Types of interference and their resolution in monolingual language production

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Abstract

There is accumulating evidence that speakers recruit inhibitory control to manage the conflicting demands of online language production, e.g., when selecting from among co-activated representations during object naming or when suppressing alternative competing terms in referential language use. However, little is known about the types of conflict resolution mechanisms underlying the production processes. The aim of this research was to assess the relative contribution of various forms of interference arising at different stages of information processing as well as their control to single- and multi-word utterance production.

The systematic review of picture-word interference (PWI) studies (Study 1) was conducted to trace the origins of semantic context effects in order to address the question of whether spoken word production can be seen as a competitive process. The various manipulations of PWI task parameters in the reviewed studies produced a mixture of findings that were either contradictory, unable to discriminate between the rival theories of lexical access, or of questionable validity. Critically, manipulations of distractor format and of whole-part relations with varied association strength produced sufficiently strong evidence to discount post-lexical non-competitive accounts as the dominant explanations for observed interference effects, constraining their locus to early rather than late processing stages. The viability of competitive hypotheses was upheld; however, this is contingent on the relative contribution of pre-lexical processes, which remains to be confirmed by future research.

The relative contribution of different conflict resolution mechanisms (measured by the anti-saccade, arrow flanker and Simon arrow tasks) to object naming under prepotent (the PWI task) and underdetermined competition (picture naming task with name agreement, NA, manipulation) was further investigated in Study 2, while Study 3 extended the notion of separability of the inhibitory processes to grammatical encoding (grammatical voice construction and number agreement computation). In Study 2, only the flanker effect was a significant predictor of the PWI but not NA effect, while the remaining inhibitory measures made no significant contribution to either the PWI or NA effect. Participants with smaller flanker effects, indicative of better resolution of representational conflict, were faster to name objects in the face of competing stimuli. In Study 3, only utterance repairs were

reliably predicted by the flanker and anti-saccade effects. Those who resolved representational conflict or inhibited incorrect eye saccades more efficiently were found to self-correct less often during online passive voice construction than those with poorer resolution of inhibition at the representational and motor output level. No association was found between the various inhibitory measures and subject-verb agreement computation.

The negative priming study with novel associations (Study 4) was an attempt at establishing the causal link between inhibition and object naming, and specifically whether inhibition that is ostensibly applied to irrelevant representations spreads to its associatively related nodes. Response times to the associated probe targets that served as distractors in previous prime trials were no different than response times to non-associated probe targets. Possible explanations are discussed for the lack of the associative negative priming effect.

The studies described here implicate two types of interference resolution abilities as potential sources of variability in online production skills, with the underlying assumption that better resolution of conflict at the representational and motor output level translates to faster naming and more fluent speech. There is insufficient evidence to determine whether the representational conflict is lexical or conceptual in nature, or indeed whether it is inhibitory in the strict sense. It also remains to be established whether interference that likely ensues at the response output stage is due to some criterion checking process (self-monitoring), recruitment of an inhibitory mechanism (response blocking) or both.

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CHAPTER 1: INTRODUCTION

The introductory chapter provides a theoretical background of the studies conducted for the purpose of this research project. Section 1 outlines the stages of single- and multi-word utterance production. Section 2 depicts language production as an inherently competitive process, with an overview of competitive and non-competitive accounts of lexical selection as based on picture-word interference research. Section 3 reviews findings on the link between inhibitory control and monolingual language production, with an emphasis on distinct types of inhibitory mechanisms that may underlie both lexical and syntactic processing under conditions of increased competition. Section 4 discusses the potential application of the negative priming paradigm in language production research, with a focus on how inhibitory processes may modulate accessibility of lexical and syntactic structures. The aims and organisation of the thesis are summarised in section 5.

1.1 Language production as a complex cognitive mechanism

By mid-adulthood, the average native speaker of English has accumulated in her mental dictionary approximately forty-five thousand lexical entries (Brysbaert, Stevens, Mandera, & Keuleers, 2016). Uttering a word that best captures the conceptual properties of a to-be-named object, given a brief 600-millisecond timeframe (i.e., the average picture naming latency; Indefrey & Levelt, 2004), is no small feat, not only because of the sheer volume of one's internal lexicon, but also because converting a percept or an abstract idea into speech involves a great deal of computation. To illustrate the bulk and complexity of the mental operations associated with naming even a simple common object (e.g., "cheese") an overview of the language production stages is presented below (see also Figure 1).

