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On the categorical nature of the semantic interference effect in the picture–word interference paradigm

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Two picture–word interference experiments are reported in which the boundaries of the semantic interference effect are explored. In both experiments, participants named pictures (e.g., a picture of a car) that appeared with superimposed word distractors. Distractor words from the same semantic category as the word for the picture (e.g., CAR) produced semantic interference, whereas semantically related distractors from a different category (e.g., BUMPER) led to semantic facilitation. In Experiment 2, the semantic facilitation from semantically related distractors was replicated. These results indicate that a semantic relationship between picture and distractor does not necessarily lead to interference and in fact can lead to facilitation. In all but one case tested until now, a semantic relationship between picture and distractor has led to semantic facilitation. The implications of these results for the assumption that the semantic interference effect arises as a consequence of lexical competition are discussed.

The picture–word interference paradigm, in which participants name pictures while ignoring distractor words, has been used to inform both theories of attention and theories of language production (see, e.g., MacLeod, 1991, for an overview). A well established effect in this paradigm is the *semantic interference effect* (SIE): When the distractor word and the picture belong to the same semantic category (e.g., CAT, *dog*), naming latencies are longer than when they are unrelated (e.g., MAT, *dog*; see, Glaser & Düngelhoff, 1984; Glaser & Glaser, 1989; La Heij, 1988; Lupker, 1979; Rosinski, 1977).[1] In the context of language production research, the SIE has been interpreted as supporting the assumption of lexical selection by competition (see, e.g., Roelofs, 1992; Schriefers, Meyer, & Levelt, 1990). Here, we evaluate such an interpretation and bring experimental data that help to understand the origin of the SIE.

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Many models of lexical access assume that the ease with which a lexical node is selected depends not only on its level of activation but also on that of other lexical nodes (e.g., Costa & Caramazza, 2002; Roelofs, 1992; Starreveld & La Heij, 1995). If at the time of selection other lexical nodes are highly activated, selection of the target lexical node will be delayed. The SIE is assumed to reveal the greater lexical competition produced by related than by unrelated distractors. Related distractors interfere more because they are, hypothetically, more activated than unrelated distractors. This differential level of activation arises because the picture's semantic representation (*dog*) activates the lexical node of the related distractor (CAT) but not that of the unrelated distractor (MAT; see Roelofs, 1992). As a result, the activation level of the lexical node CAT is higher (i.e., it receives activation from two sources: the picture's semantic representation and the distractor presentation) than that of the distractor MAT (which receives activation from one source only: the distractor presentation), which makes the former a stronger competitor than the latter.

However, there are three observations that are problematic for the interpretation of the SIE in terms of lexical selection by competition. First, if part of the interference produced by a distractor is due to lexical competition, then lexical nodes with relatively low levels of activation (low-frequency words) should interfere less than those with higher levels of activation (high-frequency words).

However, this is not the case; low-frequency distractors interfere more than high-frequency distractors do (Miozzo & Caramazza, 2003).

Second, if the SIE reflects lexical competition, then it should not be present when verbal responses are not necessary. However, semantic interference (SI) has been observed for manual responses (Lupker & Katz, 1981; but see Schriefers et al., 1990).

Third, of special interest in the present context is the observation that a semantic relationship between target and distractors does not always lead to SI. When target and distractors are related by virtue of being associates, SI is not observed (Alario, Segui, & Ferrand, 2000; Lupker, 1979; Mahon, Costa, Shapiro, & Caramazza., 2002; Schriefers et al., 1990). Given that the semantic representations of associatively related distractors and targets are supposed to prime each other, SI should in principle be observed. However, it is unclear whether one can compare coordinate relationships to associative relationships. This is because associative relationships are heterogeneous: Whereas some associates are clearly semantically related, others are not.

However, there is another situation in which targets and distractors are clearly semantically related and nevertheless SI is not observed: Related basic-level distractors (e.g., CAT) produce *facilitation* when the task involves oral picture categorization (e.g., to a picture of a dog, the subject responds "animal"; Glaser & Düngelhoff, 1984; Roelofs, 1992; see Vitkovitch & Tyrrell, 1999, for similar findings in a subordinate-level naming task).

