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Distractor strength and selective attention in picture-naming performance

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Abstract Whereas it has long been assumed that competition plays a role in lexical selection in word production (e.g., Levelt, Roelofs, & Meyer, 1999), recently Finkbeiner and Caramazza (2006) argued against the competition assumption on the basis of their observation that visible distractors yield semantic interference in picture naming, whereas masked distractors yield semantic facilitation. We examined an alternative account of these findings that preserves the competition assumption. According to this account, the interference and facilitation effects of distractor words reflect whether or not distractors are strong enough to exceed a threshold for entering the competition process. We report two experiments in which distractor strength was manipulated by means of coactivation and visibility. Naming performance was assessed in terms of mean response time (RT) and RT distributions. In Experiment 1, with low coactivation, semantic facilitation was obtained from clearly visible distractors, whereas poorly visible distractors yielded no semantic effect. In Experiment 2, with high coactivation, semantic interference was obtained from both clearly and poorly visible distractors. These findings support the competition threshold account of the polarity of semantic effects in naming.

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Humans have an amazing capability of quickly selecting words they want to produce out of an immense mental dictionary. A debated topic in the literature concerns how we do this. In other words, what are the mechanisms subserving lexical selection? For a long time, competition was accepted as a mechanism involved in this selection (Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992; Starreveld & La Heij, 1996). More recently, however, Finkbeiner and Caramazza (2006) reported findings challenging this view, and they presented an account of lexical selection without competition. In this article, we first briefly describe the two opposing accounts. Next, we give a brief, critical summary of the evidence in favor of response exclusion, and we argue that the evidence is, in fact, compatible with the competition view. We then propose an alternative account of the findings of Finkbeiner and Caramazza (2006) that preserves the competition assumption and present the results of two new experiments supporting this alternative account of the findings.

Over the years, researchers have found effects from context words on picture-naming latencies, using the picture–word interference (PWI) paradigm. In this paradigm, participants have to name a picture (e.g., the picture of a cat) while trying to ignore a distractor word either superimposed onto the picture (Glaser & Düngelhoff, 1984; Rosinski, 1977) or presented auditorily (Schriefers, Meyer, & Levelt, 1990). A well-known context effect is semantic interference, manifested in longer response times (RTs) for pictures in the context of a category-coordinate (related) distractor word (e.g., *dog*), relative to a semantically unrelated distractor (e.g., *pen*). This semantic interference effect has typically been interpreted as reflecting the competition between the lexical representations of the target picture name and the distractor (Levelt et al., 1999; Roelofs, 1992). According to this account, semantically related words are linked via a conceptual network. When a conceptual representation is activated, it spreads activation to semantically related words via this network, and all the activated words compete for selection. The stronger this competition becomes, the longer it takes to select the word that is eventually produced. This delay in selection is what underlies the semantic interference effect. It should be noted, however, that the PWI paradigm taps not only into word selection, but also into selective attention. These attention mechanisms allow the participants to respond to the target picture, rather than to the distractor word. Mechanisms of selective attention are an explicit part of some models of PWI task performance (Roelofs, 1992, 2003; Starreveld & La Heij, 1996). For example, the WEAVER++ model favors processing of the target over the distractor by reactively blocking the latter (e.g., Roelofs, 2003).

Recently, an alternative explanation of the semantic interference effect in the PWI paradigm has been proposed, called the *response exclusion* account. Under this account (Finkbeiner & Caramazza, 2006; Janssen, Schirm, Mahon, & Caramazza, 2008; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007), the observed delay in the context of semantically related words arises at a later stage in word production, when articulatory responses to distractors are removed from an output buffer, close to articulation onset. Importantly, evidence for an output buffer locus of the semantic interference effect would take away the need for assuming competition during lexical selection.

Three assumptions lie at the core of the response exclusion account. The first one is that people form an articulatory response to a distractor word and this response then enters the output buffer. The second assumption is that only one response can occupy the output buffer at a time. The response to the distractor will reach the output buffer before the response to the picture. Therefore, in a next step, the response to the distractor needs to be excluded from the buffer and replaced by the picture name. The third assumption holds that the mechanism excluding a response from the buffer is sensitive to semantic information. If the response to the distractor shares semantic features (or other task-relevant properties) with the picture name, the process replacing the distractor by the picture name will be delayed, yielding the semantic interference effect. Note that response exclusion concerns an account of selective attention in PWI task performance, describing how target, rather than distractor, information gains control over responding. On the response exclusion view, the semantic interference effect is not informative about the processes underlying lexical selection, but the effect is informative about how selective attention operates in the PWI paradigm.

The evidence for response exclusion revisited

A number of findings from the PWI paradigm has been taken as evidence for the response exclusion hypothesis: (1) the distractor frequency effect (Miozzo & Caramazza, 2003), (2) semantic facilitation from part–whole distractors (Costa, Alario, & Caramazza, 2005), (3) the reverse semantic distance effect (Mahon et al., 2007), (4) distractor effects in delayed naming (Janssen et al., 2008), and (5) semantic facilitation from masked distractors (Finkbeiner & Caramazza, 2006). Before turning to this last piece of evidence, which is central to the present study, we briefly discuss the other evidence.

The distractor frequency effect is the finding that high-frequency distractor words produce less interference in picture naming than do low-frequency distractors (Miozzo & Caramazza, 2003). According to the response exclusion account, as compared with low-frequency distractors, high-frequency distractors enter the buffer more quickly. Therefore, they are removed from the buffer earlier, which reduces the interference. In contrast, under the assumption that high-frequency words have a higher resting level of activation than do low-frequency words, one could hypothesize that, under a competitive word selection process, high-frequency distractors should interfere more than low-frequency distractors. The fact that the empirical finding goes in the opposite direction than the apparent prediction from competition models has been taken as evidence against competition in lexical selection.

However, the distractor frequency effect has received an alternative explanation in the literature, which preserves the assumption of lexical competition (Roelofs, Piai, & Schriefers, 2011). In a competition model such as WEAVER++ (Roelofs, 1992, 2003), an attentional mechanism ensures that picture naming is favored over distractor word reading by reactively blocking the distractor (e.g., Roelofs, 2003). The speed of blocking depends on the speed with which the distractor word is recognized (Roelofs, 2005), and lexical frequency is a factor determining the speed of word recognition (e.g., Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004). Consequently, as compared with low-frequency distractors, high-frequency distractors are blocked out more quickly and, therefore, yield less interference, as has been empirically observed. Thus, both the response exclusion account and competition models like WEAVER++ provide an explanation of the distractor frequency effect.

The next piece of evidence concerns the semantic facilitation from part–whole distractors, which is the finding that picture-naming RTs are shorter, relative to unrelated distractors, when the distractor word denotes a constituent part of the pictured object, such as the word *bumper* superimposed on a pictured car (Costa et al., 2005). Because the distractor effect is one of semantic facilitation rather than interference, Costa et al. took their finding as evidence against competition models.