1.1.2 Stages of single word production

There is broad agreement that naming an object begins with perception (an object is perceived) and culminates in articulation (an object's name is produced) (e.g., Glaser, 1992; Johnson, Paivio, & Clark, 1996; Levelt, Roelofs, & Meyer, 1999). The intermediate stages are less consistently delineated and their specification varies depending on tradition. From the psycholinguistic perspective, the stages can be broadly described in two steps: (1) mapping a semantic representation on to an abstract lexical representation and (2) mapping a lexical representation on to a phonological representation (e.g., Dell & O'Seaghdha, 1992; Rapp & Goldrick, 2000). Some models flesh these out in more detail. Conceptualisation entails accessing semantic information of a to-be-named object (e.g., tacit cheese-knowledge) but also some pragmatic decision-making (e.g., the level of specification: should I call it *food* or *Emmental*; the target language: should I say *cheese* or *ser*?). Lexicalisation is also subdivided into lexical selection and phonological encoding. The former involves retrieval of abstract lexical units called *lemmas* (Kempen & Huijbers, 1983; Levelt et al., 1999) which carry the word's syntactic information but are not yet phonologically specified. For instance, when accessing the lemma *cheese*, one automatically registers its grammatical class (noun), number (singular), type of noun (mass), and in the case of gendered languages such as Polish, also the word's grammatical gender (*ser* is masculine). In some models (e.g., Levelt et al., 1999; Roelofs, 1992), lexical encoding subsumes retrieval of morphological information (*cheese* represents a single structure – the word's stem, but the lemma *loves* consists of two morphological units, a stem and an inflection). During the phonological encoding the lemma's phonological segments (/tʃ/,/iː/,/z/), its syllabification (one syllable) and metrical structure (the lexical stress located on the first and only syllable) are specified. This is followed by phonetic encoding, during which the lemma's phonological units are adjusted for contextual variations in articulation (Levelt et al., 1999). Finally, the so prepared phonological and phonemic representations (lexemes) are mapped on to a motor response so that the desired speech signal is produced (articulation).

1.1.3 Stages of multi-word utterance production

Assembling a sentence requires considerably more work than that involved in the production of a single word (Bock, 1995). To build a sentence, the speaker must not only retrieve and process multiple items (e.g., noun and verb representations), but also compute the relations between them (Altmann & Kemper, 2006; Bock & Levelt, 1994). At the conceptual level, this broadly means deciding on "who is doing what to whom", that is, establishing the agent, the patient and the theme of the to-be-communicated message. The message in the utterance *He loves cheese* includes notions about a positive state of a masculine agent towards a non-specific object from a certain class of foods. To linguistically encode this conceptualised message, the speaker must activate the best-fitting noun and verb lemmas, retrieve their syntactic information (e.g., tense, aspect, number and person) and assign grammatical functions (e.g., nominative, dative, accusative) to the verb's arguments (functional encoding). During the formulation of *He loves cheese*, the masculine pronoun lemma is assigned to the nominative (subject) function, the mass noun lemma to the accusative function (direct object), and the verb lemma to the predicate function. This is followed by positional encoding, during which a specific word order, one that obeys the grammatical constraints of a given language, is imposed on the sentence constituents.

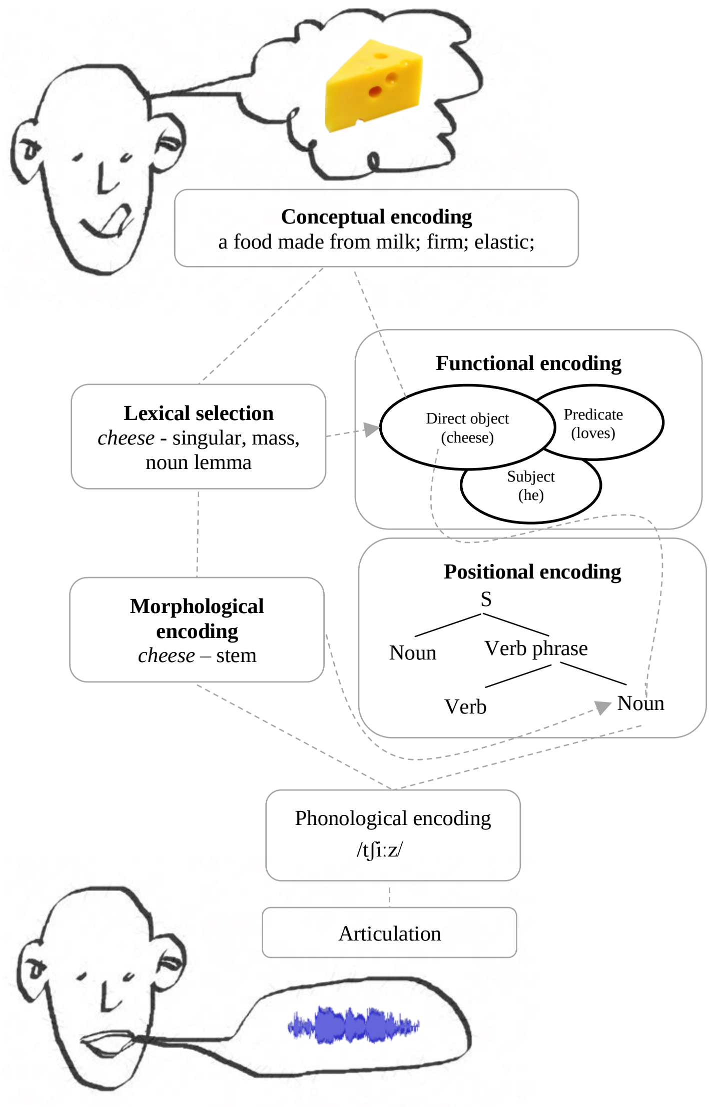

Figure 1. A schematic of the cognitive architecture for language production adapted from Bock (1999); production of "cheese" for the utterance "He loves cheese".

