Lexical Retrieval is not by Competition: Evidence from the Blocked Naming Paradigm

Eduardo Navarrete[1], **Paul Del Prato**[2], **Francesca Peressotti**[1], and **Bradford Z. Mahon**[2,3,4]

[1]Dipartimento di Psicologia dello Sviluppo e della Socializzazione, Università di Padova, Italy

[2]Department of Brain & Cognitive Sciences, University of Rochester, USA

[3]Department of Neurosurgery, University of Rochester Medical Center, USA

[4]Center for Language Sciences, University of Rochester, USA

Abstract

A central issue in research on speech production is whether or not the retrieval of words from the mental lexicon is a competitive process. An important experimental paradigm to study the dynamics of lexical retrieval is the blocked naming paradigm, in which participants name pictures of objects that are grouped by semantic category ('homogenous' or 'related' blocks) or not grouped by semantic category ('heterogeneous' or 'unrelated' blocks). Typically, pictures are repeated multiple times (or cycles) within both related and unrelated blocks. It is known that participants are slower in related than in unrelated blocks when the data are collapsed over all within-block repetitions. This semantic interference effect, as observed in the blocked naming task, is the strongest empirical evidence for the hypothesis of lexical selection by competition. Here we show, contrary to the accepted view, that the default polarity of semantic context effects in the blocked naming paradigm is facilitation, rather than interference. In a series of experiments we find that interference arises only when items repeat within a block, and only *because* of that repetition: What looks to be 'semantic interference' in the blocked naming paradigm is actually less repetition priming in related compared to unrelated blocks. These data undermine the theory of lexical selection by competition and indicate a model in which the most highly activated word is retrieved, regardless of the activation levels of nontarget words. We conclude that the theory of lexical selection by competition, and by extension the important psycholinguistic models based on that assumption, are no longer viable, and frame a new way to approach the question of how words are retrieved in spoken language production.

Address for correspondence: Bradford Z. Mahon, Meliora Hall, University of Rochester, Rochester, NY. 14627-0268, mahon@rcbi.rochester.edu.

Keywords

speech production; semantic interference; semantic facilitation; blocked naming; cyclic naming; lexical retrieval

1.Introduction

An issue of central importance to all models of speech production concerns the mechanism through which words are retrieved from the mental lexicon. Research on this issue can be divided into two different approaches, according to how they have traditionally emphasized different aspects of the question of how words are retrieved. One tradition, based largely on analyses of errors in spontaneous speech and brain damaged patients, sought to explain how the system determined which representation at the lexical level (of the many possible words) corresponds to the communicative intention (i.e., which word is the 'target'; Dell, 1986; Caramazza, 1997; Rapp & Goldrick, 2000). That class of models made few if any commitments about the precise timing of *when* a given target word would be retrieved in different contexts. A second tradition was based on the assumption that the chronometry of word retrieval was a more vital issue to be tackled than explaining *which* word was produced (Levelt, Roelofs, Meyer, 1999), and thus, this second tradition stipulated *which* lexical representation was the target word, and sought to explain the precise timing of *when* that word was retrieved. The most widely discussed and detailed computational implementation within this second tradition is WEAVER++ (Roelofs, 1992; 1993; 2003; Levelt et al., 1999), although a number of other models have been proposed that involve lexical competition, most notably the models of La Heij and colleagues (La Heij, 1988; Bloem & La Heij, 2003; Bloem, van den Boogaard, & La Heij, 2004; see also Howard, Nickels, Coltheart, & Cole-Virtue, 2006). In addition, a range of authors have argued for lexical competition without proposing a formal model (e.g., Abdel Rahman & Melinger, 2007; Belke, Meyer, & Damian, 2005; Caramazza & Costa, 2000; Costa, Miozzo, & Caramazza, 1999; Damian & Bowers, 2003; Damian & Martin, 1999; Damian, Vigliocco, & Levelt, 2001; Hantsch & Madebach, 2013; Hantsch, Jescheniak, & Schriefers, 2005, 2009; Mulatti & Coltheart, 2012; in press; Santesteban, Costa, Pontin, & Navarrete, 2006; Schriefers, Meyer, & Levelt, 1990; Vigliocco, Lauer, Damian, & Levelt, 2002; Vitkovitch & Tyrrell, 1999).

According to the hypothesis of lexical selection by competition, the time required to retrieve the target word from the mental lexicon increases proportionally to the summed level of activation of nontarget words. Typically, 'nontarget' words refer to words that are semantically related to the target word (but see Abdel Rahman & Melinger, 2009a), as words that are related in meaning to the target are automatically activated in the course of lexical retrieval. Thus if a participant is producing the word 'dog', then nontarget words such as 'cat', 'horse', 'bark', 'leash' (etc.), will be activated by virtue of automatic spreading of activation within the semantic network, and between semantic representations and their corresponding lexical representations. This leads to the core prediction that is made by the hypothesis of lexical selection:

Target picture naming latencies will be slower in contexts in which nontarget words are highly activated compared to contexts in which nontarget words are not highly activated.

The project of the current study is to test this prediction in as direct a way as possible. This is important, because the hypothesis of lexical competition is one of the most widely assumed theoretical constructs in research on speech production. Thus, if this hypothesis is not viable, and we are compelled to adopt an alternative model of word retrieval, then a number of phenomena and models would need to be reconsidered. We first discuss previous research on this topic that has used the picture-word and continuous naming paradigms, and then turn to the principal focus of the current study: the causes of semantic facilitation and interference in the blocked naming paradigm.

The Picture-Word Interference Paradigm

The picture-word interference paradigm is a variant of the Stroop task (Stroop, 1935), where instead of naming target ink colors as in the Stroop task, participants name pictures of common objects while ignoring embedded distractor words (for early work see Rosinski, 1977; Lupker, 1979). Initially, the principal source of evidence that was marshalled in support of the hypothesis of lexical selection by competition was the so-called semantic interference effect. The semantic interference effect refers to the observation that picture naming latencies (e.g., 'dog') are slower when the distractor word is a semantic category coordinate of the target (e.g., cat) compared to when it is unrelated (e.g., car; e.g., Glaser, & Düngelhoff, 1984; Rosinski, 1977; Schriefers et al., 1990; Damian & Bowers, 2003). The semantic interference effect seemed to provide strong evidence for the view that lexical selection was a competitive process (e.g., Roelofs, 1992). This is because all models were in agreement that the word representation corresponding to a related distractor would be more highly activated than the word representation corresponding to an unrelated distractor, and thus the slower target naming latencies in the related condition putatively indexed increased competition for target selection. However, that basic logic was challenged by a comprehensive review and analysis that showed the semantic interference effect was the exception rather than the rule. All else equal, the default pattern in the picture-word paradigm is that naming latencies speed up as distractors become more semantically similar to targets (Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). For instance, participants are faster to name target items when the distractors describe actions associated with the targets (picture = dog, distractor = bark), or parts of the target object (picture = dog, distractor = tail), compared to unrelated distractors (Mahon et al., 2007; Costa, Alario, & Caramazza, 2005). Even in the original Stroop task, participants are faster to name the ink color of related noncolor words (name 'red' ink color of the word fire) than the same ink color of unrelated distractors (name 'red' ink color of the word grass; Dalrymple-Alford, 1972; for discussion see Mahon, Garcea, & Navarrete, 2012; Mahon and Navarrete, in press; Roelofs & Piai, in press; Mulatti & Coltheart, in press).

The most direct test of the hypothesis of lexical selection by competition, within the picture-word paradigm, is provided by a manipulation of within-category semantic distance. The hypothesis of lexical selection by competition predicts that participants should be, if anything, slower to name pictures (e.g., dog) with within-category semantically-close

distractors (e.g., <u>wolf</u>) compared to within-category semantically-far distractors (e.g., <u>lizard</u>). Contrary to that core prediction, Mahon et al (2007) found that participants are, if anything, *faster* to name target pictures as the within-category semantic distance decreases between distractors and pictures.

We subsequently argued that the semantic interference effect, as the exception that must be explained, was not a lexical level effect but rather a post-lexical effect at the level of the response buffer (for discussion, see Dhooge & Hartsuiker, 2010; 2011a; 2011b; 2012; Dhooge, De Baene, & Hartsuiker, 2013; Finkbeiner & Caramazza, 2006a; Janssen, Schirm, Mahon, & Caramazza, 2008; Mahon et al., 2007; 2012; Miozzo & Caramazza, 2003; but see Mädebach, Oppermann, Hantsch, Curda, & Jescheniak, 2011; Piai, Roelofs, & Schriefers, 2011). In response to that argument, a number of authors have suggested ways in which the scope of competition at the lexical may be restricted or constrained, in one or another way, in order to accommodate observations of semantic facilitation (see La Heij, Kuipers, & Starreveld, 2006; Kuipers & La Heij, 2008; 2012; Hantsch & Mädebach, 2013; Hantsch, Jescheniak, & Mädebach 2012; Hantsch et al., 2005; 2009; Mädebach & Hantsch, 2013; Piai, Roelofs, & Schriefers, 2012; Abdel Rahman & Melinger, 2009a; for responses see Finkbeiner & Caramazza, 2006b; Mahon & Caramazza, 2009; Mahon et al., 2012; Mahon & Navarrete, under review; Navarrete & Mahon, 2013; see also Bormann, 2011).

Thus, the evidential status of the semantic interference effect with respect to the hypothesis of lexical competition is questionable (for a recent review see Spalek, Damian, & Bölte, 2013). At a minimum, dual-task paradigms such as the picture-word and Stroop paradigms are complex and require many auxiliary assumptions in order to be used to extrapolate inferences about lexical selection. Our own view is that the collective implication of the available data from the picture-word and Stroop paradigms is that lexical selection is not a competitive process: As has been proposed by models based on analyses of error data, the most highly activated word is selected, without regard for the levels of activation of nontarget words (Dell, 1986; Rapp & Goldrick, 2000). According to such a model, related distractor words would only prime the target, but not slow it down, at the lexical level.

The Cumulative Semantic Cost

An arguably more direct means for evaluating the hypothesis of lexical selection by competition would be to manipulate the context in which a picture is named, while avoiding the complicating influence of a distractor word that must be ignored. One such paradigm that accomplishes this is the continuous naming paradigm. Participants name a series of pictures from multiple semantic categories, in a seemingly random order. Unbeknownst to subjects, the pictures are arranged within the list so that they can be analysed by 'ordinal position within category' across the list. Thus, response times for all pictures that correspond to the first item within category are averaged together (e.g., the first animal, the first vehicle, the first piece of furniture, encountered in the list). Similarly, response times for each subsequent within-category ordinal position encountered in the list are averaged across categories. Brown (1981) and later Howard and colleagues (2006) found that picture naming latencies increase with each within-category item that participants name—a phenomenon referred to as the 'cumulative semantic cost' (for related work, see Wheeldon & Monsell,

1994; Tree & Hirsh, 2003; Vitkovitch, Cooper-Pye, & Leadbetter, 2006; Vitkovitch, Cooper-Pye, & Ali, 2010; Vitkovitch, & Cooper-Pye, 2012). The Cumulative Semantic Cost is linear at least out to five ordinal positions within category (e.g., $R^2 = .96$ in Navarrete, Mahon, & Caramazza, 2010; see also Alario, & Moscoso del Prado Martin, 2010; Costa, Strijkers, Martin, & Thierry, 2009; Howard et al., 2006; Belke, 2013; Belke & Stielow, in press; Oppenheim, Dell, & Schwartz, 2010; Runnqvist, Strijkers, Alario, & Costa, 2012).

The cumulative semantic cost has attracted interest because it is a long lasting effect: interference is propagated across many intervening trials spanning tens of seconds. Howard and colleagues (2006) argued that lexical competition was a necessary component of an explanation of the cumulative semantic cost, but that lexical competition was not sufficient. The reason that lexical competition was argued to not be sufficient was that, according to all models, including that outlined by Howard and colleagues (2006), activation at the lexical level decays rapidly, and thus would return to baseline during the intervening time (trials) between within-category items. Howard and colleagues therefore reasoned that a longer lasting mechanism was required and invoked long lasting changes in the weights between semantic and lexical representations. Oppenheim and colleagues (2010, see also Oppenheim, Dell, & Schwartz, 2007) took that idea further in showing that a model that included only incremental learning, but not lexical competition, was able to explain the cumulative semantic cost (see also Vitkovitch & Humphreys, 1991; Damian & Als, 2005; Navarrete, et al., 2010).

The basic idea behind the incremental learning account is that when a picture (e.g., dog) is correctly named, the connection between its semantic features and its lexical items will be strengthened, while the connections between those same semantic features and nontarget but related lexical items (e.g., 'cat', 'wolf', 'lizard') will be weakened. This account explains two phenomena: **i)** repetition priming, whereby naming latencies decrease when a given item is named a second time (name 'dog' a second time), and **ii)** the cumulative semantic cost, as the next within category item to be named (e.g., 'cat') will have a weaker semantic-to-lexical connection for having previously named 'dog'. Importantly, Oppenheim and colleagues' (2010) computational work demonstrates that the cumulative semantic cost does not distinguish between competitive and noncompetitive models. This is because they showed that lexical competition was not necessary in order to explain the cumulative semantic cost. Thus, while the cumulative semantic cost continues to provide a basis for understanding incremental learning effects in semantic-to-lexical connections it is not an obviously useful tool with which to study whether activation levels of nontarget words influences target selection time.

The Blocked Naming Paradigm

The final experimental paradigm that has been used to provide insight into the mechanisms of word retrieval is the blocked naming paradigm. In the blocked naming paradigm participants are required to name a series of pictures in two semantic contexts (i.e., two different types of blocks). In homogenous or related contexts, all pictures within a block come from the same superordinate semantic category (e.g., 'car', 'airplane', 'truck', 'motorbike', 'bus'). In heterogeneous or unrelated contexts, all pictures within a block come

from different semantic categories (e.g., 'car', 'hammer', 'dog', 'apple', 'chair'; see Kroll & Stewart, 1994). An important aspect of the way that this task has come to be widely implemented, since the work of Damian and colleagues (2001), is that all pictures are repeated multiple times within a block. Each repetition of the set of pictures within a block is termed a 'cycle'. There are two principal observations: **i)** There is, if anything, semantic facilitation for the first within-block cycle, whereby naming latencies are faster in a semantically related compared to a semantically unrelated context; and **ii)** There is semantic interference for the second cycle onward (i.e., all cycles after the first), whereby naming latencies are slower for pictures in a semantically related context compared to an unrelated context. The observation that an initial semantic facilitation effect (first cycle) changes polarity to a semantic interference effect (all subsequent cycles) has been replicated in at least two studies (Abdel Rahman & Melinger, 2007; Navarrete, Del Prato & Mahon, 2012). Other studies reported an interaction between cycle and semantic context, without specifying the effect at the first cycle (e.g., Belke, 2008; Belke et al., 2005a; Belke, Brysbaert, Meyer & Ghyselinck, 2005b; Biegler, Crowther, & Martin, 2008; Damian & Als, 2005; Abdel Rahman & Melinger, 2011; Schnur, Schwartz, Brecher, & Hodgson, 2006; Schnur, Schwartz, Kimberg, Hirshorn, Coslett, & Thompson-Schill, 2009). Typically, the data from the blocked naming task are not broken down by cycle, so that an overall interference effect is observed when collapsing across cycle.

