Context Effects and Selective Attention in Picture Naming and Word Reading: Competition versus Response Exclusion

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Abstract

For several decades, context effects in picture naming and word reading have been extensively investigated. However, researchers have found no agreement on the explanation of the effects. Whereas it has long been assumed that several types of effect reflect competition in word selection (e.g., Levelt, Roelofs, & Meyer, 1999), recently it has been argued that these effects reflect the exclusion of articulatory responses from an output buffer (Finkbeiner & Caramazza, 2006). Here, we first critically evaluate the findings on context effects in picture naming that have been taken as evidence against the competition account, and we argue that the findings are, in fact, compatible with the competition account. Moreover, some of the findings appear to challenge rather than support the response exclusion account. Next, we compare the response exclusion and competition accounts with respect to their ability to explain data on word reading. It appears that response exclusion does not account well for context effects on word reading times, whereas computer simulations reveal that a competition model like WEAVER++ (Levelt et al., 1999) accounts for the findings.

Key words: lexical competition; naming; output buffer; reading; selective attention

One of the workhorses in studying spoken word production is the picture-word interference paradigm. In this paradigm, speakers name pictures while trying to ignore superimposed written distractor words or spoken distractor words presented over headphones (e.g., Damian & Martin, 1999; Glaser & Düngelhoff, 1984; Schriefers, Meyer, & Levelt, 1990). Response time (RT) is the main dependent measure. A central finding obtained with picture-word interference is that naming pictures takes longer when the distractor word is of the same semantic category as the picture name (e.g., pictured cat, categorically related word DOG) than when the distractor is unrelated (e.g., pictured cat, word PIN), an effect often referred to as "semantic interference". This semantic effect (i.e., RT semantic > RT unrelated) is only obtained when speakers have to select a word to name the picture, but not when a manual response is required (Schriefers et al., 1990). This finding suggests that the semantic effect arises during lexical selection for word production. Given that the effect is one of interference rather than facilitation, lexical selection has been taken to be a competitive process (e.g., Abdel Rahman & Melinger, 2009; Hantsch, Jescheniak, & Schriefers, 2005; Levelt, Roelofs, & Meyer, 1999; Starreveld & La Heij, 1996; Roelofs, 1992, 2003). The assumption is that semantically related distractor words increase lexical competition relative to unrelated distractor words. This account of semantic interference has been computationally implemented in a number of models of word production, including WEAVER++ (Levelt et al., 1999; Roelofs, 1992, 2003, 2006) and the model of La Heij and colleagues (i.e., Bloem & La Heij, 2003; Starreveld & La Heij, 1996).

It should be noted that the picture-word interference paradigm not only taps into word production but also into attentional mechanisms. These mechanisms allow the participants to respond to the target picture rather than to the distractor word. Such attentional mechanisms are an explicit part of the models of Roelofs (1992, 2003) and Starreveld and 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).

Recent research has challenged the competition account and researchers have proposed that lexical selection is not a competitive process. According to such a non-competitive account, a word is selected if its activation exceeds some threshold or, alternatively, the highest activated word is selected after a fixed period of time (e.g., Dell, 1986). Thus, selection is assumed to be independent of the activation state of other words. A prominent non-competitive explanation of the semantic interference effect is given by the response exclusion account (e.g., Finkbeiner & Caramazza, 2006; Janssen, Schirm, Mahon & Caramazza, 2008). According to this account, the semantic interference effect arises post-lexically and reflects the exclusion of an articulatory response to the distractor word from an output buffer. Response exclusion concerns a proposal for a mechanism of selective attention, describing how target rather than distractor information gains control over responding. On the response exclusion view, the semantic interference effect tells us nothing about the processes underlying lexical selection, but the effect is informative about how selective attention operates in the picture-word interference paradigm. The response exclusion account of context effects in word production holds that (1) articulatory responses to written distractor words obligatorily enter an output buffer, and (2) these articulatory responses are removed from the buffer through a process of response exclusion in picture naming, whereas they are simply overwritten in word reading (Finkbeiner & Caramazza, 2006). This latter assumption refers to a word-word version of the picture-word interference paradigm in which the targets are words (i.e., the task is word reading) and the distractors are also words (e.g., Glaser & Glaser, 1989).

The remainder of the article is organized as follows. We start by critically evaluating findings from picture naming that have been taken as evidence against the competition account and in favor of the response exclusion account. We argue that the findings are, in fact, compatible with the competition account. Moreover, some of the findings appear to challenge rather than support the response exclusion account. Next, we compare the response exclusion and competition accounts with respect to their ability to explain data on context effects in word reading, a task that has somewhat been neglected in recent discussions. We argue that the response exclusion account is challenged by findings on word reading RTs. Moreover, we present the results of computer simulations showing that a competition model like WEAVER++ accounts for the findings.

Effects of Distractor Words in Picture Naming

The semantic interference effect of distractor words in picture naming has long been interpreted as reflecting lexical competition between the target picture name and the distractor word (e.g., Levelt et al., 1999; Roelofs, 1992; Starreveld & La Heij, 1996). According to this account, semantically related words are linked via a conceptual network. When a word 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. The semantic interference effect reflects stronger lexical competition for semantically related than unrelated distractor words.