1.2 Language production as a competitive endeavour

To add to the complexity of the production process, some authors propose that it is also inherently competitive. The sources of competition are many (for a review, see Smallwood & Schooler, 2006). A trace may be particularly active in mind and difficult to dismiss because of its prior mention (recency effect) or the frequent exposure to a particular stimulus (frequency effect). Competition may also arise as a result of activation of a lexical item from another (often dominant) language, leading to cross-language interference. Distraction in the form of an internally generated thought (proclivity for mind-wandering) or an irrelevant stimulus in the external environment (e.g., a listener's raised eyebrows) may similarly divert the speaker's attention from the communicative intention, and consequently interfere with the production process. Within-language interference, which is the focus of the current work, is yet another type of competition that originates in the language network *per se* and is thought to be driven primarily by the process of spreading activation (e.g., Collins & Loftus, 1975). This is illustrated in the examples below.

Once an object such as *cheese* has been identified (i.e., a structural representation is mapped on to a conceptual representation), the activation of its semantic information (tacit cheese-knowledge) spreads to other conceptual candidates that partly match the input criteria (e.g., MILK, BUTTER). The conceptual nodes activate their respective lexical units, which may in turn interfere with the selection of the target lemma/lexeme (paradigmatic competition) (e.g., Schriefers, Meyer, & Levelt, 1990). During the mapping of lexical items on to relevant word forms, phonologically related items may also become activated, competing with the target's segmental units (e.g, Breining, Nozari, & Rapp, 2016; Wheeldon, 2003). In multiword utterance production, higher accessibility of certain verb lemmas primes the selection of specific syntactic structures (e.g., Bock, 1987; Ferreira & Engelhardt, 2006), which may nonetheless be incompatible with the communicative context, leading to interference. Utterance production may be additionally hampered by syntagmatic competition, i.e., words that have already been spoken (as evidenced in perseveration errors) or are about to be spoken (as evidenced in anticipatory errors) as part of the sentence (Dell, Oppenheim, & Kittredge, 2008).

1.2.1 Observational evidence for the competitive nature of language production

There is ample observational evidence to suggest that co-activated but context-inappropriate representations compete with the target, at least in the metaphorical sense of the word. Naturally occurring speech errors (e.g., saying "He will *always* forget that cat" instead of "He will *never* forget that cat"; Nick Ferrari on LBC radio; 12 April 2016; or, "None of us had a *bra*" when "None of us had a *brolly*" was intended; a private conversation) demonstrate that non-target representations are activated simultaneously with the intended item, hindering the production process. Aphasic patients also often substitute the target word with a semantically related "competitor" (e.g., saying *table* when naming a picture of a chair; Code, 2010). In tip-of-the-tongue states, a word that is phonologically related to the target (e.g., *procreate* when the word *procrastinate* is being sought after; own example) often comes to mind and may be produced in its stead (e.g., Brown, 1991).

1.2.2 Picture-word interference paradigm – the empirical workhorse in the "lexical selection by competition" debate

Several sources of experimental evidence similarly point to the competitive nature of language production. The bulk of this evidence comes from studies utilising the picture-word interference (PWI) paradigm, but there is also relevant literature on blocked cyclic naming (e.g., Belke & Stielow, 2013; Breining et al., 2016), continuous naming (e.g., Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Rose & Abdel Rahman, 2017), and inhibitory priming (e.g., Vitkovitch & Humphreys, 1991; Wheeldon & Monsell, 1994). In the PWI task, a target picture is named in the presence of a distractor (typically a word superimposed on the picture), which the participant is asked to ignore. Since the original observation by Rosinski (1977) that distractor words from the same semantic category as target pictures (e.g., the word *horse* superimposed on a picture of a DOG) result in slower picture naming than their unrelated controls (e.g., the word *table* superimposed on a picture of a DOG), over three thousand papers have been published to describe the phenomenon known variously in the literature as the *semantic interference effect*, *semantic context effect*, *semantic category effect*, *picture-word interference effect*, and *context effect.* With the exception of the latter, all the above terms can now be considered misnomers because not every type of semantic relation leads to interference, not every effect is inhibitory, and stimuli other than words have been found to interfere with production. For example, whole-part relations (e.g., CAR-*bumper*), which are also semantic, typically yield facilitation (Costa, Alario, & Caramazza, 2005). Phonologically related distractors (e.g., DOG-*doll*) consistently speed up naming (Meyer & Schriefers, 1991). Pictorial distractors that are categorically related to targets (e.g., APPLE-BANANA) neither precipitate nor delay picture naming, but can slow down production if adequately activated at the lexical level (e.g., Jescheniak, Matushanskaya, Mädebach, & Müller, 2014).