However, a possible alternative explanation for the facilitation effect obtained by Costa et al., which preserves the assumption of lexical competition, concerns the nature of the relationship between the pictures and distractors used. Many of the picture–distractor pairs also had strong associative relations, as in the example of *bumper* and *car*. Associates have been shown to induce facilitation, relative to unrelated distractors (e.g., Alario, Segui, & Ferrand, 2000; La Heij, Dirkx, & Kramer, 1990). Thus, the strong associative relation in many of the picture–distractor pairs used by Costa et al. could have driven the observed facilitation effect. Note that this explanation still has to be tested empirically.

The reverse semantic distance effect refers to the finding of Mahon et al. (2007) that semantically close distractor words (e.g., a picture of a horse with *zebra* as a distractor) produce less interference than do semantically far distractors (e.g., *frog* as a distractor) in picture naming. According to competition models, semantically close distractors should compete more than semantically far distractors, contrary to what Mahon et al. observed. However, semantic distance effects in agreement with competition models have been obtained in other studies. Using a semantic blocking paradigm, Vigliocco, Vinson, Damian, and Levelt (2002) found that, in line with the competition account, naming was slower in blocks of trials with semantically close pictures than in blocks of trials with semantically far pictures. Moreover, so far, two studies have failed to replicate Mahon et al.'s finding on the semantic distance effect caused by distractor words in picture naming (Abdel Rahman, Aristei, & Melinger, 2010; Lee & de Zubicaray, 2010). The observed pattern in these studies was comparable to Vigliocco et al.'s findings and in agreement with competition models: Semantically close distractors yielded more interference than did semantically far distractors. Thus, as long as it is not empirically clarified why these different studies obtained diverging results, theoretical conclusions based on the effect of semantic distance should be considered with caution.

A number of studies have reported distractor word effects in delayed naming. Janssen et al. (2008) observed semantic interference in delayed picture naming, when picture names were selected before distractor word onset. Moreover, Dhooge and Hartsuiker (2011) observed a distractor frequency effect in delayed naming. These findings are contrary to what the competition account predicts. However, in the studies of Janssen et al. and Dhooge and Hartsuiker (2011), participants had to decide between naming the picture and reading the word aloud, depending on the color of the distractor word, which may have triggered special processes yielding the delayed effects. Moreover, several studies could not replicate the semantic interference effect in delayed picture naming (Mädebach, Oppermann, Hantsch, Curda, & Jescheniak, 2011; Piai, Roelofs, & Schriefers, 2011). Semantic interference was present in immediate naming throughout the RT distribution, whereas the effect was absent throughout the RT distribution in delayed naming. Again, as long as it is not empirically clarified why these different studies obtained diverging results, theoretical conclusions based on findings from delayed naming should be considered with caution. Further critical analyses of the response exclusion account can be found in La Heij, Kuipers, and Starreveld (2006) and Mulatti and Coltheart (in press).

The evidence that is central to the present article comes from a study by Finkbeiner and Caramazza (2006). These authors manipulated the visibility of the distractor word in a picture-naming task. When the distractor is masked, they argued, participants cannot detect it consciously, and thus, no articulatory response to the distractor will be formed. With the output buffer being unoccupied, no response needs to be excluded from the buffer. As a consequence, related distractors should yield facilitation, since the masked distractor will not compete with the picture name but, rather, prime it via the conceptual–lexical network. This is indeed what Finkbeiner and Caramazza (2006) observed. Under masked conditions, related distractors facilitated picture naming, relative to unrelated distractors. By contrast, when the distractor was not masked, the same set of picture–distractor pairs yielded semantic interference. According to Finkbeiner and Caramazza (2006), the competition account never predicts semantic facilitation from related distractors (neither under masked nor under visible conditions), since the related distractor should always increase the competition with the picture name. A similar argument has been put forward in a recent article that reported a replication of semantic facilitation from masked distractors (Dhooge & Hartsuiker, 2010).

One should note, however, that the facilitation effect elicited by semantically related masked distractors is not in disagreement with the competition hypothesis (see, e.g., Abdel Rahman & Melinger, 2009; Roelofs, 1992, 1993, 2006, 2008b). Rather, if distractors do not enter in competition with the picture name for selection, they facilitate lexical selection (e.g., Roelofs, 1992, 1993, 2006, 2008b). In what follows, we argue that the findings of Finkbeiner and Caramazza (2006) may be explained by adopting the assumption of a competition threshold.

The competition threshold hypothesis

As was pointed out above, Finkbeiner and Caramazza (2006) and Dhooge and Hartsuiker (2010) accounted for the semantic facilitation effect from masked distractors in terms of the response exclusion hypothesis. When the distractor is not consciously perceived, no articulatory response will be formed, and thus, the distractor will not enter the output buffer.

In the present article, we examine an alternative explanation for the effects obtained with the masking procedure, the competition threshold hypothesis. This hypothesis does not rely on the assumption of unconscious perception of masked distractors and assumes lexical selection by competition. Under the competition threshold hypothesis, distractor words enter the competition for selection only if they exceed a certain level of activation. Under this view, the net effect of semantically related distractors is one of interference if the distractors enter the competition but may be one of facilitation if distractors do not compete for selection (see also Abdel Rahman & Melinger, 2009, for an account in terms of a trade-off between semantic facilitation induced by the context and lexical competition).

According to the competition threshold hypothesis, distractors become competitors only if they receive enough activation to exceed the competition threshold. The function of such a threshold is to operate as an attentional filter (e.g., Broadbent, 1958, 1970, 1971; Broadbent & Gregory, 1964), determining which elements will enter the competition space for response selection. Spreading activation is a powerful and efficient mechanism making candidates available in parallel, thus enabling a speaker to have a range of candidates quickly available (see Roelofs, 2003, 2008b, for discussions). However, competition is also a costly mechanism in that it increases the metabolic demands of the brain (e.g., Kan & Thompson-Schill, 2004; Schnur et al., 2009), and it may make the selection of the target response difficult. So, it is more beneficial if only the most plausible candidates enter the competition, and these candidates are those with a reasonably strong activation. Different factors can have an influence on the activation strength of the distractor word. In the present study, we investigate the influence of coactivation and of visibility of the distractor. In the following, we describe these two factors in more detail.