In contrast, according to the response exclusion account (Finkbeiner & Caramazza, 2006; Janssen et al., 2008; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007), semantic interference does not arise in lexical selection but during a later articulatory buffering stage in word production. The account assumes that people form an articulatory response to a distractor word, which enters an output buffer that can hold only one response at a time. The response to the distractor will reach the output buffer before the response to the picture. Therefore, the response to the picture has to wait until the response to the distractor has been excluded from the buffer. It is assumed that the mechanism excluding a response from the buffer is sensitive to semantic information. If the articulatory response to the distractor shares semantic features with the picture name, the duration of the process replacing the response to the distractor by the picture name will be prolonged, yielding the semantic interference effect. Several findings from picture-word interference have been taken as evidence for the response exclusion account: the distractor-frequency effect (Miozzo & Caramazza, 2003), semantic facilitation from part-whole distractors (Costa, Alario, & Caramazza, 2005), the reverse semantic distance effect (Mahon et al., 2007), distractor effects in delayed naming (Janssen et al., 2008), and semantic facilitation from masked distractors (Finkbeiner & Caramazza, 2006). We critically discuss these findings in turn.

The distractor-frequency effect is the finding that high-frequency distractor words produce less interference in picture naming than low-frequency distractors (i.e., RT high-frequency distractor < RT low-frequency distractor, see Miozzo & Caramazza, 2003). According to the response exclusion account, compared with low-frequency distractors, high-frequency distractors enter the buffer more quickly and therefore they are removed earlier, which reduces the interference. In contrast, under the assumption that high-frequency words have a higher resting-level of activation than 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, and lexical frequency is a factor determining the speed of word recognition (Roelofs, 2005b). Consequently, compared with low-frequency distractors, high-frequency distractors are blocked out more quickly and therefore yield less interference, as empirically observed. Thus, both the response exclusion account and competition models like WEAVER++ provide an explanation of the distractor-frequency effect.

Semantic facilitation from part-whole distractors is the finding that picture naming RTs are shorter compared with 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 (i.e., RT related part-whole < RT unrelated part-whole), Costa et al. took their finding as evidence against competition models. According to Costa et al., semantically related part-whole distractor words prime the selection of the picture name (so that the selection threshold is exceeded quicker), without inducing competition. Moreover, because part-whole distractors are not members of the same semantic category as the picture name, they can be excluded from the buffer as quickly as unrelated distractors. The priming of lexical selection thus yields semantic facilitation. 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 had also 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 (see Abdel Rahman & Melinger, 2009). This hypothesis may be tested empirically in future research.

The reverse semantic distance effect is 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 semantically far distractors (e.g., FROG as a distractor) in picture naming (i.e., RT semantically close < RT semantically far). 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 in blocks of trials with semantically close pictures was slower than in blocks of trials with semantically far pictures (i.e., RT semantically close > RT semantically far). Moreover, so far, studies have failed to replicate Mahon et al.'s finding on the semantic distance effect caused by distractor words in picture naming (e.g., Lee & de Zubicaray, 2010; Abdel Rahman, Aristei, & Melinger, 2010). The observed pattern in these latter studies was comparable to Vigliocco et al.'s findings and in agreement with competition models: Semantically close distractors yielded more competition than semantically far distractors. Thus, as long as it is not empirically clarified why these different studies obtain 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 (i.e., RT semantic > RT unrelated), 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. (2008) and Dhooge and Hartsuiker (2011), participants had to decide between naming the picture or reading the word aloud depending on the color of the distractor word, which may have triggered special processes yielding the delayed effects. For example, Dhooge and Hartsuiker (2011) used a dark blue color indicating the task of reading and black color indicating the task of picture naming, which are colors that are difficult to distinguish from each other. Distractor frequency may have influenced the color discrimination process rather than the language processes of interest, thereby yielding the distractor-frequency effect in delayed naming. 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 obtain diverging results, theoretical conclusions based on findings from delayed naming should be considered with caution.

Semantic facilitation from masked distractors refers to the finding of Finkbeiner and Caramazza (2006) that when distractor words are masked, they yield semantic facilitation (i.e., RT semantic masked < RT unrelated masked) rather than semantic interference. According to Finkbeiner and Caramazza (2006), participants cannot detect the distractor consciously when it is masked and consequently 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 the name via the conceptual 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 is put forward in a recent article that reported a replication of semantic facilitation from masked distractors (Dhooge &

Hartsuiker, 2010). However, semantic facilitation from masked distractors is not in disagreement with the competition account (e.g., Abdel Rahman & Melinger, 2009; Roelofs, 1992, 1993, 2006, 2008b). Under this account, when distractors do not enter in competition with the picture name for selection, they facilitate lexical selection (e.g., Roelofs, 1992, 1993, 2006, 2008b). Piai, Roelofs, and Schriefers (submitted) provided evidence that participants adopt a competition threshold and that masked distractors tend not to exceed this threshold, which yields semantic facilitation.

Whereas the seemingly problematic findings are, in fact, compatible with the competition account, some of the findings appear to challenge rather than support the response exclusion account. According to the latter account, a response to the distractor word enters the output buffer before the response to the picture. Consequently, the picture name has to wait until the distractor has been removed from the buffer. This removal process takes longer in the semantically related than unrelated condition, yielding semantic interference. Semantic facilitation from part-whole and masked distractors arises because the distractor word primes the selection of the picture name via the conceptual network. However, whereas such priming may reduce RTs when the output buffer is not occupied (i.e., when distractor words are masked), it should not differentially affect naming RTs when distractors are clearly visible and enter the buffer (i.e., in case of part-whole distractors). In the latter case, the response to the picture has to wait until the response to the distractor has been removed from the buffer, which will absorb the priming effect on lexical selection (see Mulatti & Coltheart, in press, for a similar argument). Perhaps, one may assume that the primed picture name reaches the buffer earlier than the distractor. If so, the distractor does not affect the primed response to the picture at the level of the output buffer and the priming of lexical selection surfaces in the RTs. However, unrelated distractor words increased picture naming RTs relative to neutral Xs (Costa et al., 2005), which suggests that the distractor words reached the buffer before the picture name, contrary to the above assumption. Thus, semantic facilitation from part-whole distractor words challenges rather than supports the response exclusion account.