Although the PWI effect has traditionally been explained in terms of lexical competition, accumulating evidence for its "polarity reversals" (interference turned into facilitation and vice versa) and the illusory nature of the effect (the effect emerges under one set of conditions, but disappears under another), have contributed to the development of new hypotheses about the origins of the phenomenon. This in turn has led to extensions of competitive models of lexical selection and given rise to alternative, non-competitive accounts. An outline of the most prominent of these is presented below.

1.2.2.1 Competitive accounts

1.2.2.1.1 Selection-by-competition

The most prominent model of lexical selection, the "selection-by-competition" account, assumes that the semantic interference effect reflects competition between the target word and the co-activated but context-inappropriate lexical representations (Bloem & La Heij, 2003; Bloem, van den Boogaard, & La Heij, 2004; Caramazza & Costa, 2000; Levelt, 1989; Levelt et al., 1999; Roelofs, 1992; Starreveld & La Heij, 1995; Vigliocco, Lauer, Damian, & Levelt, 2002; Vigliocco, Vinson, Lewis, & Garrett, 2004). In the context of the PWI task, the effect occurs due to higher activation of categorically related distractor words (e.g., DOG-*horse*) relative to their unrelated controls (e.g., DOG-*table*). Essentially, distractors that belong to the same semantic category as targets are activated both indirectly by the target picture through the process of spreading activation (i.e., the processing of DOG activates its related semantic nodes, such as ANIMAL, CAT, HORSE, etc., which, in turn activate their corresponding lexical representations, *animal*, *cat*, *horse*) and directly by the distractor word itself (*horse*). The lexical node *horse* thus receives activation from two sources (the target and the distractor). By comparison, an unrelated distractor (e.g., *table*) receives activation from a single source - the distractor word alone (DOG is unlikely to spread activation to *table*). A categorically related distractor is therefore a stronger competitor than an unrelated distractor, delaying the selection of the target word.

1.2.2.1.2 Selection-by-competition with a competition threshold

An important extension of the original competitive model of lexical selection (e.g., Roelofs, 1992; Levelt et al., 1999) is the idea that non-target representations must exceed a threshold to enter into competition with the target word (Piai, Roelofs, & Schriefers, 2012). The notion of a "competition threshold" was introduced to account for the elusive nature of the effect, which is detected under one set of experimental conditions, but which disappears under another. There are several ways in which to boost the lexical activation of competitors in the PWI paradigm, one of which is increasing the number of exemplars from the same semantic category as targets. Other methods have been outlined in the *Distractor Format* section (see section 2.5.1.1). In natural word production, it is conceivable that certain non-target words by virtue of either being recently heard, more frequently used or emotional in content will accrue sufficient activation to compete for selection, thus hampering the production of the target word.

1.2.2.1.3 Swinging lexical network hypothesis (SLNH)

A core idea of the swinging lexical network (Abdel Rahman & Melinger, 2009, 2019), developed specifically to address the issue of polarity reversals (interference turned into facilitation), is that the semantic context effect reflects a trade-off between facilitation at the level of conceptual encoding (activation spreading within the semantic network) and interference at the level of lexical processing (activation spreading to lexical representations, only one of which can be selected). The framework is based on two assumptions. One, activation flows bi-directionally within- (a concept will activate its related semantic nodes and a lexical node will activate its related lexical representations) and across the networks (concepts will activate their corresponding lexical representations and lexical representations will activate their respective concepts). Two, whether picture naming is delayed or precipitated depends on the cohort size of the activated lexical representations and their relative strength of activation.

In the case of categorically related target-distractor pairs (e.g., DOG-*mouse*), multiple related concepts and their corresponding lexical nodes (e.g., DOG, CAT, MOUSE) may be accessed due to an overlap in semantic features (both have four legs, have a tail, are furry, live on a farm). In addition, a similar set of semantic and lexical nodes (e.g., DOG, CAT, MOUSE, FROG) may be activated by the shared superordinate category node (ANIMALS). In both cases, target-related concepts and their affiliated lexical nodes are thought to boost the activation of the distractor word (e.g., CAT may activate *mouse*). This type of recursive activation constrains the activated cohort, increasing resonance within the network. In effect, the distractor word accrues enough activation at the lexical level to outweigh facilitation at the conceptual level, with the net result of interference.

In contrast, recursion is less likely in the case of associatively related target-distractor pairs (e.g., DOG-*leash*) for two reasons. One, there is little or no semantic feature overlap. Two, because the items do not share the same superordinate category node (one belongs to ANIMALS, the other, to ACCESSORIES), the ANIMALS node activated by the picture of a DOG and spreading activation to its related concepts (e.g., DOG, CAT, MOUSE, FROG) and their respective lemmas/lexemes is unlikely to strengthen the activation of *leash*. Greater diffusion within semantic and lexical networks results in weaker activation of the distractor word, which is unable to offset facilitation at the conceptual level, with the net result of facilitation.

