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Lexical Selection Is Competitive: Evidence From Indirectly Activated Semantic Associates During Picture Naming

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In this study, we present 3 picture–word interference (PWI) experiments designed to investigate whether lexical selection processes are competitive. We focus on semantic associative relations, which should interfere according to competitive models but not according to certain noncompetitive models. In a modified version of the PWI paradigm, distractor word pairs were simultaneously presented with the target picture. The distractor words were orthographically related directly to the target picture name (distractors: *came*ra bag*el*; target: camel), indirectly related to the name of a semantic associate of the target (distractors: *came*ra bag*el*; target: pyramid, an associate of camel), or unrelated. In a first experiment, which included only indirect relations, we failed to find interference from indirectly activated associates. However, in 2 subsequent experiments that included the associates as naming trials within the experiment, we demonstrated that indirect, orthographically mediated activation of associates produces reliable interference effects. The results indicate that semantic interference is not restricted to members of the same category and are problematic for models of lexical selection that do not include lexical competition.

Keywords: speech production, lexical competition, semantic context effects, picture–word interference, semantic associates

Current models of speech production recognize the need for three distinct types of processes: semantic, syntactic, and phonological (e.g., Dell & O'Seaghdha, 1991, 1992; Levelt, Roelofs, & Meyer, 1999). Models also acknowledge that multiple semantically related concepts are activated when producing a single word. For example, when naming a "cat," both categorically and associatively related concepts, such as *horse* and *whiskers*, are coactivated and spread activation to their corresponding lexical representations (cf. Abdel Rahman & Melinger, 2007; Aristei, Melinger, & Abdel Rahman, 2011; Saffran, Coslett, & Keener, 2003; Vanderwart, 1984, for evidence of the automatic spread of activation from a picture to both categorically and noncategorically related concepts such as associates). From this set of activated lexical representations, the target "cat" must be selected for articulation. Here the agreement between models ends. For some models, lexical selection is a competitive process; active competitors slow down target selection times (Caramazza, 1997; La Heij, Kuipers, & Starreveld, 2006; Levelt et al., 1999; Roelofs, 1992). For other models, lexical selection is noncompetitive; the time needed to select the target is unaffected by the activation levels of other lexical representations (Costa, Alario, & Caramazza, 2005; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; see below).

One source of evidence for lexical competition comes from semantic interference effects. Essentially, these effects reveal that naming pictures in the context of semantically related concepts is often slowed down and more erroneous than naming in the context of unrelated concepts (Glaser & Düngelhoff, 1984; Kroll & Stewart, 1994; Schriefers, Meyer, & Levelt, 1990; Vigliocco, Vinson, Indefrey, Levelt, & Hellwig, 2004). For example, in the picture–word interference (hereafter PWI) paradigm, participants name pictures while ignoring simultaneously presented distractor words. Categorically related distractor words (i.e., distractors drawn from the same semantic category as the target word) slow naming times relative to unrelated words. Similarly, in the semantic blocking paradigm, participants are slower to name pictures presented within blocks of categorically related objects than pictures presented with objects from different semantic categories (Belke, Meyer, & Damian, 2005; Damian, Vigliocco, & Levelt, 2001, see also Kroll & Stewart, 1994, for variants that do not involve repetition). This semantic interference effect reveals that unintended semantically related alternatives become active and slow target selection time even when naming single words.

Given the situation of multiple active candidates, the debate between competitive and noncompetitive selection mechanisms centers around the question of whether coactivated alternatives interfere with this selection process via competition or whether, in contrast, lexical selection proceeds without competition. The present paper contributes to this debate by examining whether the representations of noncategorical semantic relations compete with the target word for selection. This question is central to the debate because recent observations that only categorical—and not noncategorical— semantic relations induce classic interference effects have been interpreted as evidence against lexical competition. Here we test whether evidence for lexical competition induced by noncategorical semantic relations can be found when the experimental design sets favorable conditions for the emergence of such effects. To this end, we investigated the effects of distractor words

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that are orthographically related to a potential noncategorically related competitor of the target (e.g., distractor: camera, orthographically related to camel, which is semantically but not categorically related to the target pyramid). As discussed in detail below, such mediated relations should activate the potential competitor at the lexical level without inducing strong semantic priming at the conceptual level due to the indirect relation to the target. By thus optimizing the chances to observe such effects, we test whether small traces of interference can be found that are not observed under less optimal conditions. This logic is outlined in detail below.

We first introduce different types of direct and mediated distractor effects relevant for the present study and then turn to a discussion of competitive and noncompetitive theoretical accounts of lexical selection and how these accounts deal with mediated semantic interference effects.

Direct and Mediated Context Effects in the PWI Paradigm

In the PWI paradigm, four effects can be illustrated that are relevant to the current investigation. These effects refer to different types of distractor words that speed or slow picture naming times relative to unrelated words. First, categorically related words (e.g., as "horse" is to "cat") slow naming times (Glaser & Düngelhoff, 1984; Glaser & Glaser, 1989; La Heij, 1988). This is a *semantic interference effect* (see above). In contrast, distractor words that are semantically but not categorically related to the target (e.g., as "whiskers" is to "cat") speed naming times (e.g., Abdel Rahman & Melinger, 2007; Alario, Segui, & Ferrand, 2000; Costa et al., 2005, for part-whole relations; La Heij, Dirkx, & Kramer, 1990, for associative relations). This is known as the *semantic facilitation effect*. Distractor words that are orthographically or phonologically similar to the target name (e.g., as "cab" is to "cat") also speed naming times (Briggs & Underwood, 1982; Lupker, 1982; Underwood & Briggs, 1984). This is called *orthographic or phonological facilitation*. Finally, and most important for the present purpose, distractor words that are orthographically or phonologically related, not to the target but to a potential semantic competitor (e.g., as "cab" is to "horse" via "cat"), slow naming times (Abdel Rahman & Melinger, 2008; Jescheniak & Schriefers, 1998; Levelt et al., 1991; Peterson & Savoy, 1998). This is known as the *mediated semantic interference effect*, and we use this effect to test whether noncategorical semantic relations are active competitors.

Although related to mediated semantic interference, on its own, the phonological facilitation effect does not contribute to the debate regarding the competitive nature of lexical selection. Competitive and noncompetitive models agree that form-based facilitation arises from converging activation from both word production and perceptual input representations onto word form representations. In particular, the distractor word primes phonemes or graphemes shared by the target word, thereby facilitating word-form encoding. Both classes of model also assume that a target picture activates semantically related concepts. When combined with a semantically related distractor word, either categorical or noncategorical, this automatic spread of activation leads to facilitation, hypothesized to arise either at the conceptual level or at the lexical level. The key difference then between the two types of model is whether the slower naming times induced by categorically related distractors, as illustrated by the classic semantic interference effect, are due to lexical or postlexical processes. In the following, we outline the core assumptions from each model and walk through how each model accounts for the key distractor effects.

A Noncompetitive Model

There are several noncompetitive proposals in the literature (e.g., Dell, 1986; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Rapp & Goldrick, 2000), but we focus here on the *response exclusion hypothesis* (Finkbeiner & Caramazza, 2006; Janssen, Schirm, Mahon, & Caramazza, 2008; Mahon et al., 2007) as it is explicitly designed to account for reaction time patterns obtained in the PWI paradigm, whereas other prominent noncompetitive models are primarily designed to capture patterns of speech errors of aphasic and unimpaired speakers. The response exclusion hypothesis (hereafter REH), like other noncompetitive models, posits that the activation levels of nontarget lexical representations do not negatively affect the time needed to select the target word. According to this model, all semantically related distractor words can speed target selection times via lexicosemantic priming. Delays in naming times arise postlexically, within a single channel output, or articulatory, buffer.[1] If the name of the target picture is to be articulated, the distractor word, which has privileged access to the buffer (creating a processing bottleneck), must be disengaged. The time needed to clear the distractor word from the buffer depends on whether it satisfies response criteria set by the target word and the wider experimental setting. Distractor words that do not satisfy the "response-relevant criteria" are removed from the buffer faster than distractor words that do, clearing the way for the target. These criteria, although implicit and thus open to broad interpretation, are proposed to draw on categorical relations. For example, the criterion "name an animal" could be activated by the target picture, and the criterion "name concrete objects" could be activated by the broader experimental context. Hence, same-category distractor words slow target naming because they satisfy multiple response-relevant criteria, and different-category distractor words slow naming times less because they satisfy fewer response-relevant criteria and can thus be cleared from the response buffer more quickly. Mahon et al. (2007) thus accounted for same-category interference by invoking response-relevant criteria that apply postlexically and for different-category facilitation by invoking semantic priming effects.

Mediated semantic interference effects pose a challenge for the REH. For example, for a target picture like "couch", Jescheniak and Schriefers (1998) presented a distractor word like "soda", which is similar in form to the near synonymous competitor "sofa".[2] Because "soda" is semantically unrelated to "couch", it should be an easy distractor word to remove from the response buffer. However, Jescheniak and Schriefers (see also Peterson & Savoy, 1998) found that distractor words such as these slowed

[1] The proposal that semantic interference effects are postlexical is a unique characteristic of the REH and is not a general assumption of other noncompetitive models.

