

The mechanism underlying lexical selection: Evidence from the picture–picture interference paradigm

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In two experiments using the picture–picture and picture–word interference paradigms, we compared predictions from the swinging lexical network and the response exclusion hypothesis to determine whether the process of word selection is competitive. Further, we suggest that previous categorical effects in the picture–picture interference paradigm were due to stimuli confounds, thus readdressing the debate concerning categorical effects in the paradigm. Consistent with both hypotheses, in Experiment 1 we found faster picture naming times when distractor pictures were associatively related than when they were unrelated, explained as a result of a spread of activation at the conceptual level with little (swinging lexical network) or no (response exclusion hypothesis) contribution from lexical competition. In Experiment 2, we found a significant categorical interference effect in the picture–word interference paradigm, and this effect significantly decreased but was not facilitatory when distractors were pictures. We discuss how these results are consistent with the swinging lexical network and conclude that the process to select a word is a competitive one.

Keywords: Lexical selection; Competition; Categorical interference.

When speaking, how do we retrieve a desired word from our mental lexicon in the presence of other words? A widespread assumption is that a competitive mechanism underlies lexical selection. Specifically, the selection of a target word depends on the activation levels of both target and nontarget words (e.g., Abdel Rahman & Melinger, 2009; Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992; Starreveld & La Heij, 1995). An alternative view of lexical selection is that the selection of a target word depends solely on the

activation level of target words (e.g., Caramazza, 1997; Dell, 1986; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Oppenheim, Dell, & Schwartz, 2010). In this paper, we present two experiments in order to provide further evidence as to whether lexical selection is competitive or not.

The key difference between the two classes of theories is the impact of nontarget words' activation. Competition theories assume that target selection depends on the activation levels of not only the target word but also nontarget words.

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Computational formulations of this view are based on the Luce choice ratio (e.g., Luce, 1986). The ratio is the activation level of the target word divided by the activation levels of all words in the lexical system. Hence, the higher the activation levels of nontarget words, the more time is needed for the target word's activation to accrue and supersede some fixed amount in comparison to nontarget words in order to be selected. In contrast, noncompetition theories assume that there is an absolute threshold for lexical selection and that once a lexical node reaches the threshold, it is selected, without reference to the activation levels of nontarget words (e.g., Dell, 1986). Therefore, the two classes of theories differ in the influence of nontarget words on target word selection.

A seemingly contrasting set of effects (semantic facilitation and interference) in the same paradigm (picture–word interference) posed a challenge to both the competition and the noncompetition theories. In the picture–word interference (PWI) paradigm, participants name pictures and ignore embedded distractor words. On one hand, naming is slower when a picture (e.g., *dog*) is paired with a semantically related word (e.g., CAT) than when it is paired with an unrelated word (e.g., TABLE; e.g., Glaser & Dungenhoff, 1984; Glaser & Glaser, 1989; Schriefers, Meyer, & Levelt, 1990). This interference effect, as explained by competition theories, is due to higher levels of activation from categorically related distractor words than from unrelated distractor words.¹ However, the interference effect observed in the PWI paradigm is restricted to category membership between picture and distractor only. When the distractor words are associatively related to the target picture, a facilitation effect is observed (e.g., picture naming (e.g., *dog*) is faster in the context of semantically associative distractor words (e.g., BONE) than in the context of unrelated distractor words (e.g., TABLE; Alario,

Segui, & Ferrand, 2000; Costa, Alario, & Caramazza, 2005; see Mahon et al., 2007, for a review). These findings are difficult to reconcile with competition theories (e.g., Levelt et al., 1999; Roelofs, 1992, 2003), because without making additional assumptions, competition theories predict that all semantically related words should produce an interference effect in the PWI paradigm compared to unrelated words. On the other hand, without positing further assumptions, the categorical interference and associative facilitation effects also present a challenge to noncompetition theories. Noncompetitive theories predict that both category and association should produce facilitation effects because of the spread of activation from semantically related distractor words to the targets' concepts, which should facilitate target identification at the conceptual level (Mahon et al., 2007). Thus, on the face of it, competitive and noncompetitive theories have difficulty reconciling both semantic facilitation and interference effects in the PWI paradigm.

To account for this apparent polarity of semantic effects in the PWI paradigm, additional assumptions were added to a competition account (in the form of the swinging lexical network; Abdel Rahman & Melinger, 2009) and a noncompetition account (in the form of the response exclusion hypothesis; Mahon et al., 2007) of lexical access. The swinging lexical network assumes that interference and facilitation effects in the PWI paradigm are caused by a trade-off between conceptual facilitation and lexical competition (Abdel Rahman & Melinger, 2009). Whether lexical competition is strong enough to override conceptual facilitation depends on the number of competitors activated by *both* the target and the distractor (i.e., semantically related vs. unrelated distractors to a target). For example, a target picture (e.g., *dog*) and a categorically related word (e.g., CAT, related by virtue of a shared category node and semantic features) will

¹ One important assumption is that there is a spread of activation between related targets and word distractors at the conceptual level (e.g., Caramazza, 1997; Dell, 1986). Because the concepts of targets and semantically related distractors share semantic features, the lexical representations of the related distractors receive activation from two sources (the target picture and the distractor word), whereas those of the unrelated distractor words receive activation only from one source (the distractor word). Thus, the semantically related distractor becomes a stronger competitor than the unrelated distractor.

spread *converging* activation to competitors that share the same category node and semantic features. This is known as “one-to-many” competition, and lexical interference will dominate the conceptual facilitation. By contrast, the associatively related word (e.g., BONE) exhibits only “one-to-one” competition with the target (e.g., *dog*) because the activation from the target and distractor does not converge onto other related concepts. Thus, conceptual facilitation dominates lexical interference (Abdel Rahman & Melinger, 2009). The swinging lexical network thus explains how semantic facilitation and interference in the PWI paradigm depend on the nature of relatedness between targets and distractors.