Another finding that challenges rather than supports the response exclusion account concerns the influence of stimulus onset asynchrony (SOA) on the distractor-frequency effect. Dhooge and Hartsuiker (2010) presented high- and low-frequency distractor words at preexposure SOAs of -300, -200, or -100 ms (i.e., before picture onset) or simultaneously with the picture (SOA = 0 ms). They observed a significant 24-ms distractor-frequency effect at SOA = 0 ms, a significant effect of 12 ms at SOA = -100 ms, and non-significant effects of 7 ms and 3 ms at SOA = -200 ms and -300 ms, respectively. Roelofs et al. (2011) demonstrated through computer simulations that WEAVER++ accounts for the decrease of the distractor-frequency effect at distractor-preexposure SOAs. Dhooge and Hartsuiker (2010) argued that the effect of SOA supports the response exclusion account because “the longer the time interval between the stimuli, the more likely it is that the response to the distractor has been excluded, and so the smaller the distractor frequency effect is” (p. 881). In terms of the response exclusion account, the distractor-frequency effect occurs because a response to high-frequency distractors enters the buffer earlier than a response to low-frequency distractors, and hence the removal can start earlier for high- than low-frequency distractors. However, whereas SOA = -100 ms would give both high- and low-frequency distractors a head-start in the removal process of 100 ms, the SOA reduces the distractor-frequency effect by only 12 ms (at SOA = 0 ms, the effect is 24 ms). Similarly, an SOA of -200 ms would give both high- and low-frequency distractors a head-start in the removal process of 200 ms, but it reduces the distractor-frequency effect by only 17 ms. Thus, rather than supporting the response exclusion account, the SOA findings actually challenge the account.

To conclude, we have critically evaluated the major findings that have been taken as evidence for the response exclusion account (i.e., the distractor-frequency effect, semantic facilitation from part-whole distractors, a reverse semantic distance effect, distractor effects in delayed naming, and semantic facilitation from masked distractors). Contrary to what proponents of the response exclusion account maintain, the findings appear to be compatible with the competition account. Moreover, a few findings could not be replicated. Finally, some of the findings appear to challenge rather than support the response exclusion account.

Effects of Distractor Words and Pictures in Word Reading

In the remainder of the article, we compare the response exclusion and competition accounts with respect to their ability to explain relevant data on context effects in word reading. We argue that the response exclusion account is challenged by the data, whereas a competition model like WEAVER++ accounts for the findings. Table 1 lists five findings on context effects in word reading that are used to evaluate the response exclusion and competition accounts in the present article. The findings have also previously been used to evaluate models of spoken word production (Roelofs, 2007a).

As we reviewed above, categorically related distractor words yield semantic interference (i.e., RT semantic > RT unrelated) in immediate picture naming when the distractors are clearly visible. Moreover, relative to a neutral condition, unrelated distractor words yield interference (i.e., RT unrelated > RT neutral) and identical distractor words yield facilitation (i.e., RT identical < RT neutral). For example, in naming a pictured cat, the unrelated distractor word PIN increases the naming RT compared with a neutral series of Xs, henceforth referred to as “general interference”, and the identical distractor word CAT yields facilitation (Glaser & Düngelhoff, 1984).

The pattern of results is different when participants read words aloud while trying to ignore distractor pictures. For example, they say “cat” in response to the word CAT, while ignoring a pictured dog (semantic), a pictured pin (unrelated), a pictured cat (identical), or an empty rectangle (neutral). In word reading, no general interference (i.e., RT unrelated = RT neutral) and no semantic effect (i.e., RT semantic = RT unrelated) is obtained from picture distractors (Finding 1 in Table 1, see Glaser & Düngelhoff, 1984; Roelofs, 2003, 2007a, 2007b, 2008a, 2008b). Moreover, identity facilitation is also absent (i.e., RT identical = RT neutral).

Whereas distractor pictures do not affect word reading RTs, when a distractor *word* (as opposed to a distractor picture) is presented in word reading, general interference (i.e., RT unrelated > RT neutral) but not a semantic effect (i.e., RT semantic = RT unrelated) is obtained (Finding 2, e.g., Glaser & Glaser, 1989; La Heij, Happel, & Mulder, 1990; Roelofs, 2006). In this word-word task, participants are presented with two written words in the centre of a computer screen and they have to read aloud the word designated as the target while trying to ignore the other word. The target is indicated by the relative timing of the onsets of the words (i.e., name the first or second word that appears on the screen, e.g., Glaser &

Glaser, 1989), by spatial position (i.e., the distractor is always presented at a fixation point and the target appears above or below it, e.g., La Heij et al., 1990), or by underlining the target word (e.g., Roelofs, 2006). Regardless of how the target word is indicated, a distractor word effect is obtained. For example, relative to a neutral condition with a series of Xs, the semantically related and unrelated words DOG and PIN yield interference in word reading (i.e., RT semantic > RT neutral and RT unrelated > RT neutral). However, there is no difference in effect between DOG and PIN (i.e., RT semantic = RT unrelated), which means that a semantic effect is absent. Also, identity facilitation is obtained. Relative to the neutral condition, the identical distractor word CAT facilitates reading CAT (i.e., RT identical < RT neutral).