[2] Jescheniak and Schriefers's (1998) study was conducted in German, not English. An example from their study is as follows: a picture of a rooster, which has the German names "Hahn" and "Gockel," was combined with the distractor word Gondel [gondola], which is phonologically related to Gockel.

reaction times relative to unrelated words, illustrating the mediated semantic interference effect. These results challenge the REH because the distractor word that enters the response buffer is not response relevant and therefore should induce the same effect on naming times as do other unrelated words.

A Competitive Model

Again, several different competitive models have been developed (e.g., Caramazza, 1997; La Heij et al., 2006; Levelt et al., 1999; Roelofs, 1992). Here, we focus on a recent modification of traditional competitive models designed to capture both semantic facilitation and interference, namely, the lexical cohort account (hereafter LCA; Abdel Rahman & Melinger, 2007, 2009a, 2009b). This competitive account views all semantic effects as reflecting a trade-off between conceptual facilitation and lexical competition. The LCA assumes that all semantically related distractor words prime the target's conceptual representation, producing facilitation. In some cases this facilitation is offset by a larger opposing competition effect at the lexical level. What determines the polarity of observed net semantic context effects is whether the activation from the target and distractor words converges onto a lexical cohort or not.

A *lexical cohort* is defined as a set of interrelated lexical representations that are all highly active. The notion of a lexical cohort is similar to the idea of *clustering coefficient*, a network measure of item interrelatedness that has been used to account for neighborhood effects in word production and comprehension (Chan & Vitevitch, 2009, 2010; Watts & Strogatz, 1998). Like a high clustering coefficient, a lexical cohort is achieved when members of a set of interrelated concepts mutually enhance each other's level of activation. The presence or absence of a lexical cohort is important for the emergence of semantic interference because target selection times are sensitive to the activation level of the whole system, not just the most active competitor (Levelt et al., 1999; Roelofs, 1992). On an intuitive level, this means that it is fairly easy to identify the target from among a small set of weakly active representations, but identifying the target from among a bigger set of highly active representations is more difficult. When lexical competition is easily resolved, the associated processing cost is insufficient to outweigh the concomitant semantic facilitation produced at the conceptual level.

Abdel Rahman and Melinger (2007, 2009a, 2009b) argued that same- and different-category distractors differ precisely in terms of whether or not they engage a lexical cohort. A categorically related distractor word will activate many of the same conceptual representations that are activated by the target itself, as represented in the top frame of Figure 1. This convergence of activation arises because categorically related words share many semantic features as well as category membership (Kurtz & Gentner, 2001). These active concepts in turn spread activation to their corresponding lexical representations, and that is the lexical cohort. Noncategorically related distractor words have a very different impact on the conceptual network. Different-category distractors are unlikely to share many features or semantic neighbors with the target word. For example, although *camel* and *pyramid* are related to each other, they are not featurally similar, nor do they share many other semantic neighbors. *Camel* will be linked to other animals, most of which are irrelevant to the concept *pyramid*, and *pyramid* will be

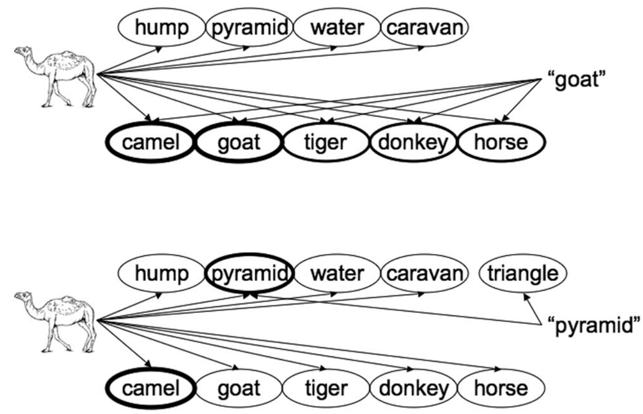

Figure 1. Portion of the conceptual network illustrating convergence (top frame) from a categorically related distractor word and divergence (bottom frame) from a noncategorically related distractor word. Darker circles reflect more strongly activated concepts.

linked to other buildings and monuments, such as *temple, crypt, The Acropolis,* and to physical features such as *stone* and *triangle*, most of which are not core characteristics of *camels* (Nelson, McEvoy, & Schreiber, 1998). Therefore, the activation from the distractor and target, respectively, spreads onto distinct subsections of the semantic network, as represented in the bottom frame of Figure 1. This results in broad but shallow activation. The weakly primed conceptual representations still activate their corresponding lexical representations, but none of them are particularly strong apart from the target and distractor themselves. As a result, competition for selection is easier to resolve and, crucially, insufficient to outweigh the concomitant conceptual priming that the distractor induces.

Because lexical entries must be selected from among competitors whereas concepts simply receive more or less activation, Abdel Rahman and Melinger (2009b) reasoned that an increasing number of coactivated concepts and lexical nodes has a stronger influence on lexical interference than on conceptual facilitation. Therefore, when no cohort is active, conceptual facilitation will dominate lexical competition; when a lexical cohort is active, lexical interference will outweigh the concurrent conceptual facilitation.

This trade-off account explains mediated semantic interference effects by invoking the same basic processes responsible for directly induced interference. In particular, the bottom-up form-based activation from the distractor word converges with the top-down activation induced by the target picture.[3] This results in one competitor that is significantly more lexically active than an unrelated distractor word, because the latter's activation does not converge with that of the target picture. Because the competitor

[3] Note that this interpretation requires either (a) interactivity between lemma and wordform levels, allowing the activation on wordform representations to spread up to the lemma level (Dell, 1986), or (b) lexical competition to apply between lexemes rather than, or in addition to, between lemmas (Starreveld & La Heij, 1996). For present purposes, we take no position on this point and feel that both options are consistent with other aspects of the lexical cohort account.

has been indirectly activated from the bottom-up only, the normal conceptual facilitation should be absent or greatly reduced. This is because the "competitor" is not explicitly presented and the distractor word itself is unrelated to the target. With greatly reduced conceptual facilitation stemming from the distractor word, small traces of lexical competition induced by a single competitor should emerge if the competitor is sufficiently active. Consider the example in which the picture "pyramid" is presented together with the distractor "camera." Camera shares little semantic content with pyramid; thus, no semantic priming is expected. Nevertheless, orthographically priming "camel" increases its potential to slow target naming times. Of course, whether or not the resulting competition produces measurable interference effects will depend on the extent to which the competitor is activated by the distractor word and the sensitivity of the experimental methodology. Even under optimal conditions, it is expected that mediated semantic interference from noncategorical competitors will be very small and difficult to detect.

Importantly, an indirect relation should selectively enhance the activation status of the competitor at the lexical level and considerably less so at the conceptual level. Even though we are not aware of direct empirical evidence that concepts receive stronger activation when their name is directly presented than when their name has partial form overlap with an otherwise unrelated word (the mediated condition), we assume that this is the case—if only because fewer processing steps are involved in the direct than the indirect condition. Furthermore, there are indications that the early activation of orthographic and phonological neighbors is very quickly suppressed and affects only the earliest stages of the word recognition process (e.g., Lukatela & Turvey, 1994). Thus, concept activation of neighbors should be weak. As a result, the weak lexical competition typical of noncategorical contexts should not be offset by conceptual facilitation.

In summary, the REH explains the absence of interference from noncategorical distractor words on their irrelevance to the task, which renders them easier to remove from the response buffer. The LCA explains the same observation by an absence of an active lexical cohort, which allows conceptual facilitation to overpower the lexical competition generated by a single strong competitor. Further investigation of mediated interference effects should allow the differentiation between these models, as only the latter model can easily account for these effects.

Mediated Interference and the Double Distractor Method

Following the logic outlined above, the LCA predicts that mediated semantic interference should not be restricted to categorical relations; they should extend to noncategorical relations as well, if the right favorable conditions can be identified.

Mediated semantic interference effects are not easy to detect. For example, they are not observed when the semantic relationship between target and competitor is weak (e.g., target: hamster; competitor: goat; distractor: goal; Levelt et al., 1991; Peterson & Savoy, 1998). However, experiments that have maximized either semantic overlap (Hantsch, Jescheniak, & Schriefers, 2005; Hermans, Bongaerts, De Bot, & Schreuder, 1998; Jescheniak & Schriefers, 1998; Peterson & Savoy, 1998) or segmental overlap between target and competitor (Abdel Rahman & Melinger, 2008) have been successful in revealing mediated semantic interference. For example, naming times are significantly slower when the distractor word is phonologically related to a near synonym of the target (Jescheniak & Schriefers, 1998; see also Peterson & Savoy, 1998) or a translation equivalent of the target (Hermans et al., 1998). Presumably, sufficient lexical activation is needed in order to observe these effects, and when the semantic relationship between target and competitor is comparatively weak, this minimal threshold may not be satisfied.