It has been shown that masking a word results in a reduction of the evoked neural activity, relative to the activity evoked by visible words (Dehaene et al., 2001). Dehaene and colleagues demonstrated that visible words activated a network of brain areas associated with word reading (cf. Fiez & Petersen, 1998), such as the left fusiform gyrus, left parietal cortex, and anterior cingulate cortex, among others. Masked words, however, evoked activity only in the left precentral sulcus and in the left fusiform gyrus, an area associated with visual word forms (cf. L. Cohen et al., 2000), but did not evoke activation of the anterior cingulate. Crucially, the anterior cingulate cortex is a brain area commonly found to be activated in interference tasks such as the Stroop and the PWI tasks (for a review, see Roelofs, 2008a). This area is assumed to be sensitive to the competition induced by interference tasks. On the basis of these neuroimaging findings, we assume that masking reduces the input strength of the distractor word. Consequently, masked distractors are less likely to exceed the competition threshold than are unmasked distractors. Note that from this perspective, it is not relevant whether the distractor words are consciously perceived or not. What matters for our hypothesis is whether the distractor's activation exceeds the competition threshold, and this may depend on the distractor's visibility. So, even when masking the distractor does not prevent conscious stimulus perception, decreasing the distractors' visibility may be sufficient to reduce its input strength below the competition threshold. Since unconscious perception of the distractor does not play a role in our hypothesis, we use the term *poorly visible* to refer to distractors that were presented with a masking procedure and *clearly visible* to refer to distractors that were not.

The activation strength of a distractor word can also be influenced by the amount of activation it receives from other nodes in the conceptual–lexical network, a factor we refer to as *coactivation* (see also Abdel Rahman & Melinger, 2009, for a similar proposal). We manipulated coactivation in two different ways. First, we manipulated response set membership. *Response set* refers to the set of items that are correct responses in the experiment (Broadbent, 1970, 1971; Broadbent & Gregory, 1964). The importance of response set membership in interference tasks has been shown for the Stroop task (Klein, 1964; Lamers, Roelofs, & Rabeling-Keus, 2010), but it is still debated for the PWI task (Caramazza & Costa, 2000, 2001; Roelofs, 2001). In the Stroop task, color words that function as responses in the experiment produce more interference than do color words that are not part of the response set (Klein, 1964). The effect of response set membership has been shown to arise due to selective allocation of attention to allowed responses in the experiment (Lamers et al., 2010)—for example, through increasing the base-level activation of response set words (e.g., J. D. Cohen, Dunbar, & McClelland, 1990). When we apply this view to the PWI task, this implies that using picture names as distractor words will lead to a higher base-level activation of these distractor words. Thus, on a given trial, the distractor word is more likely to exceed the competition threshold and to enter the lexical competition. Moreover, by having the distractors as members of the response set in an experiment, the activation of semantically related items is also increased.

Second, we manipulated coactivation by manipulating the number of target pictures belonging to the same semantic category. In one case, pictures of four different exemplars of each category occurred in the experiment (e.g., pictures of four different animals). In the other case, only one picture of each semantic category occurred in the experiment. We assumed that, in the former case, the different exemplars of the same category would prime each other. Thus, when one exemplar of a given semantic category was presented as a distractor while another exemplar of this category was named, the chance that the distractor would exceed the competition threshold should increase. In summary, coactivation may be a powerful factor influencing the strength of the distractor (cf. Roelofs, 2001). If distractors are highly coactivated, they are more likely to exceed the competition threshold than are distractors with low coactivation.

To conclude, we hypothesized that distractors compete with the picture name for selection only if their activation exceeds a competition threshold. If they stay below this threshold, they may facilitate lexical selection because they boost the activation of the picture name through spreading activation via the conceptual network (Roelofs, 2008c). We introduced two factors that might affect whether a distractor's activation exceeds this threshold: distractor visibility and coactivation.

In Experiment 1, we tested the prediction that, in the absence of high coactivation, both poorly and clearly visible distractors may lack input strength to exceed the competition threshold. If so, both poorly and clearly visible distractors may yield facilitation due to spreading activation via the conceptual network. Alternatively, the combination of low coactivation and poor visibility may make distractor activation so weak that it not only stays below the competition threshold, but also does not prime the picture name to a measurable degree. Clearly visible distractors with low coactivation, in turn, may remain below the competition threshold, but the distractor may be activated strongly enough to prime the picture name to a measurable degree. In Experiment 2, we "switched on" coactivation and again compared the effect of distractor visibility. Although masking may decrease the input strength of distractors, once coactivation is high, poorly visible distractors may exceed the competition threshold and yield interference. Moreover, the distractor strength of clearly visible distractors should exceed the competition threshold with high coactivation and, thus, yield interference.

Experiment 1

Experiment 1 assessed the effect of distractor visibility with low coactivation. The experiment was very similar to Finkbeiner and Caramazza's (2006) Experiment 2, although the structure of the trials was slightly modified. Finkbeiner and Caramazza (2006) presented the picture in the masked condition with the backward mask superimposed on the picture. The pictures in the visible condition, however, appeared unobstructed, thereby creating a difference in the visibility of the distractors *and* of the pictures between the masked and the visible conditions. We opted for presenting the picture unobstructed in both visibility conditions, keeping the trials in both poorly and clearly visible conditions as similar as possible. Furthermore, all stimuli were always presented in the center of the screen.

Method

Participants Eighteen native speakers of Dutch (5 male) from the participant pool of Radboud University Nijmegen participated in the experiment. They received 5 Euros for their participation. All participants had normal or corrected-to-normal vision.

Materials and design Sixteen pictures of common objects were selected from the picture gallery of the Max Planck Institute for Psycholinguistics, Nijmegen, together with their Dutch basic-level names. Each picture belonged to a different semantic category. The pictures were white line drawings on a black background; the images' size on the screen was approximately 3.5 × 3.5 cm. For the related condition, each target picture was paired with a category-coordinate distractor word. The unrelated distractor words were determined by re-pairing each picture name with a different distractor. The semantic relation of the distractor with the picture forms our first independent variable, which we call *distractor type*. In total, there were 32 picture–distractor pairs, and the distractor words were not members of the response set. A list of the materials can be found in Appendix 1. Backward masks were created for each picture–distractor pair. These consisted of randomly generated consonant strings, such that the consonants used for each pair did not occur in either the name of the picture or the distractor word. The distractor words and the backward masks were presented in fixed-width Courier New font, size 36, color white. The materials were presented in both poorly and clearly visible conditions, forming our second independent variable, *distractor visibility*. The 32 picture–word pairs were presented 4 times in each visibility condition. The randomization of the materials was blocked per repetition such that a given pair could appear again only after all pairs had been presented before. The randomizations were generated using Mix (van Casteren & Davis, 2006), with the following constraints: (1) One distractor type condition did not appear on more than 3 consecutive trials and (2) whether a certain picture would first appear in the semantically related or unrelated condition was counterbalanced across participants. The independent variables were manipulated within participants and within items. One unique list was used per participant for each visibility condition, totaling 256 trials. Distractor visibility was blocked, and all participants took part in the poorly visible condition first, followed by the clearly visible condition.

Procedure and apparatus Participants were seated comfortably in front of a computer monitor, approximately 50 cm away from it. The presentation of stimuli and the recording of responses were controlled by Presentation Software (Neurobehavioral Systems). Stimuli were presented on a 17-in. monitor, using a resolution of 1,280 × 1,024 pixels and a refresh rate of 75 Hz. Vocal responses were measured with a voice key.