Despite the bivalent polarity of semantic context effects in the blocked naming paradigm, most discussion has focused on the interference effect, and has either ignored or explained away the facilitation effect. Specifically, taking 'semantic interference' as the empirical fact that requires explanation, it has been widely argued that due to spreading activation from semantic to lexical levels of processing, the word representations of the other items within a related block will be more highly activated than the word representations of other items within an unrelated block. Accordingly, lexical selection by competition predicts (correctly, it has been argued) slower naming latencies in related blocks than in unrelated blocks (e.g., Abdel Rahman & Melinger, 2007, 2011; Aristei, Melinger, & Abdel Rahman, 2011; Belke et al, 2005a; Damian et al., 2001; Santesteban et al., 2006; Schnur et al., 2009). This type of an explanation is the received view in the field—there has been little, if any, critical discussion of this argument. However, if lexical selection is not a competitive process (as we would conclude from the picture-word and Stroop paradigms, e.g., Mahon et al., 2007; 2012), then it follows that the received explanation of what is occurring in the blocked naming task must be incorrect. The project of this article is to test the received view and to unpack, from a new perspective, the inferences about how words are retrieved from the mental lexicon that are supported by the pattern of effects observed in the blocked naming paradigm.

Reinterpreting the Blocked Naming Paradigm

The fact that semantic facilitation is observed in the first within-block cycle in the blocked naming paradigm has generally been ignored for its potential relevance to understanding the mechanisms involved in word retrieval. However, prior work using related paradigms also found that picture naming is *facilitated* if the item named on the previous trial is related, compared to when it is unrelated (e.g., Huttenlocher & Kubicek, 1983; Sperber, McCauley,

Ragain, & Weil, 1979; Humphreys, Riddoch, & Quinlan, 1988; Lupker, 1988; Biggs & Marmurek, 1990; for more recent work see Hartsuiker, Pickering, & de Jong, 2005; Tydgat, Diependaele, Hartsuiker, & Pickering, 2012). The theory of lexical selection by competition offers no natural explanation of semantic facilitation in the first within-block cycle of the blocked naming task, nor of previous demonstrations of facilitation induced by an immediately-preceding related context.

Proponents of lexical competition have sought additional mechanisms to explain the presence of semantic facilitation in the first cycle of the blocked naming paradigm. For instance, Belke and colleagues (2005a) argued that lexical competition requires "*some potentiation, through repetition, to become observable*" (p. 687), an idea that may resonate with the suggestion of a 'swinging' lexical network as proposed by Abdel Rahman and Melinger (2009a; see also Abdel Rahman & Melinger, 2007, 2011; for discussion, see Mahon & Caramazza, 2009; Abdel Rahman & Melinger, 2009b). But, is there any *a priori* reason why competition should need repetition to be potentiated? In other contexts, repetition was not thought to be important in order for competition to exert an influence over response times. In other words, there is nothing in the theory of lexical competition that indicates *repetition* should be a relevant factor in determining when lexical competition occurs. The elegance of the theory of lexical competition (e.g., Roelofs, 1992) was that activation levels of words determined competition, and activation levels of words were themselves determined by the structure of lexical semantic representations and the dynamics of activation flow between the semantic and lexical levels. However, setting aside whether there is any motivation for invoking 'repetition' as a relevant factor in triggering lexical competition, the account of Belke and colleagues (2005a) explains only the *lack* of interference in the first cycle, not the presence of facilitation (for discussion on this point see Navarrete et al., 2012).

An alternative way to conceptualize the bivalent nature of semantic context effects in the blocked naming paradigm is to consider the facilitation that is observed in the first cycle as what is informative about the mechanism of lexical retrieval. According to a noncompetitive model (e.g., Dell, 1986) the most highly activated word is selected, and the time of that selection event (provided it is a correct trial) is not affected by the levels of activation of nontarget words (for further discussion, see Damian & Als, 2005; Finkbeiner & Caramazza, 2006a; Mahon et al., 2007; Navarrete et al., 2010; 2012; Oppenheim et al., 2010). Such a model naturally explains the semantic facilitation effect that is observed for the first within-block cycle: A related semantic context will prime the word representation of the target, boosting its level of activation, and speeding its retrieval (for a parallel account in word recognition, see e.g., McRae & Boisvert, 1998). This type of semantic priming would occur in related (i.e., homogenous) blocks, in which pictures come from the same category, but not in unrelated (i.e., heterogeneous) blocks, in which pictures come from different categories. This explanation also provides a natural account of the observation that if filler items are interposed among the related items, for instance geometric shapes that must be named, the facilitation effect observed in the first cycle is abolished (see Navarrete et al., 2012; see also Damian & Als, 2005).

According to a model of lexical access in which lexical selection (i.e., lexical retrieval) is not by competition, the issue then arises as to why there is interference after the first cycle in the blocked naming task. Navarrete and colleagues (2012) argued that the incremental learning account advanced by Oppenheim and colleagues (2007; 2010) could explain the emergence of semantic interference, if it were the case that there was reduced repetition priming for items presented in related contexts compared to items presented in unrelated contexts. This would be because while items presented in an unrelated context undergo *only* strengthening of semantic-to-lexical mappings, the same strengthening that occurs in a related context will be immediately countermanded by incremental weakening from having to name other within category items (see Navarrete et al., 2012, for preliminary evidence). In other words, 'semantic interference' in the blocked naming paradigm is not in fact an interference effect: it arises because of a baseline shift in the unrelated condition, not because the related condition is slowing down.

We believe that an explanation of the emergence of 'interference' in the blocked naming paradigm in term of a 'baseline shift' in the unrelated condition can already be seen in published data. Figure 1 replots the findings from an experiment reported in Navarrete and colleagues (2012) in which within-category semantic distance was manipulated in a blocked naming paradigm. Thus, items within a block could be very close within category (e.g., 'dog', 'fox', 'wolf'), relatively far within category (e.g., 'dog', 'lizard', 'whale'), or unrelated (e.g., 'dog', 'table', 'car'). The graph shows the findings from the first within-block cycle, in which response times are fastest for the within-category semantically-close blocks, intermediate for within-category semantically-far blocks, and slowest for the unrelated blocks. That pattern is entirely in line with what would be predicted by a noncompetitive model of lexical selection, and contrary to what would be predicted by lexical selection by competition: increasing within-block semantic similarity leads to faster response times. What is relevant for present purposes though is what happens in the second within-block cycle: Now there is a flip where the slowest condition is the within-category semantically-close condition and the fastest condition is the unrelated condition. A very large repetition priming effect can be seen, comparing the data from the first and second cycles, where there is (averaging across all conditions) a ~15% speeding of response time. The critical point here is that the amount of repetition priming is different in different conditions. This can be appreciated if response times from the first cycle across all of the conditions are reduced the same amount, proportionally (i.e., 15%), from values in the first within-block cycle. Those hypothetical data are plotted in Figure 1, and show that if all that occurred were proportional repetition priming, there would be no 'semantic interference' in the second within-block cycle. Thus, the 'emergence' of the semantic interference effect in the second cycle is equivocal in that it could be due to interference (i.e., lexical competition) or, it could be due to relatively *less* repetition priming in the related condition compared to the unrelated condition (see also Navarrete et al., 2012, Figure 5 for independent evidence consistent with this argument).

Because in Navarrete and colleagues (2012), as in *all* other studies using the blocked naming paradigm, the same items appear in both the related and unrelated conditions, it is not possible to truly tease apart (putative) semantic interference from differential repetition

priming in the unrelated compared to the related condition. Thus, the goal of the present investigation was to test the hypothesis that the emergence of 'semantic interference' in the blocked naming paradigm is the result of a baseline shift caused by greater repetition priming in the unrelated condition. If this hypothesis is confirmed, then it would mean that the semantic interference observed in the blocked naming task could not be taken as evidence for the hypothesis of lexical competition. In that case, we would be left with the pattern of semantic facilitation as observed in the first within-block cycle as the data point that requires explanation, which would strongly favor a model of word retrieval that does not include lexical competition.

Redesigning the blocked naming task

Previous research with the blocked naming paradigm does not permit an evaluation of whether the emergence of semantic interference with within-block repetition is due to relatively *faster* naming latencies in the unrelated condition (baseline shift) or to relatively *slower* naming latencies in the related condition (lexical competition). The reason is that previous work confounds 'repetition within the experiment' with 'repetition within a block'. Thus, in a typical implementation of the blocked naming task (e.g., Damian et al., 2001; for recent reviews see Navarrete et al., 2012; Belke & Stielow, in press), **i)** All items appear in both related and unrelated blocks (within subject), and **ii)** All items are presented multiple times within each related and unrelated block.

In the present research we take a novel approach and separate the factors 'repetition in the experiment' from 'repetition within the block'. To accomplish this, the small but consequential design changes were introduced that: **i)** Each picture was presented once per block, and blocks were repeated multiple times, and **ii)** Different pictures were presented in related and unrelated contexts (counterbalanced across participants with a split-half materials / super-subject design). Figure 2 illustrates the design used in Experiment 1. All items were first presented twice in unrelated contexts. At the third presentation, half of the items were presented in related blocks, and were presented in related blocks for the remainder of the experiment. The other half of the items continued to be presented in unrelated blocks, and were presented in unrelated blocks for the remainder of the experiment. These design changes allow us to evaluate the polarity of semantic effects as a function of item repetition, while removing the (potentially) confounding contribution of within-block repetition.

According to lexical selection by competition, all that matters in determining whether interference is observed is the context in which an item is named—thus from that theoretical perspective, the new experimental design used herein should make no difference: after the second repetition (in our case, the third block) semantic interference should emerge and manifest as a slowing of response latencies in the related condition. In other words, because the first time that items appear in a related block is the third time they will have been named in the experiment, interference should be present in their first presentation in a related block. However, if 'semantic interference' is in fact an artifact of a baseline shift caused by greater within-block repetition priming in the unrelated, compared to the related, condition, then

there is no reason to observe interference at all, since items never repeat within a block. In other words, semantic facilitation should be observed for all blocks (i.e., all repetitions).

A second prediction that can be tested is whether picture naming latencies become progressively slower or progressively faster within a related block. In other words, do picture naming latencies speed up or slow down with each additional within category item that is named? According to the hypothesis of lexical selection by competition, naming latencies should (if anything) slow down with each additional within category item that is named. This is because there will be more and more activation building up for nontarget within category items the further into the related block participants go (see also the version of the 'biased activation' account by Belke, 2013, for details on this prediction). However, according to a noncompetitive model of lexical selection, naming latencies should become (if anything) progressively faster the further into a related block that participants go. This is because, the further into the block a participant progresses, the more related contextual priming of the current target will be present, which will speed up target retrieval.

To anticipate our results, we find that: **i**) Semantic facilitation is observed out to 12 repetitions of blocks, so long as items do not repeat multiple times within a block, **ii**) When semantic facilitation is analyzed by ordinal position within block, facilitation *increases* with ordinal position within block, and finally, **iii**) The emergence of interference when items repeat within a block is not caused by slowing down in the related condition, but rather by differential repetition priming in the unrelated condition. Thus, the emergence of 'semantic interference' depends on a baseline shift whereby the unrelated condition *speeds up* with within-block repetition. In the General Discussion we argue that these three new findings are contrary to the core prediction of lexical selection by competition. This means that the hypothesis of lexical selection by competition is no longer viable, and motivates a fresh look at models of how words are retrieved from the mental lexicon in speech production.

2. Experiment 1

The goal of this experiment was to dissociate 'repetition' at the experiment level from within-block repetition. To that end, a block consisted of only a single presentation of an image. Blocks contained pictures from the same semantic category (i.e., related or homogenous blocks) or pictures from different semantic categories (i.e., unrelated or heterogeneous blocks).

Method

Participants—Twenty native English speakers (students at the University of Rochester, USA) took part in the experiment. Participants in this and subsequent experiments had normal or corrected to normal vision and participated in only one experiment.

Materials—Fifty black-and-white photographs were selected. Thirty of them belonged to 6 different semantic categories, with 5 items in each category (see Appendix). The rest of the pictures were fillers, and did not come from the same categories as those of the critical items; filler items were not analyzed. Pictures were taken from the Internet and sized to fit within a square of 400×400 pixels.

Design—Pictures were presented a total of 6 times (i.e., across six blocks) throughout the experiment. Pictures appeared in two semantic contexts: in related and in unrelated blocks. Related blocks always contained critical items from the same semantic category, while unrelated blocks contained items (experimental and/or fillers) from different semantic categories. Each block consisted of 5 trials.

For the first two presentations of all pictures, they were always presented in an unrelated context. After the first two presentations, the critical items were divided into two sets, half of which continued to be presented in an unrelated context and half of which were presented in a related context for the remainder of the experiment (see Figure 2). The split of the pictures into two sets was counterbalanced across subjects. With this manipulation, and because items appeared only once within block, we could effectively separate the factor 'repetition in the experiment' from 'repetition in a given context or block', since the first time that an item was seen in a related context was actually the third time that that item was named in the experiment. And, following that particular item, the fourth time that it was seen in a related context was actually the sixth time that it was seen in the experiment. The critical question, however, is whether the first time that an item is presented in a related context yields interference or facilitation relative to the unrelated baseline—this is the critical test because the first time an item is presented in a related context is the third time that the item has been presented in the experiment. Thus, if all that matters is 'repetition' (e.g., Belke et al., 2005a), then items should show interference the first time they are presented in a related context. However, if what matters is repetition within a block, then items should show facilitation throughout the entire experiment, as they never repeat within a block.

In order to explore semantic effects as a function of within-block ordinal position (see *Ordinal Position Within Block* analysis below), we ensured that the lag distance (i.e., the number of intervening trials) between two presentations of the same picture across the experiment (i.e., across blocks) was equivalent in the related and the unrelated conditions ($p > .8$). This equivalence was not engineered but rather a reflection of random assignment of pictures to within-block positions, and random assignment of block order. The only constraint was that all pictures appeared the nth time before any picture appeared the $n^{th} + 1$ time. As there was no within-block repetition, all repetition of pictures was a repetition of a block.

Procedure—Participants were seated approximately 60 cm from the screen. Participants were asked to name the pictures as fast and as accurately as possible. There was no familiarization phase. The experimental session consisted of a total of 60 blocks of 5 trials per block (i.e., 300 trials in the whole experiment). There was a short pause between each block. Participants initiated the next block by pressing the space bar. Participants were not corrected by the experimenter throughout the experimental session.

An experimental trial consisted of the following events. A fixation cross was shown in the center of the screen. In order to prevent participants from falling into a rhythm about when they were producing responses, the duration of the fixation cross was (randomly) varied among 250 ms, 450 ms, 650 ms and 850 ms durations. After the fixation cross, the target

picture was presented for 500 ms. Response latencies were measured from the onset of the picture. The next trial began 1500 ms after the onset of participants' response or 3000 ms after the offset of the target. Stimulus presentation, response times and response recording were controlled by the program DMDX (Forster & Forster, 2003).

Analyses—Three types of responses were excluded from the analyses of response times: **i)** production of clearly erroneous picture names; **ii)** verbal dysfluencies (stuttering, utterance repairs); and **iii)** naming latencies less than 250 ms or greater than 1500 ms. Following those criteria a total of 5.9% of the data were excluded. For all analyses in this article, degrees of freedom were Greenhouse-Geisser corrected when the assumption of Sphericity was violated.