On the other hand, the response exclusion hypothesis (Mahon et al., 2007) is also proposed to account for both the facilitation and interference effects in the PWI paradigm. This hypothesis assumes that categorical interference actually occurs at a postlexical level and does not involve lexical competition. In the PWI paradigm, word distractors always occupy the single channel response output buffer before the target picture name arrives in the buffer. This is because words have a privileged relationship to articulation (Mahon et al., 2007, p. 526). Because the output buffer is then occupied by a response that is not the target response, it needs to be cleared (unblocked) before target articulation takes place. Clearing the buffer takes time, and the amount of time depends on the conceptual relatedness between targets and distractor words. When a distractor is categorically related and therefore shares criteria that must be satisfied by a correct response with the target (e.g., target is *dog*, criterion is “*naming an animal*”, distractor is CAT), it takes more time to reject the distractor, clear the buffer, and choose the correct response. By contrast, rejecting associatively related distractors does not take any longer than rejecting unrelated distractors because they do not possess the necessary criteria for response selection (e.g., BONE does not satisfy criterion “*naming an animal*”). Therefore, these distractors produce a facilitation effect due to conceptual priming. The response exclusion hypothesis explains the interference effect produced

by categorically related distractors as a postlexical effect and the facilitation effect produced by associatively related distractors as a conceptual effect.

Although the swinging lexical network and the response exclusion hypothesis both account for categorical interference and associative facilitation effects in the PWI paradigm, we turn to another production paradigm—the picture–picture interference (PPI)—paradigm to help discriminate between the two hypotheses in their assumptions of whether lexical selection is competitive (swinging lexical network) or not (response exclusion hypothesis). The PPI paradigm is similar to the PWI paradigm except that pictures are used as distractors instead of words. Because picture naming latencies are faster in the context of phonologically related distractor pictures than in the context of unrelated distractor pictures (phonological facilitation effect; e.g., Meyer & Damian, 2007; Morsella & Miozzo, 2002; Navarrete & Costa, 2005; but see Jescheniak et al., 2009), this suggests that the distractor pictures are processed to the phonological level. If lexical selection occurs prior to phonological encoding, as most language production models assume (e.g., Bloem & La Heij, 2003; Levelt et al., 1999; Roelofs, 1992), the phonological facilitation effect suggests that distractor pictures activate their lexical nodes similar to the effect of distractor words in the PWI paradigm (although distractor pictures activate lexical nodes from the conceptual level while distractor words have a direct route to lexical activation via a lexical reading route; Roelofs, 1992, 2003). Thus, we can use the PPI paradigm to test hypotheses about the nature of lexical selection.

Both the swinging lexical network and response exclusion hypotheses make predictions concerning the effect of associatively, categorically, and unrelated distractor pictures in the PPI paradigm on naming. Regarding an associative relationship between target and distractor picture, both hypotheses predict that associatively related distractor pictures will create a facilitation effect in naming. The swinging lexical network assumes that the conceptual facilitation overrides the one-to-one competition produced by associates, and the response exclusion hypothesis proposes that in the absence

of a privileged relationship to the output buffer, all categorically/associatively related distractor pictures should produce a conceptual facilitation effect.

Critically, the swinging lexical network and response exclusion hypotheses diverge in their predictions concerning the effect of categorically versus unrelated picture distractors on naming. Because the swinging lexical network proposes that semantic effects are caused by a trade-off between lexical competition and conceptual facilitation, in the PPI paradigm this hypothesis predicts interference from categorically related distractor pictures by assuming that the one-to-many competition at the lexical level overrides conceptual facilitation. In contrast, the response exclusion hypothesis predicts a facilitation effect because pictures do not have a privileged relationship to the buffer. Given that no exclusion mechanism is involved, the only predicted effect is conceptual facilitation (see Mahon et al., 2007, p. 526). Thus, a PPI paradigm with associatively/categorically related and unrelated distractors will provide evidence to discriminate between these two hypotheses and further determine whether lexical selection is a competitive or noncompetitive process.

Although it is well established that categorically related distractor words yield interference in the PWI paradigm, the effects of categorically related distractor pictures in the PPI paradigm are inconsistent. Glaser and Glaser (1989, Experiment 6) found interference in the context of categorically related distractors (consistent with the swinging lexical network), La Heij, Heikoop, Akeboon, and Bloem (2003) found semantic facilitation (consistent with the response exclusion hypothesis), while others found no effect at all of categorically related distractor pictures on picture naming response times (Damian & Bowers, 2003; Navarette & Costa, 2005; Roelofs, 2008). The inconsistent results are at least partially due to methodological flaws (Damian & Bowers, 2003; La Heij et al., 2003). For example, in Glaser and Glaser's Experiment 6, whereas a PWI task usually consists of more than 20 pictures from many different categories, Glaser and Glaser used only nine pictures from three semantic categories (i.e., body parts, furniture, and animals). Furthermore, those nine

pictures were used as both target and distractor pictures throughout the experiment, potentially resulting in the nine pictures' names being highly activated and interfering with target picture naming. Second, which picture was considered the "target" picture was determined exclusively by the order of presentation of the two stimuli. However, the stimulus onset asynchrony (SOA) between both pictures was so short (–50 ms, 50 ms, 100 ms) that subjects probably had difficulty identifying which pictures were supposed to be the targets as supported by the large number of naming errors (related: 10.2%; unrelated: 11.0%) and the especially large number of errors due to naming the distractor picture (related: 8.3%, unrelated: 7.7%; for more detail; see La Heij et al., 2003). To address the methodological issues, La Heij et al. (2003) performed the same experiment but selected 40 picture pairs from several different semantic categories, where no picture appeared as both the target and distractor. Under these new experimental conditions, participants produced faster naming latencies in the context of semantically related versus unrelated distractor pictures, a finding consistent with the response exclusion hypothesis. However, half of the semantically related distractors were related to their targets by category (e.g., *horse* and *sheep*), while the other half of their distractors were related to their targets by both category and association (e.g., *hand* and *finger*), potentially contaminating the results (the association strength was .09 on a scale of 0 to 1, where the larger the number the greater the association, based on association norms by Nelson, McEvoy, & Schreiber, 2004). As a result, because of the methodological problems and inconsistent results in previous PPI studies, it is difficult to conclude whether the swinging lexical network or response exclusion hypothesis provides the most accurate description of the underlying mechanism of lexical selection.