Figure 1 illustrates the data patterns (taken from Roelofs, 2006). The figure shows the mean RTs for word reading in the context of semantically related, unrelated, or identical distractor words, or neutral series of Xs. The distractor words were presented at three different SOAs, namely -150 ms (i.e., preexposure of the distractor word by 150 ms), 0 ms, and 150 ms (i.e., postexposure of the distractor word by 150 ms). Reading RTs were shorter on identical than neutral trials with distractor preexposure (i.e., SOA = -150 ms) but not at the other SOAs. Moreover, RTs were longer on semantic and unrelated trials than on neutral trials at the SOAs of -150 and 0 ms, but not at SOA = 150 ms. This general interference effect was largest at the SOA of 0 ms. Clearly, there was no semantic effect at any of the SOAs.

A very similar pattern of results is obtained when Dutch participants produce a gender-marked noun phrase in response to the word, while trying to ignore distractor words (Finding 3, see Roelofs, 2006). For example, they say “de kat” (“the cat”) in response to the written word KAT (*cat*), with the article marking the grammatical gender of the noun (i.e., “de” and “het” indicate non-neuter and neuter gender, respectively). Again, relative to a neutral condition with a series of Xs, the semantically related and unrelated distractor words HOND (*dog*) and PIN (*pin*) yield interference in producing “de kat” (i.e., RT semantic > RT neutral and RT unrelated > RT neutral). However, there is no semantic effect (i.e., RT semantic = RT unrelated). Relative to the neutral condition, the identical distractor word KAT facilitates the production of “de kat” (i.e., RT identical < RT neutral). In this experiment, the grammatical gender of the target word and the distractor word was always the same, so the differential effect of distractor words (i.e., semantically related and unrelated versus identical) cannot be due to a difference in grammatical gender.

Finkbeiner and Caramazza (2006) argued that the absence of semantic interference of word distractors in word reading is predicted by the response exclusion account. They stated that “any to-be-articulated response already in the output buffer will be overwritten by the response to the most recently presented written word (unless it has already met the relevant provenance criteria for production and is already in the course of being produced). In the case of the word-word paradigm, then, interference effects are not observed because non-target responses are not excluded on the basis of their response relevance, they are overwritten, directly and obligatorily, by the target word stimulus” (p. 1034).

However, if articulatory responses to target words simply overwrite responses to distractor words in the output buffer, it remains unclear why semantically related and unrelated distractor words yield general interference (i.e., RT semantic > RT neutral and RT unrelated > RT neutral), whereas identical words yield facilitation (i.e., RT identical < RT neutral). Simply overwriting a buffered response should not yield any effect. One may perhaps argue that interference and facilitation arise before target word planning reaches the output buffer. In particular, perhaps interference and facilitation may arise when the phonological form of the target word is selected (cf. Caramazza, 1997). Here, an identical distractor word would provide converging phonological information, whereas the semantically related and unrelated distractor words would yield diverging information. The converging and diverging distractor information in selecting the phonological form may influence the reading RTs.

However, although converging information from identical distractor words (e.g., the distractor word CAT in saying “cat” to the target word CAT) may cause the target word to exceed the selection threshold earlier and thereby decrease reading RTs, semantically related and unrelated distractor words (e.g., distractors DOG and PIN) will not influence how quickly the threshold is exceeded, according to the response exclusion account. This is because words are not selected by competition under this account. As indicated earlier, non-competitive accounts hold that a word is selected if its activation exceeds some threshold or that the highest activated word is selected after a fixed period of time. Neither of these types of selection explains the interference (i.e., RT semantic > RT neutral and RT unrelated > RT neutral) induced by word distractors in word reading. Thus, assuming that the interference and facilitation effects arise before the output buffer is reached does not save the response exclusion account. Of course, one does not have to assume that both the facilitation and interference effects arise before the buffer. The facilitation effect may arise from phonological form priming, whereas the interference from both unrelated and semantically related words arises in the buffer. However, the latter is no option if articulatory responses to written distractor words are simply overwritten in the buffer, as assumed by the response exclusion account (Finkbeiner & Caramazza, 2006).

An alternative account of the interference and facilitation of word distractors in word reading is that the effects arise during word recognition rather than word production. That is, relative to a series of Xs, the presence of a different word on the screen may hamper recognition of the target word, whereas the presence of an identical word may help recognizing the target word. There are number of reasons why this may be the case. First, the target and distractor words may compete for visual attention. It is generally assumed that the capacity of visual attention is limited, allowing only the processing of a limited amount of information at a time. A distractor word may divert some of the attentional capacity away from the target word, thereby delaying the target reading response (cf. Hock & Egeth, 1970). It is possible that the identical condition diverts attention from the target, but lends activation to the same representation, thereby speeding recognition. In the neutral case, the Xs divert attention away but do not activate the target, and in the unrelated and semantic conditions, recognition is hampered more than in the neutral condition. This might explain the interference and facilitation effects from word distractors in word reading. Second, distractor words may help or hinder early orthographic processing of the target word. That is, the presence of redundant orthographic information in the identical condition (e.g., target CAT, distractor CAT) may facilitate recognition of the target word, whereas the presence of conflicting orthographic information in the semantically related and unrelated conditions (e.g., target CAT, distractor DOG or PIN) may hamper target word recognition. Thus, early attentional or orthographic influences may yield the facilitation and interference effects of distractor words in word reading. If so, these effects are compatible with the response exclusion account.