In the principal analyses, two within-subject factors, Semantic Context (two levels: Related and Unrelated) and Presentation (four levels: 3–6), and their interaction were modelled (again, by 'presentation' we effectively mean 'block' as items were not repeated within block). For this analysis, the first trial from each block was excluded as no semantic context is present for those trials. The critical question here is whether there is interference for the first instance that the factor Semantic Context is varied (i.e., at presentation, or block, 3), given that it is varied after participants have already named each picture twice in an unrelated context. It is also possible that two presentations (i.e., repetitions) of the items are not enough for the interference effect to emerge, in the sense that competition could be argued to require *more* repetition to be sufficiently potentiated as to affect response times. If this were the case, an interaction between Semantic Context and Presentation is predicted, such that the interference effect may be observed for the final blocks (e.g., blocks 5 and 6). Separate analyses were carried out treating subjects and items as random factors, yielding F1 and F2 statistics, respectively.

In an additional set of analyses carried out over items only, we explored the magnitude of the semantic effect (i.e., related versus unrelated) by ordinal position within block. To that end, we averaged, on an item-by-item basis, the naming latencies for each within-block ordinal position (1 to 5) in related and unrelated blocks separately, collapsing across the factor Presentation; this analysis was restricted to presentations 3 through 6, as there is a related and unrelated context only for those presentations (there were only unrelated blocks for presentations 1 and 2). We then determined the semantic effect for each within-block ordinal position by subtracting the latency in the related condition from the latency in the unrelated condition.

Results

Analysis of Context and Repetition in the Experiment—Mean naming latencies and error rates by condition are reported in Table 1. In the analysis of naming latencies the only significant effect was the main effect of Semantic Context (F1 (1, 19) = 5.48, p < .04, η_p^2=.22; F2 (1, 29) = 16.99, p < .01, η_p^2=.36), with faster response times in related blocks than in unrelated blocks. Neither the main effect of Presentation nor the interaction between those factors was significant (ps > .12). There were no effects in the error analysis (ps > .18). The response time effects are displayed in Figure 3A.

Analysis of Ordinal Position Within Block—Figure 3B plots the contextual effects (related *minus* unrelated) by ordinal position within block (collapsing across presentations, or blocks, 3–6). As can been seen, the magnitude of the contextual effect increases with ordinal position within block (the linear trend is significant: F1 (1, 29) = 5.49; p < .03; η_p^2=.15; slope = −11 ms/position; R^2 = .92). Critically, the contextual effect is facilitation, meaning that the amount of semantic facilitation *increases* with within-block ordinal position.

Discussion

The results from Experiment 1 show that semantic facilitation is observed out to six presentations when pictures are not repeated multiple times within a block. In addition, the results of Experiment 1 show that semantic facilitation is a cumulative phenomenon, as reflected by the near linear increase of the magnitude of the effect across ordinal position within-block.

One concern that may arise in regard to this demonstration that semantic facilitation can survive repetition within the experiment, is that, perhaps we simply did not repeat the items enough to sufficiently potentiate competition so as to affect response times. Setting aside whether there is any theoretical motivation for the view that competition requires repetition to be potentiated (see above), we believe such a concern would be unfounded, as previous studies have reported a polarity switch between the first and second within-block cycles. However, it might be argued that in previous studies, the same items appear in the related and unrelated contexts, so subjects will see an item multiple times in one context (e.g., multiple times in an unrelated block) before seeing that item multiple times in the other context (i.e., in the related block).[i] Thus, it is important to resolve this issue empirically. In the next experiment we explored the semantic facilitation effect by increasing the number of the repetitions (i.e. presentations) to 12.

The data from Experiment 1 also do not allow us to distinguish which of two possible factors explains why semantic interference typically emerges after the first cycle. One factor could be that in our experiment, unlike in typical cyclic experiments, a given picture did not appear in both a related and unrelated context for a given participant. The other factor is that in our experiment, also unlike typical blocking naming experiments, items were not repeated within a block. Thus, in Experiment 2, in addition to repeating items 12 times throughout the experiment we also introduced a manipulation to test whether interference would be observed if items were repeated multiple times within a block.

3. Experiment 2

There were two goals in Experiment 2. The first goal was to test whether with additional repetition of the items, following the same experimental design as in Experiment 1, an interference effect emerges. This was addressed in Experiment 2a, by simply doubling the

---

[i]This type of objection cuts both ways, however. After all, in the 'standard' blocking task, participants name the pictures several times before naming the same pictures in related blocks (i.e., in the familiarization task and/or in unrelated blocks). Critically, notwithstanding such repetition, there is semantic facilitation at the first cycle of related blocks (Abdel Rahman & Melinger, 2007; Navarrete et al., 2010).

number of times that blocks were presented from 6 to 12. The second goal was to show that repetition per se is not relevant for the interference to emerge, but rather, repetition within a block. To test this hypothesis, Experiment 2b used exactly the same materials and design as Experiment 2a, with the only difference that at presentations 7 and 10, pictures were repeated three times within a block, rather than being presented only once per block. Thus, presentations 7–9 were all in the same block, and also, presentations 10–12 were in the same block. If within-block repetition is the critical variable, then an interference effect should emerge at presentation 8 and be preserved through to presentation 9. The question can then be asked whether at presentation 10, which is the first presentation of a new block, there is facilitation or interference. If it is the history of an item in the experiment rather than the history of the item in the current block that matters, then presentation 10 should show interference (assuming interference is observed at presentations 8 and 9). If however, what is important is whether repetition has occurred within the current block, then presentation 10 should show facilitation, with interference emerging anew at presentation 11 and being preserved through to presentation 12. Figure 4 provides a schematic of the experimental design used in Experiment 2b. Because Experiments 2a and 2b draw on the same set of materials and follow the same design with the only difference being what happens to items after presentation 6, the two experiments are presented and analyzed in parallel.

Method

Participants and Materials—Forty native English speakers from the same population as Experiment 1 took part in the experiment (20 participated in Experiment 2a and 20 in Experiment 2b). The same pictures as in Experiment 1 were used.

Design and procedure—The same design as in Experiment 1 was used with the following differences. **i**) In Experiment 2a, pictures were presented a total of 12 times according to the same design used in Experiment 1. That is, the first two presentations were always in an unrelated context. At presentation 3, half of the categories were then presented in a semantically related context and the other half continued in an unrelated context (counterbalanced across participants). Once a picture was assigned to a related context (at presentation 3) it remained in a related context through presentation 12 (and the same for unrelated contexts). As in Experiment 1, pictures were randomly ordered within blocks and blocks within the experimental sequence, with the constraint that all pictures were presented the *nth* time before any given picture was presented the $n^{th} + 1$ time. **ii**) In Experiment 2b, the first 6 presentations were the same as in Experiment 1 (and the same as presentations 1–6 in Experiment 2a). However, beginning at presentation 7, the next three presentations were always within block. Thus, instead of having only one presentation per block, presentations 7, 8 and 9 were all within a single block—for both the related and unrelated contexts. The same was the case for presentations 10, 11, and 12 (all within-block repetitions). All other aspects of the design were the same as in Experiment 2a (see Figure 4 for a schematic of the design used in Experiment 2b).

Results

In the principal analyses, two within-subject factors, Semantic Context (two levels: Related and Unrelated) and Presentation (10 levels: 3 to 12), one between-subject factor, Experiment

(two levels: Experiment 2a and Experiment 2b), and their interactions were modeled. We do not report the main effect of Experiment as it is based on between subject comparisons in overall response time, and is not germane to any of the theoretical issues at stake.

Analysis of Context and Repetition in the Experiment—Mean naming latencies and error rates by condition are reported in Table 2. The analysis of naming latencies for positions 3 through 12 showed a main effect of Semantic Context (F1 (1, 38) = 11.39, p < .01, η_p^2=.23; F2 (1, 58) = 11.14, p < .01, η_p^2=.16), with faster response times for related blocks than for unrelated blocks. Critically, the triple-order interaction between the factors Semantic Context, Presentation and Experiment was significant (F1 (9, 342) = 2.68, p < .01, η_p^2=.06; F2 (9, 522) = 2.21, p < .03, η_p^2=.04). The response time effects are displayed in Figure 5 (Panels A and B).

In order to explore the triple-order interaction, further analyses were performed exploring the effects of Semantic Context and Presentation, separately in each experiment. In Experiment 2a, the main effect of Semantic Context was significant (F1 (1, 19) = 8.15, p < .02, η_p^2=.3; F2 (1, 29) = 8.02, p < .01, η_p^2=.22), with faster response times for related blocks than for unrelated blocks. Neither the main effect of Presentation nor the interaction between those factors was significant (Fs > .12). In Experiment 2b, the main effect of Semantic Context was marginally significant (F1 (1, 19) = 3.23, p = .08, η_p^2=.14; F2 (1, 29) = 3.43, p = .07, η_p^2=.1). The main effect of Presentation was significant (F1 (9, 171) = 2.32, p < .02, η_p^2=.11; F2 (9, 261) = 4.85, p < .01, η_p^2=.14). Critically, in Experiment 2b the interaction between semantic context and presentation was significant (F1 (9, 171) = 7.35, p < .01, η_p^2=.27; F2 (9, 261) = 6.59, p < .01, η_p^2=.18).

As can be appreciated in Figure 5B, the interaction between Presentation and Semantic Context in Experiment 2b was caused by the fact that the first presentation within the two 'long' blocks (i.e., blocks beginning at presentations 7 and 10) showed facilitation, while the second and third presentations of those blocks (i.e., presentations 8/9 and 11/12) showed interference. This pattern was confirmed through further analyses that were performed over positions 7 through 12, separately for each Experiment. The main effect of Semantic Context was significant in Experiment 2a (F1 (1, 19) = 5.05, p < .04, η_p^2=.21; F2 (1, 29) = 6.09, p < .03, η_p^2=.17) but not in Experiment 2b (Fs < 1). The main effect of Presentation was not significant in Experiment 2a (ps > .18) but significant in Experiment 2b (F1 (5, 95) = 2.63, p < .03, η_p^2=.12; F2 (5, 145) = 3.12, p < .02, η_p^2=.1). Critically, the interaction between Semantic Context and Presentation was not significant in Experiment 2a (Fs < 1), indicating equivalent facilitation across presentations. However, in Experiment 2b the interaction was significant (F1 (3.34, 63.49) = 5.34, p < .01, η_p^2=.22; F2 (3.18, 92.38) = 4.75, p < .01, η_p^2=.14).

Inspection of the graph in Figure 5B indicates that interference is present at presentations 8 and 9, and then again at presentations 11 and 12. To quantify these patterns, we collapsed

presentations 7 and 10 (i.e. first cycle), presentations 8 and 11 (i.e., second cycle), and presentations 9 and 12 (i.e., third cycle). Paired t-tests revealed a facilitation effect in the first cycle (t1 (19) = −3.11, p < .05; t2 (29) = −1.82, p = .08) and interference effects in the second and third cycles (Cycle 2: t1 (19) = 1.81, p = .08; t2 (29) = 2.27, p < .04; Cycle 3: t1 (19) = 3.07, p < .01; t2 (29) = 2.35, p < .03). These data indicate that repetition within a block, rather than repetition *per se*, is the critical factor determining the emergence of 'interference'. Indeed, interference emerged at presentation 8, which is the second time that an item was repeated within a block and was preserved through to presentation 9. However, presentation 10 which is the next presentation of that item, but now as the first presentation in a new block, did not show interference but rather reverted to facilitation; interference then re-emerged again at presentation 11 and was preserved through to presentation 12.

In the analysis of error rates, the effect of Semantic Context was significant (F1 (1, 38) = 6.83, p < .02, η_p^2=.15; F2 (1, 58) = 21.2, p < .1, η_p^2=.26), with more errors in homogeneous blocks than in heterogeneous blocks. All other effects were not significant (ps < .26).

Analysis of Ordinal Position Within Block—Figure 5 plots the context effects (related *minus* unrelated) by ordinal position within block for Experiments 2a (Figure 5C) and 2b (Figure 5D). The data from Experiment 2a (Figure 5C) collapse across presentations 3 through 12, while the data from Experiment 2b (Figure 5D) collapse across presentations 3 through 6. The analysis of the linear trend was significant in both experiments (Experiment 2a: F1 (1, 29) = 6.81; p < .02; η_p^2=.19; slope = −12 ms/position; R^2 = .79; Experiment 2b: F1 (1, 29) = 7.76; p < .01; η_p^2=.21; slope = −16 ms/position; R^2 = .95), replicating the pattern observed in Experiment 1 (Figure 3B).

Discussion—Experiment 2a replicated the observation that when there is no repetition within block, a semantically related context facilitates naming latencies, and extends that finding out to 12 repetitions of the items in the experiment. Experiment 2b showed that the critical factor determining whether (and when) semantic interference is obtained is within-block repetition. Dramatic evidence for this conclusion is provided by the observation that facilitation is observed at the 10th presentation in Experiment 2b, which is the first presentation of a new block, even though the previous two presentations of those items (i.e., 8 and 9) yielded interference. However, presentations 11 and 12, which then repeat items within the block, again show 'semantic interference'.

To directly test the hypothesis that 'semantic interference' arises because of differential repetition priming in the unrelated context compared to the related context, we conducted further analyses on the data from Experiment 2b, collapsing presentations 7 and 10 (i.e., first cycle), and 8 and 11 (i.e., second cycle), separately for each of the two semantic contexts (related and unrelated). Thus, the data were reduced to a 2×2 design of Cycle (First/Second) and Semantic Context (Related/Unrelated). Figure 6 shows the resulting means. An ANOVA showed that the interaction between the two factors was significant (F1 (1, 19) = 23.12, p < .01, η_p^2=.54; F2 (1, 29) = 10.76, p < .01, η_p^2=.27). Paired samples t-tests between the first and the second presentations (i.e., cycles) revealed that repetition priming was significant for the unrelated context (t1 (19) = 4.43, p < .01; t2 (29) = 7.19, p < .01) but not

for the related context (ps > .64). These data indicate that 'semantic interference' in the blocked naming paradigm arises because of a baseline shift in the unrelated condition that is caused by differential repetition priming (see Navarrete et al., 2012 for precedent on this claim and additional convergent evidence).

Experiments 2a and 2b also replicated the observation that semantic facilitation increases with ordinal position within block. This finding runs directly against the basic expectation of the hypothesis of lexical selection by competition. For instance, on Belke's (2008) implementation of the 'biased-selection' model (see Thompson-Schill & Botvinick, 2006), the cognitive system will strategically boost the levels of activation of the words within the current block. When that set of words are all related, they will be even more highly activated than when they are unrelated. Thus, according to that framework, interference should *accrue* within block (i.e., facilitation decrease), rather than facilitation increasing (see also Abdel Rahman & Melinger, 2011; Belke & Stielow, in press, for similar proposals that are likewise challenged by these data).