The purpose of our study was to discriminate between the swinging lexical network and response exclusion hypotheses to provide evidence for the mechanism of lexical selection, while improving upon previous PPI designs. To demonstrate feasibility of the PPI paradigm given previous inconsistent results (Glaser & Glaser, 1989; Damian &

Bowers, 2003; La Heij et al., 2003; Navarette & Costa, 2005; Roelofs, 2008) and to test predictions from the swinging lexical network and response exclusion hypotheses, in Experiment 1 we conducted a PPI experiment with associatively related and unrelated picture distractors, finding a facilitation effect predicted on both theoretical and empirical grounds. In Experiment 2, to distinguish between the swinging lexical network and response exclusion hypotheses, we employed the PWI and PPI paradigms with the same categorically related versus unrelated conditions, while improving upon the problematic designs of previous PPI studies. First, to resolve the confounded associative and categorical relationship between targets and distractors in La Heij et al.'s (2003) materials, we used Nelson et al.'s (2004) association norms to select target and distractor pictures to ensure no or extremely low association strength. Second, to signal which of the two pictures in the PPI was the target, instead of using order of presentation (as in Glaser & Glaser, 1989, and La Heij et al., 2003), target pictures were presented in green and were superimposed with distractor pictures in red, a method adopted in recent PPI studies (e.g., Jescheniak et al., 2009; Meyer & Damian, 2007; Navarrete & Costa, 2005). Lastly, we tested the strength of the categorical relationship between picture and distractor by conducting a PWI experiment with the same materials but using distractor words instead of distractor pictures. To our knowledge, ours is the first study to distinguish the associative and categorical effects in the PPI paradigm, thus readdressing the debate concerning categorical effects in the PPI paradigm. To preview the results, we found a significant interaction between the size of the categorical interference effect in the PWI and PPI, finding interference in PWI, and no facilitation in the PPI experiment, a result inconsistent with the response exclusion hypothesis. The lack of categorical interference in the PPI is consistent with the swinging lexical network if it is assumed that picture distractors have a more direct link to conceptual representations than do word distractors (in line with proposals by Roelofs, 1992), a point we return to in the General Discussion.

EXPERIMENT 1: PPI WITH ASSOCIATION

Method

Participants

In Experiments 1–2, participants were native English speakers at Rice University who received experiment credit for their participation. Before participating, all subjects gave informed consent in accordance with the protocol approved by the Institutional Review Board of Rice University. Twenty-one subjects took part in Experiment 1.

Materials

Thirty pictures were used as target pictures, and an additional 30 pictures were used as associatively related distractors (pictures were taken from Snodgrass & Vanderwart, 1980). These associatively related distractors (association rate: .15) were chosen based on Nelson et al.'s (2004) association norms, which measure the degree of association between two words (the larger the number, the greater the associative relatedness, on a scale of 0 to 1). Unrelated distractor pictures (association rate: 0) were selected from the same set of 30 related distractors, but shuffled such that there was no semantic or associated relationship between targets and unrelated distractors. The associative picture pairs were significantly more associated than the unrelated pairs, $t(29) = 4.23$, $p < .001$. Because items were identical in associatively related and unrelated conditions, there was no difference between conditions in age of acquisition, familiarity, word frequency, number of letters, or number of syllables. Additionally, there was no phonological relationship (onset or rhyme) between targets and related and unrelated picture distractors. We selected a different set of 30 pictures to use as filler distractors (unrelated to the target) in order to reduce the proportion of related items to one third of all trials. Each of the 30 target pictures was displayed in green on top of one of three different distractor pictures in red: an associatively related distractor, an unrelated distractor, and an unrelated filler. These pictures were altered, edited, and superimposed using Adobe

Photoshop. The complete set of target–distractor pairs is reported in Appendix A.

Design

The experiment contained 90 trials, 30 in the associatively related, 30 in the unrelated, and 30 in the unrelated filler conditions. The 90 trials were split into three different blocks of 30 trials each. Every target occurred exactly once in each block with an associatively related, unrelated, or filler distractor picture. This allowed the two conditions (associatively related and unrelated) to be evenly distributed across the blocks (10 trials of each condition per block). Trial presentation within each block was pseudorandomized such that no consecutive target pictures were semantically or phonologically related, and no two associatively related conditions occurred consecutively. Each subject saw all three blocks, and the order of block presentation was balanced among all 21 participants. Three warm-up trials using practice items were included at the beginning of each block.

Procedure

The experiment was conducted using DMDX software (Forster & Forster, 2003). All subjects were tested individually in a testing room and with an experimenter in the room to record errors. Each item comprised two superimposed pictures, one in red and one in green, which were displayed on a colour monitor. The combined pictures were scaled to 300 × 300 pixels. The participants were instructed to name the green pictures and ignore the red pictures.

There were a total of three phases throughout the course of the experiment. First was the learning phase, in which participants familiarized themselves with the exact names of the 30 target pictures. Pictures were shown with their names underneath but without superimposed distractors, and they stayed on the screen until the subjects named them out loud. In order to familiarize participants with the procedure of the experiment, they were also given a practice phase in which they were presented all 30 target pictures with superimposed distractor pictures that did not appear in any of the experimental trials (but were

the same pictures as those used for fillers). The third and final phase was the experimental phase. During this phase, a fixation point (+) was displayed in the centre of the screen for 700 ms and was then replaced by the picture–picture stimulus. Stimuli disappeared as soon as the participants responded. If the voice key was not triggered, the picture was shown for 3 s before the next trial began. The subjects were asked to respond as quickly and as accurately as possible. Experiment 1 lasted 15 min.

