produce under distractor-visible conditions (i.e., a negative correlation between priming and interference is predicted). This prediction is based on the assumption that the semantic priming effect may serve as an independent index of the amount of spreading activation between the prime and the target (e.g., Carr, McCauley,

[7] We note that this prediction is predicated on a specific and independent assumption about the automaticity of encoding printed stimuli into production-ready representations. The prediction goes through, only if it is also assumed that the mere onset of a printed word will lead, automatically, to the engagement of the articulators. In other words, it may be the case that once the response channel is occupied by a printed stimulus (i.e., the target word) the onset of a distractor word at positive SOAs will not replace, as it were, the (target) representation that is already engaging the articulators.

Sperber, & Parmelee, 1982; Dell'Acqua & Grainger, 1999; Finkbeiner, Forster, Nicol, & Makamura, 2004; McRae & Boisvert, 1998). In other words, as in our manipulation of within-category semantic distance, we might suppose that within the materials selected by Finkbeiner and Caramazza (2006b), there will be natural variation in the within-category semantic distances between the semantically related distractors and pictures. Such variation would be captured in the magnitude of the semantic priming effect on an item-by-item basis. Thus, the existence of a negative correlation between the semantic priming and the semantic interference effects, on an item-by-item basis, would serve the important purpose of replicating the empirical phenomenon reported in Experiments 5–7.

We conducted this analysis on the data from Finkbeiner and Caramazza (2006b), as the issue was not directly addressed in their study. The analysis was limited, following the reasoning above, to those items that showed priming (related < unrelated) in the masked priming experiment ($n = 55$ of 84 total items). The overall priming effect for these items was 88 ms (semantic-category coordinate < unrelated). These same items showed 41 ms of semantic interference (semantic-category coordinate > unrelated) in the experiment with visible distractors within the same participants. As depicted in Figure 2, the results of this analysis indicate that the correlation between the priming effect (positive difference scores = semantic-category coordinate condition < unrelated condition) and the interference effect (positive difference scores = semantic-category coordinate condition > unrelated condition) is negative ($r = -.32$, $p < .02$). This negative correlation remained, and was marginally reliable, in a more stringent analysis using partial correlations to control for differences in frequency and length in letters between each pair of related and unrelated distractors ($r = -.28$, $p = .063$). These data indicate that as priming increases, interference decreases, and they converge with the theoretical bottom line message of this article: The time required to select the target lexical node does not depend on the levels of activation of nontarget nodes.

Conclusion

Two empirical generalizations emerge from our argument. First, the semantic interference effect depends on a manipulation of response-relevant criteria between the related and unrelated distractor word conditions. Second, when response-relevant criteria of distractor words are held constant, decreasing semantic distance