In the Introduction we reviewed findings from the picture-word paradigm that have been argued to be problematic for the hypothesis of lexical selection by competition—namely, that all else equal, target picture naming latencies become faster as distractors become more semantically similar to targets. Piai and colleagues (2012) have recently argued that the polarity of the semantic effects (i.e., facilitation and interference) in the picture-word task depends on whether or not distractor words exceed a "competition threshold" (for further discussion, see Roelofs & Piai, in press; for related accounts, see Abdel Rahman & Melinger, 2009a; Madebach & Hantsch, 2013). The "competition threshold" would operate as a filter determining which distractors will compete during target response selection. If a semantically related distractor exceeds the "competition threshold" during the lexicalization of the target picture, interference is observed due to lexical competition. By contrast, if a semantically related distractor does not exceed the "competition threshold", semantic facilitation is observed due to spreading activation via the conceptual network. Setting aside the merits of the 'competition threshold' account of effects within the picture-word paradigm (for critical discussion, see Mahon & Navarrete, under review; Navarrete & Mahon, 2013), the 'competition threshold' hypothesis is ill equipped to explain the patterning of facilitation and interference in the blocked naming paradigm that we have reported. This is because there is no difference of semantic context between those instances in which interference is observed and in which facilitation is observed: all that differs is whether or not items repeat within a block.

Another account that maintains the assumption of lexical selection by competition is the proposal of Belke (2013). Belke adopts the model of Vigliocco, Vinson, Lewis and Garrett (2004), in which there is a conceptual level of semantic features/primitives, then a level of holistic lexical semantic representations, and then a lexical level, including lexical selection by competition. In that framework, incremental weakening was located at the concept-to-semantic connections. However, the arguments articulated above against the hypothesis of lexical competition would apply as well to the proposal of Belke (2013). The reason why is that competition is maintained at the lexical level, and so it will necessarily be the case that the nontarget word representations corresponding to the other items within a related block

will be more highly activated than the nontarget word representations of the other items in an unrelated block. Thus, that theory also fails to provide an account of extended semantic facilitation in the blocked naming task (i.e., out to 12 repetitions).

In summary, accounts of picture-word semantic facilitation that *do not* dispense with lexical competition explain facilitation in the picture-word paradigm in one of two ways: Either **i)** some type of a restriction is placed on which items (or in which circumstances the same items) can enter into competition with the target, or **ii)** while items are not restricted from competing with the target, it is assumed that, in certain circumstances, the priming of the target representation is greater than the competition induced by competing nontarget words (see Abdel Rahman & Melinger, 2009a;b; Mahon and Caramazza, 2009). As noted above, neither assumption is able to handle the pattern of facilitation in the blocked naming task that we have reported, as all that differs between presentations in which interference or facilitation is observed, is whether or not items repeat within a block. We believe there is a common reason why accounts such as the 'competition threshold' hypothesis (Piai et al., 2012; Roelofs & Piai, in press), the 'biased selection' model (Belke, 2008), the 'swinging network' hypothesis (Abdel Rahman & Melinger, 2009a), or the related accounts of Hantsch and Madebach (2012) and Mulatti and Coltheart (in press), fail to explain the patterning of facilitation and interference that we have reported. The reason is that 'semantic interference' in the blocked naming task is not an 'interference' effect at all, but rather a baseline shift brought about by greater repetition priming in the unrelated than in related condition. From this perspective, there is no 'interference effect' that requires explanation, hence no motivation to assume lexical competition in the first place, and hence no need to develop auxiliary assumptions in order to account for semantic facilitation in the blocked naming paradigm.

4. General Discussion

All previous discussions of the blocked naming paradigm have assumed that interference is the default effect that is induced by a related semantic context (compared to an unrelated context). Semantic facilitation, as observed in blocked naming, is widely believed to be a transient effect of no real theoretical consequence for understanding the dynamics of word retrieval (e.g., Abdel Rahman & Melinger, 2007, 2011; Aristei et al., 2011; Belke, 2008; 2013; Belke et al, 2005a; 2005b; Belke & Stielow, 2013; Damian et al., 2001; Ganushchak, & Schiller, 2008; Maess, Friederici, Damian, Meyer, & Levelt, 2002; Santesteban et al. 2006; Schnur et al., 2006; 2009; Vigliocco et al., 2002). The findings that we have reported overturn the conventional wisdom about what is occurring in the blocked naming paradigm. The empirical generalization that semantic interference is the default pattern is incorrect: facilitation is the default pattern observed when manipulating semantic context. This conclusion is based on the observation that facilitation is observed to be present out to 12 presentations of items in an experiment. Thus, repetition in the experiment is not relevant for inducing semantic interference in the blocked naming task. Interference is observed only when items repeat *within* a block, and is present only for the remainder of that *particular* block in which the items are repeated—not the remainder of the experiment. In addition, we found that semantic facilitation accumulates with ordinal position within block. Thus, not only is the default polarity of semantic contextual effects in the blocked naming paradigm

facilitation, but that facilitation *increases,* rather than decreases, within any given related block.

We believe that the key for understanding the causes of 'semantic interference' in the blocked naming is that when items repeat within a block, the related condition does not slow down with repetition, but rather, the unrelated condition *speeds up*. The effect of within-block repetition is not to 'potentiate competition' (e.g., Belke et al., 2005a) but more simply, to produce differential repetition priming effect in unrelated contexts (compared to related contexts). Figure 6 shows this aspect of the emergence of 'semantic interference' by distilling the data from Experiment 2b down to a 2×2 design of Cycle (First/Second, i.e., within block repetition) and Semantic Context (Related/Unrelated). As can be seen, the presence of 'semantic interference' in the second cycle is caused by differential speeding up in the unrelated condition.

The observations of accumulative (i.e., within block) and extended (i.e., over many repetitions) semantic facilitation in the blocked naming paradigm, together with our proposed account of the experimental conditions under which interference arises, collectively undermine the view of lexical selection by competition (e.g., Abdel Rahman & Melinger, 2007, 2009a, 2011; Aristei et al., 2011; Belke, 2008; Belke & Stielow, in press; Belke et al, 2005a; 2005b; Costa, Miozzo, Caramazza, 1999; Damian & Bowers, 2003; Damian et al., 2001; Geng, Kirchgessner, & Schnur, 2013; Hantsch et al., 2005, 2009; 2012; Humphreys, Lloyd-Jones, & Fias, 1995; La Heij, 1988; Levelt et al., 1999; Piai et al., 2012; Roelofs, 1992, 2003; Roelofs & Piai, in press; Santesteban et al., 2006; Schriefers et al., 1990; Starreveld & La Heij, 1995; Vigliocco et al., 2004). As discussed above, there have been a number of ways in which the hypothesis of lexical competition has been squared with problematic findings in the picture-word paradigm (Piai et al., 2012; Roelofs & Piai, in press; Abdel Rahman & Melinger, 2009a; Hantsch & Madebach, 2013; but see Mahon & Caramazza, 2009; Mahon & Navarrete, under review; Navarrete & Mahon, 2013). However, none of those theories are equipped to explain the patterning of interference and facilitation that we have reported. We conclude that the hypothesis of lexical selection by competition is empirically falsified.

In the remainder of this discussion, we focus on the positive implications of the findings that we have reported and consider several open issues that remain to be explained. There are three new empirical findings, which we here generalize into empirical hypotheses. All else equal:

i. A semantically related context facilitates picture naming latencies.

ii. The amount of facilitation increases with exposure to a related context (i.e., increases with ordinal position within block).

iii. Slower naming latencies are present in a related context compared to an unrelated context when items repeat within each context multiple times; the 'interference' that is observed arises due to differential repetition priming in the unrelated compared to the related condition.

These three new findings motivate a fresh look at how words are retrieved in speech production. We first outline a model of word retrieval, and then consider how these three findings are explained by the model.

4.1 A model in outline

There are two 'decision points' in word retrieval: the semantic level, at which the target lexical concept is selected, and a late post-lexical level, at which the utterance is 'checked' just before articulation. This type of framework is in contrast to a competitive model of lexical retrieval in which there is a 'decision point' at the lexical level. On our view, there is no decision point at the lexical level—what happens at the lexical level is a direct reflection of what happened at the semantic level: Once the communicative intention is established and the target lexical concept is selected, then the most highly activated word representation at the lexical will be retrieved, without regard to the levels of activation of nontarget words. A similar account can be found in the "complex access, simple selection" proposal by La Heij (2005). Terminologically, the phrase 'lexical selection' implies conflict at the lexical level during word retrieval; we would suggest that a more appropriate term is 'lexical retrieval' as there is no conflict at the lexical level.

Another way to think about this is that the language production system is cognitively penetrable at the semantic level and at the late post-lexical level, while word-selection-through-phonological-encoding is a ballistic (i.e., encapsulated) process: In goes a concept and out comes a phonologically specified word. That process of word-selection-through-phonological-encoding can be sped up but not slowed down. We assume, as do all other models, that there can be (and often are) multiple activated representations at the lexical level. The fact that the system makes errors, and that errors arising at the lexical level can be semantically related to the target (Dell, 1986; Caramazza & Hillis, 1990), is evidence for the assumption that multiple representations are activated at the lexical level at the time of word selection. Errors are either caught post-lexically by a speech monitor (see Dhooge & Hartsuiker, 2010; 2011a; 2011b; 2012) or actually uttered.[ii]

If there is no competition in the language production system, as the term is understood, for instance in WEAVER++ (Roelofs, 1992; 2003), this does not mean that there are no conflicts—conflicts can arise at the semantic and post-lexical levels. We have separately argued (Mahon et al., 2007; Mahon et al., 2012) that the Stroop and picture-word phenomena of semantic interference and distractor frequency occur due to a response conflict between the distractor word and the target picture name at the late post-lexical level (for an early version of this account, see Miozzo & Caramazza, 2003). We referred to this account as the Response Exclusion Hypothesis (Mahon et al., 2007). Dhooge and Hartsuiker (e.g., 2011; 2011b) have argued that the late post-lexical stage at which the distractor

---

[ii]An interesting (and we believe novel) expectation that may be generated from the framework that we have outlined is that the same experimental situations that speed up lexical access through semantic priming, will also result in more errors arising at the lexical level. This is because situations in which related concepts are strongly priming the target will ipso facto be situations in which their corresponding (nontarget) word representations will be highly activated, and so the probability of making an error and selecting the wrong word should increase. In this regard, the presence of speed-accuracy tradeoffs in certain experimental situations, would be informative about the dynamics of word retrieval (see also Mahon et al., 2007 for some discussion on this issue). This is an issue that could also be addressed computationally.

frequency effect occurs corresponds to the speech monitor. Thus, the post-lexical level at which speech must become a single channel is one level at which response conflict can arise. However, this level of processing, and therefore the Response Exclusion Hypothesis as a theory about the processes occurring at that level, are not relevant for understanding the patterning of 'semantic interference' and semantic facilitation that occurs in the blocked naming paradigm. This is because the blocked naming paradigm does not involve a nontarget prepotent response that would engage the articulators in place of the target, as is the case for the Stroop and picture-word paradigms.

As reviewed in the introduction, there are two principal paradigms used to study lexical access and which involve straight picture naming: the continuous naming paradigm and the blocked naming paradigm. The signature effect from the continuous naming paradigm is that there is a long lag semantic cost (i.e., spanning multiple trials) associated with repeated access to a given semantic category. A number of investigators have now argued (Belke, 2013; Damian & Als, 2005; Howard et al., 2006; Navarrete et al., 2010; Oppenheim et al., 2010) that the long lag nature of the cumulative semantic cost compels an explanation in terms of incremental adjustments to connection weights, presumably between semantic and lexical representations (but see Belke, 2013, for an account that situates incremental learning at the concept-to-semantic level). It is important to underline that even proponents of lexical competition (e.g., Belke, 2013; Howard et al., 2006) have invoked incremental learning mechanisms to explain long lasting semantic interference. That theoretical move is based on the recognition that lexical level activation (the substrate of competition) has too short of a half-life to be able to be a basis for a phenomenon with such longevity. The relevant issue for present purposes is to unpack exactly how such long lag cumulative semantic costs contribute to the patterning of semantic interference and facilitation we have reported in the blocked naming paradigm.

Explaining semantic facilitation and interference in the blocked naming paradigm—We suggest that there are three 'forces' at work in the blocked naming paradigm that in concert produce the full pattern of findings: **i)** a purely facilitatory mechanism that can speed up lexical retrieval by *semantic priming*, but not slow it down; **ii)** *incremental strengthening* of semantic-to-lexical connections for correctly retrieved words, **iii)** *incremental weakening* of semantic-to-lexical connection for words that are semantically related to correctly retrieved words (i.e., words that are activated but not retrieved). We note that each of these hypotheses has been articulated in detail by others in previous discussions (Damian & Als, 2005; Howard et al., 2006; Vitkovitch & Humphreys, 1991), and in conjunction, although in a different context, by Oppenheim and colleagues (2007; 2010).[iii] An important distinction to keep clear is that 'repetition priming', on this type of an account (e.g., Oppenheim et al., 2007; 2010), is a long lasting phenomenon that derives from strengthening of semantic-to-lexical level connections, while semantic priming is a short-

[iii]We follow precedent in assuming that the relevant strengthening and weakening of connections occurs over semantic-to-lexical level connections; however, it is possible that the effect could be occurring at an earlier level (for discussion, see Belke, 2013). Navarrete, Mahon and Caramazza (2010) provided some evidence that would motivate locating incremental weakening, at least in part, at the semantic-to-lexical level (but see Belke, 2013). But, and independent of those findings and arguments, it is likely that such effects occur at multiple levels of processing, simultaneously, within the semantic system, as well as at the interface of the semantic and lexical levels. Thus, further empirical work is necessary to target the precise levels at which different phenomena arise.

lived phenomenon that does not involve strengthening of semantic-to-lexical level connections. Semantic priming involves spreading of activation from related concepts, to the target word representation. Semantic priming is short-lived since it vanishes if a single filler item is interposed among two related items (Damian & Als, 2005; Navarrete et al., 2012).

As shown in Figures 3 and 5, semantic facilitation is present over many presentations of items (up to at least 12) and is a cumulative phenomenon within block. Both manifestations of semantic facilitation in the blocked naming task can be explained by the same core assumption: If the time to retrieve the target word is not affected by the levels of activation of nontarget words (Dell, 1986; Rapp & Goldrick, 2000; Oppenheim et al., 2010; Mahon et al., 2007; Navarrete et al., 2010) naming a picture will be facilitated in a related context compared to an unrelated context. This is because semantic and lexical representations will be primed by semantically related items from the same blocks (i.e., what is referred to as 'semantic priming' above; for additional evidence of 'semantic priming' in picture naming, see Huttenlocher & Kubicek, 1983; Sperber et al., 1979; Humphreys et al., 1988; Lupker, 1988; Biggs & Marmurek, 1990). Furthermore, within the first cycle in a related block, the second item would receive priming from the first item, while the third item would receive priming from the second item and to a lesser degree, from the first item. The fourth item would receive priming from the third item, and to a lesser degree from the second and first items (etc.). Under this scenario one would expect semantic priming to increase as a function of ordinal position within block, and hence semantic facilitation to increase with ordinal position within block (as observed).