Results

Response times were discarded from the analyses whenever any of the following occurred: (a) A picture was named incorrectly; (b) subjects made a noise (e.g., loud breath, cough); (c) the voice-key failed to trigger; or (d) response times (RTs) deviated from a participant's mean by more than three standard deviations. In Experiment 1, 3.9% of the data points were removed. Paired-sample *t* tests comparing RTs or errors when distractor pictures were associatively related and unrelated were computed using both subjects (t_1) and items (t_2) as random variables.

In the error analysis, there was no difference between associatively related (.02) and unrelated (.02) conditions ($ts < 1$). In the analysis of response times, there was a significant difference between the two conditions, with faster response times in the associatively related (698 ms) than in the unrelated (727 ms) condition, $t_1(20) = 4.96$, $p < .001$; $t_2(29) = 2.62$, $p = .01$ (see Table 1).

Discussion

In Experiment 1, target pictures were named more quickly in the context of associatively related than in the context of unrelated distractor pictures, consistent with both the swinging lexical network (Abdel Rahman & Melinger, 2009) and the response exclusion (Mahon et al., 2007) hypotheses. The swinging lexical network assumes that the conceptual facilitation is greater than any one-to-one lexical competition created by the associated pictures, while the response exclusion hypothesis

Table 1. Response times and error rates in Experiments 1 and 2

<i>Experiment</i>	<i>Associatively related</i>	<i>Categorically related</i>	<i>Unrelated</i>	<i>Difference^a</i>
Experiment 1 (PPI)	698 (.02)		727 (.02)	29*
Experiment 2 (PWI)		693 (.04)	671 (.04)	22*
Experiment 2 (PPI)		686 (.03)	684 (.03)	2

Notes: Response times in ms. Error rates in parentheses. PPI = picture–picture interference. PWI = picture–word interference.

^aDifference between related and unrelated conditions.

* $p < .05$.

proposes that in the absence of a privileged relationship from pictures to the output buffer, all categorically/associatively related distractor pictures should produce a conceptual facilitation effect.

Experiment 1 suggests that previous inconsistent results in associative PPI (i.e., Glaser & Glaser, 1989 vs. La Heij et al., 2003) were due to the nature of the relationship between target and distractor pictures. Although the La Heij et al. (2003) experiment was designed to compare naming with categorically related versus unrelated distractor pictures, the categorical picture pairs were significantly more associated than the unrelated pairs (association norms for the categorically related (.09) and unrelated (0) conditions were significantly different from each other, $t(39) = 3.91$, $p < .001$, and no different in association norms from the materials in Experiment 1 (La Heij et al.'s Experiment 2: .09; our Experiment 1: .15), $t(68) = 1.54$, $p = .13$, which resulted in a semantic facilitation effect in the PPI experiment. Thus, the La Heij et al. categorical “facilitation” effect appears to be a result of unwanted association relationships between targets and distractors.

To discriminate between the response exclusion hypothesis and swinging lexical network, in Experiment 2 we manipulated the categorical relationship between target pictures and word/picture distractors. As described in the introduction, the response exclusion hypothesis predicts faster naming times in the presence of categorically related than in the presence of unrelated picture distractors because there is a spread of activation at the conceptual level, but no interference created by lexical competition. In contrast, the swinging lexical network does not predict facilitation at all.

Because there is both interference produced by lexical competition and a spread of activation at the conceptual level, the swinging lexical network predicts either the same amount of categorical interference as traditionally seen in the PWI, or a reduced amount as a result of a combination of conceptual facilitation and lexical interference. We conducted Experiment 2 using the same materials in both PWI and PPI paradigms.

EXPERIMENT 2: PWI AND PPI WITH CATEGORY

Method

Participants

Ninety native English speakers took part in Experiment 2. Forty-five subjects participated in the PWI with categorically related and unrelated distractors, and a different 45 participated in the PPI with the same stimuli.

Materials and design

In this experiment, 30 line drawings were used as target pictures (taken from Snodgrass & Vanderwart, 1980) and 30 distractors (words for the PWI paradigm and line drawing pictures for the PPI paradigm; pictures were taken from Snodgrass & Vanderwart, 1980) were used as categorically related and unrelated distractors. Regarding association strength between the categorically related and target pairs, save for six pairs with an association of less than .02, the rest of the pairs had no association. The association rates of our materials were significantly lower than the

association rates of the materials in Experiment 1 (Experiment 2: .003; Experiment 1: .15), $t(58) = 4.14$, $p < .001$, and significantly lower than the materials in La Heij et al. (2003; Experiment 2: .003; La Heij et al.'s Experiment 2: .09), $t(68) = 3.26$, $p = .001$. Therefore, we assume that the semantic relationships between our targets and distractors in Experiment 2 are purely categorical, and we can look specifically at the effects of categorically related distractors without any unwanted association relationships. Furthermore, we used the latent semantic analysis (Landauer, Foltz, & Laham, 1998) as a measure of semantic distance. Picture pairs in the categorically related condition had a closer semantic distance (.31) than those in the unrelated condition (.11), $t(29) = 5.24$; $p < .001$. The complete set of target–distractor pairs is reported in Appendix B. The distractor words were in capital letters in Times New Roman 12-point font (8–10 mm). There was no difference in age of acquisition, familiarity, frequency, number of letters, or number of syllables between the categorically related and unrelated conditions. We also included a set of 30 unrelated filler distractor words/pictures. There was no phonological relationship (onset or rhyme) between targets and related and unrelated distractors. All target pictures were scaled to 300 × 300 pixels. The design for Experiment 2 was identical to the design in Experiment 1 except that the distractors were categorically related words or pictures rather than associatively related pictures.