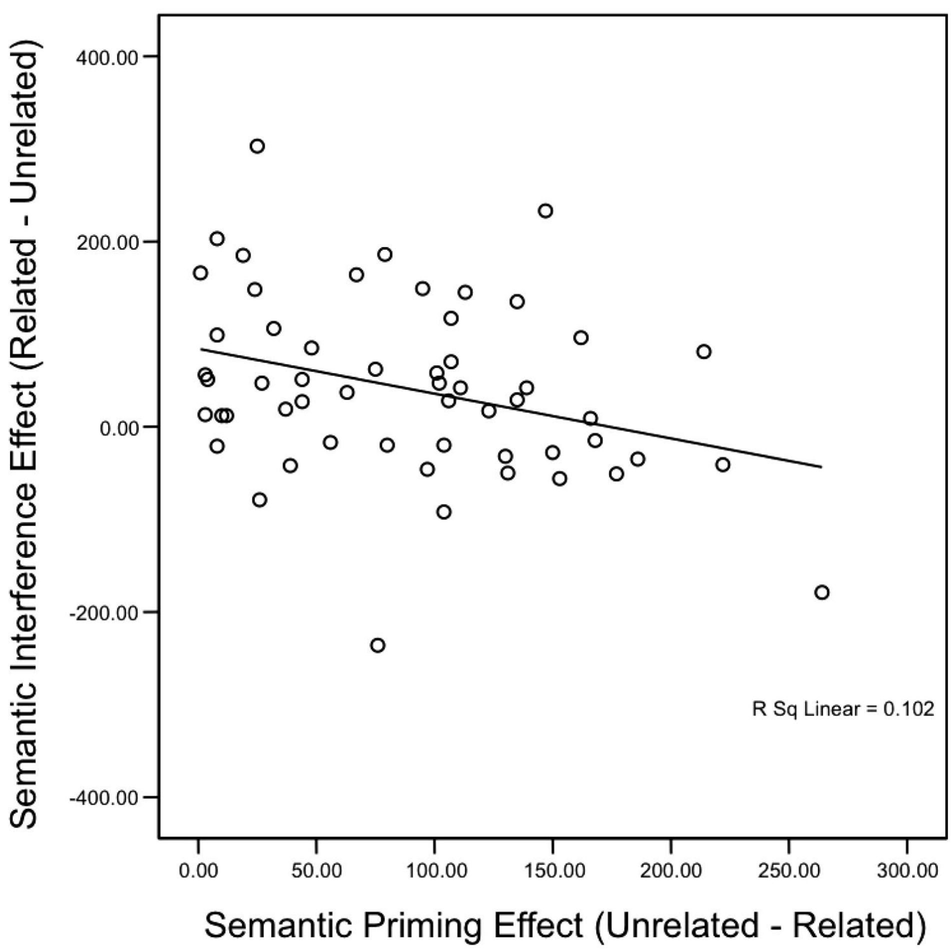

Figure 2. Scatter plot of the relation between semantic priming and semantic-category coordinate interference, based on a re-analysis of the data of Finkbeiner and Caramazza (2006b).

between distractors and targets leads to shorter naming latencies. The fact that decreasing semantic distance between distractor words and target pictures facilitates picture-naming latencies indicates that the semantic interference effect does not reflect lexical level processes. The response exclusion hypothesis was outlined, which is based on the assumption that printed words "catch" the mouth in a way that pictures and ink colors do not. Stroop-like semantic interference arises at a peripheral output level and reflects the discrete behavior of a decision mechanism that is sensitive to the coarse and categorical information that production-ready responses index. This alternative construal of the picture–word semantic interference effect has an important implication for models of lexical access. The implication of this line of argument is that semantic facilitation effects hold priority in grounding inferences about the dynamical properties of lexical selection. Such semantic facilitation effects can be explained only if it is assumed that the time required to select the target lexical node does not depend on the levels of activation of nontarget lexical nodes.

The hypothesis of lexical selection by competition has achieved the status of a received view, perhaps with such force as to overshadow critical discussion of this hypothesis and alternative explanations of the facts. Obviously, a theory cannot be dismantled by a single empirical fact. For this reason, we have undertaken the burden of reorganizing into a new explanatory framework the currently known facts from the picture–word interference and related paradigms. The full spectrum of findings that we have reported and reviewed indicates that lexical selection is not by competition. This conclusion serves as the basis for unifying two traditions of research within the broader field of lexical access in speech production (e.g., Bloem & La Heij, 2003; Caramazza, 1997; Damian & Martin, 1999; Dell, 1986; Levelt, 1999; Rapp & Goldrick, 2000; Roelofs, 1992; Schriefers et al., 1990; Stemberger, 1985).

References

Alario, F. X., Segui, J., & Ferrand, L. (2000). Semantic and associative priming in picture naming. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 53*(A), 741–764.

Belke, E., Meyer, A., & Damian, M. F. (2005). Refractory effect in picture naming as assessed in a semantic blocking paradigm. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 58*(A), 667–692.

Bloem, I., & La Heij, W. (2003). Semantic facilitation and semantic interference in word translation: Implications for models of lexical access. *Journal of Memory and Language, 48,* 468–488.

Bloem, I., van den Boogaard, S., & La Heij, W. (2004). Semantic facilitation and semantic interference in language production: Further evidence for the conceptual selection model of lexical access. *Journal of Memory and Language, 51,* 307–323.

Burt, J. S. (2002). Why do non-color words interfere with color naming? *Journal of Experimental Psychology: Human Perception and Performance, 28*(A), 1019–1038.

