Picture-Word Interference with Masked and Visible Distractors: Different Types of Semantic Relatedness Inhibit Lexical Selection

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Abstract

One question in word production is how the presence of a semantically related word affects the naming process. It has been suggested that semantic effects in picture-word interference tasks are a net result of both inhibitory and facilitatory processes that take place at different processing levels. Finkbeiner and Caramazza (2006) argued that masking distractor words removes the inhibitory component, leaving only lexical facilitation. We investigated this claim by comparing different types of semantic relationship – categorical relatedness, associative relatedness, and a combination of both – in picture-word interference with masked and visible distractors. We observed inhibitory effects in all conditions. In the visible condition, semantic category coordinates exerted the strongest inhibition, while in the masked condition, associatively related distractors interfered most. These findings are not easily reconciled with previous findings on polarity shifts of semantic effects with masked distractors. We discuss how all present findings could be explained within the same framework.

Keywords: lexical access, competition, response exclusion, picture-word interference, unconscious access

Introduction

In the last decade, models of speech production that assume a competitive process of lexical selection (e.g., Levelt, Roelofs, & Meyer, 1999) have been subjected to strong and sometimes heated criticism and equally passionate defense (see, e.g., Spalek, Damian, & Bölte, 2012, for a summary of the arguments). The majority of empirical findings for (and against) the assumption of competitive lexical selection comes from experiments using the picture-word interference paradigm (e.g., Rosinski, 1977): Participants have to name pictures presented on the screen. Pictures are presented together with to-be-ignored distractor words (either in written or in spoken form). An often-repeated finding is that participants' responses are slower when the distractor word belongs to the same semantic category (e.g., fruit) as the target word (e.g., Schriefers, Meyer, & Levelt, 1990) than when it belongs to an unrelated category. This has been taken as evidence for lexical competition: Target and distractor word are connected at the conceptual level through a common category node and prime each other. This results in two strongly activated representations, making the selection of the target representation more difficult and hence, more time-consuming (e.g., Roelofs, 1992).

An alternative explanation for the effects observed in the picture-word interference paradigm has been formulated in the so-called response exclusion hypothesis (e.g., Mahon et al., 2007): There is no competition between the lexical entries of a target word (the picture name) and a co-activated competitor (the distractor word). Interference arises at a later, post-lexical, processing level: Before a word can be pronounced, it occupies a single-channel output buffer. If the element in the buffer is the target word, it can be articulated; if it is the distractor, it has to be removed from the buffer before the target can enter the buffer and, eventually, be produced. According to Mahon and colleagues, the buffer knows about basic semantic properties of its entries. A word which is relevant to the experimental (or communicative) goal is more difficult to remove from the buffer than a word that is irrelevant to the task. Therefore, if the task is to name the picture of an animal, for example "dog", a distractor like "mouse" will be more difficult to remove from the buffer than a distractor like "pear".

The idea that interference occurs at a post-lexical processing level has received some support from findings with masked distractor presentation in picture-word interference studies: Finkbeiner and Caramazza (2006) had participants name pictures with visible distractors, replicating the semantic interference effect. When they presented the same stimuli but masked distractors such that participants weren't consciously aware of the distractors' identity, the semantic inhibition effect turned into a strong and reliable facilitation effect. Finkbeiner and Caramazza argue that the unconscious presentation prevented the distractor word from occupying the response buffer. Therefore, no competition effect was observed. However, the distractor words were still active enough to prime semantically related items in the mental lexicon, causing a net effect of facilitation. The finding that masking a distractor word turns inhibition into facilitation has been replicated by Dhooge and Hartsuiker (2010).