We have argued that the critical factor that determines when 'semantic interference' is observed is within-block repetition (see also Navarrete et al., 2012). The question then becomes: What mechanism within the speech production system would lead to differential repetition priming in the unrelated compared to the related condition? An elegant solution is offered by the incremental learning account of Oppenheim and colleagues (2007; 2010), according to which repetition priming is explained by incremental strengthening of semanticto-lexical connections. This would occur for both related and unrelated blocks in which items are repeating within the block. However, according to that model, in related blocks, there will also be incremental weakening of semantic-to-lexical connections for within-block items. Thus, in related blocks, there is an intersection of the set of items that will undergo weakening of semantic-to-lexical connections and the set of items that undergo strengthening of semantic-to-lexical connections (i.e., repetition priming). In unrelated blocks, there is a disjunction of the two sets: the items within the block undergo strengthening (i.e., repetition priming), while the items that would be weakened are within category items that are not part of the current block. The suggestion here is that the presence of weakening occurring over the items in related blocks would account for the *lack* of repetition priming in those blocks. On the other hand, in situations in which unrelated items are repeating within block, response latencies will reflect repetition priming due to strengthening occurring over the items in those blocks. And, as noted above, it is the presence of the repetition priming effect in the unrelated condition that leads to the emergence of what appears to be a 'semantic interference effect' (see Figure 6).

Evidence consistent with this interpretation can be found in Experiment 3 of Belke and colleagues (2005b). In that experiment, half of the related and unrelated blocks contained the same items across eight cycles, while the other half of related and unrelated blocks contained different items in the first four cycles (i.e., 1–4) and in the last four cycles (i.e., 5–8). Belke and colleagues found that naming latencies in the fifth cycle were slower in blocks with different items in cycles 5–8 than in blocks with the same items across the 8 cycles, congruent with the notion that there was no repetition priming, as the first time those items were named in the block was in the fifth cycle. Critically, the 'semantic interference' in cycles 5–8 was not modulated according to whether or not the items were previously named in cycles 1–4. The lack of an interaction between blocks containing 'new' and 'old' items and the 'semantic interference' in cycles 5–8 is consistent with the view that there is weakening of semantic-to-lexical connections for semantic coordinate items, irrespective of whether or not they are part of the blocks.

Our explanation is committed to the prediction that incremental weakening of semantic-to-lexical connections will also occur in unrelated blocks, but the effects of that incremental weakening will not be expressed in that current block because all items in such a block are from different categories. In other words, naming each item in an unrelated context will result in weakening of connections to other related items, both items that are present in the experiment (in other blocks) and items that are not included in the experiment. This prediction of a cumulative semantic cost across unrelated blocks can be directly tested if the data are reorganized and analyzed into terms of ordinal position within category (collapsing across presentation or block). Figure 7A plots the data by ordinal position within category, separately for unrelated and related contexts, collapsing across the 3rd through 6th presentations, for all experiments (i.e., Experiment 1, and Experiments 2a and 2b). Note, that in the related condition, ordinal position within block and ordinal position within category are the same. As can be seen in Figure 7A, there is a cumulative semantic cost across ordinal position within category for the unrelated context ($F1_{(4, 228)} = 9.75$, $p < .01$, $\eta_p^2 = .14$; $F2_{(4, 112)} = 7.47$, $p < .01$, $\eta_p^2 = .21$)[iv]. The analysis of the linear trend was significant ($F1_{(1, 57)} = 18.96$; $p < .01$; $\eta_p^2 = .25$; $F2_{(1, 28)} = 14.53$; $p < .01$; $\eta_p^2 = .34$; collapsing across experiments: slope = 8.6 ms/position; $R^2 = .61$), but as can be seen in the figure, the data do deviate from the degree of linearity that is observed in the continuous naming paradigm. These data indicate that long lasting semantic costs are indeed present in the blocked naming task (see also Oppenheim et al., 2010; Oppenheim, 2012; Navarrete et al., 2012).[v] Importantly, and as shown in Figure 7A as well, the accumulative nature of semantic facilitation effects in the related condition is not an artifact of what is occurring in the unrelated condition, as response times become progressively faster with ordinal position

---

[iv]In this analysis, one within-subject factor (Ordinal Position Within-Category, five levels: 1 to 5) and one between-subject factor (Experiment, three levels: Experiments 1, 2a and 2b) and their interaction were modelled. In the item analysis, one data point was not available due to participants' errors. The effect of Experiment was significant in the item analysis only ($F1_{(2, 57)} = 1.66$, $p = .19$, $\eta_p^2 = .05$; $F2_{(1.48, 41.61)} = 17.3$, $p < .01$, $\eta_p^2 = .38$). The interaction between these two factors was not significant ($F1 < 1$; $F2_{(8, 224)} = 1.62$, $p = .12$, $\eta_p^2 = .05$). We are grateful to Gary Oppenheim and two anonymous reviewers for bringing this aspect of the data to our attention, and raising this set of issues.

[v]Note that this analysis is different from that reported by Belke and Stielow, 2013, who tested for a cumulative cost across cycles; the authors found no cumulative cost across cycles.

within category/block in the related condition, considered alone and not referenced to the unrelated condition ($F1$ $(3.42, 194.97) = 11.07$, $p < .01$, $\eta_p^2 = .16$; $F2$ $(4, 116) = 6.94$, $p < .01$, $\eta_p^2 = .19$)[vi]. An analysis of the linear trend showed that response times decrease with each additional within-category item that is named ($F1$ $(1, 57) = 29.62$; $p < .01$; $\eta_p^2 = .34$; $F2$ $(1, 29) = 20.22$; $p < .01$; $\eta_p^2 = .41$; Collapsing across experiments: slope $= -11.2$ ms/position; $R^2 = .87$).

By hypothesis, semantic priming and incremental weakening of semantic-to-lexical representation are both continuous phenomena where their magnitude is determined by activation levels. The activation levels that underlie the two processes are in turn determined by a common cause, which is the structure of lexical-semantic representations and the dynamics of how activation spreads from semantic to lexical levels of representation. The difference is that while semantic priming is a short-lived 'online' phenomenon that indexes the current activation state of the system, incremental weakening is a long term structural change that is induced in the connections of the system through an error learning mechanism. However, if it is the case that semantic priming and incremental weakening are in fact two manifestations of the same underlying distribution of activation levels during production events, then the expectation would follow that the two phenomena should be 'yoked' in their magnitude. As an initial test of this expectation, Figure 7B plots the two lines of Figure 7A against one other (i.e., one corresponding to the weakening mechanism across unrelated blocks and the other corresponding to semantic priming within related blocks). As can be seen, there is a reasonably tight negative relation between them, suggesting at least preliminarily, that semantic priming and incremental weakening may be mirror manifestations of the same underlying distributions of activation levels at the lexical level.[vii]

Is Picture Naming a type of Cued Recall?: The existence of 'costs' associated with having previously retrieved semantically related information is a broad phenomenon. For instance, retrieval-induced forgetting refers to the observation that recall of a previously studied word is impaired if related items are retrieved in the period between study and recall (e.g., Anderson, 2003). In other words, retrieval of unpracticed items from practiced categories is worse than retrieval of unpracticed items from unpracticed categories. Previous research has explored the relations between the retrieval-induced forgetting and semantic interference in

---

[vi]The effect of Experiment was significant in the item analysis only ($F1$ $(2, 57) = 1.4$, $p = .25$, $\eta_p^2 = .04$; $F2$ $(1.52, 44.25) = 14.35$, $p < .01$, $\eta_p^2 = .33$). The interaction between these two factor was not significant ($F1$ $(8, 228) = 1.31$, $p = .24$, $\eta_p^2 = .04$; $F2 < 1$).
[vii]Another source of (at least preliminary) evidence for the proposal that the magnitude of behavioral effects caused by semantic priming and incremental weakening should be mirror reflections of one another is provided in Figure 1. That figure presents the results of the data from Experiment 2 of Navarrete and colleagues (2012). In Navarrete and colleagues we manipulated within-category semantic distance using the 'standard' version of the blocked naming paradigm (where all blocks had multiple cycles of items). The within-category semantically-close condition showed the most semantic facilitation in the first cycle, but then the most relative 'interference' in cycles 2 and 3. In other words, at the second cycle, the within-category semantically close context was slower than the within-category semantically-far context. If it is assumed that the amount of repetition priming is not sensitive to activation levels, then the relatively slower response times in the within-category semantically close compared to the within-category semantically far condition would be explained by the relatively greater incremental weakening that occurred in the former compared to the latter condition. However, this extension of the account is admittedly ad hoc and requires an additional and *a priori* empirical test.

picture naming, for instance with respect to the cumulative semantic cost (Navarrete et al, 2010; Oppenheim et al, 2010), and the phenomenon of first-language attrition in bilingual speakers (Levy, McVeigh, Marful, & Anderson, 2007; but see Runnqvist & Costa, 2012).

Taking a step back, the similarities across paradigms may suggest a slightly different view of the task of picture naming itself. Picture naming, as it is studied in the context of language production, is generally considered within a framework in which the picture serves to 'determine' the target word: identification of the target name is modeled as the process of 'tracing out the line of activation' between the stimulus and the word representation. Another way to view the task of picture naming is less as *indicating* what the target word should be, but as *cueing* a response. On this view, picture name retrieval is an active and generative process that is constrained by, not given by, the picture. For instance, if a subject were provided with the cue: Produce the name of a fruit that begin with 'a', the great majority of participants will say 'apple', even though 'apricot' is an equally valid response. The reason why participants would overwhelmingly respond with 'apple' has to do with a number of factors (frequency, familiarity, typicality, etc.), but the point is that the eventual response of participants is only partly constrained by the 'cue', and then semantic and phonological memory must be actively 'searched' in order to find a correct item that matches the cue. In this same way, it may be useful to consider pictures as cues that (strongly) bias memory search for the corresponding concept, because there are empirical phenomena observed with cued recall tasks that bear striking similarities to phenomena observed in picture naming (e.g., Brade & Wagner, 2002; Crescentini, Shallice, & Macaluso, 2010; Martin & Cheng, 2006; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997). The suggestion here is that, understanding how pictures 'cue' words is not an issue that should be relegated to models of semantic memory, apart from considerations of how words are retrieved, but rather may involve the mappings from semantics to words, and thus the language production system directly.

5.Conclusion

The data we have reported demonstrate that semantic facilitation is the default pattern when pictures are blocked by semantic context, and that 'semantic interference' emerges only when there is within-block repetition. We further showed that the emergence of what masquerades as 'semantic interference' is caused by differential repetition priming in the unrelated condition. Two inferences follow from these data. **i)** Models of word retrieval that include lexical selection by competition are untenable, and noncompetitive models should be explored and developed in the context of data previously attributed to lexical competition. Given the success of models that do not assume lexical competition in explaining speech errors, both in normal participants and patients with aphasia, it is particularly interesting to see if they can also be extended to explain the patterns of response time effects observed in speech production (e.g., Dell et al., 2008). **ii)** The emergence of 'semantic interference' in the blocking naming task can be explained by an incremental learning mechanism by which connection weights are adjusted (e.g., Oppenheim and colleagues, 2010). That theoretical framework emphasizes interactions between semantics and lexical level representations, and suggests that there may be important relationships

between the semantic effects observed in speech production and other well characterized memory phenomena.

Acknowledgments

Appendix

Experimental materials organized by semantic category.

Animals: deer, donkey, goat, horse, zebra.

Clothes: dress, glove, pants, shirt, sock.

Fruit: apple, banana, lemon, orange, strawberry.

Furniture: bed, chair, couch, stool, table.

Tableware: cup, fork, knife, ladle, spoon.

Transportation: bus, car, motorcycle, taxi, truck.

References

Abdel Rahman R, Melinger A. When bees hamper the production of honey: Lexical interference from associates in speech production. Journal of Experimental Psychology: Learning, Memory and Cognition. 2007; 33:604–614.

Abdel Rahman R, Melinger A. Semantic context effects in language production: A swinging lexical network proposal and a review. Language and Cognitive Processes. 2009a; 24:713–734.

Abdel Rahman R, Melinger A. Dismissing lexical competition does not make speaking any easier: A rejoinder to Mahon and Caramazza (2009). Language and Cognitive Processes. 2009b; 24:749–760.

Abdel Rahman R, Melinger A. The dynamic microstructure of speech production: Semantic interference built on the fly. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2011; 37:149–161.

Alario F-X, Moscoso del Prado Martin F. On the origin of the cumulative semantic inhibition effect. Memory & Cognition. 2010; 38:57–66. [PubMed: 19966239]

Aristei S, Melinger A, Abdel Rahman R. Electrophysiological chronometry of semantic context effects in language production. Journal of Cognitive Neuroscience. 2011; 23:1567–1586. [PubMed: 20515409]

Anderson MC. Rethinking interference theory: Executive control and the mechanisms of forgetting. Journal of Memory & Language. 2003; 49:415–445.

Belke E. Effects of working memory load on lexical-semantic encoding in language production. Psychonomic Bulletin and Review. 2008; 15:357–363. [PubMed: 18488652]

Belke E. Long-lasting inhibitory semantic context effects on object naming are necessarily conceptually mediated: Implications for models of lexical-semantic encoding. Journal of Memory and Language. 2013; 69:228–256.

Belke E, Stielow A. Cumulative and non-cumulative semantic interference in object naming: Evidence from blocked and continuous manipulations of semantic context. Quarterly Journal of Experimental Psychology. (in press).

Belke E, Meyer AS, Damian MF. Refractory effects in picture naming as assessed in a semantic blocking paradigm. Quarterly Journal of Experimental Psychology. 2005a; 58A:667–692. [PubMed: 16104101]

Belke E, Brysbaert M, Meyer AS, Ghyselinck M. Age of acquisition effects in picture naming: Evidence for a lexical-semantic competition hypothesis. Cognition. 2005b; 96:B45–B54. [PubMed: 15925568]

Biggs T, Marmurek H. Picture and word naming: Is facilitation due to processing overlap? American Journal of Psychology. 1990; 103:81–100.

Biegler KA, Crowther JE, Martin RC. Consequences of an inhibition deficit for word production and comprehension. Cognitive Neuropsychology. 2008; 25:493–527. [PubMed: 19086200]

Bloem I, La Heij W. Semantic facilitation and semantic interference in word translation: Implications for models of lexical access. Journal of Memory and Language. 2003; 48:468–488.

Bloem I, van den Boogaard S, La Heij W. Semantic facilitation and semantic interference in language production: Further evidence for the conceptual selection model of lexical access. Journal of Memory and Language. 2004; 51:307–323.

Bormann T. The role of lexical-semantic neighborhood in object naming: implications for models of lexical access. Frontiers in Psychology. 2011; 2:127. [PubMed: 21713062]

Brade D, Wagner AD. Semantic Retrieval, Mnemonic Control, and Prefrontal Cortex. Behavioral and Cognitive Neuroscience Reviews. 2002; 1:206–218. [PubMed: 17715593]

Brown AS. Inhibition in cued retrieval. Journal of Experimental Psychology: Human Learning and Memory. 1981; 7:204–215.

Caramazza A. How many levels of processing are there in lexical access? Cognitive Neuropsychology. 1997; 14:177–208.

Caramazza A, Costa A. The semantic interference effect in the picture-word interference paradigm: Does the response set matter? Cognition. 2000; 75:B51–B64. [PubMed: 10771280]

Caramazza A, Hillis AE. Where do semantic errors come from? Cortex. 1990; 26:95–122. [PubMed: 2354648]

Costa A, Miozzo M, Caramazza A. Lexical selection in bilinguals: Do words in bilingual's lexicon compete for selection? Journal of Memory and Language. 1999; 41:365–397.