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology, 14,* 177–208.

Caramazza, A., & Costa, A. (2000). The semantic interference effect in the picture–word interference paradigm: Does the response set matter? *Cognition, 75,* B51–B64.

Caramazza, A., & Costa, A. (2001). Set size and repetition in the picture–word interference paradigm: Implications for models of naming. *Cognition, 80,* 291–298.

Carr, T., McCauley, C., Sperber, R., & Parmelee, C. (1982). Words, pictures, and priming: On semantic activation, conscious identification, and the automaticity of information processing. *Journal of Experimental Psychology: Human Perception and Performance, 8*(A), 757–777.

Chiarello, C., Shears, C., & Lund, K. (1999). Imageability and distributional typicality measures of nouns and verbs in contemporary English. *Behavior Research Methods, Instruments, & Computers, 31,* 603–637.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavioral Research Methods, Instruments, & Computers, 25,* 257–271.

Costa, A., Alario, F.-X., & Caramazza, A. (2005). On the categorical nature of the semantic interference effect in the picture–word interference paradigm. *Psychonomic Bulletin and Review, 12,* 125–131.

Costa, A., & Caramazza, A. (1999). Is lexical selection in bilingual speech production language-specific? Further evidence from Spanish-English and English-Spanish bilinguals. *Bilingualism: Language and Cognition, 2,* 231–244.

Costa, A., Mahon, B., Savova, V., & Caramazza, A. (2003). Level of categorization effect: A novel effect in the picture–word interference paradigm. *Language and Cognitive Processes, 18,* 205–233.

Costa, A., Miozzo, M., & Caramazza, A. (1999). Lexical selection in bilinguals: Do words in bilingual's lexicon compete for selection? *Journal of Memory and Language, 41,* 365–397.

Cree, G. S., & McRae, K. (2003). Analyzing the factors underlying the structure and computation of the meaning of chipmunk, cherry, chisel, cheese, and cello (and many other such concrete nouns). *Journal of Experimental Psychology: General, 132,* 163–201.

Dalrymple-Alford, E. C. (1972). Associative facilitation and interference in the Stroop color–word tests. *Perception and Psychophysics, 11,* 274–276.

Damian, M. F., & Bowers, J. S. (2003). Locus of semantic interference in picture–word interference tasks. *Psychonomic Bulletin and Review, 10,* 111–117.

Damian, M. F., & Martin, R. C. (1999). Semantic and phonological codes interact in single word production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* 345–361.

Damian, M. F., Vigliocco, V., & Levelt, W. J. M. (2001). Effects of semantic context in the naming of pictures and words. *Cognition, 81,* B77–B86.

Dean, M. P., Bub, D. N., & Masson, M. E. J. (2001). Interference from related items in object identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 733–743.

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review, 3,* 283–321.

Dell'Acqua, R., & Grainger, J. (1999). Unconscious semantic priming from pictures. *Cognition, 73,* B1–15.

Dunbar, K., & Macleod, C. M. (1984). A horse race of a different color: Stroop interference patterns with transformed words. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 622–639.

Dyer, F. N. (1973). The Stroop phenomenon and its use in the study of perceptual, cognitive, and response processes. *Memory and Cognition, 1,* 106–120.

Finkbeiner, M., & Caramazza, A. (2006a). Lexical selection is not a competitive process: A reply to La Heij, et al. (2006). *Cortex, 42,* 1032–1035.

Finkbeiner, M., & Caramazza, A. (2006b). Now you see it, now you don't: On turning semantic interference into facilitation in a Stroop-like task. *Cortex, 42,* 790–796.

Finkbeiner, M., Forster, K. I., Nicol, J., & Makamura, K. (2004). The role of polysemy in masked semantic and translation priming. *Journal of Memory and Language, 51,* 1–22.

Finkbeiner, M., Gollan, T., & Caramazza, A. (2006). Bilingual lexical access: What's the (hard) problem? *Bilingualism: Language and Cognition, 9,* 153–166.

Forster, K. I., & Forster, J. C. (2003). DMDX: A windows display program with millisecond accuracy. *Behavioral Research Methods, Instruments, and Computers, 35,* 116–124.