As noted by several researchers (e.g., LaHeij, Dirkx, & Kramer, 1990), studies on semantic inhibition effects usually do not report the degree of association between target and distractor word. Pairs such as *cat* and *dog* and *cat* and *horse* are both related because they belong to the category animals. However, *cat* and *dog* are also associatively related because they often co-occur in the language, and if people are asked to freely associate words in response to *cat*, *dog* is often one of the first associates produced. Finkbeiner and Caramazza (2006) don't provide a list of their materials, but Dhooge and Hartsuiker (2010) do. Perusal of their Appendix shows that they used categorically related picture-distractor pairs that were only weakly associated (e.g., *spoon – knife*; *monkey – bear*), but also pairs that were strongly associated (*lion – tiger*; *apple – pear*), and, most critically, pairs that can be thought of as part-whole-relationships (*farm – shed*; *pot – lid*). The last type of relationship has been shown to cause facilitatory effects even in visible picture-word interference paradigms (Costa et al., 2005). While the data pattern observed by Dhooge and Hartsuiker is clear cut and shows a 15ms interference effect in visible naming and a 12ms facilitation effect in masked naming, it is possible that different items are responsible for the effects observed in visible and masked naming: If the inhibition observed with visible distractors is driven by the categorically related items, then a manipulation that makes them less salient competitors might allow the facilitation caused by the associated and part-whole relations to come to the fore.

In order to investigate this possibility, we used three different types of semantic relationship in our study, categorically related target-distractor pairs, associatively related target-distractor pairs, and categorically and associatively related (in the following: combined) target-distractor pairs. Crucially, unlike in the study by Dhooge and Hartsuiker (2010), the categorically related items never were in a part-whole relationship, and strongly and weakly associated pairs were distributed across two different conditions. Before turning to our study, we will briefly review the literature on the effects of categorically and associatively related context words in picture naming.

Studies investigating categorical and associative relationships at SOA 0 (with written distractors) mainly found an effect of the former: Lupker (1979) used categorically related distractors and associatively related distractors in a picture-word interference study. He found that while the former caused interference, the latter had no effect. In a second experiment, he used distractors that were either categorically related or categorically and associatively related. He found that the inhibitory effect was exactly the same for both types of distractors. He concluded that categorical relatedness inhibits word production, and that this effect is not modulated by the association strength of the two category coordinates.

A study by LaHeij, Dirkx, and Kramer (1990) provides a different finding: They selected categorically related target-distractor pairs that were either highly associated or weakly associated and used these items in a picture-word interference paradigm with different SOAs. At SOA 0, they observed inhibition for weakly associated category coordinates but not for highly associated ones. They argue that in the case of highly associated category coordinates the inhibitory effect is offset by an associative priming effect.

Investigating the time-course of these effects more closely, Alario, Segui, and Ferrand (2000) carried out an experiment on picture naming primed by pre-exposed words (in essence a picture-word interference paradigm with negative SOA). They discovered that associatively related words facilitate picture naming, but only if they are presented around 200 ms before picture onset. By contrast, categorically related words inhibit picture naming, but only if they are presented 100 ms (or less) before picture onset. So, it seems that associative relationships prime a target word whereas categorical relationships compete with a target word. However, these two mechanisms also seem to have a different time-course.

In contrast to the findings by Alario et al. (2000), Abdel Rahman and Melinger (2007) observed inhibition with categorically related distractor words and facilitation with associatively related distractor words with the same time-course. In their study, spoken distractor words were presented 150 ms before the target pictures.

To sum up, the findings on associative distractor words in picture-word interference, while somewhat inconsistent, support the assumption that an associative relation between target and distractor facilitates target naming.

Given the observation that there is a facilitatory component to both associative and categorical distractors and that masking a distractor enhances the facilitatory component, we wanted to investigate how masking affects picture naming with categorically related, associatively related, and combined distractors. Participants named the pictures both with visible distractors and with masked distractors. For visible distractor presentation we predict an interference effect for categorically related distractor words. For associatively related distractor words, we expect to see either a facilitatory effect or a null effect. Finally, for combined items, we expect to see either an effect of equal size as for the categorically related items (as Lupker, 1979, did) or an attenuation of the effect as in LaHeij et al. (1990).

If masking the distractor effectively prevents it from entering a response buffer, no inhibitory effects are expected in the masked condition. Instead, categorically related and associatively related distractors should yield facilitation which should be greatest for combined distractors.