1.2.2.2 Non-competitive accounts

According to non-competitive accounts of lexical access, word retrieval is a “ballistic” process (Navarrete, Del Prato, Peressotti, & Mahon, 2014); a lexical item is selected once it has reached an activation threshold (or after a certain time delay) *irrespective of* the co-activation of related but irrelevant representations.

1.2.2.2.1 Response exclusion hypothesis (REH)

According to the response exclusion hypothesis (Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; see also "response selection", Finkbeiner & Caramazza, 2006; Miozzo & Caramazza, 2003; and "response plausibility", Lupker & Katz, 1981) the interference effect commonly observed in the PWI task arises due to the confound of “response relevance” (some stimuli appear to be more plausible as responses than others) rather than the direct manipulation of semantic relatedness (and thereby activation spread and competition) between targets and distractors. The delay in naming a pictured object is thus a procedural artefact that has little to do with how words are selected during picture naming. The hypothesis is based on two assumptions. One, distractor words have the articulatory advantage over target pictures (naming a word is quicker than naming a picture). As such, they are more likely to access the articulatory buffer first and must be removed from it, if a target picture's name is to be articulated. Two, the speed with which a distractor response is cleared from buffer depends on how quickly the system can decide whether or not the response satisfies some "response relevance criteria"; the more plausible the response associated with the distractor, given the task requirements, the longer it takes to produce the desired word. For example, in the case of categorically related (e.g., DOG-*mouse*) and unrelated target—distractor pairs (DOG-*table*), the unrelated word *table* will be rejected sooner than the related word *mouse* because the former violates an implicit semantic category criterion (i.e., naming an animal).

In the case of associatively related stimuli that are not co-ordinates, the cost of removing distractor responses from the articulatory buffer is similar across the related and unrelated conditions because both distractor responses are equally implausible given the task. For example, when one is naming a picture of a SHIP, both *anchor* and *button* in the target-distractor pairs SHIP-*anchor* versus SHIP-*button* can be easily dismissed as potential responses because both denote *parts* in a task in which participants name *whole* objects. Similarly, when naming a picture of a BED, it is comparatively easy to reject the verb *sleep* (BED-*sleep*) and the verb *drive* (BED-*drive*) as viable responses because both distractor words violate the implicit rule of naming *an object* (using a noun) as opposed to naming *an action* (using a verb). This minimal cost associated with removal of associatively related distractor responses from the response buffer is outweighed by the benefit of semantic priming (e.g., the concept of ANCHOR primes SHIP), resulting in quicker picture naming in the related condition.

1.2.2.2.2 Verbal self-monitoring

A monitoring mechanism proposed by Dhooge & Hartsuiker (2010, 2012) appears to be a suitable candidate for the "articulatory buffer clearing" job. Essentially, the delay in production can be understood in terms of the extra time needed by the verbal self-monitor to perform checks on a response that has been selected (exceeded a threshold and entered the articulatory buffer) but not yet articulated (is blocking the articulatory buffer). The monitor has to decide whether or not the response fulfils certain constraints. These could be implicit response relevance criteria (the account is compatible with REH), lexicality criterion (whether or not the response sounds like a word), appropriateness criterion (whether or not the response is socially appropriate) and so on. Indeed, empirical findings suggest that the mechanism is biased towards non-words (i.e., the speaker is less likely to produce nonsense speech; Baars, Motley, & MacKay, 1975), is sensitive to the social context (i.e., the speaker is less likely to produce a swearword than an incorrect neutral word; Severens, Kühn, Hartsuiker, & Brass, 2012) and needs time to perform the required operations (i.e., the activity of the monitoring mechanism is compromised under time pressure; Gehring, Goss, Coles, Meyer, & Donchin, 1993)

1.2.2.2.3 Concept exclusion hypothesis (CEH)

It is possible that semantic information supplied by the distractor word interacts with picture processing from very early on, at the object recognition stage (within the access of stored structural knowledge) or during the process of mapping of a structural representation onto a relevant conceptual representation (object identification). There is indeed evidence that conceptual knowledge modulates early visual processing of objects (e.g., Bar, 2004; Gauthier, James, Curby, & Tarr, 2003). Within the context of the PWI paradigm, several authors have indicated a pre-lexical locus of the semantic context effects. Lupker & Katz (1981) argued that a delay in picture naming observed when the target and distractor share the same semantic category (and thus activate closely related concepts) could be attributed to the process of conceptual disambiguation. Jescheniak et al. (2014) and Matushanskaya, Mädebach, Müller, & Jescheniak (2016) acknowledge that their data do not rule out an early, pre-lexical locus of the effect. Costa, Mahon, Savova, & Caramazza, (2003) suggest that the PWI effect reflects the ease with which a concept is selected for lexicalisation (semantic selection account), placing the locus of the observed effects before lexical access. Although these assertions are not couched in any single, coherent account, they will be discussed in the current work under the umbrella term of “concept exclusion hypothesis” (CEH). Crucially, even though, figuratively speaking, structural or conceptual representations may compete for selection, or may need to be blocked once wrongly selected by a cognitive system, the interference effects are traced to stages that do not directly involve lexical access; hence they are not competitive in the narrow lexical sense of the word.