Fox, L. A., Shor, R. E., & Steinman, R. J. (1971). Semantic gradients and interference in naming color, spatial direction, and numerosity. *Journal of Experimental Psychology: General, 91,* 59–65.

Francis, W. N., & Kucera, H. (1982). *Frequency analysis of English usage.* Boston: Houghton Mifflin.

Glaser, W. R., & Düngelhoff, F.-J. (1984). The time course of picture–word interference. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 640–654.

Glaser, W. R., & Glaser, M. O. (1989). Context effects on Stroop-like word and picture processing. *Journal of Experimental Psychology: General, 118,* 13–42.

Goldrick, M., & Rapp, B. (2002). A restricted interaction account (RIA) of spoken word production: The best of both worlds. *Aphasiology, 16,* 20–55.

Goodman, G. S., Haith, M. M., Guttentag, R. E., & Rao, S. (1985). Automatic processing of word meaning: Intralingual and interlingual interference. *Child Development, 56,* 103–118.

Hantsch, A., Jescheniak, J. D., & Schriefers, H. (2005). Semantic competition between hierarchically related words during speech planning. *Memory and Cognition, 33,* 984–1000.

Hartsuiker, R. J., & Kolk, H. H. J. (2001). Error monitoring in speech production: A computational test of the perceptual loop theory. *Cognitive Psychology, 42,* 113–157.

Hartsuiker, R. J., Pickering, M. J., & de Jong, N. H. (2005). Semantic and phonological context effects in speech error repair. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 5,* 921–932.

Humphreys, G. W., Lloyd-Jones, T. J., & Fias, W. (1995). Semantic interference effects on naming using a post-cue procedure: Tapping the links between semantics and phonology with pictures and words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 961–980.

Ischebeck, A. (2003). Differences between digit naming and number word reading in a flanker task. *Memory and Cognition, 31,* 529–537.

Janssen, N., Schirm, W., Mahon, B. Z., & Caramazza, A. (2007). *Semantic interference in a delayed naming task: Evidence for the response exclusion hypothesis.* Manuscript submitted for publication.

Jescheniak, J. R. D., & Levelt, W. J. M. (1994). Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 824–843.

Job, R., Rumiati, R., & Lotto, L. (1992). The picture superiority effect in categorization: Visual or semantic? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1019–1028.

Klein, G. S. (1964). Semantic power measured through interference of words with color-naming. *American Journal of Psychology, 77,* 576–588.

Klopfer, D. S. (1996). Stroop interference and color–word similarity. *Psychological Science, 7,* 150–157.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language, 33,* 149–174.

Kuipers, J. R., La Heij, W., & Costa, A. (2006). A further look at semantic context effects in language production: The role of response congruency. *Language and Cognitive Processes, 21,* 892–919.

La Heij, W. (1988). Components of Stroop-like interference in picture naming. *Memory and Cognition, 16,* 400–410.

La Heij, W., Dirkx, J., & Kramer, P. (1990). Categorical interference and associative priming in picture naming. *British Journal of Experimental Psychology, 81,* 511–525.

La Heij, W., Happel, B., & Mulder, M. (1990). Components of Stroop-like interference in word reading. *Acta Psychologica, 73,* 115–129.

La Heij, W., Heikoop, K. W., Akerboom, S., & Bloem, I. (2003). Picture naming in picture context: Semantic interference or semantic facilitation? *Psychology Science, 45,* 49–62.

La Heij, W., Kuipers, J.-R., & Starreveld, P. A. (2006). In defense of the lexical-competition account of picture–word interference: A comment on Finkbeiner and Caramazza (2006). *Cortex, 42,* 790–796.

La Heij, W., Starreveld, P. A., & Steehouwer, L. C. (1993). Semantic interference and orthographic facilitation in definition naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 352–368.

La Heij, W., Van der Heijden, A. H. C., & Schreuder, R. (1985). Semantic priming and Stroop-like interference in word-naming tasks. *Journal of Experimental Psychology: Human Perception and Performance, 11,* 62–80.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation.* Cambridge, MA: MIT Press.