However, the visual attention account fails to explain why distractor words affect responding, whereas distractor pictures do not (Finding 1; see Roelofs, 2003, for discussion). If the presence of a written distractor word diverts visual attention away from the target word, relative to series of Xs, it remains unclear why distractor pictures have no such effect, relative to no picture or an empty rectangle in the neutral condition (Roelofs, 2006). Thus, competition for visual attention alone is unlikely to be responsible for the interference and facilitation effects. Moreover, the assumption that the interference and facilitation effects arise during early orthographic processes is challenged by the observation that similar distractor effects are obtained when the distractor words are auditorily presented in word reading (Roelofs, 2005a). To conclude, visual attention or early orthographic influences do not provide a good account of the facilitation and interference effects of distractor words in word reading. Therefore, these effects remain a challenge for the response exclusion account.

Effects of Distractors in Generating Noun Phrases and Categorizing Words

Distractor words yield general interference effects in word reading (i.e., RT unrelated > RT neutral), challenging the response exclusion account. To save the account, one may perhaps drop the assumption that written words obligatorily overwrite buffered reading responses. Instead, the response exclusion process may decide whether an articulatory response to a word should remain in the output buffer or whether another articulatory response should enter it (as response exclusion is assumed to do in picture naming), depending on which of the two words is the target. However, this should yield a semantic effect, as it does in picture naming, contrary to what is empirically observed (Glaser & Glaser, 1989; La Heij et al., 1990; Roelofs, 2006).

Perhaps one may assume that the response exclusion process does not use semantic information for making its decision in word reading. After all, semantic information is not necessary for oral reading (cf. Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). If the response exclusion process does not use semantic information in word reading, this would explain the absence of a semantic effect. The general interference by unrelated words (i.e., RT unrelated > RT neutral) may occur because the presence of two different words (i.e., target and distractor) still requires a decision about which word to use for responding. This decision may delay the reading response relative to a series of Xs as distractor. For the same reason, the decision may be delayed by semantically related words relative to the neutral Xs. If semantic information plays no role in response exclusion in word reading, the delay would be the same for semantically related and unrelated words (i.e., there is no semantic effect), as empirically observed (Finding 2, Figure 1).

However, according to the model of Caramazza and colleagues (e.g., Caramazza, 1997), semantic information is required in accessing a word’s grammatical gender. Thus, semantic information is accessed in generating a gender-marked noun phrase in response to a written word (e.g., in saying “de kat” in Dutch in response to the word KAT). In this case, it is implausible to assume that the response exclusion process does not use semantic information. Of course, semantic information could be used to retrieve the word’s grammatical gender without the same type of information necessarily being used in the process of response exclusion. However, such an assumption would be ad hoc and demand an explanation of why semantic information does play a central role in the response exclusion process in other task situations (e.g., Finkbeiner & Caramazza, 2006). The use of semantic information in response exclusion predicts a semantic effect from word distractors in generating gender-marked noun phrases in response to target words, contrary to what is empirically observed (Finding 3, Roelofs, 2006). Empirically, the distractor words yield general interference and identity facilitation effects relative to neutral trials (i.e., RT unrelated > RT neutral and RT identical < RT neutral) in generating gender-marked noun phrases in response to words, but distractor words yield no semantic effect (i.e., RT semantic = RT unrelated). Moreover, if one instead assumes that the response exclusion process does *not* use semantic information in generating gender-marked noun phrases, the account would fail to explain the observation that distractor *pictures* (as opposed to distractor words) do yield a semantic effect, namely semantic facilitation (i.e., RT semantic < RT unrelated), in generating gender-marked noun phrases in response to words (Finding 4, Roelofs, 2003, 2006). In these experiments, the grammatical gender of the target word and distractor picture was always the same, so the facilitation is a semantic rather than grammatical gender effect.

Proponents of the response exclusion account may perhaps argue that the interference effects of distractor pictures are not specific effects on word planning or managing the output buffer, but are global nonspecific effects on ongoing processes. That is, participants are simply distracted by anything that is presented while they are reading the words. The distraction operates at a global level and has nothing to do with the reading response. However, global distraction fails to explain why pictures do not cause any distraction in simple word reading (Finding 1). For example, in reading aloud the word CAT, there is no difference in effect between a pictured dog (semantically related), a pictured pin (unrelated), a pictured cat (identical), and an empty rectangle (neutral), as observed by Glaser and Düngelhoff (1984) and Roelofs (2003, 2007a, 2007b, 2008a, 2008b). This indicates that the interference of distractor pictures in generating noun phrases is a specific effect on lexical processing and not simply a global distraction effect. Moreover, global distraction would fail to explain why distractor pictures yield semantic facilitation (i.e., RT semantic < RT unrelated) in generating noun phrases in response to words (Finding 4). This indicates that the content relationship between the distractor picture and the word reading response matters. To conclude, the response exclusion account fails to explain why distractor pictures yield general interference and semantic facilitation on RTs in generating noun phrases in response to words, whereas the pictures yield no effect at all in simple word reading.

One may argue that the semantic effect of distractor pictures in generating gender-marked noun phrases in response to words arises during selection of a phonological form for the target word, before the output buffer is reached. The difference in semantic effect of picture and word distractors in generating noun phrases (i.e., distractor pictures yield a semantic effect, whereas distractor words do not) would then be the result of processes that happen in word selection rather than during response exclusion. However, the effect of distractor pictures and words in generating the gender-marked noun phrases is one of interference of unrelated distractor pictures and unrelated distractor words relative to a neutral condition (i.e., RT unrelated > RT neutral, which consists of a series of Xs for words and an empty rectangle for pictures), whereas semantically related distractor pictures yield facilitation relative to the unrelated condition (i.e., RT semantic < RT unrelated). The response exclusion account assumes no competition in word selection (i.e., a word is selected if its activation exceeds some threshold or the highest activated word is selected after a fixed period of time). This may explain the semantic facilitation of semantically related distractor pictures relative to unrelated pictures, but it fails to explain the interference of unrelated distractor pictures and words relative to neutral distractors.