The contrasting polarities of semantic contextual effects observed in picture naming and picture categorization could be attributed to either of two factors: (1) the different types of semantic relationship (subordinate vs. coordinate) held by distractors and targets or (2) the different task demands involved in picture categorization and naming. This is because the contexts leading to semantic facilitation and SI differ in important ways. Facilitation is observed when the task involves categorization or the distractors belong to a different level of categorization, and SI is observed when the task involves picture naming and the distractors are at the same level of categorization. Thus, in principle, the presence of semantic facilitation in categorization tasks could be accommodated by models that assume lexical competition if further assumptions are made regarding the different task demands involved in picture naming and categorization. It is thus an open and important empirical question whether the presence of interference or facilitation can be explained by differences in task demands (categorizing vs. picture naming) or by the type of relationship between the components of picture–word pairs (category membership vs. coordinate relation, etc.). In the experiments reported herein, we aim to resolve this uncertainty by holding fixed one of these variables (task) while manipulating the other (type of semantic relationship). We do so by exploring, in a picture naming task, the effect of semantically related distractors that are at the same level of categorization as the target.[2]

Although the existence of SI is beyond dispute, the nature and boundaries of the phenomenon remain unclear. In this article, we explore the boundaries of the SIE by assessing the effects of related basic-level distractors (e.g., ANCHOR for a picture of a boat) in a basic-level picture naming task. One important consideration when choosing the semantic relationship to be explored is that, in the relevant dimensions, it should be similar to the conditions in which SI is present (i.e., picture–word pairs should be clearly semantically related *and* of the same level of categorization). Thus, the two components of the picture–word pairs should be (1) of the same level of categorization, (2) of the same grammatical class, and (3) clearly semantically related. However, in order to assess whether or not SIE generalizes to contexts other than coordination, pictures and distractors must belong to different semantic categories. The "has-a" relationship fulfills these requirements. First, concepts that hold a "has-a" relationship are clearly semantically related—that is, the distractor words (e.g., BUMPER) refer to parts of or properties of the objects to be named (e.g., a car). For example, the concept of a car entails, to some extent, the concept of a bumper, since cars have bumpers. Second, the lexical items of distractors and pictures are from the same level of categorization and the same grammatical class. If the change in polarity of semantic contextual effects is not due solely to task-specific processes but, rather, to the type of semantic relationship between targets and distractors, then it is possible that the "has-a" and "coordinate" relationships lead to different results. Otherwise, we should observe SI for both types of relationships in the same experimental context.

The theoretical question at stake is whether one can use the SIE in this paradigm as evidence in support of lexical selection by competition. Given the crucial role that has been attributed to this effect in discussions of the dynamics of lexical access, but also given the narrow contexts in which it is observed, it is important to properly characterize the effect of semantic relatedness. The explanation of the SIE for coordinate relationships in terms of lexical competition predicts that, under the same task demands, a semantic relationship (either coordination or a "has-a" relationship) between targets and distractors will lead to a slower selection of the target lexical node because of the high level of activation of the distractor lexical node. Thus, failure to observe SIE for "has-a" relationships would require a modification of the explanation for the SIE in terms of lexical competition.

EXPERIMENT 1

Method

Participants. Twenty-two students at Harvard University, all native speakers of English, participated in the experiment.

Materials. Each of 22 pictures appeared along with four distractor words (27-point bold Helvetica font) individually superimposed on the picture: (1) a semantically related "has-a" distractor—

that is, a word corresponding to a part of the object depicted in the picture (e.g., BUMPER for the picture of a car; the part of the object to which the distractor referred was not visible in the picture); (2) an unrelated word that was closely matched pairwise with the "has-a" distractor in number of letters and word frequency (e.g., PARROT); (3) a categorically related distractor—that is, a word from the same semantic category as the picture (e.g., TRUCK); and (4) an unrelated word that was closely matched pairwise with the coordinate semantic distractor in number of letters and word frequency (e.g., TITLE). (See Appendix A for a list of the pictures and distractor words.) The pictures also appeared with a filler distractor (a string of Xs). Each picture appeared in all five conditions. Three more unrelated picture–word pairs were used as warm-up trials at the beginning of each block. Picture–word pairs were phonologically unrelated. Stimuli were presented in five blocks of 25 trials (22 experimental trials plus 3 warm-up trials). Each condition was represented an equivalent number of times (four or five) in each block, and each picture appeared only once. Trials were randomized within blocks with the restriction that distractors of the same condition appeared on no more than two consecutive trials. Five different block orders were constructed. The participants were distributed similarly across the block orders (4 participants in three of the orders and 5 in each of the other two).

Procedure. The participants were tested individually. Before the experiment, the participants were familiarized with the pictures and feedback was given when their response deviated from the expected name. During the experiment, the participants were instructed to name the pictures as quickly and as accurately as possible while ignoring the distractors. A trial consisted of the following events: (1) A question mark appeared in the center of the screen until the participant pressed the space bar; (2) a fixation point (+) appeared for 200 msec, followed by the stimulus; and (3) a response triggered the voice key and terminated the stimulus. The intertrial interval was 2,000 msec.