1.3 Slaves to the brain's circuitry or masters of control?

Despite much activation going on in the background (in the form of unwanted representations being available for selection along with target concepts, lexical units and/or motor response codes), the selection of words is in fact fairly precise and efficient. Speaking unfolds at the rate of up to six words per second (Levelt et al., 1999), with few errors (one error per 1000 words; Levelt et al., 1999) and relatively few disfluencies (ca. six per 100; Tree, 1995). What mechanisms allow us to manage the conflicting demands of online language production so that what comes out of one's mouth is purposeful, smooth and intelligible? Several authors have proposed that the resolution of within-language interference is mediated by an inhibitory control function (inhibition, for short). Before reviewing the literature on the role of inhibition in language production, it is important to unpack the various meanings that have been attached to the concept of inhibition and to explain how the term with its many alternative names is applied in the psycholinguistic context.

1.4 The many facets of inhibition in psycholinguistic research

The notion of inhibition in psycholinguistic research that focuses on language production has come to represent many different phenomena. This is reflected in the various terms found in the literature, such as *interference* (*resolution*), *competition* (*resolution*), *conflict* (*resolution*), *inhibitory* (*cognitive*) *control* and their derivatives (*inhibitory, competitive*, etc.), that are often used interchangeably to refer to changes in overt linguistic behaviour, the underlying mechanisms that explain these changes, or the cognitive abilities that serve to optimise this behaviour. Such is the lure of the metaphor of inhibition, that it may sometimes be invoked in relation to a linguistic behaviour, which could otherwise be explained by non-inhibitory (non-competitive) processes.

1.4.1 Inhibition as a decrement in performance

A sizeable proportion of language production studies have viewed inhibition in terms of a measurable decrement in performance on a language production task.

This decrement is typically expressed as an experimental effect, i.e., the difference in overt linguistic behaviour observed across experimental and control conditions. A range of effects have been reported in the literature, each with its unique label specific to the experimental paradigm used, e.g., *competitor priming effect* (Wheeldon & Monsell, 1994), *inhibitory effect* (Vitkovitch & Humphreys, 1991), *semantic inhibition effect* (Howard et al., 2006), *semantic interference effect* (e.g., Costa et al., 2005; see more alternative terms in Section 1.2.2), *semantic context effect* (e.g., Belke & Stielow, 2013), *refractory effect* (Belke, Meyer, & Damian, 2005) and others. What these effects demonstrate is that production is slower, more error-prone and less fluent on experimental trials relative to the baseline, and that this can be attributed to higher activation of non-target linguistic representations (lexical competitors) that are thought to interfere with the production process. The activation of lexical competitors can be experimentally induced through various task manipulations. For example, in the study by Wheeldon & Monsell (1994), names that were previously elicited by definitions on prime trials and whose semantics overlapped with that of the target words on object naming (probe) trials delayed their retrieval compared to unrelated target words. Due to the shared conceptual representations and the recent retrieval of a competitor's name on prime trials, it was more likely to be sampled as an answer on experimental trials, delaying the point at which the correct name was selected. Words that have been recently produced and that fall within the same semantic category as targets will also tend to be erroneously selected under time pressure (Vitkovitch & Humphreys, 1991). Their activation is thought to exceed that of the target word due to the strengthening of connections between semantic and phonological representations of the word as a result of priming.

A similar line of reasoning has been extended to other effects, such as the *blocking effect* in the blocked cyclic naming paradigm (e.g., Belke et al., 2005; Damian, Vigliocco, & Levelt, 2001) and the *cumulative semantic interference effect* in the continuous naming paradigm (Brown, 1981; Howard et al., 2006). In the semantic blocking paradigm, in which objects are either blocked in homogenous sets representing a single semantic category (e.g., *skirt, trousers, vest, coat, vest, skirt, trousers, etc*., the same objects are repeated in several cycles within a block) or heterogeneous sets containing exemplars from different semantic categories (e.g., *skirt, apple, table, duck, apple, table, duck, skirt*), response latencies are longer in the homogenous (semantically related) than in the heterogeneous (unrelated) condition, with the greatest increase in naming times observed in the second cycle, after which the effect increases more slowly or disappears altogether. In the continuous naming paradigm, semantically related target objects are interspersed with filler objects belonging to different semantic categories (e.g. ***skirt***, *apple, table, duck*, ***trousers***). Cumulative semantic interference reflects a linear increase in naming latencies as a function of the number of previously retrieved names of objects from the same semantic category. Both effects are thought to arise as a result of repetitive activation of non-target words that partially match the semantic input of the target word, which nevertheless adversely affect the selection of the target because of their activation head start.