Similarly, distractor pictures yield general interference (i.e., RT unrelated > RT neutral) and semantic facilitation (i.e., RT semantic < RT unrelated) in word categorizing (Finding 5, e.g., Glaser & Düngelhoff, 1984; Roelofs, 2003, 2007b, 2008b). In this task, participants produce a category name in response to the written word. For example, participants respond "animal" to the word CAT, while trying to ignore a pictured dog (semantically related), a pictured pin (unrelated), a pictured cat (identical), or an empty rectangle (neutral). Relative to the neutral condition, unrelated distractor pictures yield general interference (i.e., RT unrelated > RT neutral), whereas semantically related pictures yield facilitation relative to unrelated pictures (i.e., RT semantic < RT unrelated). There is no identity effect (i.e., RT identical = RT neutral). Thus, as with generating gender-marked noun phrases in response to words, unrelated distractor pictures yield general interference and semantically related pictures facilitate responding relative to unrelated pictures in word categorizing (e.g., Glaser & Düngelhoff, 1984; Roelofs, 2003, 2007b, 2008b). Response exclusion may explain the semantic facilitation of semantically related distractor pictures relative to unrelated pictures, but it fails to explain the interference of unrelated distractor pictures relative to neutral rectangles in word categorizing. To account for these findings in the context of the response exclusion hypothesis, one may argue that the semantic facilitation arises before the buffer, whereas the interference from unrelated distractor pictures relative to the neutral condition arises in response exclusion. However, as pointed out above, the latter assumption fails to explain why distractor pictures do not affect word reading (Finding 1).

To conclude, the response exclusion account is challenged by key findings on context effects of pictures and words in word reading, in the generation of gender-marked noun phrases in response to words, and in word categorization. Given that the response exclusion account has difficulty explaining the context effects, it becomes important so see whether a competition model can explain the findings.

Simulations of Effects of Distractor Words in Word Reading

In this section, we discuss how WEAVER++ accounts for the context effects of distractor words in word reading. Elsewhere (Roelofs, 2003, 2006, 2007b), the model's account of the context effects (i.e., general interference, semantic, and identity effects) in word categorizing and noun phrase production are discussed in depth and successful computer simulations of the key findings are reported. In the present article, we concentrate on the distractor word effects in word reading and their time course, as observed by Roelofs (2006) and others. These data have not been addressed in depth before by simulation. We first briefly explain how word reading relates to picture naming in the model. Next, we report the results of computer simulations of the effect of word distractors on word reading. The simulations show that the key findings are explained by the model.

According to the WEAVER++ model (Levelt et al., 1999; Roelofs, 1992, 2003), naming pictures involves the activation of concepts, lemmas, morphemes, phonemes, and syllable motor programs in associative memory. For example, naming a pictured cat involves the activation in a lexical network of the representation of the concept CAT(X), the lemma of *cat* specifying that the word is a noun (for languages such as Dutch, lemmas also specify grammatical gender), the morpheme <cat>, the phonemes /k/, /æ/, and /t/, and the syllable motor program [kæt]. In the model, activation spreads from level to level, whereby each node sends a proportion of its activation to connected nodes. The model assumes that perceived pictures have direct access to concepts, for example, CAT(X), and only indirect access to word forms (e.g., <cat> and /k/, /æ/, and /t/), whereas perceived words have direct access to word forms and only indirect access to concepts. Consequently, naming pictures requires concept selection, whereas words can be read aloud without concept selection. The latter is achieved by mapping input word forms (e.g., the visual word CAT) directly onto output word forms (e.g., <cat> and /k/, /æ/, and /t/), without engaging concepts and lemmas.

Distractor pictures yield no interference and no facilitation in simple word reading (Finding 1). Because words can be read aloud in the model by directly mapping orthographic input forms onto output phonological forms, picture distractors have no effect at all on word reading (i.e., RT semantic = RT unrelated = RT identical = RT neutral), as empirically observed. Simulations demonstrating this property of the model are reported in Roelofs (2003).

Distractor words yield general interference (i.e., RT unrelated > RT neutral) but not a semantic effect (i.e., RT semantic = RT unrelated) in simple word reading (Finding 2). We ran new computer simulations examining the effect of word distractors on word reading in the model. The simulation protocol and the parameters values were exactly the same as in earlier simulations of word reading by the model (Roelofs, 2003). The present simulations concerned reading a word in the context of a semantically related, unrelated, or identical distractor word, or a neutral item. For example, the model simulated the oral reading of the word CAT in the context of the word DOG (semantically related), the word PIN (unrelated), the word CAT (identical), or a series of Xs (neutral), similar to what the participants did in the experiment of Roelofs (2006). The SOAs in the simulations were -150 ms (distractor word preexposure), 0 ms, and 150 ms (distractor word postexposure), as in the real experiment. The simulations concerned the process of word-form encoding (i.e., morphological, phonological, and phonetic encoding, see Roelofs, 1997). To obtain absolute reading times, a constant of 360 ms was added to the simulated encoding times for those aspects of reading that were not simulated, such as orthographic and articulatory processes.

Figure 2 shows the simulations results. Reading RTs in the model are shorter on identical than neutral trials with distractor preexposure (i.e., SOA = -150 ms) but not at the other SOAs. Moreover, RTs are longer on semantic and unrelated trials than on neutral trials at the SOAs of -150 and 0 ms, but not at SOA = 150 ms. Interference is largest at zero SOA. Clearly, there was no semantic effect at any of the SOAs. These results correspond to what is empirically observed, as illustrated in Figure 1. Thus, the model accounts for the empirical observations.