Before the experiment, participants were presented with a booklet to get familiarized with the experimental pictures and their names. They were instructed to name the pictures that would appear on the screen and to ignore what preceded the picture. Next, a block of 16 practice trials was administered. In this practice block, the 16 pictures from the experimental materials were presented once, with a trial structure identical to the trials in the poorly visible condition, except that the masked stimulus, between the forward and the backward masks, was a series of four Xs. Participants named each picture once and were corrected in case the wrong name was used. Next, the poorly visible block was administered, followed by the clearly visible block.

A trial in the poorly visible block began with a forward mask (##########) presented for 507 ms. The forward mask was immediately replaced by the distractor word, displayed in lowercase.[1] The distractor remained on the screen for 53 ms. Next, the backward mask was presented for 13 ms, immediately followed by the picture. The picture remained unobstructed on the screen for approximately 800 ms. An empty screen was displayed for the remaining 1,700 ms until the next trial started.

In the clearly visible condition, each trial began with a fixation cross presented on the centre of the screen for 507 ms. The distractor word, displayed in uppercase letters, replaced the fixation cross and remained on the screen for 53 ms. Next, a blank screen was presented for 13 ms, immediately followed by the unobstructed presentation of the picture. The picture remained on the screen for approximately 800 ms, followed by a blank screen for the remaining 1,700 ms of the trial. An example of the trial structures is shown in Fig. 1. The registration of the vocal responses started as soon as the picture was displayed on the screen and lasted 2.5 s.

After the experiment proper, participants were asked what they thought they had seen between the hash symbols and the picture during the poorly visible condition. None of the participants reported seeing any Dutch words.

Analysis At each trial, the experimenter evaluated the participants' vocal responses. Trials on which the voice key was triggered by a sound that was not the participant's response and naming RTs shorter than 100 ms were discarded and not included in the error percentages. Responses that contained a disfluency, a wrong pronunciation of the word, or a wrong response word were coded as errors and subsequently were excluded from the statistical analyses of the naming RTs.

We submitted RTs to by-participant (F_1) and by-item (F_2) analyses of variance with distractor type (related and unrelated) and distractor visibility (poorly and clearly visible) as factors. Errors were submitted to logistic regression analysis.

[1] In the clearly visible condition, distractors were presented in uppercase. In presenting poorly visible distractors in lowercase and clearly visible distractors in uppercase, we followed the original procedure of Finkbeiner and Caramazza (2006).

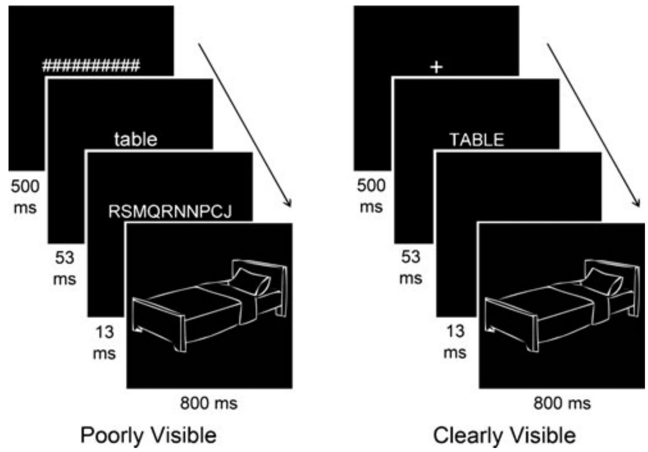

Fig. 1 Example of the structure of a poorly and a clearly visible trial in Experiments 1 and 2

Results

Table 1 shows the mean RTs, the standard deviations, and the mean error percentages for poorly and clearly visible distractors. The error analyses revealed that no factor was a significant predictor in the logistic regression model, all *p*s > .100. Pictures were named, on average, 8 ms faster in the related condition than in the unrelated condition, $F_1(1, 17) = 6.63$, $MSE = 757$, $p = .019$; $F_2(1, 15) = 9.64$, $MSE = 443$, $p = .007$. Pictures were named 8 ms faster in the poorly visible condition than in the clearly visible condition, although the effect was significant only in the by-item analysis, $F_1(1, 17) = 1.13$, $MSE = 3{,}934$, $p = .301$; $F_2(1, 15) = 5.07$, $MSE = 662$, $p = .039$. Distractor type and distractor visibility interacted, $F_1(1, 17) = 7.88$, $MSE = 436$, $p = .012$; $F_2(1, 15) = 4.69$, $MSE = 630$, $p = .047$. No semantic effect was obtained in the poorly visible condition, *F*s < 1; but semantic facilitation was present in the clearly visible condition, $F_1(1, 17) = 23.47$, $MSE = 357$, $p < .001$; $F_2(1, 15) = 13.20$, $MSE = 543$, $p = .002$.

Table 1 Mean response times, standard deviations, and percentages of errors (PEs) as a function of distractor visibility and distractor type in Experiment 1

Distractor Type	Distractor Visibility					
	Poorly Visible			Clearly Visible		
	M	*SD*	PE	*M*	*SD*	PE
Related	662	122	1.6	663	136	1.3
Unrelated	664	125	1.7	678	146	2.2
Difference	-2		-0.1	-15		-0.9

Note. Mean response times and standard deviations are given in milliseconds

Discussion

Experiment 1 was designed to investigate the role of distractor visibility. As was argued, poor visibility of the distractor was assumed to decrease its input strength. We hypothesized that, with low coactivation, poorly visible distractors might yield facilitation or fail to induce semantic context effects. The latter is what we found: Naming was equally fast for related and unrelated poorly visible distractors. Moreover, we hypothesized that clearly visible distractors might have enough activation to induce context effects in picture naming. With low coactivation, clearly visible distractors showed semantic facilitation rather than interference. The facilitation suggests that the distractors failed to exceed the competition threshold and, thus, did not enter the competition process. However, their activation still induced a semantic context effect (in this case, a facilitation effect) due to priming via the conceptual level.

In basic-level picture naming, it is unusual that category-coordinate distractors facilitate picture naming, relative to unrelated distractors (e.g., Roelofs, 1992). Semantic facilitation is obtained, for example, in the case of picture categorization (e.g., Glaser & Düngelhoff, 1984; Kuipers, La Heij, & Costa, 2006) or in certain word translation tasks (e.g., La Heij, Hooglander, Kerling, & Van der Velden, 1996). However, the conditions under which we find semantic facilitation in the present experiment—in particular, low coactivation and brief distractor preexposure—are only rarely used in PWI studies. Roelofs (1992, 1993) found semantic facilitation from related distractors with low coactivation when the distractors were presented 100 ms preceding the picture, but not when they were presented simultaneously with the picture, in which case no semantic effects were obtained. So, both in Roelofs (1992, 1993) and in the present experiment, there was low coactivation, and the distractor preceded the picture. This appears to be sufficient to decrease the input strength of the distractor below the competition threshold. By contrast, when distractors are presented under conditions of high coactivation, which is the case in most PWI studies (e.g., Glaser & Düngelhoff, 1984), or are presented simultaneously with the picture under low coactivation for a longer period (e.g., 600 ms; Caramazza & Costa, 2000), the input strength of the distractors exceeds the competition threshold. Thus, it appears that the finding of semantic facilitation in basic-level naming in the present experiment is related to the use of specific experimental parameters decreasing the distractor's input strength.