Another common way to raise the activation of non-target items is to present them as visual (either words or pictures) or auditory distractors, a technique employed in the picture-word interference paradigm (e.g., Schriefers et al., 1990). Here, a delay in performance on experimental trials, in which the distractor word is categorically related to the target picture, is interpreted as a by-product of co-activation of unwanted representations that hamper the selection of the most sought-after word. Put differently, the speed with which an object's name is isolated is determined by activation of non-target names.

The term *inhibition* when used to explain the effects described above can thus be understood in the sense of a "hindrance". To say that language production is "inhibited" or that it is "competitive" in nature, is really to say that it is hindered by representations that are strongly activated but which are nonetheless irrelevant to the communicative goal. Such a conception of inhibition does not specify the theoretical underpinnings of the processes that lead up to a delay (an error or a disfluency) or those that contribute to successful lexical selection. It merely describes a by-product of language production, which may well result from the operation of inhibitory mechanisms.

1.4.2 Inhibition in a mechanistic sense

Another way to conceive of inhibition in the context of language production is in terms of the underlying mechanisms – those accounting for the behavioural effects in the form of slowed, error-prone and/or disfluent speech, i.e., the means by which competition is instantiated, and those explaining successful selection, i.e., the means by which lexical selection is accomplished in the face of competing inputs (inhibition). Competitive models of language production (e.g., Howard et al., 2006; Stemberger, 1985) postulate a mechanism of *lateral inhibition* by which activation of a competitor can delay target selection. Competition arises because each activated word sends inhibitory links to every other word. The greater the activation of the competitor, the longer it takes for the target to reach a critical threshold. A word may be selected upon reaching an absolute threshold, but since activated words inhibit each other, the point at which this word can satisfy the criterion may be delayed by competitors with strong inhibitory links. Competition may also be instantiated through a decision criterion mechanism, such as *Luce's ratio* (Levelt et al., 1999; Roelofs, 1992), which also takes into account the activation level of other candidates. The system will select the first candidate to be activated more than the others by some differential amount. Greater activation of a competitor thus will slow down selection, regardless of whether there is lateral inhibition. Both differential and absolute threshold selection models assume competition because having multiple strong lexical candidates makes it harder to select the winner, although the former entails inhibitory links in order to be competitive, while the latter does not.

A different mechanism that has been postulated to explain some of the inhibitory effects observed in competitor priming tasks is *self-inhibition*. For example, Vitkovitch, Kirby & Tyrrell (1996) and Vitkovitch, Rutter, & Read (2001) observed that perservatory errors in a speeded naming task were apparent only at longer lags (when a competitor was presented several trials prior to the target), but not at short intervals between prime and probe presentation (when a competitor immediately preceded the target). Similarly, Wheeldon & Monsell (1994) observed increased naming times in response to objects on probe trials that were presented several trials after the prime trial rather than immediately afterwards. A possible explanation of these findings is that a lexical candidate that has been selected enters a brief refractory phase during which it is temporarily unresponsive. With its activation below some resting state, for a brief time it does not interfere with probe object naming (cf. an alternative explanation by Wheeldon & Monsell, 1994). Such a mechanism would be particularly useful in sequential tasks, but also in natural speech production (a form of a rapid sequential activity), in which lexical items have to be activated, but also de-activated for short periods of time to prevent their reiteration in speech. Such decay in the selected word's activation (a form of self-inhibition) has indeed been posited in Dell's (1986) multi-word production model.

1.4.3 Inhibition – automatic or strategic?

Inhibition can further be understood in terms of bottom-up (automatic) processes of co-activation (strongly activated candidates compete for selection and thus "inhibit" production) and top-down (strategic) mechanisms which bias selection according to task-specific criteria (e.g., Belke & Stielow, 2013; Roelofs, 1992). The latter may again be instantiated by lowering the activation of an unwanted word or by boosting the activation of a target. Belke & Stielow (2013) refer to a verb generation task, in which the speaker produces a verb to a noun-cue, e.g. *dog*. Multiple representations may be activated in response to the cue (e.g., *bark*, *bone*), increasing the difficulty of selection, and the speaker selects the one that fulfils the response-relevance criteria, i.e., produce a verb. This mechanism is analogous to a "buffer clearing" mechanism in the PWI task proposed as an alternative (non-competitive) explanation of the semantic interference effect (e.g., Mahon et al., 2007), whereby a word is selected based on its plausibility as an answer. A biased-selection account does not specify how biasing is implemented – whether via excitatory or inhibitory links. It merely suggests that in low constraint contexts (with multiple competitors), an additional biasing mechanism may be needed to single out a response based on task set requirements.