Another way that the lexical activation of competitors can be boosted is to present two orthographically related distractor words rather than just one. Abdel Rahman and Melinger (2008) demonstrated that simultaneously presenting two distractor words, one with word-initial segmental overlap and a second with word-final segmental overlap, produces significantly more form facilitation than presenting just a single form-related distractor with either initial or final segmental overlap. (See the General Discussion for further details about this methodology.) Using this double-distractor method, we successfully evoked reliable mediated categorical interference effects. We suggested that the two distractors increased the amount of orthographic overlap, thereby enhancing the competitor's activation up to a level needed to observe mediated interference effects. Here, we adopt this same approach to try to induce mediated semantic interference effects for different category distractors.

Outline of the Experiments

The LCA assumes that conceptual facilitation outweighs lexical competition when no lexical cohort is activated. Mediated interference effects from noncategorical competitors are predicted because the conceptual facilitation normally induced by the semantically related distractor word should be greatly diminished, allowing lexical competition in the absence of a lexical cohort to emerge. The REH, on the other hand, assumes that distractor words that do not satisfy the response-relevant criteria should not delay target naming times. Therefore, they do not predict mediated semantic interference from noncategorically related words. The only way the REH could conceivably account for mediated semantic interference effects is to assume that, at least on some of the trials, the primed competitor gains access to the response buffer rather than the distractor word. Although this is unlikely, it is possible and would provide an avenue for the REH to account for previously observed mediated semantic interference effects. However, such an explanation would not explain mediated semantic interference from noncategorical competitors, because the primed competitor does not satisfy the response-relevant criteria. Therefore, testing for mediated semantic interference effects from noncategorically related competitors serves as a stronger test of these two models.

To evaluate these hypotheses, we tested for mediated semantic interference induced by noncategorically related distractor pairs in the PWI paradigm. In the series of experiments reported below we boost the activation levels of noncategorically related semantic competitors at the lexical level by presenting distractor word pairs that are orthographically related to the competitor. The activation boost of the potential competitor arises primarily via bottom-up form priming and considerably less so via top-down conceptual priming. We operationalized noncategorical relations by using semantic associates drawn from word association databases. Semantic associations reflect both textual and experiential co-occurrence and should, in the majority of instances, be captured by connections at the conceptual level (Schulte im Walde, Melinger, Roth, & Weber, 2008).[4]

In Abdel Rahman and Melinger (2008), all demonstrations of mediated semantic interference from categorically related competitors included the competitors as naming trials in the experiment. That design element may be crucial to achieving sufficient competitor activation to induce observable interference effects, especially from noncategorical relations. However, according to the strongest reading of the LCA, including the competitors as naming trials should not be required; competition from a single strongly active competitor in the absence of conceptual facilitation should be sufficient. The question is, does the orthographic overlap in our experiments prime the noncategorical competitor sufficiently to constitute “a strong lexical competitor”? We use the double distractor method in order to maximize the chances that it does, but it is unclear whether presenting two orthographically related distractor words creates the appropriate conditions for mediated semantic interference when the competitors are not included in the experiment. Therefore, we first test the strongest reading of the LCA by including only naming trials for the targets, but not the associates. This first experiment includes naming trials for the target pictures under two distractor conditions, indirectly related (e.g., the distractors *camera* and *bagel*, orthographically related to camel, paired with the picture pyramid) and unrelated (e.g., the distractors *camera* and *bagel* paired with another picture, such as witch). In Experiments 2 and 3 we adopted the design previously used by Abdel Rahman and Melinger, which included naming trials for the competitors as well. This modification to the design allowed us to ensure that our orthographic manipulation was effective by testing for direct orthographic facilitation effects and also to further enhance the activation levels of competitors. Thus, distractors were either directly or indirectly related to the picture name or were unrelated.

Experiment 1

Here we used multiple orthographically related words to test whether we could find any evidence for lexical competition between the target name and an associatively related word. Because Abdel Rahman and Melinger (2008, Experiment 2) demonstrated that orthographic facilitation could be enhanced by presenting two orthographically related words, one with word initial segmental overlap and one with word final segmental overlap, we adopted their double distractor procedure in the hopes of boosting the lexical activation of the associative competitor sufficiently to produce observable semantic interference effects. To that end, target pictures were presented together with two distractor words that were either orthographically related to an associate (e.g., target: pyramid; distractors: camera, bagel, orthographically related to camel) or unrelated.

According to the REH, the distractor words should be easy to purge from the response buffer because they are unrelated to the target. The indirectly activated competitor should not gain access to the response buffer, but even if it did, the REH would still not predict an interference effect because the noncategorically related competitor also does not satisfy the implicit response-relevant criteria. In contrast, the LCA predicts that indirectly activated competitors should produce small but detectable interference effects because the conceptual priming usually engendered by a related distractor should be significantly reduced. Without conceptual facilitation, even a small interference effect resulting in the absence of a lexical cohort should be sufficient to produce observable effects, if they are within the testable limits of the paradigm.

Method

Participants. Twenty-four native speakers of German were paid for their participation. All reported normal or corrected-to-normal visual acuity and normal color vision.

Stimuli. Thirty black-and-white line drawings, equally distributed between 10 categories, were selected. Thirty strong associates were identified from a corpus of German semantic association norms (Melinger & Weber, 2006). None of the associates were category members of their corresponding targets.

Four distractor word pairs were created for each target picture, two indirectly related and two unrelated. To create the indirectly related condition, we combined one word that shared initial segments with the associate of the target and one word that shared final segments with the associate (e.g., target: Axt [English: axe]; associate: Holz [English: wood]; distractors: *Honig, Stolz*; see Appendix A). The pairs of indirectly related distractors were reassigned to new pictures to create the unrelated condition. Thus, in the unrelated condition, the word pairs have initial and end segmental overlap with a semantic associate of another picture within the experiment (see Figure 2 for an example of stimulus presentation). For each condition, two different word pairs were presented with each picture. This design characteristic, which was also used by Abdel Rahman and Melinger (2008), allows multiple repetitions of the pictures while avoiding the possibility of inducing learned associations between pictures and distractor pairs. All distractor words were semantically and orthographically unrelated to the target picture.

Of the target picture names, 12 were monosyllabic, 15 were bisyllabic, and three were trisyllabic. In 53 out of 60 cases (~90%), the associate name was completely contained within the two distractor words, as in *K*ittel + B*issen* containing the associate “Kissen”. In 22 cases, the associate name could be obtained by combining the onset of one distractor word and the rhyme or offset of the other distractor word, as in the above example. Furthermore, in many of these cases, there was redundant segmental overlap, as in the vowel *i* shared by the two distractor words. Syllable boundaries of the distractor words were often not respected (e.g., all the distractors for monosyllabic associates). In only 11 instances could the syllables from the distractors be extracted intact and recombined to create the associate, as in *Kir*sche + Ler*che* to create Kirche. In 10 instances the associate comprised the body of one distractor syllable and the coda of another, as in *Pfe*nnig + Mo*rd* to create Pferd.

[4] Semantic associations that have high textual co-occurrence have been argued to also have excitatory links at the wordform level (e.g., Cutting & Ferreira, 1999; McKoon & Ratcliff, 1992). Although that may be correct, such links could not explain mediated semantic interference effects, as only a facilitative effect would be predicted.

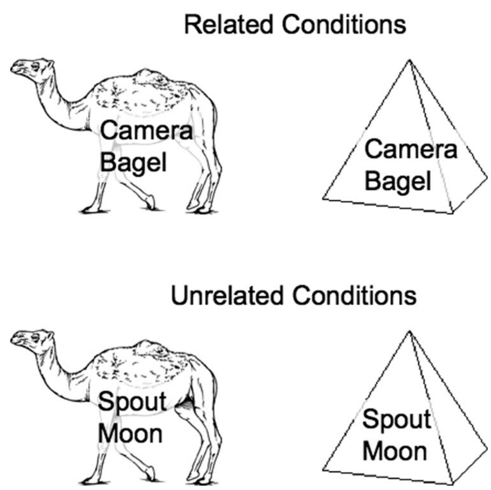

Figure 2. Hypothetical English example for picture and distractor pair presentation in the two experimental conditions of Experiment 1 and the four experimental conditions in Experiments 2 and 3. Top: Presentation of target pictures with directly related distractor word pairs (right) and indirectly related distractor pairs that are orthographically similar to an associatively related competitor (camel; left). Bottom: Unrelated conditions for the two types of target pictures. The unrelated distractor pairs were directly and indirectly related to another target picture in the experiments (e.g., the target picture spoon). Only pictures on the right (e.g., pyramid) were included in Experiment 1.

Pictures were scaled to 3.5 × 3.5 cm. Distractors were presented in red and were arranged one above the other. In half of the pictures the distractor word with initial segmental overlap was in the top position, and in half of the pictures the distractor word with word final segmental overlap was in the top position. Controlling the relative position of initial versus end overlap across stimuli should reduce the impact of strategic scanning patterns. Relative to the picture, the words were placed to have maximal integration without obscuring the visibility of the picture. This position was constant across conditions.