Results and discussion

RT data were preprocessed in the same way as in Experiment 1, and 3.9% of the data points were removed. We removed from analysis 2 of the 30 items (i.e., *horse–monkey*; *drawner–chair*), which had error rates of more than three standard deviations from the mean error rate.

In order to compare the category effects between PWI and PPI, we computed two analyses of variance (ANOVAs) with participants (F_1) and items (F_2) as random variables. Fixed variables were paradigm (PPI vs. PWI) and condition (categorically related vs. unrelated). Paradigm was a

between-subject and within-item variable, while condition was a within-subject and within-item variable. In the error analysis, there were no significant effects ($F_s < 1$). There was no significant difference in naming latencies between PPI and PWI ($F_s < 1$). There was a marginal main effect of condition such that the categorically related condition showed longer response times (690 ms) than the unrelated condition (678 ms), $F_1(1, 88) = 24.25$, $p < .001$, $MSE = 284.45$; $F_2(1, 27) = 2.90$, $p = .10$, $MSE = 3,554.01$. There was a significant interaction between experiment and condition, indicating that the size of the category effect was greater in the PWI paradigm (22 ms) than in the PPI paradigm (2 ms), $F_1(1, 88) = 16.49$, $p < .001$, $MSE = 266.26$; $F_2(1, 27) = 3.55$, $p = .07$, $MSE = 913.36$. When we examined PWI and PPI separately, in the PWI paradigm, a planned t test (two-tailed) demonstrated significantly slower response times in the categorically related (693 ms) than in the unrelated conditions (671 ms), $t_1(44) = 7.17$, $p < .001$; $t_2(27) = 3.40$, $p = .002$ (see Table 1). However, in the PPI paradigm, there was no significant difference between categorically related (686 ms) and unrelated conditions (684 ms), $t_s < 1$ (see Table 1).

Although we cannot easily know all the causes of a null effect, we describe below how effects of paradigm and stimuli are unlikely to have contributed to the null effect, thus concluding that the null effect is due to the influence of two different semantic effects: interference and facilitation. First, the null effect was not a result of having pictures as distractors, as we observed a significant facilitation effect using the PPI paradigm in Experiment 1. Further, phonological facilitation was observed in previous studies with exactly the same paradigm (e.g., Meyer & Damian, 2007; Morsella & Miozzo, 2002; Navarrete & Costa, 2005). Second, the null effect was not due to a weak categorical relationship between targets and related pictures. The categorical interference effect observed in the PWI paradigm suggests that the categorical relationship between targets and related distractors was strong enough to lead to measurable semantic effects. Because elsewhere it is assumed that the categorical interference in the PWI paradigm is primarily due

to the response exclusion mechanism whereas the categorical facilitation in the PPI and PWI paradigms reflects the conceptual priming (cf. Mahon et al., 2007), we further checked that our materials were strongly categorically related. Employing latent semantic analysis (Landauer et al., 1998), we compared the semantic distance between our materials and the Mahon et al. (2007; PWI, Experiments 5 and 6) materials, which elicited a significant facilitation effect in a semantically close (e.g., *horse-zebra*) compared to a far condition (e.g., *horse-whale*; an effect argued to be purely conceptual, see Mahon et al., 2007). We found that the semantic distance was equivalent between our categorically related materials and the semantically close picture-word pairs in Mahon et al. [Ours: .31 vs. Experiment 5: .38, $t(48) = 1.37$, $p = .18$; vs. Experiment 6: .40, $t(52) = 1.68$, $p = .10$]. Additionally, our unrelated pairs were farther in semantic distance than the Mahon et al. picture-word pairs in the semantically far condition [Ours: .11 vs. Experiment 5: .24, $t(48) = 3.49$, $p < .001$; vs. Experiment 6: .22, $t(52) = 2.68$, $p < .01$]. Thus, as measured with two different metrics, the categorical relationship for the materials in Experiment 2 (PPI) was a significantly strong one. Third, the lack of a categorical interference effect when distractors were pictures (Experiment 2, PPI) is consistent with previous studies (e.g., Damian & Bowers, 2003; Navarrete & Costa, 2005; Roelofs, 2008²). Navarrete and Costa (2005), using the same paradigm, found no difference in naming latencies between categorically related and unrelated conditions. Damian and Bowers (2003) used a slightly different paradigm in which distractor pictures or words were embedded within the target pictures and also found no effect from the picture distractors. Although La Heij et al. (2003) reported that picture naming was faster in the context of categorically related than in the context of unrelated distractor pictures, as suggested in Experiment 1 (PPI-association), the facilitation effect was caused by associated relationships between categorically

related and unrelated picture pairs. Thus, to our knowledge, no study has found a facilitative (or interfering) category effect in the PPI paradigm. Finally, to verify that the results of the PPI with category were not influenced by the visual complexity and similarity of picture pairs, we asked 12 participants to rate the visual complexity of the target-distractor picture pairs when they were superimposed and the visual similarity of the pairs when there were not superimposed on a scale of 1 to 7 (less to more complex/similar). There was no significant difference in visual complexity when target pictures were superimposed with their categorically versus unrelated distractors ($t_s < 1$). For visual similarity, there was a significant if small difference in visual similarity between the target pictures and categorically related (2.96) vs. unrelated distractors (2.21), $t(27) = 2.20$, $p = .04$. We found that two target items (i.e., *television* and *shirt*) were substantially more visually similar to their categorically related (i.e., CAMERA: 5.8; DRESS: 4.9) than to unrelated distractors (i.e., GIRAFFE: 1.0; ARM: 1.4) in comparison to ratings for other items. When we removed these items, the difference in visual similarity ratings between categorically related (2.78) and unrelated distractors (2.28) was no longer significant, $t(25) = 1.58$, $p = .13$, but this only reduced the 2-ms effect to a 0-ms effect in the PPI paradigm between categorically related (686 ms) and unrelated (686 ms) picture distractors ($t_s < 1$). Therefore, we believe that this null effect has important implications for the mechanism of the lexical selection (we return to this point in the General Discussion).