Results and Discussion

Responses different from the expected names, dysfluencies, recording failures, and outliers (reaction times > 3 *SD*s) were excluded from the analyses (accounting for 5.9% of the total data). Two variables were analyzed separately: category relatedness (categorically related vs. unrelated) and semantic "has-a" relatedness (semantically related vs. unrelated).

The main effect of semantic category relatedness was significant [$F_1(1,21) = 19.2$, $MS_e = 573.3$, $p < .001$; $F_2(1,21) = 8.7$, $MS_e = 1{,}465.4$, $p < .007$], revealing that naming latencies were *longer* in the related condition. The main effect of "semantic-part relatedness" was significant [$F_1(1,21) = 15.1$, $MS_e = 366.4$, $p < .002$; $F_2(1,21) = 5.6$, $MS_e = 982.8$, $p < .03$]. However, in this case latencies were *shorter* in the related condition. Finally, latencies for all distractor words were longer than for the X-string distractor (all ps $< .01$). No significant differences were observed in the error analyses (see Table 1 for error rates by condition).

These results reveal that in picture naming (1) categorically related distractors interfere *more* than categorically unrelated distractors and (2) semantically (but not categorically) related distractors interfere *less* than semantically unrelated distractors. Thus, a mere semantic relationship between target and distractor does not lead to SI in picture naming, but to semantic facilitation, provided that the components of the picture–word pairs are not categorically related. In Experiment 2, we test the reliability of this newly discovered phenomenon.

Table 1
Mean Naming Latencies (RTs, in Milliseconds), Standard Deviations (*SD*s), Error Rates (%Error), and Effects as a Function of Type of Distractor in Experiment 1

Distractor Type	RT	*SD*	%Error	Effect (Related−Unrelated)
Semantically related	696	60	6.2	−23
Semantically unrelated	719	60	4.9	
Categorically related	748	73	8.3	32
Categorically unrelated	716	58	4.9	
XXX	662	54	4.8	

EXPERIMENT 2

Experiment 2 departs in an important way from Experiment 1 in that the same distractors were used in both the related and unrelated conditions (the pictures and words were paired in two different ways to build the two conditions). Thus, any difference between conditions cannot be attributed to differences in the intrinsic properties of the distractors. Also, the percentage of related picture–word pairs was reduced to 25%, thereby reducing the possibility that the participants would develop strategies. Finally, a new set of materials was used to test the robustness of the observed effect.

Method

Twenty-four students at Harvard University took part in the experiment. Thirty-two pictures appeared along with two experimental distractors: a word corresponding to a part of the picture and an unrelated word. The pictures were also paired with two other unrelated filler distractors. Thus, each picture appeared four times. Each distractor appeared twice (once as a related distractor and once as an unrelated distractor); for example the picture *eagle* appeared with TALONS and with BURNERS, and the same distractors appeared with the picture *stove*. (See Appendix B for a list of the pictures and distractor words.) The participants were distributed equally among the four different block orders. The details of the design and procedure were similar to those of Experiment 1.

Results

One participant was excluded because of his long latencies (RTs > 3 *SD*s from the participants' mean). Following the same criterion as in Experiment 1, 6.9% of the trials were discarded. Error rates were similar across conditions (see Table 2).

Naming latencies were shorter in the related condition than in the unrelated condition [$F_1(1,22) = 5.6$, $MS_e = 420.1$, $p < .027$; $F_2(1,31) = 4.5$, $MS_e = 716.3$, $p < .042$], replicating the semantic facilitation observed in Experiment 1.

GENERAL DISCUSSION

A new phenomenon has been reported in this article: In the picture–word interference paradigm (in a picture naming task), semantically related distractors from a dif-

Table 2
Mean Naming Latencies (RTs, in Milliseconds), Standard Deviations (*SD*s), Error Rates (%Error), and Effects as a Function of Type of Distractor in Experiment 2

Distractor Type	RT	*SD*	%Error	Effect (Related − Unrelated)
Semantically related	729	65	6.6	−15
Semantically unrelated	744	72	7.0	

ferent semantic category than the picture lead to semantic facilitation. This result contrasts with the SIE. That is, when the picture of a car is named, the distractor BUMPER produced semantic facilitation and the distractor TRUCK produced SI. Thus, even when the task does not require categorization, semantically related distractors do not necessarily lead to SI.

It appears that the SIE is a rather narrow effect, since it is not present when the two components of a semantically related picture–word pair belong to different levels of categorization or to different semantic categories (until now, only the coordinate relationship has led to reliable SI). These results reveal that the polarity of the semantic effects in this paradigm cannot be attributed solely to task demands. This is because, in the same task (basic-level naming), semantically related distractors produced interference or facilitation, depending on whether or not they belonged to the pictures' semantic category.