Why is general interference (i.e., RT unrelated > RT neutral) but not a semantic effect (i.e., RT semantic = RT unrelated) obtained with word-word stimuli in the model? According to WEAVER++, when lemmas are not selected to accomplish the task, response selection takes place at the form level, where one morpheme is competitively chosen over another.

Consequently, in reading aloud the target word CAT in the context of the words DOG or PIN, the morphemes <dog> and <pin> activated by the distractor words compete with the target <cat> during the selection of morphemes (and, as in picture naming, during the selection of motor programs in phonetic encoding, see Roelofs, 1997), whereas the distractor word CAT helps in selecting the morpheme <cat>. Although perceived distractor words activate their lemmas and corresponding concepts in the network, this activation does not differentially affect the reading response because of the network distance (cf. Roelofs, 2003, 2008a). Thus, semantic influences do not reach form selection. Hence, although interference is obtained with word-word stimuli (i.e., both DOG and PIN delay the reading response), a semantic effect does not occur (i.e., the effect does not differ between DOG and PIN).

Moreover, the magnitude of the interference and facilitation effects of distractor words in word reading varies with SOA. General interference (i.e., RT unrelated > RT neutral) is maximal at SOA = 0 ms, whereas identity facilitation (i.e., RT identical < RT neutral) occurs at the distractor-preexposure SOA of -150 ms. In WEAVER++, the time course of interference and facilitation reflects activation decay and distractor blocking, which is a mechanism of selective attention in the model (Roelofs, 2003, 2005b). In performing picture-word interference tasks, the model favors processing of the target over the distractor by reactively blocking the latter. Reactive blocking implies that the attentional modulation develops after an initial processing response to both targets and distractors. The speed of blocking depends on the speed of availability of the distractor information. Because of distractor blocking and spontaneous decay of activation, there is not much activation from preexposed distractor words in the lexical network around target word onset. Similarly, there is little network activation from postexposed distractor words around target onset. Because distractor word activation in the network is maximal when the distractor is presented around target onset, interference is maximal at short SOAs in the model. Facilitation is constant at preexposure SOAs because of a floor effect in speeding up responding. Thus, interference peaks at zero SOA, whereas facilitation occurs at the distractor-preexposure SOA, in agreement with the empirical findings (see Figure 1, Roelofs, 2006).

The WEAVER++ model's account of the absence of semantic effects in word reading predicts that the effects should occur when picture distractors are presented and the lemma level is involved in generating a response to words, such as in generating gender-marked noun phrases and in word categorizing. This is exactly what is empirically observed. Distractor pictures yield semantic facilitation in generating gender-marked noun phrases in response to words (Finding 4) and in word categorizing (Finding 5). In both cases, the effect is one of interference of unrelated pictures relative to a neutral condition (i.e., RT unrelated > RT neutral) and facilitation of semantically related pictures relative to unrelated ones (i.e., RT semantic < RT unrelated). However, there is no semantic effect in the model when words (instead of pictures) are presented as distractors in generating gender-marked noun phrases (Finding 3), for reasons described above. Also, in word categorizing, there is no identity effect of picture distractors. In Roelofs (2003, 2006, 2007b), successful WEAVER++ simulations of these findings are reported. Thus, the model explains the findings in Table 1, whereas the response exclusion account in its present form does not.

Summary and Conclusions

In the present article, we critically evaluated findings on context effects in picture naming that have been taken as evidence against the competition account and in favor of the response exclusion account. We argued that the seemingly problematic findings are, in fact, compatible with the competition account. This held for the distractor-frequency effect, the semantic facilitation from part-whole distractors, and the semantic facilitation from masked distractors. Furthermore, a few findings could not be replicated. This held for the reverse semantic distance effect and the semantic interference in delayed naming. Moreover, we argued that semantic facilitation from part-whole distractor words and the SOA effect on the distractor-frequency effect challenge the response exclusion account. Finally, we compared the response exclusion and competition accounts with respect to their ability to account for relevant data on word reading. We argued that the response exclusion account is challenged by findings on context effects on word reading RTs. Moreover, we presented the results of computer simulations showing that a competition model like WEAVER++ explains the findings. The challenge for proponents of the response exclusion view is now to modify the account in a principled way and to demonstrate through computer simulations that the modified account can explain the findings, as we showed for the competition account implemented in WEAVER++.

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Table 1

Five Findings on Context Effects of Pictures and Words in Word Reading that are used in Evaluating the Response Exclusion and Competition Accounts in the Current Article

No.	Finding
1	Distractor pictures yield no general interference (i.e., RT unrelated = RT neutral), no semantic effect (i.e., RT semantic = RT unrelated), and no identity effect (i.e., RT identical = RT neutral) in simple word reading.
2	Distractor words yield general interference (i.e., RT unrelated > RT neutral) and identity facilitation (i.e., RT identical < RT neutral) but not a semantic effect (i.e., RT semantic = RT unrelated) in simple word reading.
3	Distractor words yield general interference (i.e., RT unrelated > RT neutral) and identity facilitation (i.e., RT identical < RT neutral) but not a semantic effect (i.e., RT semantic = RT unrelated) in generating gender-marked noun phrases in response to words.
4	Distractor pictures yield general interference (i.e., RT unrelated > RT neutral), semantic facilitation (i.e., RT semantic < RT unrelated), and identity facilitation (i.e., RT identical < RT neutral) in generating gender-marked noun phrases in response to words.
5	Distractor pictures yield general interference (i.e., RT unrelated > RT neutral) and semantic facilitation (i.e., RT semantic < RT unrelated) but not an identity effect (i.e., RT identical = RT neutral) in word categorizing.