Procedure and design. Each trial began with a centrally presented fixation cross on a light gray screen. After 500 ms, a picture–word pair was presented for 2 s, resulting in an interstimulus interval of 2.5 s. Stimulus onset asynchrony was 0. Participants were instructed to name the picture as quickly and accurately as possible. No instructions were provided regarding the distractor words. Naming latencies were measured with a voice key.

The experimental design included the within-participants and items factor relatedness (indirectly related or unrelated); participants saw every picture presented in every condition. The experiment consisted of 240 trials comprising eight repetitions of each of the 30 pictures. Each picture occurred four times in each condition and twice with each of its distractor pairs (see Appendix A).

The experiment started with a practice block in which participants named each picture and were corrected if necessary. The main experiment lasted under 30 minutes and included 2 experimental blocks separated by a short break. Each picture–distractor pair combination occurred once in the first block and once in the second block; thus, a second occurrence of a picture–distractor pair could not occur until the entire set of pictures in all conditions was cycled through once. Within a block, pictures were presented in a pseudorandomized sequence to prevent consecutive picture presentations.

Results and Discussion

Table 1 presents the mean reaction times (RTs) for correct naming trials and mean percentages of errors in the two experimental conditions. Trials with incorrect naming, stuttering, mouth clicks, or vocal hesitations were coded as errors and discarded. Trials with naming latencies deviating more than 2.5 standard

Table 1
*Mean Reaction Times (RTs, in milliseconds), Standard Errors (*SE*), Error Percentages, and Percentage of Trials Excluded From the Analysis for Experiments 1–3*

Distractor condition	RT	*SE*	Errors	Excluded	Effect (overlap–unrelated)
			Experiment 1: German		
Indirectly related: Targets					
Orthographic overlap	730	17.3	3.3	5.6	−4
Unrelated	734	19.4	3.8	6.4	
			Experiment 2: German		
Directly related: Associates					
Orthographic overlap	662	17.1	7.5	10.1	−61
Unrelated	723	15.3	9.3	11.6	
Indirectly related: Targets					
Orthographic overlap	747	17.7	11.5	14.1	10
Unrelated	737	16.3	9.7	12.2	
			Experiment 3: Dutch		
Directly related: Associates					
Orthographic overlap	687	9.4	2.7	5.9	−39
Unrelated	726	10.7	2.6	5.6	
Indirectly related: Targets					
Orthographic overlap	720	10.9	3.0	5.8	14
Unrelated	706	9.8	3.2	6.4	

deviations from a participant's mean RTs in each condition were also discarded. As error rates were extremely low in this experiment (<4%), they were not analyzed.

Paired-sample *t* tests revealed no effect of distractor relatedness (*M*diff = 4 ms, *t*s < 1). Thus, in this experiment we found no evidence for interference from indirectly activated semantic associates. However, there are reasons to hesitate before concluding that semantic associates do not enter into competition with the target. First, it is possible that our unrelated condition was too conservative, because distractors in that condition also elicited the mediating associates due to the fact that each unrelated distractor pair had initial and end overlap with an associate of another picture. However, this was unlikely to adversely affect the emergence of mediated interference, because previous studies have investigated the impact of this feature of the unrelated condition and found it to be irrelevant to the emergence of mediated semantic interference effects (Abdel Rahman & Melinger, 2008, Experiments 3 and 4). More critically, although the distractor words were selected to maximize form priming, we have no measure of how effective the distractor words were at activating the associates in this experiment. Second, in this experiment the amount of activation directed toward the associate competitor was quite small and less than that in prior experiments that have shown mediated semantic interference. For example, in Abdel Rahman and Melinger (2008) the category competitors to which the distractor words were orthographically related were themselves part of the experiment (Experiments 3 and 4), potentially boosting their overall activation levels sufficiently to allow interference effects to be observed. Several studies have demonstrated that including the competitors within the response set boosts or strengthens the competition effects (Roelofs, 1992), although it is not a prerequisite for traditional categorical semantic interference (Caramazza & Costa, 2000). Thus, as in other previous studies in which the mediated semantic interference effects were not observed (Levelt et al., 1991), it is possible that in this experiment we did not activate the competitors sufficiently to reveal competition effects despite simultaneously reducing the amount of facilitation at the conceptual level.

Therefore, to enhance interpretability in the event of another null effect and to boost the level of activation of the associate across the board, we additionally included the associate competitors as picture naming trials within the experiment in Experiment 2. The associate pictures were presented with the same distractor pairs presented in the indirectly related condition, to test for direct orthographic effects.

Experiment 2

Here we again tested for semantic competition between the target and an indirectly activated associative competitor using the same materials from Experiment 1. Additionally we included a second set of pictures corresponding to the associate competitors presumed to be activated by the distractor word pairs in Experiment 1. Thus, from Experiment 1 we again had the target picture pyramid combined with either the distractor word pair "camera bagel," orthographically related to the associate "camel," or an unrelated word pair. Also, we included a picture of a camel that was presented with the same pairs of distractor words. Hence, distractor words could be directly or indirectly related to the picture or could be unrelated. The associate pictures should measure the effectiveness of our form priming and should boost the base lexical activation level of the associates, increasing their potency as potential competitors.

Methods

Participants. Twenty-four native German speakers were paid for their participation. All reported normal or corrected-to-normal visual acuity and normal color vision. Participants with overall error rates greater than 20% were replaced.

Stimuli. The 30 black-and-white line drawings from Experiment 1 were used in this experiment. Additionally, 30 pictures of the associate competitors identified in Experiment 1 were selected. Thus, two sets of pictures were constructed: a set of 30 target pictures and a further set of 30 associates.

The distractor pairs from Experiment 1 were again paired with both the target pictures and the associate pictures, creating four distractor conditions: directly orthographically related (e.g., associate picture: Holz [English: wood]; distractors: *Honig, Stolz*), indirectly related via the associate (e.g., target: Axt [English: axe]; distractors: *Honig, Stolz*, orthographically related to the associate picture Holz; see Appendix A), unrelated to the associate, and unrelated to the target. The distractor pairs were reassigned to other pictures for the unrelated conditions. As in Experiment 1, two different word pairs were presented in each condition. Pictures were prepared exactly as in Experiment 1.

Procedure and design. With 60 pictures, the main body of the experiment consisted of 480 trials, and testing sessions lasted approximately 45 minutes. The trials were subdivided by short breaks into four experimental blocks, each consisting of 120 trials. Each picture occurred eight times over the course of the experiment, twice in each block. The design included the within-participants, between-items factor target type (targets, which hold an indirect relation to the distractors vs. associates, which hold a direct orthographic relation to the distractors) and the fully within-factor relatedness (orthographically related or unrelated). Each picture occurred four times in each relatedness condition and twice with each of its distractor pairs (see Appendix A). All other aspects of the procedure were identical to Experiment 1.

Results and Discussion

Table 1 presents the mean RTs for correct naming trials and mean percentages of errors in the four experimental conditions. Trials with incorrect naming, stuttering, mouth clicks, or vocal hesitations were coded as errors and discarded. Trials with naming latencies deviating more than 2.5 standard deviations from a participant's mean RTs in each condition were also discarded. As shown Table 1, the related condition produced faster naming times for associate pictures but slower naming times for the target pictures.

Mean RTs were submitted to analysis of variance (ANOVA) with the between-items factor target type (targets vs. associates) and the within-subjects and items factor distractor relatedness (related vs. unrelated). This analysis revealed a significant main effect of target type, $F1(1, 23) = 148.1$, $MSE = 576$, $p < .001$; $F2(1, 58) = 28.8$, $MSE = 3{,}981$, $p < .001$, reflecting that the directly related associate pictures were named faster than their target picture counterparts. It also revealed a main effect of distractor relatedness, $F1(1, 23) = 105.7$, $MSE = 157$, $p < .001$; $F2(1, 58) = 45.9$, $MSE = 448$, $p < .001$, and, most important, an interaction between target type and distractor relatedness, $F1(1, 23) = 104.3$, $MSE = 337$, $p < .001$; $F2(1, 58) = 100.8$, $MSE = 448$, $p < .001$.

The interaction reflects opposing effects of orthographically related distractor pairs on the two types of target pictures. Direct orthographic relatedness facilitates naming relative to unrelated words, *M*diff = −61 ms, $t1(23) = 17.8$, $p < .001$; $t2(29) = 12.9$, $p < .001$, whereas an indirect orthographic relationship interferes with target naming, *M*diff = 10 ms, $t1(23) = 2.23$, $p < .05$; $t2(29) = 2.2$, $p < .05$.