Any explanation of semantic contextual effects must account for the change in the polarity of the effects induced by semantically related distractors. How can this observation be explained in the framework of models that assume that SIE reflects lexical selection by competition?

These models make two critical assumptions when explaining the SIE: Activation spreads automatically within the conceptual level and to the lexical system, and lexical nodes compete for selection. Related distractors are assumed to induce SI because the activation received from the pictures' semantic representations results in higher levels of activation for related than for unrelated distractors. And, given the assumption that lexical selection is a competitive process, selection of the target lexical nodes is harder in the context of related distractors. Why, then, do distractors bearing a "has-a" relationship with the target produce facilitation instead of interference?

One possible explanation is that not all lexical nodes enter into lexical competition. There has been at least one proposal of this sort, according to which only those lexical nodes that are part of the response set enter into lexical competition. In this framework, SIE arises whenever the distractor is related *and* is also a picture in the experiment (Roelofs, 1992). Accordingly, related distractors that are not part of the response set prime the targets' semantic representations, but they do not enter into lexical competition. The result of this priming without competition is semantic facilitation. However, it has been shown that this proposal (and related modifications) does not provide an adequate account of SIE when distractors are not part of the response set (see Caramazza & Costa, 2000, 2001, and Roelofs, 2001, for discussions). Furthermore, it is unclear how this proposal could account for both SI and facilitation in the same experiment.

Another possibility is that what determines whether a representation enters into competition is its appropriateness to the naming task at hand. This hypothesis—a variant of one proposed by Lupker (1979)—holds that a crucial factor in determining the magnitude of the interference created by a distractor is its "response relevance." From this perspective, any related distractor would facilitate performance unless it is a context-appropriate response for the task at hand. It appears that in all but one of the conditions reviewed here the distractors do not conform to the "response relevance" criterion (either because they are from a different level of categorization or because they are from a different level of description of objects), and therefore they lead to facilitation. In the case of "has-a" distractors, one could argue that because these words refer to parts of the pictured objects, they do not meet the implicit task criterion of naming of whole objects. In this framework, the crucial factor determining whether interference or facilitation is present is the appropriateness of related distractors in the naming task.

In this framework, one early and crucial component of the semantic effects in this paradigm is semantic in nature, in the sense that the mechanism invoked to explain the presence of SI (e.g., response relevance, or appropriateness of response) is meaningful only at the semantic level. Given that we have to invoke a semantic process as a crucial determinant of the direction of semantic effects, it is only appropriate that we explore whether the change in the polarity of semantic contextual effects in the picture–word paradigm can be explained at this level of representation. In the following, we do so in the context of a lexical access model that retains the notion of spreading activation but dispenses with the assumption of lexical competition.

An explanation of the semantic facilitation effect emerges naturally from the notion of spreading activation: A related distractor primes the target's lexical node more than an unrelated distractor does, thereby speeding its selection. If the speed of lexical selection depends only on the target's activation level, then neither related nor unrelated distractors would compete for selection. Unlike in the model discussed above, here the level of activation of nontarget lexical nodes does not affect the selection of the target word (Caramazza & Hillis, 1990; Dell, 1986).

However, this explanation predicts that coordinate distractors would lead to facilitation. What is so special about this relationship that leads to SI when other semantic relationships lead to facilitation? Given that different semantic relationships lead to effects of different polarities, it seems reasonable to seek an explanation of this variability at the level of representation at which this variable is relevant (i.e., the semantic level).

One possible explanation of the existence of the SIE is that the interference arises at the level at which the deci-

sion is made regarding which semantic representation needs to be lexicalized (see Costa, Mahon, Savova, & Caramazza, 2003; Glaser & Glaser, 1989; Rosinski, 1977). It is possible that some of the effects in this paradigm occur when participants decide which of the two activated semantic representations (that of the picture or that of the distractor) needs to be lexicalized. Assume that participants can use general semantic dimensions, such as category membership, to discriminate between the two semantic representations. When the representations of distractor and response belong to different semantic categories, the semantic system can use categorical information to discard, very early on, the distractor's representation as a possible candidate for lexicalization. In this framework, the SIE comes about because the response relevance of a distractor is computed on the basis of its category membership.