Levelt, W. J. M. (1999). Models of word production. *Trends in Cognitive Sciences, 3,* 223–232.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22,* 1–75.

Levelt, W. J. M., Schriefers, H., Vorberg, D., Meyer, A. S., Pechmann, T., & Havinga, J. (1991). Normal and deviant lexical processing: Reply to Dell and O'Seaghdha (1991). *Psychological Review, 98,* 615–618.

Lotto, L., Job, R., & Rumiati, R. (1999). Visual effect in picture and word categorization. *Memory and Cognition, 27,* 674–684.

Lupker, S. J. (1979). The semantic nature of response competition in the Picture–Word Interference Task. *Memory and Cognition, 7,* 485–495.

Lupker, S. J., & Katz, A. N. (1981). Input, decision, and response factors in picture–word interference. *Journal of Experimental Psychology: Human Learning and Memory, 7,* 269–282.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163–203.

Mahon, B. Z., Costa, A., Shapiro, K., & Caramazza, A. (2002, June). *Grammatical Class Constraints on Lexical Selection in Speech Production: Functional and Neuroanatomical Considerations.* Poster session presented at the 2002 Science of Aphasia annual conference, Maratea, Italy.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception. *Psychological Review, 88,* 375–407.

McLeod, P., & Posner, M. I. (1984). Privileged loops from percept to act. In H. Bouma & D. G. Bouwhuis (Eds.), *Attention and performance X* (pp. 55–66). Hillsdale, NJ: Erlbaum.

McRae, K., & Boisvert, S. (1998). Automatic semantic similarity priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 558–572.

Meyer, A. S. (1992). Investigation of phonological encoding through speech error analyses: Achievements, limitations, and alternatives. *Cognition, 42,* 181–211.

Miozzo, M., & Caramazza, A. (2003). When more is less: A counterintuitive effect of distractor frequency in picture–word interference paradigm. *Journal of Experimental Psychology: General, 132,* 228–252.

Morsella, E., & Miozzo, M. (2002). Evidence for a cascade model of lexical access in speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 3,* 555–563.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review, 76,* 165–178.

Navarrete, E., & Costa, A. (2005). Phonological activation of ignored pictures: Further evidence for a cascade model of lexical access. *Journal of Memory and Language, 53,* 359–377.

Neumann, O., & Kautz, L. (1982). Semantische forderung und semantische Interferenz im benennungsexperiment [Semantic facilitation and semantic interference in a naming experiment] (Bericht Nr. 23/1982). Bochum, Germany: University of Bochum.

Pechmann, T., Garrett, M., & Zerbst, D. (2004). The time course of recovery for grammatical category information during lexical processing for syntactic construction. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30,* 723–728.

Pechmann, T., & Zerbst, D. (2002). The activation of word class information during speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 233–243.

Postma, A. (2000). Detection of errors during speech production. A review of speech monitoring models. *Cognition, 77,* 97–131.

Rapp, B., & Goldrick, M. (2000). Discreteness and interactivity in spoken word production. *Psychological Review, 107,* 460–499.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition, 42,* 107–142.

Roelofs, A. (1993). Testing a non-decompositional theory of lemma retrieval in speaking: Retrieval of verbs. *Cognition, 47,* 59–87.

Roelofs, A. (2001). Set size and repetition matter: Comment on Caramazza and Costa (2000). *Cognition, 80,* 283–290.

Roelofs, A. (2003). Goal-referenced selection of verbal action: Modeling attentional control in the Stroop task. *Psychological Review, 110,* 88–125.

Rosinski, R. R. (1977). Picture–word interference is semantically based. *Child Development, 46,* 247–253.

Santesteban, M., Costa, A., Pontin, S., & Navarrete, E. (2006). The effect of word-frequency on lexical selection in speech production: Evidence from semantic homogenous naming contexts. *Cognitiva, 18,* 75–84.

Schriefers, H., Meyer, A. S., & Levelt, W. J. M. (1990). Exploring the time course of lexical access in language production: Picture–word interference studies. *Journal of Memory and Language, 29,* 86–102.