A second aim of the study was to address a concern formulated by Kouider and Dupoux (2004). They question whether previous studies on unconscious priming truly presented words in a subliminal manner, and argue that participants are typically at least partially aware of a masked stimulus and that this partial awareness causes the priming effect. We carried out a lexical decision task on the distractor words after the picture naming study. Distractors were masked in the same way as during the picture naming study. Assessing participants' performance in the lexical decision task gave us a tool to investigate in how much (partial) awareness of the distractors modulated the effects.

Method

Participants

Forty-eight native speakers of German (thirty-five women) were recruited from the participant database of the Institute of Psychology at the Humboldt-University Berlin. Their mean age was 24.2 years. Participants received monetary compensation for their participation.

Materials

Twenty pictures of animals and objects were chosen as targets. For each of the pictures (e.g., picture LEMON), three distractor words were selected: a semantically related word (i.e., a category coordinate, e.g., *kiwi*), an associatively related word (i.e., a word from a different category, e.g., *vitamin*), and a semantically and associatively related word (e.g., *orange*). Distractor words were matched on length and frequency. The associative relation was determined pre-hoc by the intuitions of two native speakers of German and backed up post-hoc by associative relatedness ratings of the participants. Participants were asked to rate the strength of the association of two words on a scale from 1 (not associated) to 7 (very strongly associated). The categorically related items had an association strength of 2.93, the associatively related items an association strength of 4.00, and the combined items had an association strength of 5.57. As intended, the categorically related items were less strongly associated than both the associatively related items ($t(19) = 4.09$, $p < .001$) and the combined items ($t(19) = 4.62$, $p < .001$). What was not intended was that the association strength was also higher for combined items than for associatively related items ($t(19) = 11.92$, $p < .001$).

We created three unrelated conditions by recombining the related distractors with different pictures. Therefore, in each of the three conditions (categorically related, associatively related, combined), the same pictures and the same words were used in both the related and the unrelated condition.

Each participant saw a target word in all six conditions (three critical conditions and three control conditions). A different randomization was created for each participant to avoid order effects.

For the lexical decision task (see below), 20 non-words were created by using existing words and replacing one or two letters. These letter changes could occur in any position in the word. Care was taken to change each position equally often. Non-words were matched in length to the word targets.

Procedure

Participants carried out three different tasks: the picture-word interference study, a lexical decision task and a questionnaire. Order of presentation for the picture-word interference studies (visible vs. masked) was counterbalanced across participants. The questionnaire contained all related target-distractor pairs. Participants were asked to indicate how strong the association between the two concepts is, using a scale from 1 (not associated) to 7 (strongly associated). The experiments were programmed and run with Presentation (NeuroBehavioral Systems).

Visible Distractor Presentation. Participants were instructed to name the pictures on the screen and to ignore the superimposed distractor words. A trial started with a fixation cross that was presented for 500 ms. The word was presented centered on the screen for 53 ms. Picture and word were presented together for 2000 ms. Participants' responses triggered a VoiceKey and were recorded.

Delayed Distractor Presentation Participants were instructed to name the pictures on the screen and to ignore the superimposed distractor words. A trial started with a forward mask (##########) that was presented for 500 ms. The word was presented centered on the screen for 53 ms. It was replaced by the picture and a non-pronounceable mask consisting of a string of 10 consonants presented in the same location as the distractor word. The use of a consonant string as a backward mask was motivated by Finkbeiner and Caramazza (2006) who refer to findings having shown its particular effectiveness in eliminating phonological priming effects. Picture and mask were presented together for 2000 ms. Participants' responses triggered a VoiceKey and were recorded.

Lexical Decision Task A forward mask (##########) was presented for 500 ms centered on the screen. It was followed by a letter string that was presented for 53 ms. The letter string was replaced by the same mask as in the masked picture-word interference paradigm. The mask stayed in place until the participant had made a response. Participants were instructed to decide whether the briefly presented word had been an existing word of their language or not. They were encouraged to make a guess if they felt they had not seen a word at all. The results of the lexical decision task will not be analysed in the present paper, we merely used participants' overall accuracy in order to split the group in a "high-recognition" and a "low-recognition" group (see below).