In conclusion, the theoretical issue at stake has been whether the SIE in the picture–word interference paradigm constitutes evidence in support of the assumption of lexical selection by competition. We argued that some observations (e.g., the distractor word frequency effect) seem to be problematic for such an account. We further argued that if the SIE were indeed the result of lexical competition, one would expect to observe such interference for other semantic contexts. Our results reveal that even when distractors and targets are semantically related, belong to the same grammatical class, and share their level of categorization, SI is not observed. The challenge, then, for speech production models is to account for the change in the polarity of semantic contextual effects in this paradigm. Although no single result reviewed or presented herein falsifies, in and of itself, the assumption that the SIE arises as a result of lexical competition, together they make such an assumption highly unlikely.[3] Instead, semantic facilitation finds a ready explanation in a model of lexical access in which selection is achieved when only the target's activation-level is considered. In such a framework, the SIE reveals the ease with which the picture's semantic representation is selected.

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NOTES

1. There are other variables that may account for part of the variation in naming latencies in this paradigm, suggesting that distractor words affect naming latencies through different levels of processing. For instance, although the factor of visual similarity may account for part of the variation in naming latencies between related picture–word pairs, there must be a semantic component to SIE, since it is still present when the visual similarity between picture–word pairs is minimized (Damian & Bowers, 2003; La Heij, 1988). Another example is the observation that an unrelated word interferes more than a string of Xs. This effect may reflect the interference produced by the phonological representation of the distractor word during the retrieval of the target's phonological content.

2. To our knowledge, there are no other published demonstrations of facilitation in this paradigm when the task involves picture naming. However, in an unpublished study we observed facilitation when related distractors (e.g., SLEEP for a picture of a bed) belonged to a different grammatical class than the pictures' names (Mahon et al., 2002).

3. One could always reconcile the presence of semantic facilitation with lexical competition if additional assumptions are made. However, we argue that these assumptions would require locating part of the semantic effects at the semantic level, and that it is therefore more parsimonious to account for the whole set of results by appealing to only one level of representation.

APPENDIX A
Materials Used in Experiment 1

	Distractor Words			
Picture	Semantically Related	Semantically Unrelated	Categorically Related	Categorically Unrelated
wasp	STINGER	CACTUS	BEE	AUNT
gun	BULLETS	PLATES	BOMB	COAST
pen	INK	RAT	BRUSH	TEAR
plant	ROOT	COAT	BUSH	DOLL
lamp	BULB	WOLF	CANDLE	BELL
house	FLOOR	RIVER	CASTLE	ELBOW
piano	KEYS	SNAKES	DRUM	TOE
cow	MILK	FENCE	GOAT	SANDAL
violin	STRINGS	SHELLS	GUITAR	ROCKET
tiger	FANGS	FIGS	LEOPARD	SCARF
heart	VALVES	FLEAS	LUNG	BELT
book	PAGES	COLUMNS	MAGAZINE	ORCHESTRA
lion	PAWS	KNOTS	PANTHER	CHESS
orange	SECTION	LETTER	PEACH	TOAD
apple	CORE	BAG	PEAR	RAT
boat	ANCHOR	STOVE	PLANE	FARM
organ	PEDALS	CAMELS	SAXOPHONE	BANDAGE
pumpkin	SEEDS	BIRDS	SQUASH	SKULL
brain	NEURONS	LENTILS	STOMACH	TEMPLE
desk	DRAWER	JUICE	TABLE	FATHER
bus	SEATS	SHOPS	TRAIN	COFFEE
car	BUMPER	PARROT	TRUCK	TITLE

APPENDIX B
Materials Used in Experiment 2

Picture	Distractor Words: Semantically Related	Distractor Words: Semantically Unrelated
airplane	PROPELLER	TOBACCO
canoe	PADDLE	VENOM
cherry	PIT	DRAIN
church	PEW	SOOT
eagle	TALONS	BURNERS
fish	GILLS	CORK
flashlight	BATTERY	SPRINGS
keg	BEER	TAIL
pear	CORE	WINGS
lighter	FLAME	STAIRS
rifle	TRIGGER	SPINES
rose	THORNS	BRAKES
submarine	PERISCOPE	STRETCHER
tree	BRANCHES	ENGINE
truck	WHEELS	PAGES
volcano	LAVA	RUDDER
cigarette	TOBACCO	PROPELLER
snake	VENOM	PADDLE
sink	DRAIN	PIT
chimney	SOOT	PEW
stove	BURNERS	TALONS
bottle	CORK	GILLS
mattress	SPRINGS	BATTERY
dog	TAIL	BEER
bird	WINGS	CORE
house	STAIRS	FLAME
cactus	SPINES	TRIGGER
motorcycle	BRAKES	THORNS
ambulance	STRETCHER	PERISCOPE
car	ENGINE	BRANCHES
newspaper	PAGES	WHEELS
boat	RUDDER	LAVA

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