Simon, J. R., & Sudalaimuthu, P. (1979). Effects of S-R mapping and response modality on performance in a Stroop Task. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 176–187.

Snodgrass, J. G., & McCullough, B. (1986). The role of visual similarity in picture categorization. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 147–154.

Starreveld, P. A., & La Heij, W. (1995). Semantic interference, orthographic facilitation, and their interaction in naming tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 686–698.

Starreveld, P. A., & La Heij, W. (1996). Time-course analysis of semantic and orthographic context effects in picture-naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 896–918.

Stemberger, J. P. (1985). An interactive activation model of language production. In A. W. Ellis (Ed.), *Progress in the psychology of language* (Vol. 1, pp. 143–186). Hillsdale, NJ: Erlbaum.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18,* 643–662.

Vigliocco, G., Lauer, M., Damian, M. F., & Levelt, W. J. M. (2002). Semantic and syntactic forces in noun phrase production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 46–58.

Vigliocco, G., Vinson, D. P., Damian, M. F., & Levelt, W. J. M. (2002). Semantic distance effects on object and action naming. *Cognition, 85,* B61–B69.

Vigliocco, G., Vinson, D. P., Lewis, W., & Garrett, M. F. (2004). Representing the meanings of object and action words: The featural and unitary semantic space hypothesis. *Cognitive Psychology, 48,* 422–488.

Vigliocco, G., Vinson, D. P., & Siri, S. (2005). Semantic similarity and grammatical class in naming actions. *Cognition, 94,* B91–B100.

Vinson, D. P., & Vigliocco, G. (2002). A semantic analysis of noun-verb dissociations in aphasia. *Journal of Neurolinguistics, 15,* 317–351.

Vinson, D. P., Vigliocco, G., Cappa, S. F., & Siri, S. (2003). The breakdown of semantic knowledge: Insights from a statistical model of meaning representation. *Brain and Language, 86,* 347–442.

Vitkovitch, M., & Tyrrell, L. (1999). The effects of distractor words on naming pictures at the subordinate level. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 52*(A), 905–926.

Warren, R. E. (1972). Stimulus encoding and memory. *Journal of Experimental Psychology, 94,* 90–100.

Warren, R. E. (1974). Association, directionality and stimulus encoding. *Journal of Experimental Psychology, 102,* 151–158.

Wheeldon, L. R., & Monsell, S. (1994). Inhibition of spoken word production by priming a semantic competitor. *Journal of Memory and Language, 33,* 332–356.

Appendix A

Materials for Experiment 1

	Distractors			
Picture	Related verb	Unrelated verb	Related noun	Unrelated noun
bed	sleep	shoot	desk	rifle
bomb	explode	listen	cannon	saw
bread	eat	ride	cheese	camel
broom	sweep	climb	rake	chef
car	drive	read	truck	lake
chair	sit	carry	sofa	sack
church	pray	clean	temple	magazine
dart	throw	wear	arrow	jacket
door	enter	cut	window	island
axe	chop	sew	saw	cannon
pen	write	think	eraser	liver
pool	swim	meow	lake	truck
razor	shave	breathe	tweezers	kidneys
shovel	dig	weigh	hammer	ruler
waiter	serve	grow	chef	rake
gun	shoot	sleep	rifle	desk
ear	listen	explode	elbow	spoon
horse	ride	eat	camel	cheese
mountain	climb	sweep	island	window
book	read	drive	magazine	temple
bag	carry	sit	sack	sofa
soap	clean	pray	shampoo	tiger
shirt	wear	throw	jacket	arrow
knife	cut	enter	spoon	elbow
needle	sew	chop	thread	tree
brain	think	write	liver	eraser
cat	meow	swim	tiger	shampoo
lungs	breathe	shave	kidneys	tweezers
scale	weigh	dig	ruler	hammer
plant	grow	serve	tree	thread

(*Appendixes follow*)