GENERAL DISCUSSION

The purpose of our experiments was to determine whether the process of word selection is competitive, by comparing predictions from two hypotheses, the swinging lexical network (Abdel Rahman & Melinger, 2009) and the response

² Although Roelofs (2008) found no category effect in the PPI on naming latencies, he observed a category facilitation effect in a different paradigm using eye movements as a dependent measure.

exclusion hypothesis (Mahon et al., 2007). First, to establish reproducibility of effects in the picture–picture interference paradigm and test predictions from the two hypotheses, in Experiment 1, we found that response times were faster when distractor pictures were associatively related to targets than when they were unrelated. This result suggests that the previous categorical facilitation results in the PPI (La Heij et al., 2003) were due to stimuli confounds (i.e., the targets and related distractors were both categorically and associatively related.). Second, the associative facilitation effect supports both the swinging lexical network and the response exclusion hypotheses, suggesting that response times were facilitated by a spread of activation at the conceptual level with either little (swinging lexical network) or no lexical competition at all (response exclusion hypothesis). In Experiment 2, using the PWI and PPI paradigms, we found a significant interaction between the size of the interference effect in the PWI and PPI, where categorically related versus unrelated word distractors created interference in the PWI paradigm, but categorically related versus unrelated picture distractors created no interference, when controlling materials for associative relationships. Below, we discuss how these results are inconsistent with the response exclusion hypothesis and consistent with the swinging lexical network, and we conclude that the process to select a word is a competitive one.

The absence of the category effect in Experiment 2 (PPI) is inconsistent with predictions from the response exclusion hypothesis. This hypothesis assumes no competition at the lexical level. The categorical interference effect in the PWI paradigm results from distractor words' privileged access to a postlexical buffer, which must be cleared and replaced by the target name. This process takes longer when the distractor word shares certain semantic criteria with the target (e.g., name an animal). In the PPI paradigm, on the other hand, distractor pictures do not have privileged access to the postlexical buffer, so the only resulting effect is facilitation from conceptual priming. Thus, in contrast to the results of Experiment 2, the response exclusion hypothesis predicts that picture naming latencies should be

faster in the context of categorically related than in the context of unrelated distractor pictures.

The only way to save the response exclusion hypothesis is to propose that the distractor picture names are activated (contrary to that proposed by Mahon et al., 2007) and reach the buffer earlier than the target picture names. In this case, in order to name the target pictures, the distractor pictures must be excluded from the buffer. Thus it takes a longer time to process the categorically related distractor pictures than the unrelated ones, which cancels out the conceptual priming produced by the categorically related distractor pictures, resulting in a null effect. However, this assumption is highly unlikely. First, in our experiments, it is very clear for the participants that the target pictures were always the ones in green and thus unlikely that the distractor picture names arrived in the buffer earlier than the target names. Second, we compared the targets and distractors on a variety of variables that might influence the speed of processing (i.e., age of acquisition, familiarity rating, imageability rating, word frequency, number of letters, and number of syllables). We found that the target pictures had significantly higher scores on ratings of familiarity and imageability and on word frequency than the distractor pictures, and no differences were observed for other variables. Thus, it is unlikely that the distractor picture names entered the buffer before the target picture names. In summary, the null result in the PPI with category cannot be interpreted by the response exclusion hypothesis.

The swinging lexical network accounts for the lack of a category effect in the PPI paradigm by adopting an additional assumption of greater conceptual priming from distractor pictures than from words. The swinging lexical network explains the semantic effects observed in PWI and PPI as a result of trade-offs between lexical competition and conceptual facilitation. The swinging lexical network assumes that in both the PWI and the PPI paradigms, lexical competition induced by categorically related distractor words/pictures overrides conceptual facilitation, resulting in interference during naming. We argue that because pictures but not words have direct access to

concepts, concepts are more activated when distractors are pictures than when they are words, leading to greater conceptual facilitation (Roelofs, 1992, 2003) in the PPI paradigm when pictures are categorically related. As a result, the greater conceptual facilitation in the PPI versus PWI cancels out lexical competition, resulting in no category effect in PPI as seen in Experiment 2. Thus, the swinging lexical network accounts for the absence of a category effect in Experiment 2 by incorporating the additional assumption that picture distractors induce more conceptual facilitation in the PPI paradigm than do word distractors in the PWI paradigm.

The swinging lexical network is able to interpret not only the semantic effects in the PPI and PWI paradigms but also the interference effects observed in the postcued naming task and the blocked naming paradigm. In the postcued naming task, two pictures are presented simultaneously (one in red and one in green). After an interval, the pictures are replaced by a cue (green or red), which indicates the picture name to be produced. Participants then produce the corresponding picture name as quickly as possible. Here interference is observed when pictures are categorically related versus unrelated (Dean, Bub, & Masson, 2001; Humphreys, Lloyd-Jones, & Fias, 1995). Similarly, when two pictures are presented simultaneously, and participants produce both picture names (e.g., *cheery-apple*), interference is also observed (Aristei, Zwitserlood, & Abdel Rahman, 2012). Aristei et al. (2012) argue that when participants must prepare names for two pictures, the corresponding lexical representations receive strong activation, creating interference during lexical selection. In contrast, in our PPI paradigm, the participants are asked to name the green pictures only and ignore the red pictures, resulting in weaker activations of the lexical representations for the distractor pictures. Thus, a null effect is observed in Experiment 2 (PPI). On the other hand, in the blocked naming paradigm, pictures are named in blocks of items including either categorically related (e.g., *dog, elephant, fish*) or unrelated objects (e.g., *dog, car, printer*). Just like the categorical interference effect observed in the PWI paradigm, the basic effect in this paradigm is slower