To sum up, with low coactivation, we found no effect of distractor type on the RTs in picture naming with poorly visible distractors, whereas semantic facilitation was observed with clearly visible distractors. These results are in accordance with the competition threshold hypothesis.

Experiment 2

Experiment 2 was designed to investigate to what extent coactivation contributes to distractor strength. The experiment was nearly identical to Experiment 1, except that we increased, in two ways, the amount of coactivation that pictures and distractors could induce. First, there were four exemplars of each semantic category (e.g., pictures of four different animals), rather than just one exemplar of each category, as was the case in Experiment 1. Second, the distractors used in the experiment were the names of other pictures that appeared in the experiment. This should increase the base-level activation of distractors throughout the experiment and, thus, increase the chance that a distractor's activation exceeds the competition threshold. These manipulations combined should increase the amount of activation a distractor will receive from other activated lexical nodes (see also Abdel Rahman & Melinger, 2009).

If coactivation is an important factor in determining distractor strength, it will increase the chance that distractors exceed the competition threshold and, consequently, interfere with picture naming. If the increase of distractor activation by the presence of coactivation is strong enough to activate the distractor beyond the competition threshold, we should observe semantic interference with poorly and clearly visible distractors. It could, however, also be the case that the competition threshold is exceeded only by clearly visible distractors, whereas poorly visible distractors stay below the threshold but are activated strongly enough to prime the picture name. In that case, we should observe interference from clearly visible distractors and facilitation from poorly visible distractors, as Finkbeiner and Caramazza (2006) and Dhooge and Hartsuiker (2010) obtained.

Method

Participants Sixteen young adults (2 male) participated in the experiment and received a reward of 5 Euros for their participation. They were from the same participant pool as in Experiment 1, and they met the same eligibility requirements.

Materials and design Thirty-two pictures of common objects were selected from the same picture gallery as for Experiment 1. The objects belonged to eight different semantic categories, with four objects per semantic category. Each target picture was paired with a semantically related distractor, and the semantically unrelated distractors were created by re-pairing the pictures with different distractors, yielding 64 picture–distractor pairs. All distractors belonged to the response set. A list of the materials can be found in Appendix 2. Backward masks were created for each picture–distractor pair in the same way as in Experiment 1. The design was identical to that in Experiment 1. One unique list was used per participant, with a total of 512 experimental trials.

Procedure, apparatus, and analysis The procedure and apparatus were identical to those in Experiment 1. For Experiment 2, the familiarization block consisted of the 32 pictures used as experimental materials. For the debriefing, none of the participants reported seeing any Dutch words in the poorly visible condition. The same analyses were conducted as in Experiment 1.

Results

Table 2 shows the mean RTs, the standard deviations, and the mean error percentages for poorly and clearly visible distractors. The error analyses revealed that no factor was a significant predictor in the logistic regression model, all *p*s > .200. Pictures were named, on average, 10 ms faster in the poorly visible than in the clearly visible condition, $F_1(1, 15) < 1$; $F_2(1, 31) = 5.68$, $MSE = 1{,}863$, $p = .023$, and 14 ms slower in the related condition than in the unrelated condition (i.e., a semantic interference effect), $F_1(1, 15) = 12.02$, $MSE = 1{,}156$, $p = .003$; $F_2(1, 31) = 4.57$, $MSE = 6{,}722$, $p = .041$. The interaction between visibility and distractor type was not significant, *F*s < 1.

Discussion

The aim of Experiment 2 was to investigate the role of coactivation in determining the input strength of the distractor word. Coactivation was manipulated in terms of response set membership and by increasing the number of exemplars from the semantic categories used in the experiment. We obtained semantic interference in picture naming from both poorly and clearly visible distractors, and the semantic interference effect did not differ between the two visibility conditions in the mean RTs. These findings are in agreement with the competition threshold hypothesis. Moreover, they point to the importance of coactivation and response set membership in the PWI task (cf. Roelofs, 2001).

Note that the response exclusion hypothesis can explain the results of Experiment 2 without any extra assumptions. The fact that distractors are also used as targets—that is, they are part of the response set—makes them very response relevant, which is a factor determining the speed with which the output buffer can be emptied. However, the account cannot explain the results of Experiment 1. In Experiment 1, the distractors were not part of the response set. In the clearly visible condition, an articulatory response is derived for the distractors, which would predict semantic interference, rather than semantic facilitation, which is what we observed.

Table 2 Mean response times, standard deviations, and percentages of error (PEs) as a function of distractor visibility and distractor type in Experiment 2

Distractor Type	Distractor Visibility					
	Poorly Visible			Clearly Visible		
	M	*SD*	PE	*M*	*SD*	PE
Related	714	181	2.3	721	198	1.8
Unrelated	697	168	1.6	708	176	1.4
Difference	17		0.7	13		0.4

Note. Mean response times and standard deviations are given in milliseconds

Analyses of RT distributions

Whereas Finkbeiner and Caramazza (2006) obtained semantic facilitation from masked distractors, we obtained no effect in Experiment 1 and semantic interference in Experiment 2. Proponents of the response exclusion hypothesis could argue that the null effect in Experiment 1 and the semantic interference in Experiment 2 were due to differences in conscious perception of the distractors across the poorly visible trials. It could be that on a proportion of the trials, the poorly visible distractors were perceived consciously. From a response exclusion point of view, they should enter the response buffer and yield semantic interference. At the same time, on another proportion of the trials, masking may have been effective, preventing an articulatory response to the distractor to enter the buffer, which should yield facilitation. The null effect in the mean RTs of Experiment 1 could reflect the net result of a mixture of trials with interference and facilitation. In fact, such null effects in the mean RTs, resulting from different opposing underlying effects, have been reported in the Stroop literature (e.g., Heathcote, Popiel, & Mewhort, 1991). Similarly, the interference from poorly visible distractors in Experiment 2 could reflect that there was a larger proportion of trials with interference and a smaller proportion of trials with facilitation. On this account, conscious perception of the distractor words would be crucial, but the experiments were unsuccessful in preventing conscious perception on all poorly visible trials.