Because error rates were comparatively high in Experiment 2, they were analyzed, and the results largely paralleled the RT pattern. There was a main effect of target type by participants, $F1(1, 23) = 8.4$, $MSE = .001$, $p < .01$, but not by items, $F2(1, 58) = 1.06$, $MSE = .1$, $p > .1$, and no effect of distractor relatedness (Fs < 1). The interaction between distractor relatedness and target type was significant, $F1(1, 23) = 8.88$, $MSE = .001$, $p < .01$; $F2(1, 58) = 6.24$, $MSE = .01$, $p < .015$, reflecting fewer errors when distractors were orthographically related versus unrelated to the picture, $t1(23) = 2.2$, $p < .05$; $t2(29) = 1.8$, $p = .08$, and a trend toward more errors when they were orthographically related versus unrelated to the associate, $t1(23) = 2.0$, $p = .053$; $t2(29) = 1.7$, $p = .08$.

The results from Experiment 2 stand in stark contrast to those from Experiment 1. There are two important findings. First, we confirmed that directly orthographically related distractor words successfully facilitated naming. This suggests that the null effect observed in Experiment 1 was not due to insufficient form overlap between the competitor and the distractors. More important, we also observed significant mediated interference from indirectly activated associates. This result is consistent with the competitive lexical cohort account but difficult for the REH to accommodate. In particular, according to the REH, delays in naming time arise because the target word cannot enter the response buffer while it is engaged by the distractor word. Because the distractor words in the mediated condition were semantically unrelated to the target, the mechanism responsible for clearing the buffer should treat the distractors like unrelated words. As such, no delay relative to the unrelated condition is expected. In contrast, the results are consistent with the lexical cohort model in that associate interference was able to emerge when the normal conceptual facilitation could be avoided or greatly diminished.

The results of Experiment 2 are striking because they reveal a significant effect of an indirectly presented stimulus when direct presentation of that stimulus would have the opposite result. It is therefore crucial to establish the robustness and reliability of this effect, especially in light of the results from Experiment 1.

Experiment 3

Our aim in Experiment 3 was to replicate the design of Experiment 2 with new materials in a different language, namely, Dutch.

Methods

Participants. Twenty-seven native Dutch speakers were paid for their participation. All reported normal or corrected-to-normal visual acuity and normal color vision. Participants with overall error rates greater than 20% were replaced.

Stimuli. Twenty-four black-and-white line drawings, equally distributed among eight semantic categories, were selected as direct target pictures. In addition, 24 pictures of strong target associates were chosen from a corpus of Dutch semantic association norms (Lauteslager, Schaap, & Schievels, 1986). None of the associates were category members of their corresponding target counterparts.

The same four distractor conditions, constructed in the same manner as in Experiment 2, were created. Of the associate names, 14 were monosyllabic, nine were bisyllabic, and one was trisyllabic (see Appendix B). Of the 48 distractor pairs, 11 did not contain all the segments of the associate name (nearly 25%, more than double the number in Experiment 2). In 28 instances the associate could be assembled from the onset of one distractor and the rhyme or offset of the other (e.g., *k*elder + z*erk* to create “kerk”). Syllable boundaries of the distractor words were respected in only six cases. All other aspects of picture and distractor preparation were identical to Experiments 1 and 2.

Procedure and design. With 48 pictures, the experiment comprised 384 trials presented across four experimental blocks that were separated by short breaks. Unlike in Experiments 1 and 2, pictures and conditions were randomly distributed across blocks with the restriction that no picture could be repeated across two consecutive trials. Testing sessions lasted approximately 45 minutes. All other aspects of the procedure and design were identical to Experiment 2.

Results and Discussion

Table 1 presents the mean RTs for correct naming trials and mean percentages of errors in the four experimental conditions in Experiment 3. Trials with incorrect naming, stuttering, mouth clicks, or vocal hesitations were coded as errors and discarded. Trials with naming latencies deviating more than 2.5 standard deviations from a participant’s mean RTs in each condition were also discarded. Because error rates were quite low in this experiment (less than 6% of trials were excluded), they were not analyzed. The related condition again produced faster naming times for associate pictures but slower naming times for the target pictures.

Mean RTs were submitted to ANOVA with the between-items factor target type (targets vs. associates) and the within-subjects and -items factor distractor relatedness (related vs. unrelated). This analysis yielded no main effect of target type ($Fs < 3.6$); the main effect of distractor relatedness was significant in the participants analysis, $F1(1, 26) = 13.6$, $MSE = 293.62$, $p < .001$, and was marginally significant in the items analysis, $F2(1, 46) = 3.4$, $MSE = 807.26$, $p = .07$. Most important, there was a highly significant interaction between target type and distractor relatedness, $F1(1, 26) = 102.4$, $MSE = 178.43$, $p < .001$; $F2(1, 46) = 16.9$, $MSE = 807.26$, $p < .001$.

The interaction reflects opposing effects of orthographically related distractor pairs on the two types of pictures. Relative to the unrelated condition, direct orthographic relatedness facilitates naming, *M*diff = −38 ms, $t1(26) = 8.6$, $p < .001$; $t2(23) = 3.6$, $p < .001$, whereas an indirect orthographic relationship interferes with picture naming, Mdiff = 14 ms, $t1(26) = 3.5$, $p < .01$; $t2(23) = 2.0$, $p = .056$.

A strategic explanation that should be considered is that maximizing the orthographic overlap with the competitor, by way of the double distractor approach, combined with the explicit inclusion of the associate pictures in the experiment allowed participants to consciously extract the name of the associate competitor. This conscious connection may have contributed to the emergence of mediated interference effects. Such an account would seemingly predict that interference effects should increase with the ease of extracting the associate's name from the distractors. We evaluated this prediction by comparing mediated interference effects when the distractor word with initial overlap was above or below the distractor word with final overlap. We tested for an interaction between distractor relation (related vs. unrelated) and distractor position (initial over end vs. end over intial) for the target pictures from Experiments 2 and 3. Neither experiment revealed any hint of an interaction, Experiment 2: $F1(1, 23) = 2.04$, $MSE = 491$, $p > .1$; $F2(1, 28) < 1$; Experiment 3: Fs < 1, suggesting that mediated interference effects are not linked to the ease with which the associate's name can be consciously extracted from the distractor pair.

General Discussion

Semantic interference effects have long been viewed as irrefutable evidence for lexical competition. However, the failure to observe comparable effects from noncategorical relations such as associates, among other observations, has cast doubt on this interpretation. The REH reinterprets classic semantic interference as a nonlexical effect involving the evaluation of the response relevance of the distractor words (Costa et al., 2005; Costa, Mahon, Savova, & Caramazza, 2003; Mahon et al., 2007). Here, we evaluate whether interference effects can be observed from distractors that are orthographically similar to a noncategorical relation of the target picture. In light of the trade-off between conceptual facilitation and lexical interference, the lexical cohort account predicts that mediated activation of semantic relations, via orthographically related distractor words, should reveal interference. By increasing the lexical activation of semantic associates, a common type of noncategorical semantic relation, without inducing a comparable activation increase at the conceptual level, interference emerged across two data sets drawn from two different languages.

Lexical competition was not observed when only the target pictures were included in the experiment as naming trials. This finding highlights the importance of the LCA's assumption regarding strongly active competitors. We assume that directly presenting a word leads to greater lexical activation for the corresponding lexical item than priming it with orthographically related words. As such, "camel", as an associate of the target picture pyramid, would not necessarily qualify as a strong competitor when activated only indirectly, as in Experiment 1. Some additional stimulation must be required to make the competitor sufficiently potent to produce observable interference effect. That was achieved by including the competitors in the set of naming trials. The results from Experiment 2 and 3 are remarkably similar. In both instances we find mediated semantic interference from associates. The results are startling because they demonstrate that nontarget lexical alternatives that do not induce measurable interference effects when directly activated do interfere when indirectly activated. Why do these effects emerge? According to the LCA, they emerge because the conceptual activation that normally occurs when a word is presented was avoided by using the mediated procedure. By disassociating lexical and conceptual activations, lexical competition could be observed.

The mediated interference effect observed in Experiments 2 and 3 are incompatible with the REH. The distractors shown here were semantically unrelated to the target. Therefore, the REH does not predict that these words would interfere more than unrelated words because the distractor words do not, by any definition, satisfy the implicit response criteria of the target pictures. Indeed, the REH cannot account for any of the mediated semantic interference effects that have been reported in the literature without additional assumptions (Abdel Rahman & Melinger, 2008; Hantsch et al., 2005; Hermans et al., 1998; Jescheniak & Schriefers, 1998; Peterson & Savoy, 1998). Moreover, although the REH could accommodate previous mediated categorical interference effects by assuming that the orthographically primed competitor name enters the response buffer instead of the distractor word itself, such an account could not explain the present results where targets and associates were drawn from different semantic categories. To be clear, as the REH does not predict that directly activated associates will slow naming times, it cannot account for a slowdown from indirectly activated associates. Proponents of the REH might suggest that by including the intended associates in the response set we made the associates more relevant competitors. Although this may be true (see below) this alone cannot account for the present results, as facilitation has been observed in experiments in which the associate distractor words were included in the set of target pictures (Abdel Rahman & Melinger, 2007).