naming latencies in the context of categorically related pictures than in the context of unrelated pictures (e.g., Belke, Meyer, & Damian, 2005; Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994). The swinging lexical network accounts for this effect in terms of the strong lexical competition (i.e., one-to-many competition) induced by categorically related pictures. This effect is also compatible with the response exclusion hypothesis as it assumes that in the blocked naming paradigm, “previously named pictures will be available as potential responses”, which occupy the response buffer and must be excluded before producing the next picture name (Mahon et al., 2007, p. 516). Because the picture names share the criterion (e.g., *naming an animal*) in the categorically related blocks, it takes a longer time to name the pictures in the related blocks than in the unrelated blocks. However, Abdel Rahman and Melinger (2007) observed the interference effects for both categorical and associative relations. In other words, the slower naming latencies were observed not only for the blocks consisting of categorically related pictures but also for those consisting of associatively related pictures. The response exclusion hypothesis cannot interpret the interference effect produced by the associatively related pictures in the blocked naming paradigm because it assumes that a previously named associated picture does not share the criterion that must be satisfied by a correct response with the current picture (e.g., the current picture is *dog*, criterion is “*naming an animal*”, the previous picture is *bone*). Therefore, the response exclusion hypothesis predicts a facilitation effect for the associative relation in the blocked naming paradigm due to conceptual priming. In contrast, according to the swinging lexical network, in the blocked naming paradigm “associates are linked by a common semantic context node and thereby, in analogy to a common category node, inducing converging activation from the target object and a number of associates belonging to the context in which the target is named” (see Abdel Rahman & Melinger, 2007, p. 611). Hence, the weak lexical competition (i.e., the one-to-one competition) induced by the associatively related distractor in the PWI and PPI paradigms can be changed to

the one-to-many competition by introducing a common semantic context (i.e., increasing the number of competitors).

Although our results and results elsewhere (e.g., the PPI paradigm: Aristei et al., 2012; Damian & Bowers, 2003; Navarrete & Costa, 2005; the postcued naming paradigm: Dean et al., 2001; Humphreys et al., 1995; the blocked naming paradigm: Abdel Rahman & Melinger, 2007; Damian et al., 2001) are consistent with the swinging lexical network hypothesis, this hypothesis requires further specification concerning which factors contribute to the trade-offs between conceptual facilitation and lexical competition. First, as discussed above, the swinging lexical network must assume that the amount of conceptual facilitation in naming changes depending on whether the distractor is a word or a picture. Second, with regard to lexical competition under the swinging lexical network, the number of lexical nodes activated by both targets and distractors determines the amount of lexical competition, but it is unclear “how large a lexical cohort must be before it can offset a conceptual facilitation effect” (Abdel Rahman & Melinger, 2009, p. 728). Thus, we believe that exploring possible factors that influence the trade-off between conceptual facilitation and lexical interference proposed by the swinging lexical network presents exciting avenues of future research.

CONCLUSIONS

We provide evidence across two experiments in favour of competitive versus noncompetitive lexical selection, consistent with the swinging lexical network (Abdel Rahman & Melinger, 2009) and inconsistent with the response exclusion hypothesis (Mahon et al., 2007). Further, we suggest that previous results showing categorical effects in picture-picture naming were due to stimuli confounds, thus readdressing the debate concerning categorical effects in this paradigm. In Experiment 1, naming latencies were faster when distractor pictures were associatively related than when they were unrelated to the targets, suggesting that naming latencies

were facilitated by a spread of activation at the conceptual level with either little lexical interference from lexical competition (swinging lexical network) or no lexical competition at all (response exclusion hypothesis). In Experiment 2, in order to distinguish between the swinging lexical network and response exclusion hypotheses, we compared category effects between the PWI (distractors were words) and PPI (distractors were pictures) paradigms by manipulating the categorical relationship (related vs. unrelated) between target and distractors. We found a significant interaction between the size of the category effects in the PWI (interference) and PPI (no effect). These results are inconsistent with the response exclusion hypothesis, which predicts a facilitation effect in the PPI paradigm. We interpret these results in the swinging lexical network framework by assuming there is greater conceptual priming from distractor pictures than words, cancelling out interference created from lexical competition.

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REFERENCES

- Abdel Rahman, R., & Melinger, A. (2007). When bees hamper the production of honey: Lexical interference from associates in speech production. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *33*, 604–614.
- Abdel Rahman, R., & Melinger, A. (2009). Semantic context effects in language production: A swinging lexical network proposal and a review. *Language and Cognitive Processes*, *24*, 713–734.
- Alario, F.-X., Segui, J., & Ferrand, L. (2000). Semantic and associative priming in picture naming. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *53*, 741–764.
- Aristei, S., Zwitserlood, P., & Abdel Rahman, R. (2012). Picture-induced semantic interference reflects lexical competition during object naming. *Frontiers in Psychology*, *3*, 1–9.
- Belke, E., Meyer, A., & Damian, M. F. (2005). Refractory effect in picture naming as assessed in a