Costa A, Alario F-X, Caramazza A. On the categorical nature of the semantic interference effect in the picture-word interference paradigm. Psychonomic Bulletin and Review. 2005; 12:125–131. [PubMed: 15948287]

Costa A, Strijkers K, Martin C, Thierry G. The time-course of word retrieval revealed by event-related brain potentials during overt speech. Proceedings of the National Academy of Sciences of the United States of America. 2009; 106:21442–21446. [PubMed: 19934043]

Crescentini C, Shallice T, Macaluso E. Item Retrieval and Competition in Noun and Verb Generation: An fMRI Study. Journal of Cognitive Neuroscience. 2010; 22(6):1140–1157. [PubMed: 19413479]

Dalrymple-Alford EC. Associative facilitation and interference in the Stroop color–word tests. Perception and Psychophysics. 1972; 11:274–276.

Damian MF, Als LC. Long-lasting semantic context effects in the spoken production of object names. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2005; 31:1372–1384.

Damian MF, Bowers JS. Locus of semantic interference in picture–word interference tasks. Psychonomic Bulletin and Review. 2003; 10:111–117. [PubMed: 12747497]

Damian MF, Martin RC. Semantic and phonological codes interact in single word production. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1999; 25:345–361.

Damian MF, Vigliocco G, Levelt WJM. Effects of semantic context in the naming of pictures and words. Cognition. 2001; 81:B77–B86. [PubMed: 11483172]

Dell GS. A spreading-activation theory of retrieval in sentence production. Psychological Review. 1986; 3:283–321. [PubMed: 3749399]

Dell GS, Oppenheim GM, Kittredge AK. Saying the right word at the right time: Syntagmatic and paradigmatic interference in sentence production. Language and Cognitive Processes. 2008; 23:583–608. [PubMed: 20622975]

Dhooge E, Hartsuiker RJ. The distractor frequency effect in picture–word interference: Evidence for response exclusion. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2010; 36:878–891.

Dhooge E, Hartsuiker RJ. How do speakers resist distraction? Evidence from a taboo picture-word interference task. Psychological Science. 2011a; 22:855–859. [PubMed: 21642551]

Dhooge E, Hartsuiker RJ. The distractor frequency effect in a delayed picture–word interference task: Further evidence for a late locus of distractor exclusion. Psychonomic Bulletin & Review. 2011b; 18:116–122. [PubMed: 21327356]

Dhooge E, Hartsuiker RJ. Lexical selection and verbal self-monitoring: Effects of lexicality, context, and time pressure in picture-word interference. Journal of Memory and Language. 2012; 66:163–176.

Dhooge E, De Baene W, Hartsuiker RJ. A late locus of the distractor frequency effect in picture-word interference: Evidence from event-related potentials. Brain and Language. 2013; 124:232–237. [PubMed: 23400118]

Finkbeiner M, Caramazza A. Now you see it, now you don't: On turning semantic interference into facilitation in a Stroop-like task. Cortex. 2006a; 42:790–796. [PubMed: 17131581]

Finkbeiner M, Caramazza A. Lexical selection is not a competitive process: A reply to La Heij, Kuipers and Starreveld. Cortex. 2006b; 42:1032–1035.

Forster KI, Forster JC. DMDX: A windows display program with millisecond accuracy. Behavior Research Methods, Instruments & Computers. 2003; 35:116–124.

Glaser WR, Düngelhoff FJ. The time course of picture–word interference. Journal of Experimental Psychology: Human Perception and Performance. 1984; 10:640–654. [PubMed: 6238124]

Ganushchak LY, Schiller NO. Motivation and semantic context affect brain error-monitoring activity: an event-related brain potentials study. Neuroimage. 2008; 39:395–405. [PubMed: 17920932]

Geng J, Kirchgessner M, Schnur TT. The mechanism underlying lexical selection: Evidence from the picture-picture interference paradigm. Quarterly Journal of Experimental Psychology. 2013; 66(2): 261–276.

Hantsch A, Jescheniak JD, Schriefers H. Semantic competition between hierarchically related words during speech planning. Memory and Cognition. 2005; 33:984–1000. [PubMed: 16496720]

Hantsch A, Jescheniak JD, Schriefers H. Distractor modality can turn semantic interference into semantic facilitation in the picture-word interference task – implications for theories of lexical access in speech production. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2009; 35:1443–1453.

Hantsch A, Jescheniak JD, Mädebach A. Naming and categorizing objects: task differences modulate the polarity of semantic effects in the picture-word interference paradigm. Memory and Cognition. 2012; 40:760–768. [PubMed: 22371163]

Hantsch A, Mädebach A. What does the articulatory output buffer know about alternative picture names? Evidence against the response-exclusion hypothesis. Language and Cognitive Process. 2013; 28:684–700.

Hartsuiker RJ, Pickering MJ, de Jong NH. Semantic and phonological context effects in speech error repair. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2005; 5:921–932.

Howard D, Nickels L, Coltheart M, Cole-Virtue J. Cumulative semantic inhibition in picture naming: experimental and computational studies. Cognition. 2006; 100:464–482. [PubMed: 16413014]

Humphreys GW, Lloyd-Jones TJ, Fias W. Semantic interference effects on naming using a post-cue procedure: Tapping the links between semantics and phonology with pictures and words. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1995; 21:961–980.

Humphreys GW, Riddoch MJ, Quinlan PT. Cascade processes in picture identification. Cognitive Neuropsychology. 1988; 5:67–103.

Huttenlocher J, Kubicek LF. The Source of Relatedness Effects on Naming Latency. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1983; 9:486–496.

Janssen N, Schirm W, Mahon BZ, Caramazza A. Semantic interference in a delayed naming task: Evidence for the response exclusion hypothesis. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2008; 34:249–256.

Kroll JF, Stewart E. Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. Journal of Memory and Language. 1994; 33:149–174.

Kuipers JR, La Heij W. Semantic facilitation in category and action naming: Testing the message-congruency account. Journal of Memory and Language. 2008; 58:123–139.

Kuipers JR, La Heij W. Congruency effects in conceptualizing for speech. Quarterly Journal of Experimental Psychology. 2012; 65:2155–2168.

La Heij W. Components of Stroop-like interference in picture naming. Memory and Cognition. 1988; 16:400–410. [PubMed: 3173088]

La Heij W. Kroll, Judith F.; DeGroot, Annette MB.Selection Processes in Monolingual and Bilingual Lexical Access. Handbook of Bilingualism: Psycholinguistic Approaches [Paperback]. 2005

La Heij W, Kuipers J-R, Starreveld PA. In defense of the lexical-competition account of picture-word interference: A comment on Finkbeiner and Caramazza (2006). Cortex. 2006; 42:790–796. [PubMed: 17131581]

Levelt WJM, Roelofs A, Meyer AS. A theory of lexical access in speech production. Behavioral and Brain Sciences. 1999; 22:1–75. [PubMed: 11301520]

Levy BJ, McVeigh N, Marful A, Anderson MC. Inhibiting your native language: The role of retrieval-induced forgetting during second-language acquisition. Psychological Science. 2007; 18(1):29–34. [PubMed: 17362374]

Lupker SJ. The semantic nature of response competition in the Picture-Word Interference Task. Memory and Cognition. 1979; 7:485–495.

Lupker SJ. Picture naming: An investigation of the nature of categorical priming. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1988; 14:444–455.

Mädebach A, Hantsch A. Explaining semantic facilitation and interference effects in the picture-word interference task-A rejoinder to Navarrete and Mahon (2013). Language and Cognitive Process. 2013; 28:717–722.

Mädebach A, Oppermann F, Hantsch A, Curda C, Jescheniak JD. Is there semantic interference in delayed naming? Journal of Experimental Psychology: Learning, Memory, and Cognition. 2011; 37:522–538.

Maess B, Friederici A, Damian MF, Meyer AS, Levelt WJM. Semantic category interference in overt picture naming: Sharpening current density localization by PCA. Journal of Cognitive Neuroscience. 2002; 14(3):455–462. [PubMed: 11970804]

Mahon BZ, Caramazza A. Why does lexical selection have to be so hard? Comment on Abdel Rahman and Melinger's swinging lexical network proposal. Language and Cognitive Processes. 2009; 24:735–748.

Mahon BZ, Navarrete E. The CRITICAL DIFFERENCE: Semantic interference and facilitation in speech production. A response to Roelofs and Piai. Cortex. (in press).

Mahon BZ, Garcea FE, Navarrete E. Picture-word interference and the response exclusion hypothesis: A response to Mulatti and Coltheart. Cortex. 2012; 48:373–377. [PubMed: 22130091]

Mahon BZ, Costa A, Peterson R, Vargas KA, Caramazza A. Lexical selection is not by competition: A reinterpretation of semantic interference and facilitation effects in the picture-word interference paradigm. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2007; 33:503–535.

Martin RC, Cheng Y. Selection demands versus association strength in the verb generation task. Psychonomic Bulletin & Review. 2006; 13:396–401. [PubMed: 17048721]

McRae K, Boisvert S. Automatic semantic similarity priming. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1998; 24:558–572.

Miozzo M, Caramazza A. When more is less: A counterintuitive effect of distractor frequency in picture-word interference paradigm. Journal of Experimental Psychology: General. 2003; 132:228–252. [PubMed: 12825638]

Mulatti C, Coltheart M. Picture-word interference and the response-exclusion hypothesis. Cortex. 2012; 48(3):363–372. [PubMed: 21632048]

Mulatti C, Coltheart M. Color naming of colored non-color words and the response-exclusion hypothesis: a comment on Mahon et al and on Roelofs and Piai. Cortex. (In Press).

Navarrete E, Mahon BZ, Caramazza A. The cumulative semantic cost does not reflect lexical selection by competition. Acta Psychologica. 2010; 134:279–289. [PubMed: 20347062]

Navarrete E, Del Prato P, Mahon BZ. Factors determining semantic facilitation and interference in the cyclic naming paradigm. Frontiers in Psychology. 2012; 3:38. [PubMed: 22363309]

Navarrete E, Mahon BZ. A rose by any other name is still a rose: Reinterpreting the picture-word experiment of Hantsch and Mädebach. Language and Cognitive Processes. 2013; 28:701–706.

Oppenheim GM, Dell GS, Schwartz MF. Cumulative semantic interference as learning. Brain and Language. 2007; 103:175–176.

Oppenheim GM, Dell GS, Schwartz MF. The dark side of incremental learning: A model of cumulative semantic interference during lexical access in speech production. Cognition. 2010; 114:227–252. [PubMed: 19854436]

Piai V, Roelofs A, Schriefers H. Semantic interference in immediate and delayed naming and reading: Attention and task decisions. Journal of Memory and Language. 2011; 64:404–423.

Piai V, Roelofs A, Schriefers H. Distractor strength and selective attention in picture-naming performance. Memory & Cognition. 2012; 40:614–627. [PubMed: 22200912]

Rapp B, Goldrick M. Discreteness and interactivity in spoken word production. Psychological Review. 2000; 107:460–499. [PubMed: 10941277]

Roelofs A. A spreading-activation theory of lemma retrieval in speaking. Cognition. 1992; 42:107–142. [PubMed: 1582154]

Roelofs A. Testing a non-decompositional theory of lemma retrieval in speaking: Retrieval of verbs. Cognition. 1993; 47:59–87. [PubMed: 8482071]

Roelofs A. Goal-referenced selection of verbal action: Modeling attentional control in the Stroop task. Psychological Review. 2003; 110:88–125. [PubMed: 12529058]

Roelofs A, Piai V. Associative Facilitation in the Stroop Task: Comment on Mahon et al. (2012). Cortex. in press.

Rosinski R. Picture–word interference is semantically based. Child Development. 1977; 46:247–253.

Runnqvist E, Costa A. Is retrieval-induced forgetting behind the bilingual disadvantage in word production? Bilingualism: Language and Cognition. 2012; 15:365–377.

Runnqvist E, Strijkers K, Alario FX, Costa A. Cumulative semantic interference is blind to language: implications for models of bilingual speech production. Journal of Memory and Language. 2012; 66:350–869.

Santesteban M, Costa A, Pontin S, Navarrete E. The effect of word-frequency on lexical selection in speech production: Evidence from semantic homogenous naming contexts. Cognitiva. 2006; 18:75–84.

Schnur TT, Schwartz MF, Brecher A, Hodgson C. Semantic interference during blocked-cyclic naming: Evidence from aphasia. Journal of Memory and Language. 2006; 54:199–227.

Schnur TT, Schwartz MF, Kimberg D, Hirshorn E, Coslett HB, Thompson-Schill SL. Localizing interference during naming: Convergent neuroimaging and neuropsychological evidence for the function of Broca's area. Proceedings of the National Academy of Sciences. 2009; 106(1):322–327.

Schriefers H, Meyer AS, Levelt WJM. Exploring the time course of lexical access in language production: Picture-word interference studies. Journal of Memory and Language. 1990; 29:86–102.

Spalek K, Damian MF, Bölte J. Is lexical selection in spoken word production competitive? Introduction to the special issue on lexical competition in language production. Language and Cognitive Processes. 2013; 28:597–614.

Sperber RD, McCauley C, Ragain RD, Weil CM. Semantic priming effects on picture and word processing. Memory & Cognition. 1979; 7:339–345.

Starreveld PA, La Heij W. Semantic interference, orthographic facilitation, and their interaction in naming tasks. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1995; 21:686–698.

Stroop JR. Studies of interference in serial verbal reactions. Journal of Experimental Psychology. 1935; 18:643–662.

Thompson-Schill SL, D'Esposito M, Aguirre GK, Farah MJ. Role of left inferior prefrontal cortex in retrieval of semantic knowledge: A reevaluation. Proceedings of the National Academy of Sciences, U.S.A. 1997; 94:14792–14797.

Thompson-Schill SL, Botvinick MM. Resolving conflict: A response to Martin and Cheng (2006). Psychonomic Bulletin and Review. 2006; 13:402–408. [PubMed: 17048722]

Tree JJ, Hirsh KW. Sometimes faster, sometimes slower: associative and competitor priming in picture naming with young and elderly participants. Journal of Neurolinguistics. 2003; 16:489–514.

Tydgat I, Diependaele K, Hartsuiker RJ, Pickering MJ. How lingering representations of abandoned context words affect speech production. Acta Psychologica. 2012; 140:218–229. [PubMed: 22673067]

Vigliocco G, Lauer M, Damian MF, Levelt WJM. Semantic and syntactic forces in noun phrase production. Journal of Experimental Psychology: Learning, Memory and Language. 2002; 28(1): 46–58.

Vigliocco G, Vinson DP, Lewis W, Garrett MF. Representing the meanings of object and action words: The featural and unitary semantic space hypothesis. Cognitive Psychology. 2004; 48:422–488. [PubMed: 15099798]

Vitkovitch M, Tyrrell L. The effects of distractor words on naming pictures at the subordinate level. Quarterly Journal of Experimental Psychology: Human Experimental Psychology. 1999; 52(A): 905–926.

Vitkovitch M, Humphreys GW. Perseverant naming errors in speeded picture naming: It's in the links. Journal of Experimental Psychology: Learning, Memory and Cognition. 1991; 17:664–680.

Vitkovitch M, Cooper-Pye E. My word! Interference from reading object names implies a role for competition during picture name retrieval. The Quarterly Journal of Experimental Pscyhology. 2012; 65:1229–1240.