Detecting Small Traces of Noncategory Competitor Interference

The LCA did not directly predict the null effect observed in Experiment 1. Indeed, on the basis of the experimental logic outlined in the introduction, we expected to reveal weak mediated semantic interference effects. We did, however, predict that mediated interference effects should be small and be even smaller from noncategorical than from categorical competitors. As outlined in the introduction, this follows from the principle of converging and diverging activation. Our principal claim is that activation within the conceptual network converges and resonates within categories and diverges across noncategorical relations. Hence, even without the presentation of a distractor word, when a picture such as camel is presented, at the conceptual level all animals will be activated and that activation feeds back to other members of the same category, conserving the activation within the local neighborhood. In contrast, the activation sent from camel to noncategorical relations will not feed back into a cohesive set of relations but will diverge throughout the network, due to the lack of interconnectivity. As a result, the associate competitor will be less active than a coordinate competitor and competition will be even harder to detect.

O'Seaghdha and Marin (1997, see also Dell & O'Seaghdha, 1991, 1992) argued that detecting mediated semantic effects by phonologically priming a competitor was extremely difficult and "near the limit of the sensitivity of the naming task" (p. 226). We tried to increase the strength of the competitor's activation by presenting two form-related distractor words, which has been shown to produce more form facilitation than when only a single related distractor word is presented. Indeed, our direct orthographically related distractor conditions were highly effective at producing robust form priming effects (61 ms in Experiment 2 and 38 ms in Experiment 3). However, this manipulation was clearly insufficient on its own to induce reliable mediated semantic interference effects. As suggested by Dell and O'Seaghdha, we may have overestimated the sensitivity of the PWI paradigm and its ability to detect extremely small traces of competition that arises between a target and one active lexical competitor, revealing it to be even weaker than initially anticipated. We may also have overestimated the activation level of the competitor. As mentioned above, indirect activation of lexical competitors will necessarily achieve weaker activation than direct stimulation. We have introduced two manipulations to strengthen potential effects that will be discussed below. First, we have presented two form-related distractors, and second, we have included the distractor in the response set (Experiments 2 and 3). Our results demonstrate that, if the activation of the competitor can be sufficiently boosted from multiple sources, competition can emerge. This is discussed in more detail in the following sections.

Double Distractor Method

In the present study, we used a modified variant of the well-known picture–word interference paradigm whereby we presented two, rather than one, distractor words together with the to-be-named picture. Our motivation for using this variant was to maximize the amount of form priming of the associate, under the assumption that more form priming would make the associate a stronger potential competitor (Abdel Rahman & Melinger, 2008). The potential drawback of using this method is that we do not know exactly how the word recognition system treats the simultaneous presentation of two words.

One arising issue, then, is that we cannot be sure that both distractor words were processed in parallel or even at all. It is possible that on any given trial only one of the two distractors was processed. Although we have no independent measure in the current study to evaluate whether both words were processed, there is good evidence to support the assumption that they were. First, Balota and Paul (1996) found additive effects of two primes presented in quick succession in both lexical decision and word naming. Melinger and Abdel Rahman (2004) likewise found additive effects of two simultaneously presented distractor words using the same double distractor variant of the PWI paradigm used in the present study. Abdel Rahman and Melinger (2008) also found that presenting two orthographically related words, one with word initial overlap and one with word final overlap, produced significantly more form facilitation than either form-related distractor word alone. Furthermore, the presentation of two categorically related words resulted in strongly increased semantic interference effects. Together, these studies support the assumption that both distractor words not only are processed but also impact the naming latencies for the target word.

Hence, it appears that each word has its impact on target naming. But what the above studies do not reveal is whether the distractor words are processes in parallel or in sequence. The REH crucially proposes that the output buffer is a single channel buffer that can hold only a single word at a time. This assumption is central to their account of semantic interference effects, because, if the output buffer could hold more than a single word at a time, the picture name would not have to wait for the distractor word to be cleared from the buffer. Therefore, to account for the results obtained with the double distractor method, proponents of the REH would have to assume that the two distractor words are processed in sequence. It is unclear whether the "privileged access" that a written word has to the output buffer would also apply to a second distractor word, but it seems that is what the REH must maintain. Abdel Rahman and Melinger (2008, Experiment 1) also found that presenting two categorically related distractor words (e.g., picture: dog; distractors: horse + lion) produced more semantic interference than presenting a single categorically related distractor word together with an unrelated word (e.g., picture: dog; distractors: horse + table). To account for this finding within the REH, both words must gain access to the output buffer, presumably sequentially. The lexical cohort account is agnostic on the parallel versus serial question, although it clearly prefers a parallel processing interpretation.

The Contribution of Potential Competitors in the Response Set

The comparison of Experiments 1, 2, and 3 demonstrates that the inclusion of the associate pictures within the response set contributed to the emergence of the interference effect in some way. We have suggested that it should have strengthened competitor activation and thus enhanced the chances to find even small signs of competition from noncategorical competitors. In the following we outline and discuss different scenarios on how the response set has contributed to our results. One potential way the associate pictures may have influenced target naming times is by highlighting the relationship between the target and associate. Indeed, there may have been multiple cues in Experiments 2 and 3 that concretized the relationship between the target and the associate, thereby increasing the potential for competition. Thus, it is important to determine whether the interference is driven by the inclusion of the associate pictures in the response set or is due to the co-occurrence of the same related distractor pairs with both target and associate pictures. This latter possibility could emerge from a semiconscious observation by participants of the triangulation between the target picture, the associate picture, and the related distractor pair. If triangulation were crucial to the emergence of the effect, it would undermine the claim that associates are competing lexically in everyday language use. Because we included two different related distractor pairs for each picture in our experimental design, we can extract a subset of trials in which the targets and associates are presented with different related distractor pairs, thereby unbinding the stimuli.

To this end, we conducted a post hoc analysis that focused on the first quartet of naming trials (a quartet included the target picture in the related condition, the target picture in the unrelated condition, the associate picture in the related condition, and the associate picture in the unrelated condition). The criterion for including an item in the analysis was that its complete quartet had to be named before the opportunity for triangulation occurred. In particular, the first quartet was included in the analysis only if (a) the first presentation of the target picture in the related condition preceded the first presentation of the associate picture with the same distractor pair and (b) the latter also followed the first presentation of the target and associate pictures in the unrelated condition. As an example, consider the target–associate pair of Pferd (horse)–Kutsche (carriage), paired with two related distractor pairs (Pair 1: Pfund/Bord, Pair 2: Pfennig/Mord). If the first presentation of Pferd in the related condition was with Pair 1 and the first presentation of Kutsche was with Pair 2, it is possible that a whole quartet could be named before the participant saw the same related distractor pair in conjunction with both the target and the associate. Hence, no opportunity for triangulation would be present.

Based on these criteria, 20 target–associate pairs were identified from Experiment 2 but only 12 were identified from Experiment 3.[5] Therefore, we restricted this analysis to the results of Experiment 2. We included 1,896 naming trials in the analysis. Using this small, constrained set of trials, we evaluated whether the mediated semantic interference effect persists even when target and associate pictures were presented with different related distractor pairs.

These 20 targets and associated competitors were compared across the 24 participants from Experiment 2 to test for mediated interference in the absence of triangulation. Already at this early stage in the experiment, with only a quarter of the repetitions and only two thirds of the item power, we observed main effects of distractor relatedness and target type in the participants analyses only, $F1(1, 23) = 8.83$, $MSE = 1{,}335$, $p = .007$; $F2 < 1$ and $F1(1, 23) = 78.99$, $MSE = 1{,}762$, $p < .001$; $F2 < 1$, and crucially the predicted interaction of distractor relatedness and target type in both analyses, $F1(1, 23) = 51.5$, $MSE = 1{,}418$, $p < .001$; $F2(1, 27) = 15.833$, $MSE = 2{,}594$, $p < .001$. This interaction reflects an orthographic facilitation effect for the associate pictures, $M\text{diff} = -77$ ms, $t1(23) = 9.32$, $p < .001$; $t2(8) = 2.81$, $p = .023$, and a mediated semantic interference effect for the target pictures, $M\text{diff} = 32.9$, $t1(23) = 2.6$, $p = .016$; $t2(19) = 2.9$, $p = .008$. This finding suggests that the important difference between Experiment 1 and Experiments 2 and 3 is in the inclusion of the associate pictures, rather than a dependence on the coincidence of the distractor pairs with the target and the associate pictures. This argues against any strategic approach that emerges from a conscious awareness of the link between the directly related distractors and the two pictures.

Thus, this post hoc analysis examining the contribution of the binding of target and associate due to the co-occurring distractor word pairs undermines the hypothesis that our effect was dependent on a conscious awareness of the link, as we should have observed weaker or even nonsignificant interference when we removed one of the cues linking target and associate. Instead, the effect remained strong and robust, even with reduced item power.