Results

We carried out an ANOVA on the mean reaction times and error rates with the within-subject and within-item factors Type of Relationship (Categorical, Associative, Combined) and Relatedness (Related vs. Unrelated).

Table 1 presents the mean reaction times and error rates in the visible distractor condition. Table 2 presents these measurements in the masked distractor condition.

In the visible condition, for the reaction times, the effect of Type of Relationship was highly significant ($F_1(2,94) = 16.61$, MSE = 433, $p < .001$; $F_2(2,38) = 5.31$, MSE = 537, $p < .01$), as was the effect of Relatedness ($F_1(1,47) = 17.54$, MSE = 412, $p < .001$; $F_2(1,19) = 6.75$, MSE = 498, $p < .05$), showing faster reaction times for unrelated distractors than for related distractors. The interaction of the two factors was not significant (both Fs < 1).

For the error rates, the effect of Type of Relationship was not significant ($F_1(2,94) = 1.57$, MSE = 0.04, $p = .21$, $F_2 < 1$). The effect of Relatedness was marginally significant with slightly higher error rates for related distractors ($F_1(1,47) = 3.65$, MSE = 0.05, $p = .06$, $F_2(1,19) = 1.82$, $p = .19$). The interaction was not significant (both Fs < 1).

Table 1: Reaction times and error rates (in brackets) in the visible condition.

	Categorical	Combined	Associative
Related	646 (1.5)	631 (1.8)	625 (1.5)
Control	631 (0.7)	622 (1.5)	619 (0.9)
Effect	15 (0.8)	9 (0.3)	6 (0.6)

Table 2: Reaction times and error rates (in brackets) in the masked condition.

	Categorical	Combined	Associative
Related	622 (1.1)	613 (0.5)	615 (0.7)
Control	616 (0.5)	610 (0.4)	608 (0.6)
Effect	6 (0.6)	3 (0.1)	7 (0.1)

In the masked condition, for the reaction times, the effect of Type of Relationship was significant ($F_1(2,94) = 4.05$, MSE = 414, $p < .05$; $F_2(2,38) = 4.62$, MSE = 166, $p < .05$), as was the effect of Relatedness ($F_1(1,47) = 6.96$, MSE = 297, $p < .05$; $F_2(1,19) = 6.00$, MSE = 137, $p < .05$), again showing inhibition for related distractors. The interaction of the two factors was not significant (both Fs < 1).

For the error rates, the effect of Type of Relationship was not significant ($F_1(2,94) = 1.44$, MSE = 0.02, $p = .24$, $F_2 < 1$). The effect of Relatedness was significant by items ($F_1(1,47) = 1.54$, MSE = 0.03, $p = .22$, $F_2(1,19) = 4.75$, MSE = 0.004, $p < .05$). The interaction was not significant ($F_1(2,94) = 1.04$, MSE = 0.02, $p = .36$, $F_2(2,38) = 2.02$, MSE = 0.004, $p = .15$).

In order to investigate if the masking manipulation affected the critical effects, we pooled the data of both experiments and carried out an ANOVA with the factors Experiment, Type of Relationship, and Relatedness. We observed a significant effect of Experiment with faster reaction times for masked distractors ($F_1(1,47) = 5.43$, MSE = 5877, $p < .05$, $F_2(1,19) = 17.61$, MSE = 772, $p < .001$). The factors Type of Relationship ($F_1(2,94) = 19.01$, MSE = 406, $p < .001$, $F_2(2,38) = 7.51$, MSE = 426, $p < .001$), and Relatedness ($F_1(1,47) = 21.37$, MSE = 398, $p < .001$, $F_2(1,19) = 12.25$, MSE = 306, $p < .01$) also had a significant effect. Importantly, we observed a marginally significant interaction of Experiment and Type of Relationship by participants ($F_1(2,94) = 2.62$, MSE = 442, $p = .08$, $F_2(2,38) = 1.52$, MSE = 277, $p = .23$).