Vitkovitch M, Cooper-Pye E, Leadbetter A. Semantic priming over unrelated trials: Evidence for different effects in word and picture naming. Memory & Cognition. 2006; 34:715–725. [PubMed: 16933776]

Vitkovitch M, Cooper-Pye E, Ali L. The long and the short of it! Naming a set of prime words before a set of related picture targets at two different intertrial intervals. European Journal of Cognitive Psychology. 2010; 22:161–171.

Wheeldon LR, Monsell S. Inhibition of spoken word production by priming a semantic competitor. Journal of Memory and Language. 1994; 33:332–356.

New evidence from the blocked naming paradigm shows that lexical selection is not a competitive process

An incremental learning account of 'semantic interference' in the blocked naming paradigm

Semantic interference in the cyclic naming paradigm: the other side of repetition priming
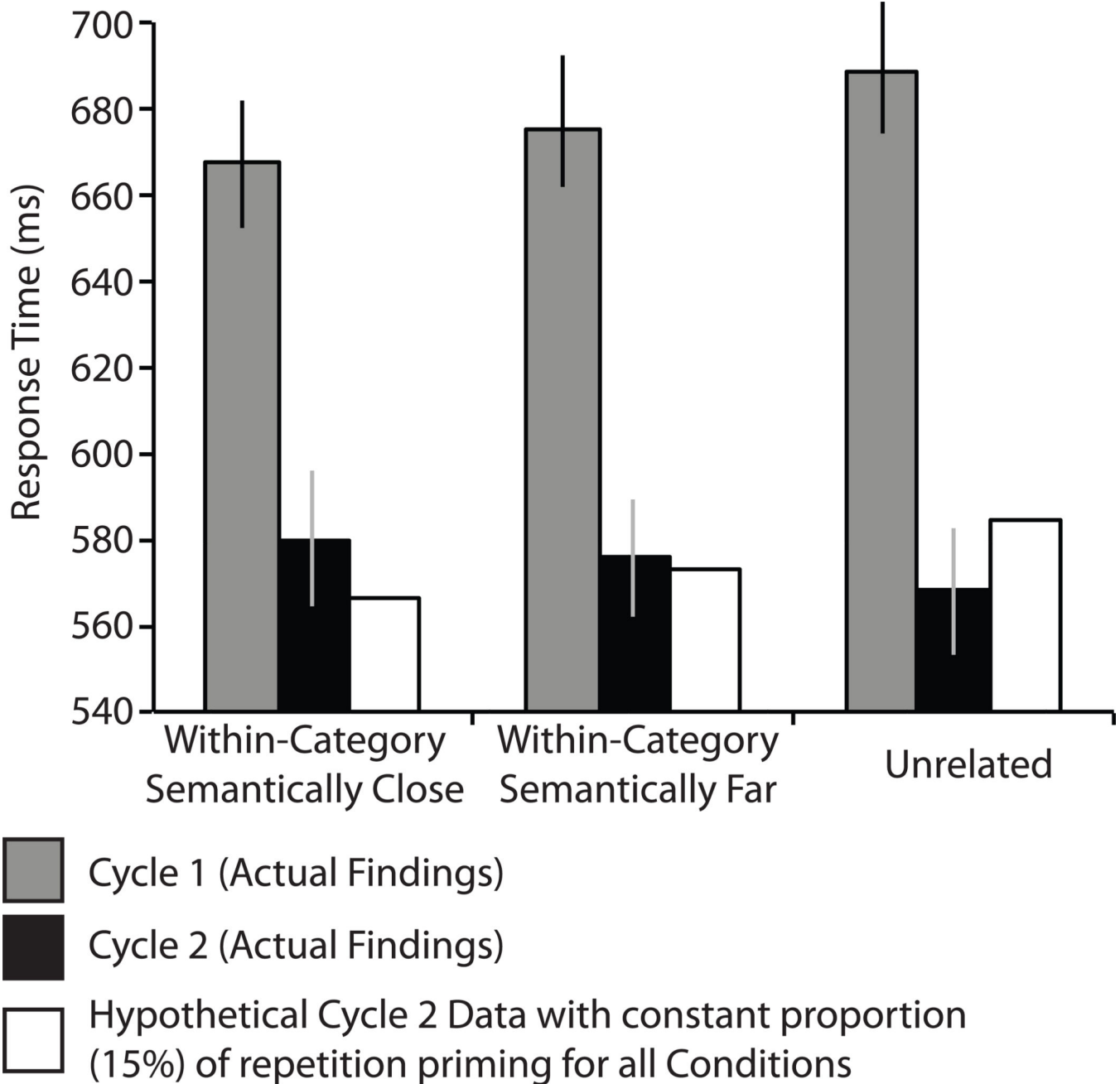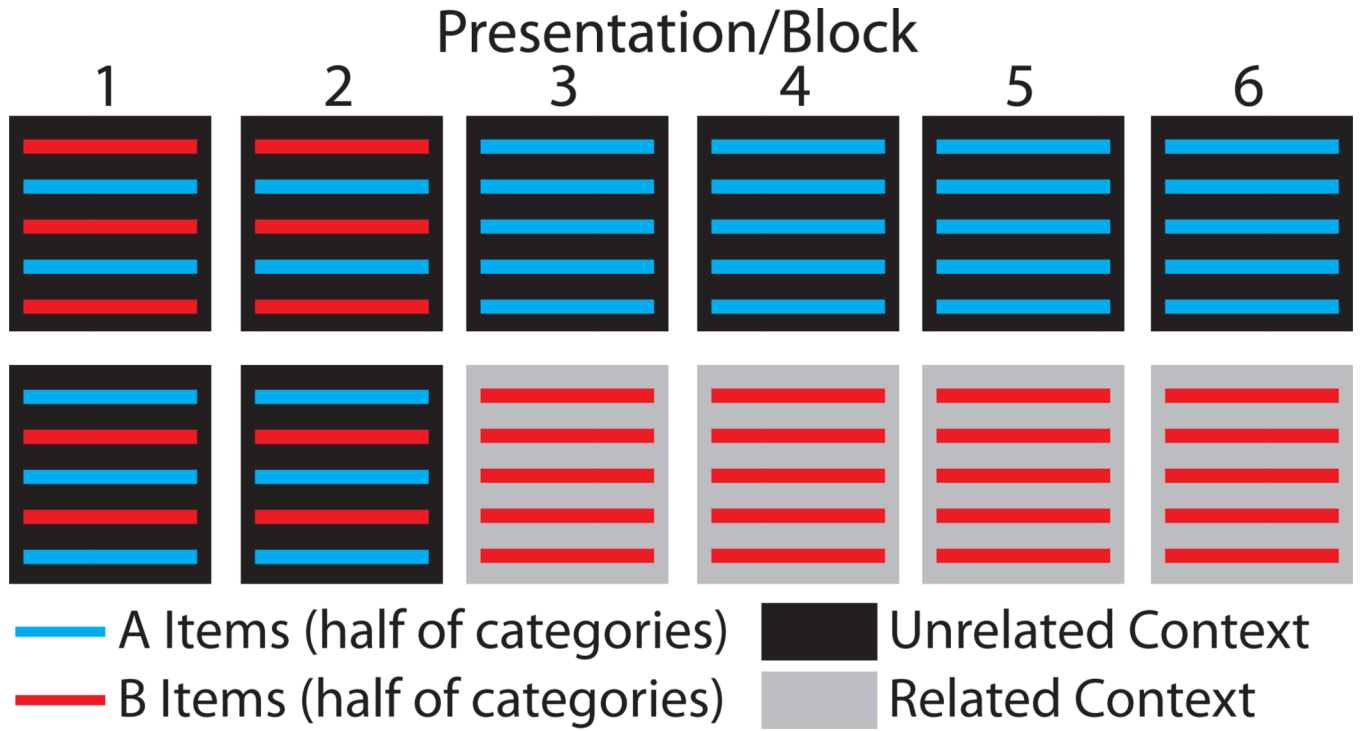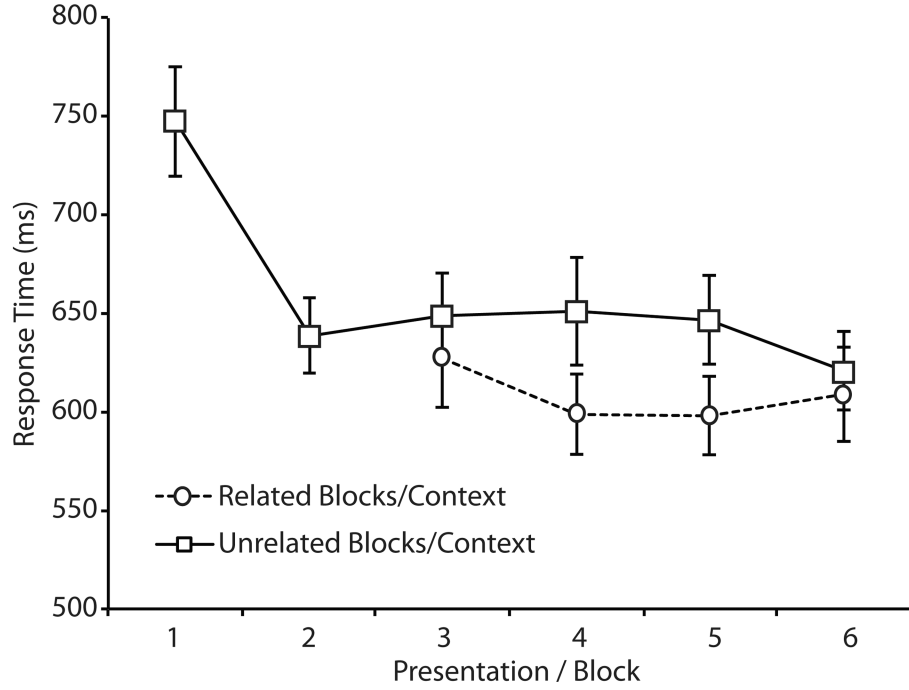
Figure 1.
Reanalysis of the data from Experiment 2 in Navarrete and colleagues (2012). The black and grey bars show actual data, indicating that **i)** there is semantic facilitation in the first cycle, and that it is, if anything, greater for semantically more close (within-category) than semantically more distant (within-category) blocks, and **ii)** there is semantic interference for the second cycle, and it is, if anything, greater for semantically more similar (within-category) than semantically more distant (within-category) blocks. As a demonstration of principle, we then computed hypothetical cycle 2 data by reducing cycle 1 response times by a proportionally equivalent amount (15%). As can be seen, if there were proportionally

equivalent repetition priming for all contexts, then semantic interference would not emerge in cycle 2. This suggests that the emergence of semantic interference may derive from a baseline shift in the unrelated condition. In other words, the emergence of semantic interference depends (by hypothesis) on greater repetition priming in the unrelated than the related conditions.
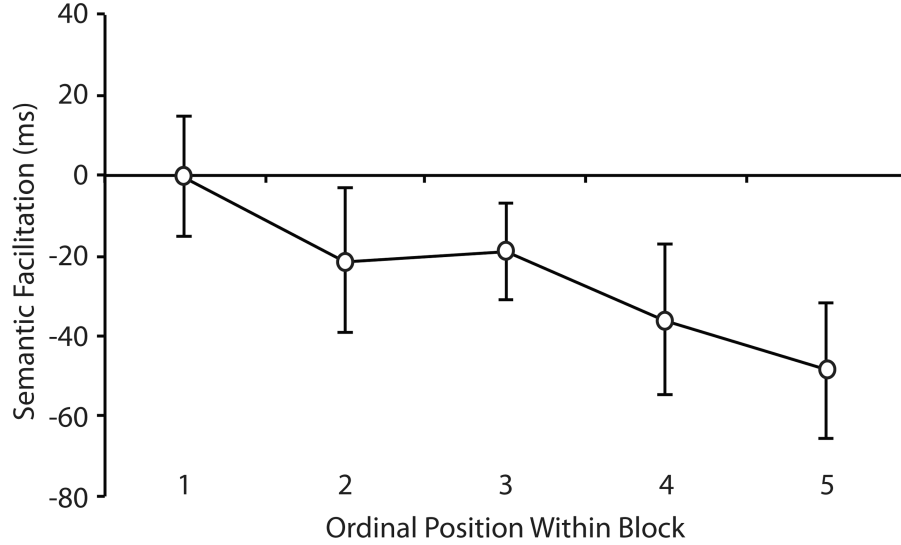
Figure 2.
Schematic of the experimental design used in Experiment 1. Blue and red lines represent (some of) the picture items, split into A and B sets for counterbalancing the design across participants. The shaded background behind the lines indicates the type of context (related or unrelated). The innovation of this design is that **i)** all items are presented in an unrelated context for the first two times that participants see (and name) the items, and then **ii)** half of the categories are presented in related contexts and the other half in unrelated contexts beginning at presentation 3 (counterbalanced across participants), and **iii)** each item is presented only once in each block. This design allows us to test whether related (i.e., homogenous) contexts lead to interference, as predicted by lexical selection by competition, or to facilitation, as predicted by noncompetitive models, while removing the (potentially) confounding factor of 'within block repetition'.

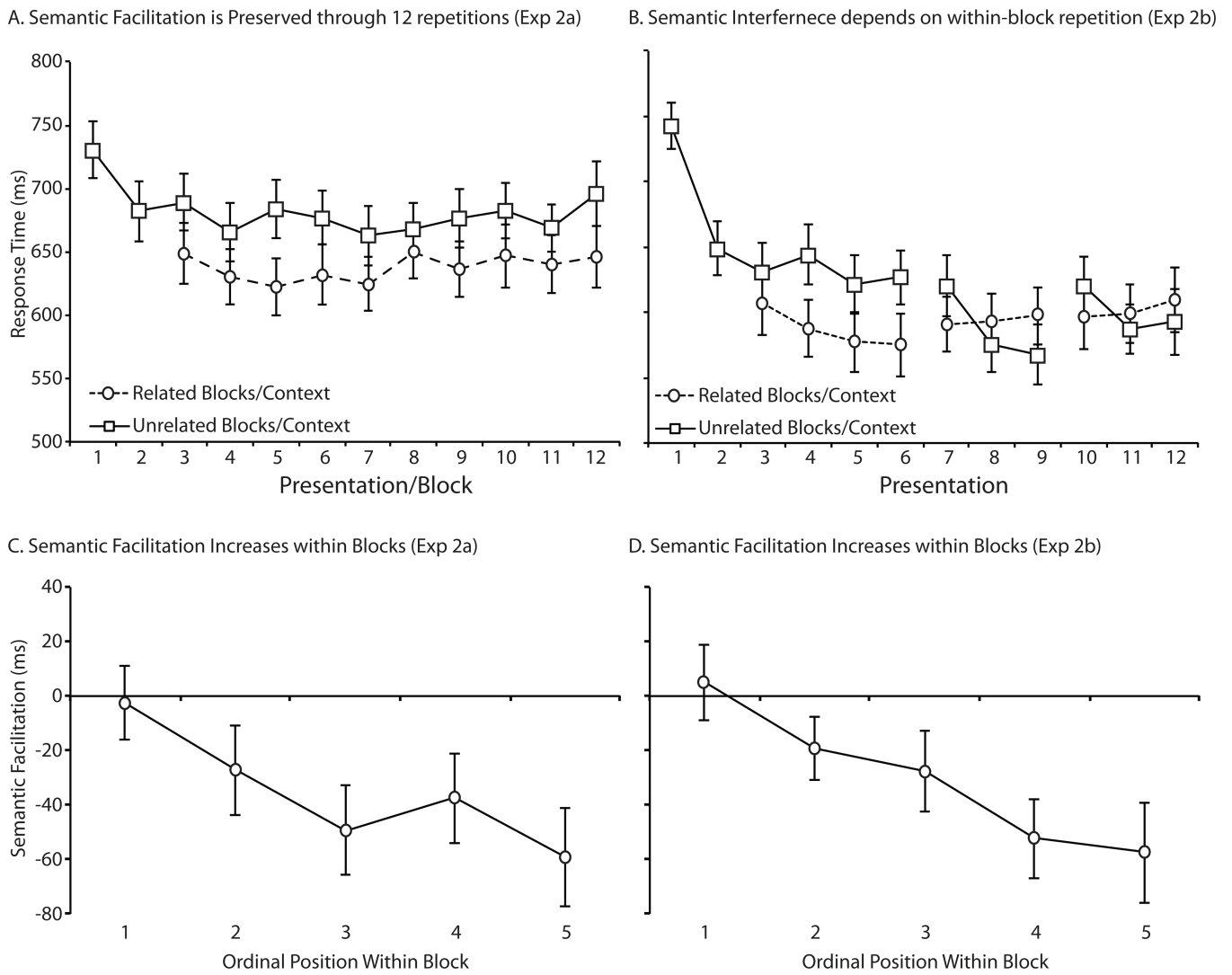## A. Semantic Facilitation is Preserved through 6 Repetitions