- semantic blocking paradigm. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, 58, 667–692.
- Bloem, I., & La Heij, W. (2003). Semantic facilitation and semantic interference in word translation: Implications for models of lexical access in language production. *Journal of Memory and Language*, 48, 468–488.
- Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology*, 14, 177–208.
- Costa, A., Alario, F.-X., & Caramazza, A. (2005). On the categorical nature of the semantic interference effect in the picture–word interference paradigm. *Psychonomic Bulletin and Review*, 12, 125–131.
- Damian, M. F., & Bowers, J. S. (2003). Locus of semantic interference in picture–word interference tasks. *Psychonomic Bulletin & Review*, 10, 111–117.
- Damian, M. F., Vigliocco, G., & Levelt, W. J. M. (2001). Effects of semantic context in the naming of pictures and words. *Cognition*, 81, B77–B86.
- Dean, M. P., Bub, D. N., & Masson, M. E. J. (2001). Interference from related items in object identification. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 27, 733–743.
- Dell, G. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review*, 93, 283–321.
- Forster, K. I., & Forster, J. C. (2003). A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, and Computers*, 35, 116–124.
- Glaser, W. R., & Dungelhoff, F. J. (1984). The time course of picture–word interference. *Journal of Experimental Psychology: Human Perception and Performance*, 10, 640–654.
- Glaser, W. R., & Glaser, M. O. (1989). Context effects in Stroop-like word and picture processing. *Journal of Experimental Psychology: General*, 118, 13–42.
- Humphreys, G. W., Lloyd-Jones, T. J., & Fias, W. (1995). Semantic interference effects on naming using a post-cue procedure: Tapping the links between semantics and phonology with pictures and words. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 21, 961–980.
- Jescheniak, J. D., Oppermann, F., Hantsch, A., Wagner, V., Maedebach, A., & Schriefers, H. (2009). Do perceived context pictures automatically activate their phonological code? *Experimental Psychology*, 56, 56–65.
- Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, 33, 149–174.
- La Heij, W., Heikoop, K. W., Akerboom, S., & Bloem, I. (2003). Picture naming in picture context: Semantic interference or semantic facilitation? *Psychology Science*, 45, 49–62.
- Landauer, T. K., Foltz, P. W., & Laham, D. (1998). Introduction to latent semantic analyses. *Discourse Processes*, 25, 259–284. Retrieved from <http://lsa.colorado.edu>
- Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, 22, 1–75.
- Luce, P. A. (1986). *Response times: Their role in inferring elementary mental organization*. New York, NY: Oxford University Press.
- Mahon, B. Z., Costa, A., Peterson, R., Vargas, K., & Caramazza, A. (2007). Lexical selection is not by competition: A reinterpretation of semantic interference and facilitation effects in the picture–word interference paradigm. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 33, 503–535.
- Meyer, A. S., & Damian, M. F. (2007). Activation of distractor names in the picture–picture interference paradigm. *Memory & Cognition*, 35, 494–503.
- Morsella, E., & Miozzo, M. (2002). Evidence for a cascade model of lexical access in speech production. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 28, 555–563.
- Navarrete, E., & Costa, A. (2005). Phonological activation of ignored pictures: Further evidence for a cascade model of lexical access. *Journal of Memory & Language*, 53, 359–377.
- Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (2004). The University of South Florida free association, rhyme, and word fragment norms. *Behavior Research Methods, Instruments, and Computers*, 36, 402–407.
- Oppenheim, G. M., Dell, G. S., & Schwartz, M. F. (2010). The dark side of incremental learning: A model of cumulative semantic interference during lexical access in speech production. *Cognition*, 114, 227–252.
- Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition*, 42, 107–142.
- Roelofs, A. (2003). Goal-referenced selection of verbal action: Modeling attentional control in the Stroop task. *Psychological Review*, 110, 88–125.
- Roelofs, A. (2008). Tracing attention and the activation flow in spoken word planning using eye movements. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 34, 353–368.

- Schriefers, H., Meyer, A. S., & Levelt, W. J. M. (1990). Exploring the time course of lexical access in language production: Picture–word interference studies. *Journal of Memory and Language*, *29*, 86–102.
- Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, *6*, 174–215.
- Starreveld, P. A., & La Heij, W. (1995). Semantic interference, orthographic facilitation, and their interaction in naming tasks. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *21*, 686–698.

APPENDIX A

All picture names and distractors used in Experiment 1: PPI with association

<i>Target</i>	<i>Associatively related</i>	<i>Unrelated</i>
acorn	SQUIRREL	BIRD
anchor	BOAT	SQUIRREL
tree	LEAF	SCARF
elephant	PEANUT	PANTS
button	SHIRT	MOUTH
cheese	MOUSE	DOG
glasses	EYE	SPIDER
whistle	MOUTH	WOOD
monkey	BANANA	BOAT
nail	HAMMER	BOOK
neck	SCARF	BANANA
nest	BIRD	HORSE
cork	BOTTLE	FLOWER
pie	APPLE	EYE
saddle	HORSE	SHIRT
shelf	BOOK	BOTTLE
swatter	FLY	RABBIT
tire	CAR	FLY
web	SPIDER	MOUSE
saw	WOOD	CAR
vase	FLOWER	RING
carrot	RABBIT	ENVELOPE
bone	DOG	CHICKEN
egg	CHICKEN	FISH
toaster	BREAD	LEAF
belt	PANTS	HAMMER
tissue	NOSE	APPLE
diamond	RING	NOSE
letter	ENVELOPE	BREAD
hook	FISH	PEANUT

APPENDIX B

All picture names and distractors used in Experiment 2

<i>Target</i>	<i>Categorically related</i>	<i>Unrelated</i>
apple	WATERMELON	TREE
banana	STRAWBERRY	NEWSPAPER
bed	SHELF	ELEPHANT
cow	RABBIT	EAR
book	NEWSPAPER	WATERMELON
bottle	PLATE	LAMP
cake	BREAD	DRESS
car	PLANE	TURTLE
chicken	ELEPHANT	STRAWBERRY
cigarette	PIPE	FLUTE
dog	MOUSE	STAPLER
drawer	CHAIR	RABBIT
eye	NOSE	PLIERS
flashlight	LAMP	VEST
flower	TREE	ARM
hand	LEG	SHELF
foot	ARM	MONKEY
horse	MONKEY	PLATE
mouth	EAR	HAT
pants	VEST	NOSE
paperclip	STAPLER	MOUSE
drum	FLUTE	CHAIR
earring	NECKLACE	ONION
saw	PLIERS	BREAD
scarf	HAT	PIPE
shirt	DRESS	LEG
celery	ONION	NECKLACE
squirrel	GIRAFFE	CAMERA
television	CAMERA	GIRAFFE
frog	TURTLE	PLANE