Because the interaction, albeit rather weak, suggests that the effects for the different types of relationship might differ in the visible and in the masked condition, we carried out paired t-tests for all three types of relationship in the two visibility conditions.

In the visible condition, the only reliable inhibition effect (by participants) was observed with categorically related distractors, $t_1(47) = 2.76$, $p < .01$, $t_2(19) = 1.92$, $p = .07$. In the combined condition, there was only a trend by participants, $t_1(47) = 1.97$, $p = .054$; $t_2(19) = 1.47$, $p = .16$. Finally, the effect for the associatively related condition was not significant, $t_1(47) = 1.63$, $p = .11$, $t_2(19) = 1.04$, $p = .31$.

In the masked condition, the pattern was reversed : The categorical relatedness effect was not significant, $t_1(47) = 1.50$, $p = .14$, $t_2(19) = 1.47$, $p = .16$, and neither was the combined effect, both ts < 1. By contrast, the associative relatedness effect was significant by participants ($t_1(47) = 2.33$, $p < .05$) and approached significance by items ($t_2(19) = 1.83$, $p = .08$).

Finally, we split the subjects in two groups, based on their accuracy in the masked lexical decision task. We used a median split, with the "low-recognition group" being correct on 49%-73% of all trials and the "high-recognition group" being correct on 73%-93% of all trials. We reanalyzed the data set with the additional between-subjects variable "Recognition" (high vs. low). There was no main effect of recognition (both Fs < 1) and no higher-level interactions of Type of Relationship and Relatedness with Recognition (all ps > .20). Even though the ANOVA showed that Recognition did not affect the data pattern, we present the descriptive data for the high- and low-recognition group in the masked condition in Tables 3 and 4.

Table 3: Results for the high-recognition group in the masked condition

	Categorical	Combined	Associative
Related	621	609	615
Control	617	610	609
Effect	4	-1	6

Table 4: Results for the low-recognition group in the masked condition

	Categorical	Combined	Associative
Related	622	616	616
Control	615	609	607
Effect	7	7	9

The descriptive data show that, if anything, those participants who recognized the masked distractors less well showed the stronger inhibitory effects in the picture-word interference study.

Discussion

Overall, we found inhibitory effects of semantically related distractors in both masked and visible distractor presentation in a picture-word interference paradigm.

The findings for the visible distractor presentation are in line with many previous findings. We observed semantic interference. The lack of a significant interaction between Type of Relationship and Relatedness suggests that the effect was equally strong for all types of relationship. The post-hoc *t*-tests, by contrast, hint at a possible difference: The interference is strongest for categorically related distractors and statistically absent for associatively related distractors, with categorically and associatively related distractors patterning in-between. This finding is generally in accordance with the result obtained by LaHeij et al. (1990).

The observation that interference persists for masked distractors is at odds with the two previous studies (Dhooge & Hartsuiker, 2010; Finkbeiner & Caramazza, 2006) discussed in the Introduction. Ignoring for the moment the issue of how different types of semantic relationship might affect the results and simply focussing on the categorical condition, the results do not indicate the predicted polarity reversal from inhibitory (visible) to facilitatory (masked) effects. At a general level, our data show that the polarity reversal for semantic effects dependent on distractor visibility is less universal than suggested by the previous studies.