## B. Semantic Facilitation Increases within Block

Figure 3.
Response time effects in Experiment 1. **A**. Mean naming latencies by Semantic Context and Presentation for Experiment 1. As can be seen, semantic facilitation is preserved through to presentation 6. **B**. Semantic facilitation increases with ordinal position within block. Semantic facilitation effects are calculated as Related *minus* Unrelated, for each corresponding ordinal position within-block. All error bars are standard error of the mean.
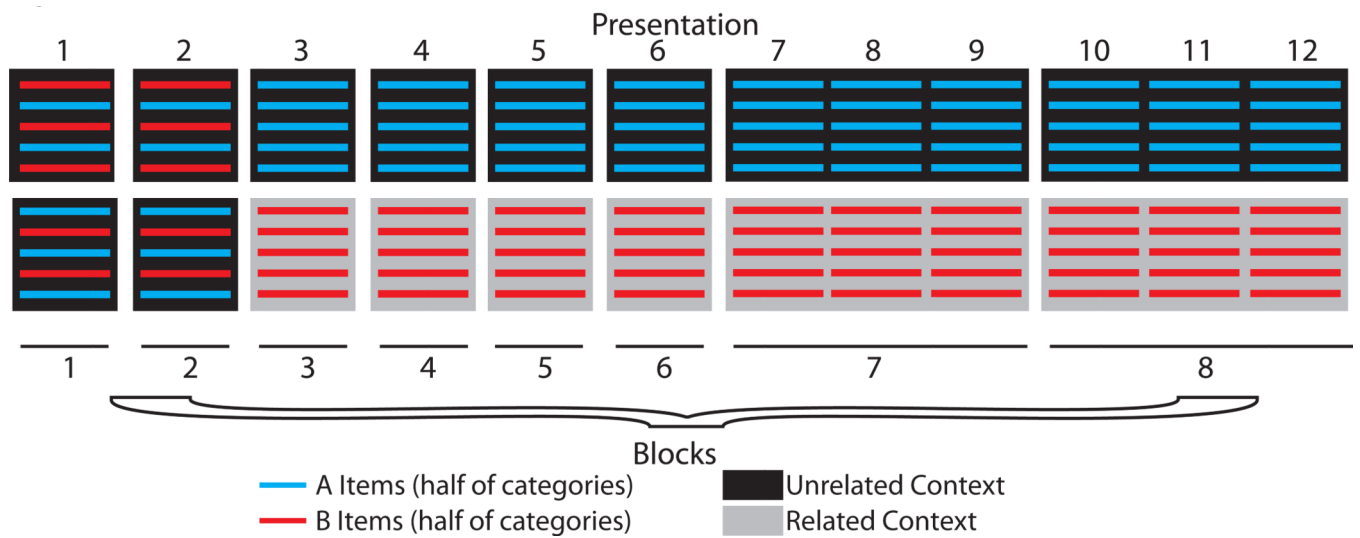
Figure 4.
Schematic of the experimental design used in Experiment 2b. In this experiment, the same design as in Experiments 1 and 2a was used, with the difference that presentations 7/8/9 were collapsed into a single block as were presentations 10/11/12. This 'cross over' design allows us to test whether the emergence of 'interference' depends on repetition within block (i.e., presentations 7/8/9), and whether once interference emerges, it is preserved for all subsequent presentations of that context in the experiment (i.e., presentation 10), or rather reverts to facilitation at the first presentation within-block (i.e., presentation 10).
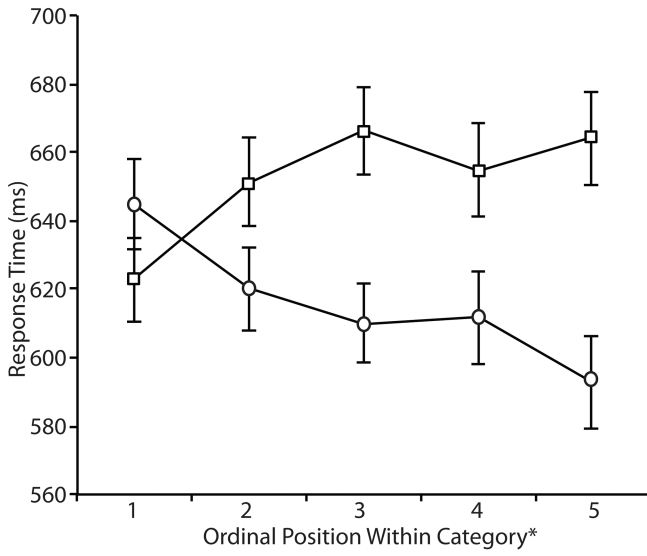
Figure 5.
Response time effects in Experiment 2. **A**. Mean naming latencies by Semantic Context and Cycle for Experiment 2a. As can be seen, semantic facilitation is preserved through to presentation 12. **B**. Mean naming latencies by Semantic Context and Cycle for Experiment 2b. As can be seen, the emergence of semantic interference depends on items repeating within blocks. **C, D**. Magnitude of the contextual semantic effect (Related *minus* Unrelated) by Ordinal position within-block for Experiment 2a (collapsing across presentations 3 to 12) and 2b (collapsing across presentations 3 to 6).
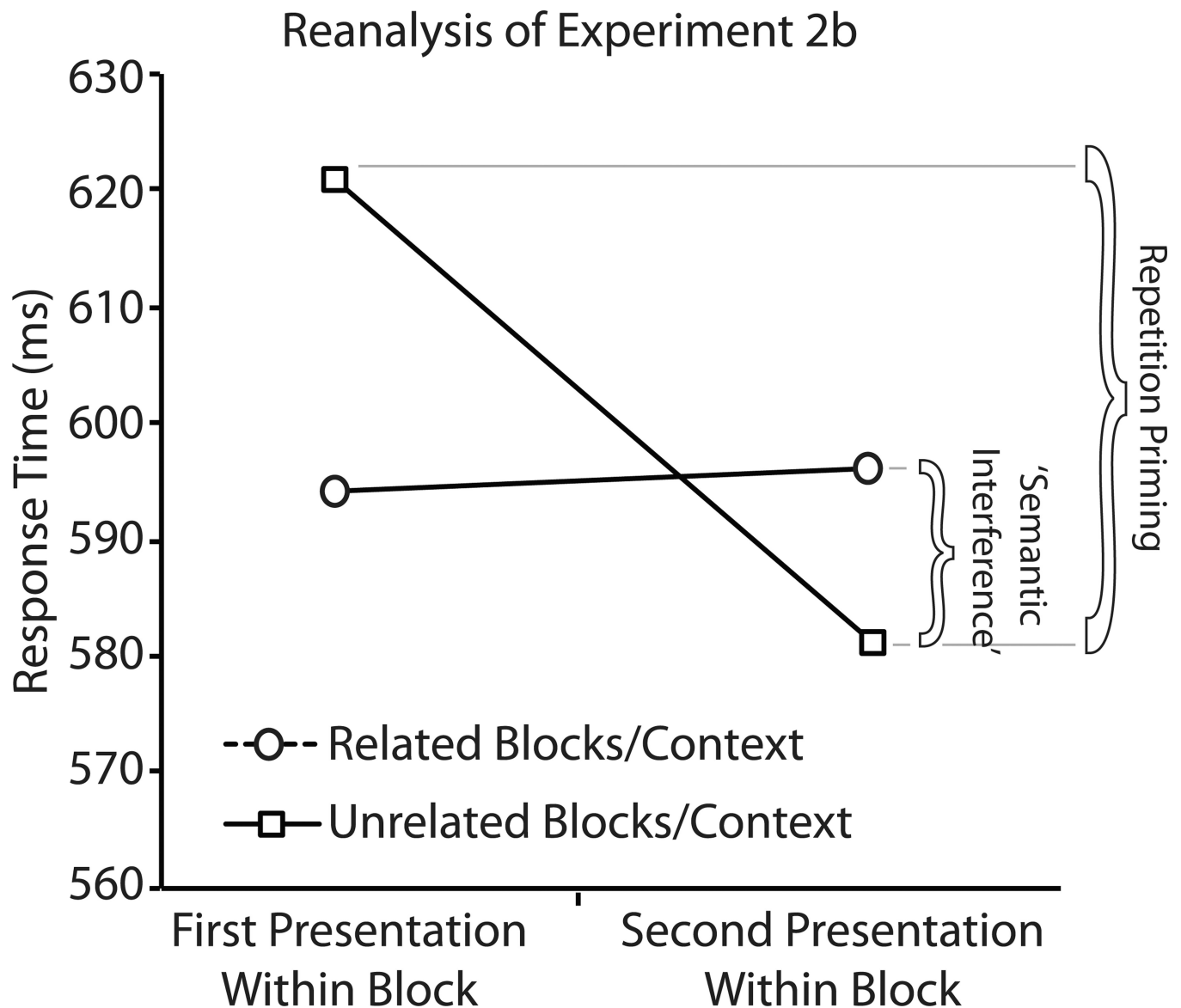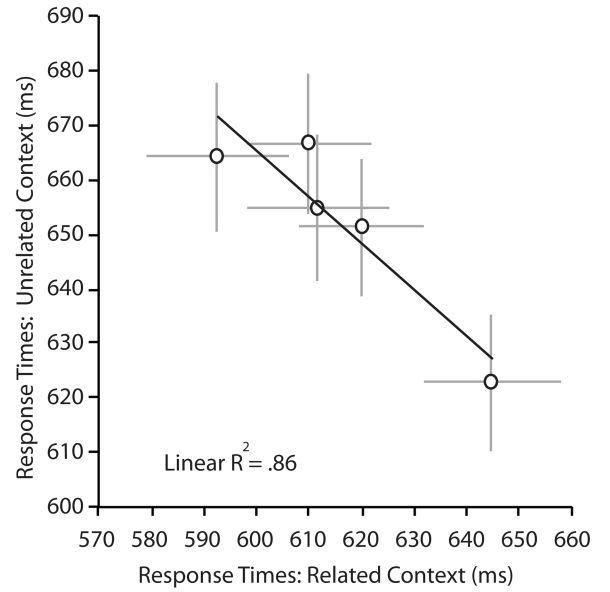
Figure 6.
Demonstration that a baseline shift in the unrelated condition due to differential repetition priming in that condition is the basis for the emergence of 'semantic interference.' The data from Experiment 2b were reduced to a 2×2 design of Semantic Context (Related/Unrelated) and Cycle (i.e., within-block presentation; First/Second). The data from presentations 7 and 10 were combined into the 'First Cycle' data points, and presentations 8 and 11 into the 'Second Cycle' data points, separately for the related and unrelated conditions. The results of this analysis show that the emergence of 'semantic interference' with within-block repetition is caused by differential repetition priming in the unrelated compared to the related condition.

A. Cumulative semantic cost in unrelated and cumulative semantic facilitation in related condition

B. Equivalent semantic cost and semantic facilitation by ordinal position within category

* Within Category = Within Block for Related
  Within Category = Across Blocks for Unrelated

Figure 7.
Response times by ordinal position within category for related and unrelated contexts. The data from all experiments (1, 2a and 2b) were combined for presentations 3 through 6 (as the design of all experiments was identical through presentation 6). **A**. The graph shows mean naming latencies by ordinal position within category, separately for related and unrelated contexts (error bars correspond to standard errors of the means, over subjects). The analysis for the unrelated condition is by definition across blocks, while the analysis for the related condition is by definition a within-block analysis (i.e., ordinal position within category and ordinal position within block in the related condition are one and the same thing). As can be seen, there is a progressive slowing of response times in the unrelated condition with ordinal position within category, but a progressive decrease in response times in the related condition. **B**. The data comprising the two lines plotted in Panel A are now plotted against each other. The tight relationship suggests that semantic priming and incremental weakening are mirror image phenomena in that they both serve as barometers of the same underlying distributions of activation levels at the lexical level.

Table 1

Mean naming latencies (RT), standard deviations (SD) in ms and error percentages (E) by Semantic Context and Presentation in Experiment 1.

| | Experiment 1 | | | | | |
| | Homogeneous/Related | | | Heterogeneous/Unrelated | | |
Presentation	Mean	SD	E	Mean	SD	E
1				748	124	8
2				639	84	5.3
3	627	110	5.4	649	97	7.5
4	599	92	5.4	651	124	3.7
5	598	90	6.7	647	100	3.9
6	609	108	7.1	621	91	5.3
Mean Pres. 3–6	608		6.1	642		5.1

Table 2

Mean naming latencies (RT), standard deviations (SD) in ms and error percentages (E) by Semantic Context and Presentation in Experiment 2.

| | Experiment 2a | | | | | | Experiment 2b | | | | | |
| | Homogeneous/ Related | | | Heterogeneous/ Unrelated | | | Homogeneous/ Related | | | Heterogeneous/ Unrelated | | |
Presentation	Mean	SD	E	Mean	SD	E	Mean	SD	E	Mean	SD	E
1				731	100	4.2				743	81	3.8
2				682	107	3.7				649	93	2.2
3	649	117	7.1	689	111	4.7	607	98	.4	631	87	1.3
4	630	108	3.3	666	102	3.0	587	84	3.3	644	107	.9
5	622	113	5	684	120	3.7	577	92	4.2	621	79	1.4
6	632	124	4.6	677	106	4	575	88	5.8	627	81	2.1
7	625	109	8.3	663	121	3.7	591	75	5	621	86	1.8
8	650	111	6.7	668	106	3.2	593	77	2.7	575	77	2.3
9	636	116	5.4	677	123	6	597	76	1.3	568	82	3
10	647	132	7.5	683	118	5.3	597	88	4.2	621	78	1.1
11	640	128	8.3	669	98	4.5	599	67	2	587	68	2.7
12	646	144	7.9	696	145	3.3	609	62	3	593	67	2.7
Mean Pres. 3–6	638		6.4	677		4.1	593		3.2	609		1.9