Alternatively and as argued above, because the target and associate pictures were all intermingled, associates may still have been partially activated when naming targets, making them stronger competitors. This account maintains the principal assumption of the LCA, namely, that all active lexical items compete for selection irrespective of how active they are. That being said, given the imperfect sensitivity of the task, very weak competitors will not always produce observable effects. It should also be noted that highlighting the relationship between target and associate cannot be the whole story. Previous experiments that included associative competitors as naming responses failed to observe interference, suggesting that merely highlighting the associative relationship and/or increasing the activation level of an associate in a nonmediated PWI experiment is insufficient to produce interference (Abdel Rahman & Melinger, 2007). Thus, mediated activation that bypasses the conceptual priming is a key element to observing associative interference effects.

Another possibility is that competition emerges only when the activation level of competitors reaches some minimal threshold of activation. La Heij, Boelens, and Kuipers (2010) have invoked an activation threshold to account for several observations in the literature, including the facilitative effects of semantically related masked distractor words (Finkbeiner & Caramazza, 2006), the absence of an interference effect in the picture–picture interference paradigm (Meyer & Damian, 2007), and their own failure to observe an object-interference effect when the object names are active. Such an assumption on the conditions required to observe interference would account for why our interference effects are present only when the associates are included within the response set. That is, it is possible that the boost in the level of activation for the associate competitor due to the presentation of two orthographically related words was insufficient to breach the threshold for entering into competition. However, when the associates were also in the response set, the additional residual activation from prior naming may have been sufficient to allow them to enter into competition. Note that the associate would be more active across the board, not only in the related condition. But, they would be more active than an unrelated competitor (also in the response set) only when they received the additional boost from the form-related distractors. Hence, under this account, in all three experiments the difference in activation levels between competitors in the associated and unrelated conditions would be equivalent. But only in Experiments 2 and 3 did the activation levels cross the threshold that allows them to affect target selection times.

A third possible explanation could rest in the relative target-set sizes used in Experiment 1 compared to Experiments 2 and 3. Experiment 1 included half the pictures of Experiments 2 and 3 (i.e., 30 vs. 60 pictures), and each picture was repeated eight times. La Heij and van den Hof (1995) demonstrated that the size of the semantic interference effect increases with larger target set sizes. Therefore, it could be that doubling the number of pictures without doubling the number of repetitions increased the semantic interference. Certainly, 30 pictures is not normally considered a small set size, but it could be that this number was insufficient when testing for mediated associative interference. Consider the fact that in La Heij and van den Hof's (1995) Experiment 1, 16 pictures each repeated eight times failed to produce reliable categorical interference. In contrast, Jescheniak and Schriefers (1998) presented only 18 items in three distractor conditions and four stimulus onset asynchronies, and they succeeded in observing reliable mediated semantic interference. So the number of items clearly is not the only factor. In the current study, we tested for a much more subtle interference effect that might have required the larger set used in Experiments 2 and 3.

[5] Due to the differences in the randomization protocols used in these two experiments, fewer items could be identified in Experiment 3 than in Experiment 2.

To conclude, we acknowledge that the composition of the set of naming trials contributed to the emergence of mediated noncategorical semantic interference in Experiments 2 and 3. However, that fact does not, by itself, undermine the support that mediated interference effects provide for lexical competition. Admittedly, mediated interference from noncategorical competitors is necessarily small and difficult to detect. Including the associates as pictures clearly served to boost the activation level of their respective lexical representations, rendering the effects of lexical competition easier to detect.

Categorical Versus Noncategorical Semantic Relations

For years, there was a lively debate as to whether nontarget lexical representations were phonologically active. Today, there is general agreement that at least some nontarget activation reaches the wordform level. The implication of past mediated semantic interference studies is that competitors from the same semantic category are phonologically coactive (Abdel Rahman & Melinger, 2008; Hantsch et al., 2005; Hermans et al., 1998; Jescheniak & Schriefers, 1998; Peterson & Savoy, 1998). The implication of Morsella and Miozzo's (2002) picture–picture study, in which phonologically related distractor pictures sped target picture naming, is that nontarget pictures are phonologically coactive. The present study is the first demonstration that associates of the target word are also coactive at the wordform level, if only very weakly.

Although direct associate distractor presentation does not result in category-like interference effects, there are good reasons to assume that associates and other noncategorical relations are lexically active. For one, several studies have demonstrated that the names of physical features of objects, such as their color, are active during object naming (Kuipers & La Heij, 2009; Navarrete & Costa, 2005). More generally, word meanings are not exclusively composed of categorical relations but also comprise associative relations between categories. Assuming that the various aspects of meaning are activated upon picture naming (which most models of speech production do), associate and other noncategorically related concepts should pass their activation to their lexical nodes. What makes noncategorical relations different from categorical relations, according to the trade-off account presented above, is that activation from a different-category distractor *diverges* onto concepts that are not interconnected. Because there is only one lexical node receiving activation from both picture and distractor processing (the lexical entry of the associate itself), the number of competing lexical representations and, hence, the amount of nontarget activation to compete with the target are strongly reduced. In the case of direct associate presentation, conceptual priming should be strong enough to mask lexically induced interference, and hence target selection should be faster than it is with categorically related distractors. We take this lack of converging activation onto a common semantic cohort—and the resulting relatively stronger conceptual priming— as a potential explanation for the difference between the two types of semantically related distractor effects.

Although our appeal to convergence and divergence is, to our knowledge, novel in the context of semantic activation spread, similar constructs have been proposed for other sorts of similarity. For instance, clustering coefficient (*C*;Watts & Strogatz, 1998) is an index of the similarity between neighbors of a target word. *C* is high when many of the target word's neighbors are also neighbors of each other; *C* is low when the target word's neighbors are not neighbors of each other. In the context of phonological similarity, *C* has been shown to influence speech errors and picture naming times in production (Chan & Vitevitch, 2010) as well as the speed of perceptual identification and lexical decision in auditory word recognition (Chan & Vitevitch, 2009). In terms of spreading activation, when *C* is high, the spread of activation remains within the set of common neighbors, converging into what Chan and Vitevitch (2010) called a "reservoir of activation." When *C* is low, activation diverges out into different subregions of the network. Clearly, our conception of converging and diverging activation at the conceptual level shares many characteristics with the clustering coefficient. It remains to be seen whether a similar level of mathematical rigor can be developed for the semantic cohort approach developed by Abdel Rahman and Melinger (2007, 2009a, 2009b) such that a semantic variant of *C* can be calculated and used to make predictions for production experiments.

Throughout this article we have contrasted the lexical cohort account, as a representative of competitive models, to the REH, as a representative of noncompetitive models. Similar to the REH, in other noncompetitive proposals (Dell, 1986; Oppenheim, Dell, & Schwartz, 2010; Rapp & Goldrick, 2000) the time required to select the target lemma is unaffected by the competitors' activation levels. Also, an active representation cannot negatively impact the activation levels of its competitors. However, in many respects the REH is an atypical exemplar of this class. We would be remiss not to recognize that other noncompetitive models localize semantic interference effects at the lexicosemantic level (Dell, 1986; Oppenheim et al., 2010; Rapp & Goldrick, 2000). For example, Oppenheim et al. (2010) recently presented an account of cumulative semantic interference, observed with a variant of semantic blocking that lacks repetition (see Howard, Nickels, Coltheart, & Cole-Virtue, 2006), which does not involve lexical competition. According to this model, interference effects arise due to changes in the weights between conceptual and lexical representations. In particular, when naming a picture of a cat, the links between the conceptual and lexical representations of semantically related words, such as "horse" and "dog" are weakened. Hence, on subsequent trials when one needs to name horse or dog, activating the relevant lexical representation is harder than it would have been had the previous naming event of "cat" not taken place. By implementing weight changes as a mechanism to induce interference, this model does not need lexical competition. However, it is unclear at present whether such a model is appropriate for interference effects induced by simultaneously presented distractor words.

It should be borne in mind that alternative noncompetitive models may be more compatible than the REH with the present results. Likewise, there are other variants of noncompetitive models that do maintain a late locus of semantic interference effects. Recently, Dhooge and Hartsuiker (2010, 2011) have suggested that the self-monitoring mechanism, rather than a single channel located in the response buffer, might underlie semantic interference effects. This proposal benefits from decades of independent evidence for a self-monitor that checks the output for congruency with the message. Although this account is more economical than the REH (by virtue of not needing to postulate an extra checking steps), it suffers from the same shortcomings in the face of mediated semantic interference effects. In particular, although it makes sense that monitoring the target response for correctness at the semantic level may be more difficult when a competitor to the target is strongly activated at that level, the same is clearly not true for associates (as they produce facilitation when presented directly), and it is unclear how such an account could explain mediated effects whereby the semantic alternates are not directly presented. In short, any postlexical response exclusion account will struggle to explain why explicit presentation of noncategorical competitors speeds naming but implicit mediated presentation slows it.