Appendix B

Materials for Experiment 2

	Distractor			
		Unrelated verb		
Picture	Related verb	Set A	Set B	Set C
Related and unrelated verb manipulation				
bomb	explode	stumble	mutter	tighten
bottle	pour	paint	lean	sing
cat	purr	veer	gush	bathe
chair	sit	hold	talk	run
church	pray	leap	snap	grin
crayon	draw	rise	pull	pass
ear	listen	wonder	arrive	forget
flower	pick	push	catch	throw
hat	wear	stay	meet	walk
helmet	protect	compare	publish	arrange
ladder	climb	spread	shout	nod
pencil	write	turn	speak	start
pot	cook	bend	roll	shut
pumpkin	carve	chase	grasp	spill
scale	weigh	float	grind	drain
shovel	dig	rub	crawl	kick
snake	hiss	flip	gape	peek
towel	wipe	stir	suck	split
tweezers	pluck	soar	whirl	chant
whistle	blow	hide	burn	jump
Semantic-category coordinate manipulation				
ant			bee	pie
boat			raft	hail
boot			sneaker	cherry
car			truck	fence
carriage			wagon	fossil
dog			wolf	robe
dolphin			whale	pants
frog			toad	tile
glove			mitten	hanger
goat			sheep	cave
hammer			mallet	blanket
helicopter			airplane	pillow
horse			mule	twig
lamp			chandelier	antenna
lettuce			spinach	parachute
octopus			squid	harp
onion			garlic	trophy
plate			saucer	cannon
pliers			wrench	badge
turkey			goose	booth

Appendix C

Materials for Experiment 3

Picture	Verb 1	Noun 1	Verb 2	Noun 2	Verb 3	Noun 3
gun	add	art	zip	fig	cease	realm
car	fail	role	shun	tact	delve	stint
camera	deny	task	sear	bout	deduce	intent
bed	save	goal	veer	heir	infer	knack
flower	send	mile	stun	germ	vacate	sludge
arm	join	sale	mend	liar	shirk	rigor
shirt	grow	idea	doze	oath	chew	neon
umbrella	hang	poem	soar	blob	retire	critic
ladder	sing	song	hurl	dusk	wed	kit
carrot	begin	thing	parch	bliss	sew	ash
book	admit	depth	scour	tempo	rouse	vigor
tweezers	learn	union	gloat	slang	expire	vanity
corn	enjoy	truth	wring	arson	enroll	enzyme
pencil	argue	unity	sever	wrath	obey	noon
cannon	spend	peace	gouge	facet	attach	lesson
toilet	remove	growth	detain	bounty	skip	fame
pig	adjust	threat	flaunt	ravine	hasten	satire
house	engage	salary	ingest	frenzy	edit	cult
belt	arrive	energy	ascend	hearth	plod	zeal
funnel	occupy	length	recite	pulpit	adapt	prose
basket	ponder	shanty	owe	ton	impose	regime
boot	coax	pang	nestle	morsel	alter	drama
bread	exalt	folly	tuck	turf	allude	trivia
broom	acquit	errand	cram	duct	await	asset
camel	teeter	marrow	expel	sonar	align	haste
cheese	allot	quota	annoy	relic	unify	gland
cup	found	guilt	wallow	wicker	detach	ballad
fork	earn	myth	amend	mercy	invent	access
frog	zoom	clan	bury	odor	mince	ounce
glasses	yearn	hobby	propel	tyrant	melt	auto
guitar	stifle	alcove	react	nerve	enact	topic
heart	evade	vista	mutter	treaty	weep	lane
kite	nab	fad	pave	plea	beg	joy
rope	lurk	dune	cancel	fusion	tempt	haven
scissors	enable	virtue	erode	greed	flee	gulf
sword	hire	fate	exert	usage	rely	gram
table	pry	foe	soak	hymn	afford	relief
top	baste	bonus	nag	ore	lick	bulb
tree	incite	stupor	pray	monk	notify	gaiety
owl	elude	truce	pour	hero	repay	trait

(*Appendixes follow*)