One way to address the possibility of a mixture of effects is by conducting RT distributional analyses. We performed both Vincentile and ex-Gaussian analyses. In Vincentile analyses, group RT distributions are examined (cf. Ratcliff, 1979). For these analyses, we rank-ordered the RTs for each participant and then divided them into 20% quantiles. We then computed quantile means for each condition and, finally, averaged the quantiles across participants. Ex-Gaussian analyses formally characterize an RT distribution by fitting an ex-Gaussian function to the RT data, which consists of a convolution of a Gaussian and an exponential function. The analysis provides three parameters characterizing a distribution: μ, reflecting the mean of the Gaussian portion; σ, reflecting the standard deviation of the Gaussian portion; and τ, reflecting the mean and standard deviation of the exponential portion (e.g., Heathcote et al., 1991; Luce, 1986; Ratcliff, 1979). Theoretically, the mean of the whole distribution equals the sum of μ and τ. Thus, ex-Gaussian analyses decompose mean RTs into two additive components, which characterize the leading edge (μ) and the tail (τ) of the underlying RT distribution.

Mean RTs are generally shorter in masked than in visible conditions (e.g., Dhooge & Hartsuiker, 2010, and the present experiments). For example, Dhooge and Hartsuiker used similar timing parameters for their masked and visible conditions, altering only the presence or absence of the backward mask. Moreover, using a visibility test, they showed that their masked distractors were not perceived consciously. RTs in the masked condition were overall shorter than those in the visible condition. Given that participants tend to be faster under masked conditions, the shortest RTs in the distribution should, in general, reflect the trials on which the masking procedure was effective. Similarly, the longest RTs should be more associated with trials on which the masking procedure was ineffective or failed. If the absence of a semantic effect from poorly visible distractors in Experiment 1 is due to a mixture of trials with facilitation and interference effects, the shortest RTs should show facilitation, whereas the longest RTs should show interference. This situation predicts a crossover between the RT curves for the related and unrelated conditions in the Vincentiles and opposing effects in the parameters μ and τ, canceling each other out in the mean RTs. Similarly, if the interference effect from poorly visible distractors in Experiment 2 is due to a large number of trials with interference, this interference should be especially prominent in the longest RTs—that is, toward the tail of the distribution—revealing a τ effect.

Figure 2 shows the Vincentized cumulative distribution curves for picture naming for the related and unrelated distractors in the two visibility conditions in both experiments. The curves for the related and unrelated poorly visible distractors in

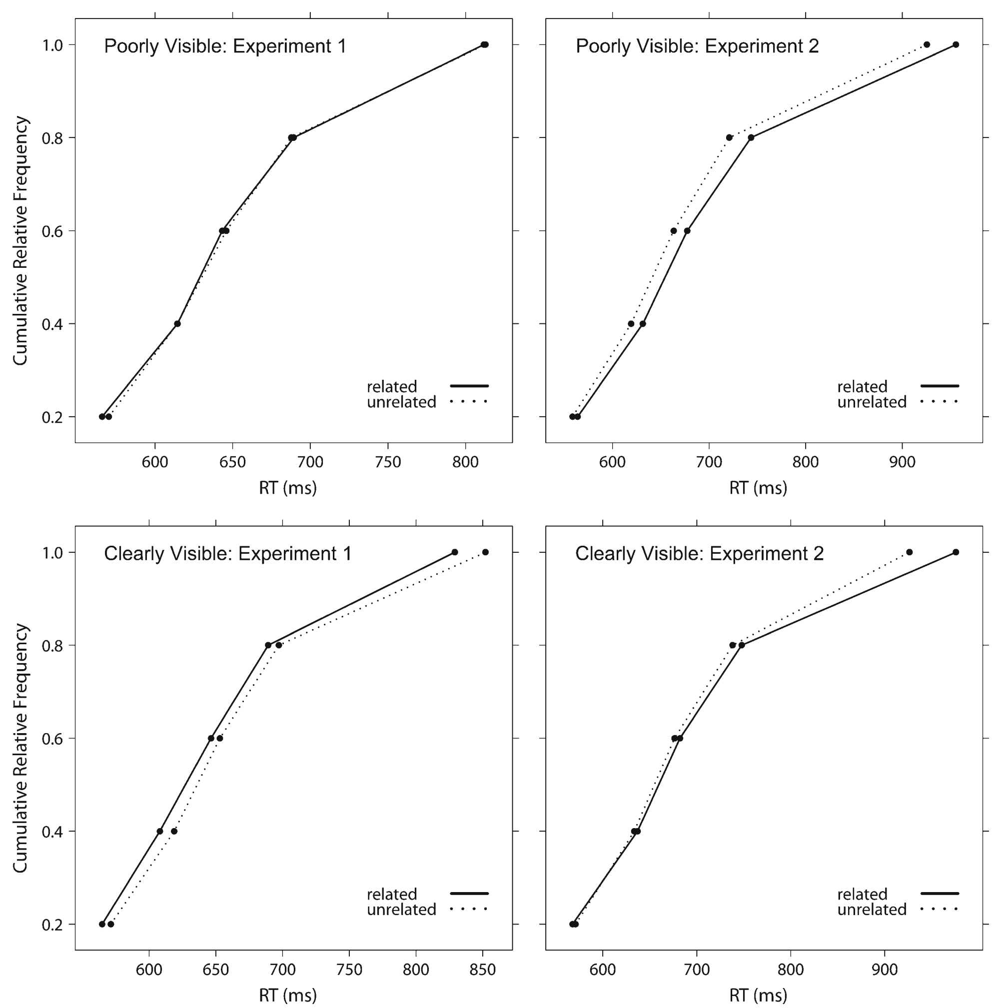

Fig. 2 Vincentized cumulative distribution curves for picture naming for related and unrelated distractors in the poorly visible (top left panel) and clearly visible (bottom left panel) conditions in Experiment 1 and in the poorly visible (top right panel) and clearly visible (bottom right panel) conditions in Experiment 2. RT = response time

Experiment 1 are entirely overlapping, showing that the null effect is not due to a mixture of underlying facilitation and interference effects. The semantic facilitation for clearly visible distractors in Experiment 1 is evidenced as a shift of the entire curve for the unrelated distractors, relative to the related distractors, showing that facilitation is present throughout the RT distribution. The semantic interference effect from poorly visible distractors in Experiment 2 is evidenced as a shift of the entire distribution for the unrelated condition, relative to the related condition, whereas the interference effect from clearly visible distractors is especially prominent toward the tail of the distribution. Thus, the Vincentile analyses show that the absence of a semantic effect of poorly visible distractors in Experiment 1 and the semantic interference of poorly visible distractors in Experiment 2 are not due to underlying mixtures of interference and facilitation effects across trials.