In conclusion, the present findings demonstrate phonological/orthographic coactivation of associates that have no categorical relation to the target. In line with previous research, however, these effects are small and observable only under specific conditions that maximize the chances for detecting even small traces of interference. Our results suggest that associates are active at the lexical level and compete with the target utterance for selection, in line with speech production models incorporating competition at the level of lexical selection.

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(*Appendices follow*)

Appendix A

Stimuli Used in Experiments 1 and 2

Picture name and translation		Orthographically related pairs			
Target Set 1	Target Set 2	Initial overlap Final overlap	Initial overlap Final overlap	Unrelated word pairs	
Pferd	Kutsche	Pfund	Pfenning	Messing	Bandit
horse	*carriage*	Bord	Mord	Wasser	Germane
Helm	Motorrad	Helfer	Helle	Vorhang	Tochter
helmet	*motorcycle*	Schelm	Alm	Kegel	Geschoepf
Straße	Auto	Strategie	Strahl	Flagge	Pfenning
street	*car*	Größe	Preuße	Asche	Mord
Frau	Kleid	Frage	Franzose	Notiz	Herbst
woman	*dress*	Sau	Stau	Ferien	Schmerz
Bein	Hose	Beileid	Beichte	Kind	Schwester
leg	*trousers*	Schwein	Verein	Wissen	Wert
Mann	Anzug	Mangel	Mango	Krebs	Besteck
man	*suit*	Vorspann	Gespann	Preis	Wesen
Baby	Wiege	Bad	Balkon	Kanu	Flamingo
baby	*cradle*	Hobby	Lobby	Gemurmel	Bursche
Computer	Schreibtisch	Code	Courage	Mangel	Enge
computer	*desk*	Blutter	Euter	Vorspann	Regel
Kissen	Sofa	Kind	Kittel	Bad	Hut
cushion	*sofa*	Wissen	Bissen	Hobby	Lohn
Noten	Klavier	Notiz	Notar	Sorte	Sohn
notes	*piano*	Ferien	Garten	Tonne	Finne
Kirche	Glocke	Kirsche	Kinn	Frage	Honig
church	*bell*	Lerche	Drache	Sau	Stolz
Engel	Harfe	Engpass	Enge	Kaempfer	Kaelte
angle	*harp*	Spiegel	Regel	Chinese	Geblaese
Banane	Affe	Bank	Bandit	Strategie	Fronzose
banana	*monkey*	Plane	Germane	Größe	Stau
Kaese	Maus	Kaempfer	Kaelte	Narr	Volk
cheese	*mouse*	Chinese	Geblaese	Fluegel	Segel
Zahn	Hai	Zar	Zahl	Engpass	Nacht
teeth	*shark*	Wahn	Bahn	Spiegel	Triangel
Holz	Axt	Hotel	Honig	Beileid	Gewinn
wood	*axe*	Malz	Stolz	Schwein	Verkehr
Nagel	Hammer	Narr	Nacht	Besuch	Mango
nail	*hammer*	Fluegel	Triangel	Tresen	Gespann
Kreis	Zirkel	Krebs	Kreide	Helfer	Helle
circle	*compass*	Preis	Gleis	Schelm	Alm
Messer	Brot	Messing	Messe	Schaf	Strahl
knife	*bread*	Wasser	Schlosser	Jahrhundert	Preusse
Huhn	Ei	Hufeisen	Hut	Pfund	Messe
rooster	*egg*	Gedroehn	Lohn	Bord	Schlosser
Herz	Artischocke	Heroin	Herbst	Geweih	Kittel
heart	*artichoke*	Erz	Schmerz	Rohr	Bissen

(*Appendices continue*)

Appendix A (*continued*)

Picture name and translation		Orthographically related pairs			
Target Set 1	Target Set 2	Initial overlap Final overlap	Initial overlap Final overlap	Unrelated word pairs	
Wasserhahn	Spuele	Wald	Watte	Code	Courage
faucet	*sink*	Kahn	Seilbahn	Bluter	Euter
Topf	Herd	Tod	Tochter	Wald	Watte
pot	*stove top*	Zopf	Geschoepf	Kahn	Seilbahn
Flasche	Trichter	Flagge	Flamingo	Bank	Notar
bottle	*funnel*	Asche	Bursche	Plane	Garten
Sonne	Insel	Sorte	Sohn	Kirsche	Kinn
sun	*island*	Tonne	Finne	Lerche	Drache
Kamel	Wueste	Kanu	Kamera	Hufeisen	Balkon
camel	*desert*	Gemurmel	Himmel	Gedroehn	Lobby
Vogel	Nest	Vorhang	Volk	Zar	Zahl
bird	*nest*	Kegel	Segel	Wahn	Bahn
Schwert	Ritter	Schaf	Schwester	Hotel	Beichte
sword	*knight*	Jahrhundert	Wert	Malz	Verein
Besen	Hexe	Besuch	Besteck	Tod	Kreide
broom	*witch*	Tresen	Wesen	Zopf	Gleis
Gewehr	Soldat	Geweih	Gewinn	Heroin	Kamera
rifle	*soldier*	Rohr	Verkehr	Erz	Himmel

Note. Only Target Set 2 was used in Experiment 1. Target Set 1 in combination with the orthographically related pairs constitutes the test of direct orthographic effects. Target Set 2 in combination with the orthographically related pairs constitutes the test of mediated associative effects. For target pictures, the top line is the German picture name with the translation below it in italics. For the related word pairs, the top word provides initial orthographic overlap with the picture name from Target Set 1, and the bottom word provides word final orthographic overlap.

(*Appendices continue*)

Appendix B

Stimuli Used in Experiment 3

Picture names and translations		Orthographically related pairs			
Target Set 1	Target Set 2	Initial overlap Final overlap	Initial overlap Final overlap	Unrelated word pairs	
Banana	Aap	bank	banket	leraar	leven
banana	*monkey*	laan	orgaan	stoppel	gemompel
Woestijn	Kameel	woeker	wonder	schat	schaak
desert	*camel*	lijn	festijn	blaar	haar
Zadel	Paard	zand	zaal	laadruim	lakei
saddle	*horse*	hotel	roedel	teken	keuken
Muur	Steen	muziek	museum	wesp	weer
wall	*stone*	schuur	uur	heg	overleg
Laken	Bed	laadruim	lakei	toeval	toeter
sheets	*bed*	teken	keuken	koord	moord
Toetsenbord	Bureau	toeval	toeter	zand	zaal
keyboard	*desk*	koord	moord	hotel	roedel
Zee	Boot	zwavel	zaagsel	woeker	regenwoud
sea	*boat*	plee	idee	lijn	pils
Rails	Trein	rekensom	regenwoud	spier	zaagsel
tracks	*train*	wals	pils	buit	idee
Weg	Auto	wesp	weer	muziek	museum
road	*car*	heg	overleg	schuur	uur
Spuit	Dokter	spier	spuug	bank	wonder
injection	*doctor*	buit	fruit	laan	festijn
Schaar	Kapper	schat	schaak	zwavel	banket
scissors	*barber*	blaar	haar	plee	orgaan
Lepel	Kok	leraar	leven	rekensom	spuug
spoon	*cook*	stoppel	gemompel	wals	fruit
Vrouw	Rok	vraag	vrachtruim	vloek	boek
woman	*skirt*	mouw	touw	zalm	zaad
Kerk	Bisschop	kelder	kenteken	beugel	vel
church	*bishop*	zerk	werk	naam	natrium
Voet	Sok	voerbak	voer	heuvel	abces
foot	*sock*	stoet	roet	demper	fluweel
Appel	Schaal	apotheek	apparaat	roe	touw
apple	*scale*	klepel	koppel	koek	vrachtruim
Fles	Kurketrekker	flits	fluweel	zerk	werk
bottle	*corkscrew*	les	abces	kelder	kenteken
Deksel	Pan	demper	décor	mouw	taboe
lid	*pan*	heuvel	plaksel	vraag	kostuum
Mes	Brood	merk	mens	protest	rest
knife	*bread*	congres	les	net	nek
Nest	Ei	net	nek	vuur	natuur
nest	*egg*	protest	rest	stuk	student
Koe	Melk	koek	kostuum	stoet	plaksel
cow	*milk*	roe	taboe	voerbak	décor
Stuur	Wiel	stuk	student	congres	les
steering wheel	*wheel*	vuur	natuur	merk	mens
Nagel	Hand	naam	natrium	klepel	roet
nail	*hand*	beugel	vel	apotheek	voer
Zakdoek	Neus	zalm	zaad	les	koppel
handkerchief	*nose*	vloek	boek	flits	apparaat

Note. Target Set 1 in combination with the orthographically related pairs constitutes the test of direct orthographic effects. Target Set 2 in combination with the orthographically related pairs constitutes the test of mediated associative effects. For target pictures, the top line is the German picture name with the translation below it in italics. For the related word pairs, the top word provides initial orthographic overlap with the picture name from Target Set 1, and the bottom word provides word final orthographic overlap.

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