Note. RT = Response time.

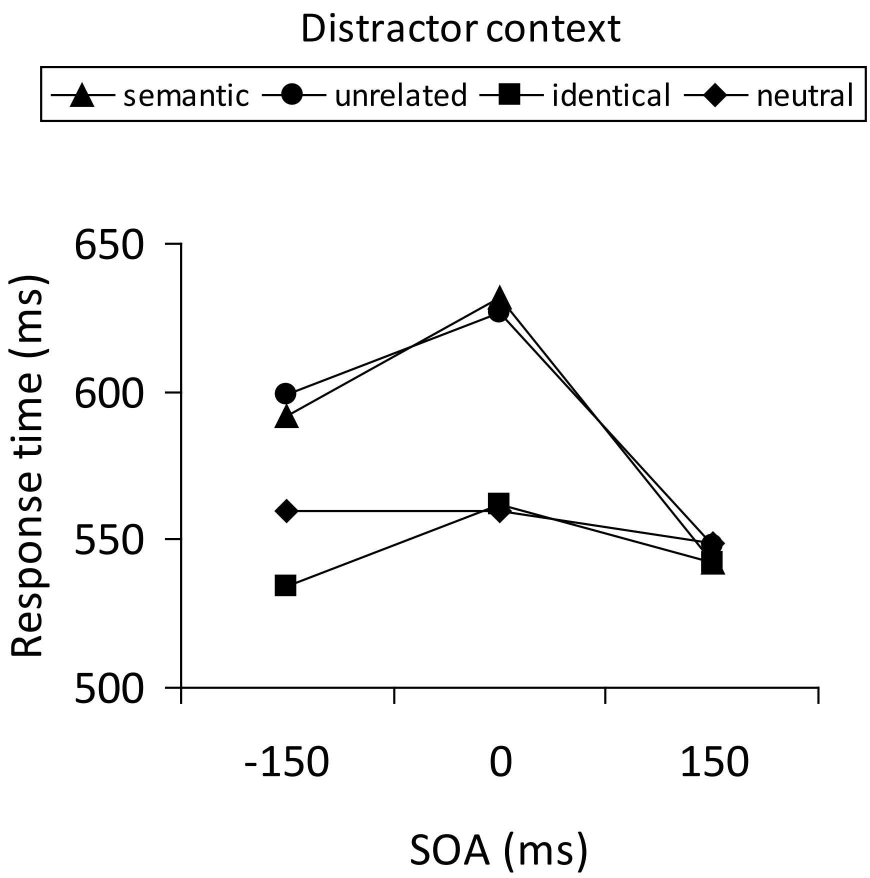

Figure 1. Mean response times for word reading in the context of semantically related, unrelated, or identical words, or neutral series of Xs. Data are from Roelofs (2006). SOA = stimulus onset asynchrony.

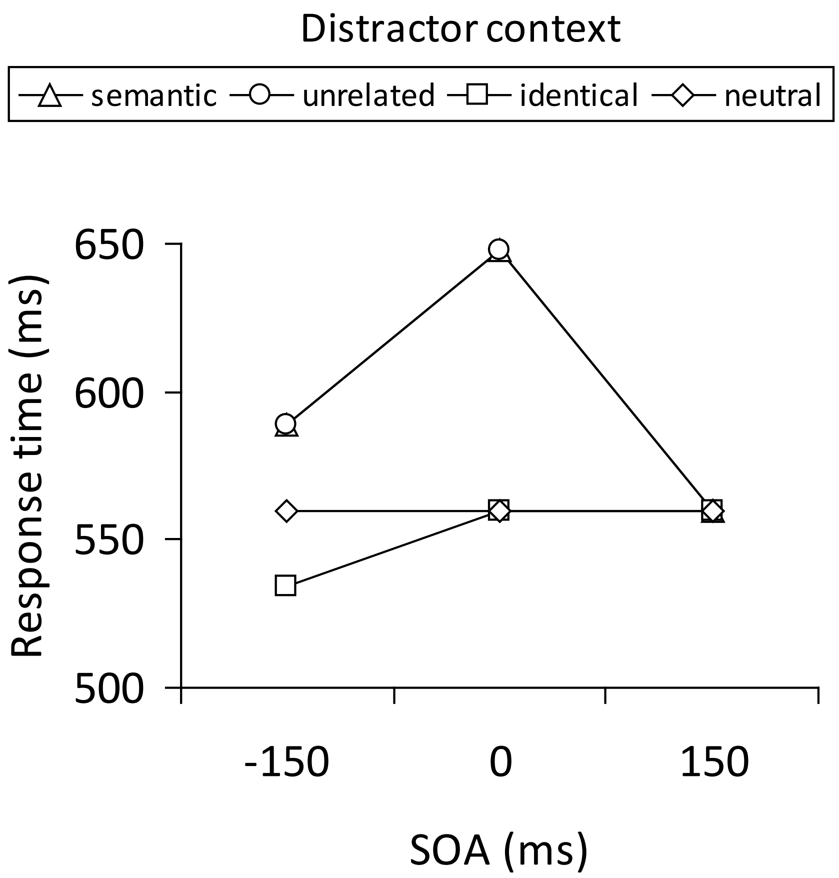

Figure 2. Mean response times for word reading in the context of semantically related, unrelated, or identical words, or neutral series of Xs in WEAVER++ simulations. SOA = stimulus onset asynchrony.