Table 3 shows the means of the ex-Gaussian parameters for poorly and clearly visible distractors of Experiments 1 and 2. In Experiment 1, for the clearly visible condition, two-tailed dependent *t*-tests revealed a marginally significant semantic facilitation in the μ parameter, $t(17) = -1.86$, $p = .081$. The remaining comparisons were not significant, all *p*s > .124. Thus, no differences were found in any of the ex-Gaussian parameters for the poorly visible condition, indicating that the RT distributions overlapped. In Experiment 2, dependent *t*-tests revealed semantic interference in the poorly visible condition in the μ parameter, $t(15) = 2.21$, $p = .043$, indicating that the semantic effect shifted the entire RT distribution. In the clearly visible condition, semantic interference was present both in σ, $t(15) = 2.81$, $p = .013$, and in τ, $t(15) = 2.96$, $p = .009$. Thus, the ex-Gaussian analyses confirm the conclusions of the Vincentile analyses that the absence of a semantic effect of poorly visible distractors in Experiment 1 and the semantic interference of poorly visible distractors in Experiment 2 were not due to underlying mixtures of interference and facilitation effects.

To conclude, the null effect of poorly visible distractors in Experiment 1 is not due to a mixture of underlying facilitation and interference effects, but instead, a semantic effect is absent throughout the whole RT distribution. Moreover, the interference effect of poorly visible distractors in Experiment 2 is not due to a greater number of trials showing interference and a smaller number showing facilitation but, instead, is due to interference that is present throughout the RT distribution.

Table 3 Mean ex-Gaussian parameter estimates (μ, σ, τ) as a function of distractor visibility and distractor type in Experiments 1 and 2

Distractor Visibility	Distractor Type	Experiment 1			Experiment 2		
		μ	σ	τ	μ	σ	τ
Poorly Visible							
	Related	579	36	83	581	54	133
	Unrelated	583	36	81	571	49	126
	Difference	-4	0	2	10	5	7
Clearly Visible							
	Related	573	35	90	584	57	138
	Unrelated	581	38	98	587	48	121
	Difference	-8	-3	-8	-3	9	17

Note. Mean ex-Gaussian parameter estimates are given in milliseconds

General discussion

The role of competition in lexical selection is a hotly debated issue. While several models assume competition as a mechanism operating in lexical selection (e.g., Levelt et al., 1999; Roelofs, 1992), recent studies have claimed that the semantic interference effect, previously taken as evidence for competition, should be accounted for as a response exclusion effect instead (e.g., Dhooge & Hartsuiker, 2010; Finkbeiner & Caramazza, 2006; but see Mädebach et al., 2011; Piai et al., 2011; Roelofs et al., 2011).

Finkbeiner and Caramazza (2006) observed semantic interference in picture naming with visible distractors, but the semantic effect was one of facilitation when distractors were presented under masked conditions. The response exclusion hypothesis accounts for this finding by assuming that, for masked distractors, no articulatory response enters the output buffer, since masked distractors are not consciously perceived. We proposed an alternative competition account of the semantic effects observed from masked and visible distractors that does not rely on the assumption of unconscious processing of masked distractors: the competition threshold hypothesis. According to this hypothesis, a threshold determines whether distractors do or do not enter in competition with the picture name for selection. This competition threshold is a mechanism of selective attention, which determines to what extent contextual information is allowed to influence lexical selection. We investigated the role of distractor visibility and coactivation as potential determinants of the input strength of the distractor word and, thus, as potential determinants as to whether the distractor does exceed the competition threshold.

In Experiment 1, with low coactivation, poorly visible distractors did not yield semantic effects in picture naming, whereas clearly visible distractors yielded semantic facilitation. Thus, different from Finkbeiner and Caramazza's (2006) findings, semantic facilitation was obtained from clearly visible distractors, which is in agreement with the competition threshold hypothesis. Experiment 2 was set up such that coactivation was high. Now, both poorly and clearly visible distractors yielded semantic interference in picture naming. Thus, different from Finkbeiner and Caramazza's (2006) findings, but in line with the competition threshold hypothesis, semantic interference was obtained for poorly visible distractors. The competition threshold hypothesis provides a mechanism of selective attention that accounts for the present results without the need to involve notions such as awareness and formulation of an articulatory response to the distractor.

We proposed that distractor visibility influences the strength of activation of distractor words. Note that we do not claim that masked words are too weakly activated to elicit any effects. This claim would be ungrounded, given a vast literature on masking showing that masked primes are powerful stimuli, capable of eliciting various kinds of effects (e.g., Forster & Davis, 1991; Grainger, Diependaele, Spinelli, Ferrand, & Farioli, 2003). Rather, our claim is that decreasing the visibility of a distractor will decrease the likelihood that that distractor will enter into competition with the picture name for selection.

Concerning the effect of coactivation, the question may be asked how our findings relate to previous investigations of response set membership (Caramazza & Costa, 2000, 2001; Roelofs, 2001). Caramazza and Costa (2000) questioned the role that response set membership plays in a competitive model such as WEAVER++. They manipulated the materials such that distractors were not members of the response set and only one exemplar of each semantic category was used. This manipulation is very similar to the one we used in Experiment 1, which was our experiment with low coactivation. Whereas Caramazza and Costa (2000) observed semantic interference from distractors with low coactivation, we obtained semantic facilitation for visible distractors. This may not be a discrepancy, however, given procedural differences between their experiment and our Experiment 1. Our distractors were presented for 53 ms preceding the picture, with a stimulus onset asynchrony of 66 ms, followed by an unobstructed picture for 800 ms. Caramazza and Costa (2000) had the picture and the distractor word presented simultaneously, with the distractor superimposed for 600 ms. Given our findings about the role of distractor visibility on the semantic effect, the apparent discrepancy is readily explained. In the case of the Caramazza and Costa (2000) study, the visibility and salience of the distractor caused it to exceed the competition threshold, despite the lack of distractor strength, due to low coactivation.

One finding in the literature that may seem to be in contrast with the account proposed here is the distractor frequency effect (Miozzo & Caramazza, 2003). It could be argued that high-frequency distractors are more likely to cross the competition threshold than are low-frequency distractors. If so, high-frequency distractors should yield more interference than should low-frequency ones. It should be noted, however, that the competition threshold hypothesis is concerned with the likelihood that a given distractor will cross the competition threshold. If distractors exceed the threshold, the distractor frequency effect can be accounted for by a distractor-blocking mechanism (see Roelofs et al., 2011), as was mentioned in the introduction. Investigations of the distractor frequency effect have made use of clearly visible distractors, presented for at least 700 ms (e.g., Miozzo & Caramazza, 2003), which should be sufficient for both the high- and low-frequency distractors to pass the threshold. Indeed, the size of the semantic interference effect has been shown to be comparable for high- and low-frequency distractors (Miozzo & Caramazza, 2003), suggesting that those distractors passed the competition threshold. Under poorly visible conditions, the distractor frequency effect is absent (Dhooge & Hartsuiker, 2010), in line with the account proposed here. Roelofs et al. (2011) reported the results of computer simulations of the experiments of Dhooge and Hartsuiker (2010) using WEAVER++, which showed the utility of our account of the distractor frequency effect and the effect of masking.