A possibility is that in our "masked" experiment, the specific masking procedure was not exactly identical to the previous studies in terms of distractor visibility. Although an effort was made to keep all relevant parameters (e.g., distractor duration, backward mask, etc.) as similar as possible, relatively minor variations in, e.g., contrast or display size could potentially affect distractor visibility. It is also the case that our study used a different language from the original studies (English and Dutch), and that words perhaps had slightly different properties. For instance, German words tend to be longer on average than English words, therefore, the amount of information that can be extracted from a word presented under masked conditions might differ among languages. Hence, perhaps our masked distractors were either too heavily masked, or not masked well enough. The first scenario - masking of distractors was too stringent - is refuted by the simple fact that we did observe a significant effect of relatedness in that experiment. Could it therefore be that our distractors were not masked well enough, i.e., that they acted in the same way as visible distractors, and hence induced similar inhibitory effects? The strongest argument against this possibility comes from the comparison of participants who recognized more words during the visibility test with those who recognized fewer words. If the inhibition effect observed in the masked condition is due to the fact that participants recognized the masked distractors too well, then the inhibitory effect should be strongest for those participants who recognized the distractors the best. Contrary to this prediction, there was no significant difference in the data pattern for "good" and "poor" recognizers; indeed, descriptively the inhibitory effect was larger for the "poor" than the "good" recognizers. This renders it unlikely that heavier masking (or perhaps, a reduction in distractor duration) would have resulted in the predicted facilitatory effect of semantic relatedness.

While we cannot say at this point which differences in the experimental procedure have caused the differences in results, it is clear that the semantic facilitation effect with masked distractors is much more susceptible to such procedural differences than the semantic inhibition effect with visible distractors. Therefore, caution is needed when using this effect for theory-building and it is necessary to better understand the experimental conditions that allow for a polarity shift.

A second important finding is that while inhibition occurred in both presentation conditions and was not statistically modulated by the exact type of semantic relationship, there were still some crucial differences. In the visible condition, the categorically related condition caused the greatest inhibition, whereas in the masked condition, the associatively related condition caused the greatest inhibition. Explanations for this pattern remain at present speculative. One possible scenario derived from earlier work on such relationships (Alario et al., 2000; La Heij et al., 1990) is that associative pairings represent direct interlexical links, perhaps at a "peripheral" level (i.e., the orthographic or phonological lexicon). If so, it is conceivable that links at such "shallow" processing levels would be more dominant with masked distractor presentation, compared to visible distractors whose effect might emerge more clearly at "deeper" (i.e., lexical-semantic or conceptual) processing levels. To our knowledge, our study represents the first attempt to address the possible dependency of effects of various types of semantic relationships on distractor visibility, and more research is clearly needed.

From a broader perspective, our data, combined with the earlier studies in the literature reporting a polarity reversal, contest the assumption that the inhibitory component in speech selection is binary in the sense that either a distractor will enter the competition or not. Rather, inhibition and facilitation can be relatively stronger or weaker, modulating the net outcome. Roelofs, Piai, and Schriefers (2011) suggest that masking a distractor word results in this word receiving a smaller weight in the competition process. Such a mechanism, depending on the magnitude of the weight change, could accommodate the entire continuum of effects. That is, for clearly visible distractors, the distractor will receive a high competition weight, resulting in an inhibitory effect. As visibility decreases, the competition weight will decrease, too, reducing the inhibitory component of the effect. With a very low competition weight, the facilitatory component of the effect (i.e., the target is primed by the distractor) will result in a facilitation effect. The challenge for future experiments would then be to precisely predict the size of the competition weights in different contexts. The response exclusion hypothesis is less able to explain such a smooth transition from inhibition to facilitation. Intermediate effects could be explained by the response exclusion hypothesis as an experimental artifact, if either facilitation or inhibition is observed on a trial-by-trial basis (i.e., if a participant observes a word in a given trial, it will enter the buffer and interfere, if (s)he does not observe a word in a different trial, it will not enter the buffer and therefore, facilitation will result). While the sum of trial-by-trial inhibition and facilitation might result in anything from facilitation to inhibition, too, this explanation is refuted by our finding that, numerically at least, the inhibition effects in masked distractor presentation were larger for those participants, who perceived the masked words *less* well.

In conclusion, previous studies have reported a polarity reversal of semantic effects in picture-word interference tasks, such that clearly visible distractors which are semantically related to the picture name generate interference, whereas visual masking of such distractors results in facilitation. This pattern was taken as supporting different loci of the facilitatory and interfering components. In our own experiments we were unable to replicate this polarity reversal; instead, our findings suggest that significant semantic interference can prevail even under masked conditions, but that the precise pattern might depend on the exact form of semantic relationship between distractor and target.

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