Appendix D

Materials for Experiment 4

Picture	Distractor: Noncoordinate	Distractor: Semantic-category coordinate
Target picture–word pairs		
whale	tank	gorilla
ship	gorilla	tank
strawberry	lobster	lemon
giraffe	lemon	lobster
caterpillar	sword	frog
grenade	frog	sword
jet	pheasant	tractor
snail	tractor	pheasant
piano	cow	harmonica
ant	harmonica	cow
horse	chair	lamb
bed	lamb	chair
table	barrel	sofa
jar	sofa	barrel
Filler picture–word pairs		
onion	fence	beaver
screwdriver	beaver	fence
carrot	faucet	mirror
bomb	mirror	faucet
snake	corn	ladle
bicycle	ladle	corn
lion	kite	kettle
guitar	kettle	kite
whistle	pearl	pliers
car	pliers	pearl
rabbit	shack	vine
canoe	vine	shack
vest	pencil	television
shovel	television	pencil

Appendix F

Materials for Experiment 6

Picture	Distractors: Semantically close	Distractors: Semantically far
turkey	chicken	hyena
fox	hyena	chicken
hat	bonnet	shirt
vest	shirt	bonnet
boot	sneaker	glove
mitten	glove	sneaker
spoon	fork	glass
cup	glass	fork
submarine	boat	plane
helicopter	plane	boat
elephant	mastodon	panther
lion	panther	mastodon
garlic	onion	yam
potato	yam	onion
lizard	snake	sheep
goat	sheep	snake
zebra	horse	dolphin
whale	dolphin	horse
frog	toad	squid
octopus	squid	toad
lobster	crab	mouse
squirrel	mouse	crab
saxophone	trumpet	guitar
banjo	guitar	trumpet

Appendix E

Materials for Experiments 5

Picture	Distractor: Semantically close	Semantically far	Unrelated A	+	Unrelated B
bed	futon	chair	pot	+	helicopter
stool	chair	futon	helicopter	+	pot
dog	wolf	lizard	grenade	+	mallet
snake	lizard	wolf	mallet	+	grenade
horse	zebra	whale	submarine	+	spoon
dolphin	whale	zebra	spoon	+	submarine
pliers	wrench	mallet	shrub	+	lizard
hammer	mallet	wrench	lizard	+	shrub
kettle	pot	spoon	futon	+	whale
ladle	spoon	pot	whale	+	futon
glass	bowl	saucer	truck	+	spear
plate	saucer	bowl	spear	+	truck
tree	shrub	grass	wrench	+	wagon
flower	grass	shrub	wagon	+	wrench
car	truck	wagon	bowl	+	grass
carriage	wagon	truck	grass	+	bowl
boat	submarine	helicopter	zebra	+	chair
plane	helicopter	submarine	chair	+	zebra
bomb	grenade	spear	wolf	+	saucer
arrow	spear	grenade	saucer	+	wolf

Note. Conditions joined by a + symbol were averaged together to form a single unrelated baseline.

Appendix G

Materials for Experiment 7 and 7b

Picture	Distractor: Semantically close	Distractor: Semantically far	Distractor: Unrelated
carrot	yam	spinach	beaver
lettuce	spinach	yam	beaver
onion	garlic	celery	kettle
asparagus	celery	garlic	kettle
lobster	crab	beetle	bolt
ant	beetle	crab	bolt
deer	moose	shrimp	shack
octopus	shrimp	moose	shack
lion	tiger	goose	vine
duck	goose	tiger	vine
whale	seal	goat	pearl
cow	goat	seal	pearl
rabbit	hamster	alligator	baton
snake	alligator	hamster	baton
skunk	raccoon	clam	faucet
snail	clam	raccoon	faucet
vest	jacket	boot	mirror
sandal	boot	jacket	mirror
dress	skirt	glove	fence
mitten	glove	skirt	fence
screwdriver	wrench	hoe	giraffe
shovel	hoe	wrench	giraffe
canoe	raft	van	ladle
car	van	raft	ladle
chair	stool	futon	tractor
bed	futon	stool	tractor
guitar	banjo	trumpet	blender
saxophone	trumpet	banjo	blender
arrow	harpoon	grenade	cello
bomb	grenade	harpoon	cello
helicopter	airplane	scooter	pliers
bicycle	scooter	airplane	pliers
plate	saucer	jar	corn
bottle	jar	saucer	corn
turtle	frog	buffalo	kite
horse	buffalo	frog	kite

Received August 3, 2006
Revision received January 3, 2007
Accepted January 5, 2007 ■