In addition to analyzing mean RTs, we also conducted RT distribution analyses to further examine the findings reflected in the mean RTs. In Experiment 1, we observed that the null effect from poorly visible distractors was not due to a mixture of underlying interference and facilitation effects, possibly emerging from a mixture of trials on which the masking procedure was effective and trials on which it was not. Rather, a semantic effect in the poorly visible condition was absent throughout the entire RT distribution. With high coactivation in Experiment 2, poorly visible semantically related distractors shifted the RT distribution, relative to unrelated distractors. Thus, interference was present throughout the RT distribution, suggesting that poorly visible related distractors consistently caused interference across the poorly visible trials, rather than producing interference on a large number of trials (reflecting ineffective masking) and facilitation on fewer trials (reflecting effective masking).

It has become increasingly clear that selective attention plays an important role in performance in the PWI paradigm (see, e.g., Roelofs, 2003, 2007, 2008c; Roelofs et al., 2011). In the selective attention literature, a distinction is made between early selection (input filtering) based on physical or perceptual features and late selection, operating at the level of response selection. Both types of selection usually play a role in task performance, as suggested by the seminal work of Broadbent and colleagues (Broadbent, 1970, 1971; Broadbent & Gregory, 1964). WEAVER++ implements assumptions about both types of attention. The competition threshold hypothesis is a concrete proposal for a late selective attention mechanism (cf. Lamers et al., 2010; Roelofs, 1992), determining which elements will enter the competition space for response selection, whereas our distractor-blocking mechanism (e.g., Roelofs, 2003; Roelofs et al., 2011) is an early selection mechanism. By stipulating two loci of selective attention in PWI, we are staying close to the literature on attention and our earlier work.

The accumulating set of findings from PWI tasks has resulted in complex empirical patterns. In order to explain these empirical patterns, assumptions taken from the field of attention have been added to the idea of competitive selection. These assumptions concern an early selective attention mechanism (e.g., Roelofs, 2003; Roelofs et al., 2011) and the current competition threshold hypothesis as a late selective attention mechanism. One may argue that these additional assumptions are ad hoc, but they do offer a principled way to account for the findings currently in the literature and have their independent roots in research on attention. Moreover, we emphasize that the assumption of both early and late loci of selective attention in PWI is not new but has been proposed and motivated in our earlier work (e.g., Lamers et al., 2010; Roelofs, 1992, 2003; Roelofs et al., 2011). The competition threshold mechanism is a further development of the idea of late attentional selectivity. Furthermore, the competition threshold assumption is a first attempt at understanding how the presently known constellation of accumulated empirical patterns relates to the nature of lexical selection. Finally, note that the alternative account for the current findings, the response exclusion hypothesis, also stipulates additional post hoc assumptions, such as the assumed sensitivity of the response buffer to any kind of information that has been shown to induce context effects in the PWI task (e.g., a word's semantic category). Different from our proposal, these assumptions are not supported by any independent research tradition. Moreover, increasing criticism of the response exclusion hypothesis (e.g., Abdel Rahman & Aristei, 2010; La Heij et al., 2006; Mulatti & Coltheart, in press; Roelofs, Piai, & Schriefers, in press) casts doubt on whether the hypothesis, although being able to explain some empirical patterns, should be maintained as a theoretically viable alternative to the lexical competition hypothesis.

Summary and conclusion

Finkbeiner and Caramazza (2006) observed semantic facilitation from masked distractors and semantic interference from visible distractors in picture naming. These findings were taken to refute competition models. In the present article, we proposed an alternative explanation of the findings of Finkbeiner and Caramazza (2006) that preserves the assumption of lexical competition. In two experiments, we examined the hypothesis that there is a lexical competition threshold that determines whether distractors will enter the competition with the picture name for selection. We investigated the role of distractor visibility and coactivation in determining the likelihood of a distractor to exceed the competition threshold. Supporting our hypothesis, we obtained semantic interference under conditions that were predicted to increase the input strength of the distractor word, causing it to surpass the threshold. Moreover, we obtained semantic facilitation under conditions that decreased distractor strength. We argued that the competition threshold hypothesis is capable of accounting for the polarity of semantic context effects in picture–word interference tasks and that the semantic facilitation from masked distractors does not represent a challenge to lexical selection by competition.

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Appendix 1

Materials from Experiment 1 (English translations in parentheses)

Picture Name	Related Distractor	Unrelated Distractor
aardbei (strawberry)	banaan (banana)	trompet
arm (arm)	neus (nose)	vliegtuig
auto (car)	vliegtuig (airplane)	konijn
gitaar (guitar)	trompet (trumpet)	schommel
glijbaan (slide)	schommel (swing)	zaag
hamer (hammer)	zaag (saw)	banaan
hert (deer)	konijn (rabbit)	beker
kaas (cheese)	worst (sausage)	sigaret
kan (pitcher)	beker (cup)	neus
kast (wardrobe)	bureau (desk)	rok
maan (moon)	zon (sun)	lepel
molen (mill)	kasteel (castle)	bureau
pijp (pipe)	sigaret (cigarette)	worst
pistool (gun)	kanon (cannon)	kasteel
trui (sweater)	rok (skirt)	kanon
vork (fork)	lepel (spoon)	zon

Appendix 2

Materials from Experiment 2 (English translations in parentheses)

	Picture Name	Related Distractor	Unrelated Distractor
Animals	hert (deer)	konijn	bureau
	konijn (rabbit)	hert	arm
	zwaan (swan)	schildpad	rok
	schildpad (turtle)	zwaan	beker
Clothing	jas (jacket)	hemd	kasteel
	hemd (singlet)	jas	oor
	rok (skirt)	trui	zwaan
	trui (sweater)	rok	dolk
Transportation	auto (car)	vliegtuig	konijn
	vliegtuig (airplane)	auto	glas

(continued)

	Picture Name	Related Distractor	Unrelated Distractor
	trein (train)	fiets	kerk
	fiets (bicycle)	trein	kast
Buildings	kerk (church)	fabriek	been
	fabriek (factory)	kerk	neus
	molen (mill)	kasteel	kan
	kasteel (castle)	molen	jas
Weapons	dolk (dagger)	zwaard	trui
	zwaard (sword)	dolk	tafel
	kanon (cannon)	pistool	bord
	pistool (gun)	kanon	bed
Service	kan (pitcher)	beker	molen
	beker (cup)	kan	schildpad
	bord (plate)	glas	kanon
	glas (glass)	bord	vliegtuig
Furniture	bed (bed)	tafel	pistool
	tafel (table)	bed	zwaard
	bureau (desk)	kast	hert
	kast (wardrobe)	bureau	fiets
Body parts	neus (nose)	arm	fabriek
	arm (arm)	neus	trein
	been (leg)	oor	auto
	oor (ear)	been	hemd

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