1.4.4 Inhibition from a functional perspective

Inhibition may also be understood from a more functional perspective, as a cognitive ability that varies between individuals and whose main task is optimise production. A role for inhibition in language production has been inferred from convergent empirical evidence that suggests the use of inhibition, in one form or another. Drawing on well-established findings from across cognitive domains, both with healthy and clinical populations, a number of individual differences studies have claimed that inhibition may underlie production of words and longer utterances. Those with better inhibition abilities, as inferred from performance on classic inhibitory control tasks (e.g., stop signal task), statistical proxies (steeper slopes of the slower delta segments), or neural proxies (e.g., anxiety associated with reduced

GABAergic function) were generally faster at naming, produced fewer syntactic errors and better adjusted their speech to the perspective of their interlocutor (Shao, Roelofs, Martin, & Meyer, 2015; Sikora, Roelofs, Hermans, & Knoors, 2016; Snyder et al., 2010).

1.4.5 Inhibition - a superfluous concept?

Certain patterns of behaviour can be explained without recourse to inhibition/ competition. In models such as Dell's (1986), lexical selection proceeds independently of the "background noise" (co-activated but context-irrelevant representations), with occasional errors, delays, and disfluencies in speech interpreted as by-products of some decision processes. Instead, it is dictated by the activation threshold alone (the word with most activation gets selected) or by a time delay (a word is selected because the speaker is pressed for time). The connectionist model developed by Oppenheim, Dell, & Schwartz (2010) does not envisage a role for inhibition or competition for that matter during word selection, but inhibition/ competition is part of the learning process. Each act of retrieval leads to the strengthening of connections between the semantic and lexical representations of the chosen word and the weakening of connections between the semantic and lexical representations of the unselected words. So, this decrease in the weights between co-activated non-target words and the activated semantic features could be said to be inhibitory. The selection itself involves a booster mechanism which is applied to all the activated lexical representations, repeatedly raising their activation by a constant factor until the activation of the most highly activated item sufficiently exceeds the activation of all the other items.

1.5 Separate mechanisms view of inhibition in cognitive science research

Both theoretical work (e.g., Kok, 1999; Nigg, 2000; Verbruggen, McLaren, & Chambers, 2014) and empirical findings on inhibition (e.g., Chuderski et al., 2012; Friedman & Miyake, 2004; Pettigrew & Martin, 2014; Rey-Mermet, Gade, & Oberauer, 2018; Stahl et al., 2014) have argued against a common inhibitory factor. Several of these authors have suggested that the various cognitive measures used to assess inhibition may in fact reflect separable component processes and that the concept of inhibition as a single psychological construct should be abandoned altogether. With these arguments in mind, the current work takes a deconstruction approach towards the concept of inhibition. In doing so, it adopts the distinction based on the temporal locus criterion, i.e. whether the processes operate at an early sensory, intermediate representational or late response-related stage. This taxonomic division corresponds to both theoretical (e.g., Kok, 1999; Nigg, 2000) and data-driven models of inhibition (e.g., Friedman & Miyake, 2004; Stahl et al., 2014). For example, Stahl et al. (2014) provide empirical support for three distinct sources of interference: stimulus interference (i.e., distracting information in the environment that may involuntarily capture one's attention) corresponding to the input stage, proactive interference (i.e., goal-irrelevant cognitions or representations) corresponding to the intermediate representational stage, and response interference (i.e., involuntarily activated, task-irrelevant response options) corresponding to the output stage. There is also evidence for further dissociation between inhibition at the response selection and response execution levels (Aron, 2011; Nee, Wagner, & Jonides, 2007; Stahl et al., 2014). The former refers to the selection of a response from two equipotent response codes. The latter applies to withholding, modification or stopping of an already selected response. Multiple tasks have been used to assess these various sources of interference. Here, we utilised three well-established conflict paradigms that have been described in the literature as involving conflict at different levels of information processing.

The Eriksen flanker (Eriksen & Eriksen, 1974) test is used to assess the ability to resist or resolve interference from information in the external environment that is irrelevant to the current goal (Friedman & Miyake, 2004). In the arrow version of the task, participants are asked to identify the direction of the middle arrow while ignoring the flanking arrows. The target and the flanking arrows point in the same direction on compatible trials, and in opposite directions on incompatible trials. Responses are slower and more error-prone on incompatible trials relative to the baseline and this decrement in performance is thought to reflect the need to resolve perceptual conflict (flankers have greater visual saliency than the target), representational (conceptual) conflict, some conflict at the level of response selection (the conflicting arrows may also automatically activate competing response codes), and little to no conflict at the level of response execution (Nee at al., 2007; van den Wildenberg et al., 2010). The measure is thus a useful tool for examining interference resolution at these different points in the flow of information processing, and individual differences in the interference effects can be used to make inferences about the efficiency of cognitive processes engaged during conflict resolution.

Another well-studied conflict paradigm that provides a measure of interference resolution is the Simon task (Simon, 1990). In the arrow-based version of the task (Simon arrow task[1]), participants identify the direction of the target arrow that is presented either to the left or right of a central fixation point. Performance is slowed and more error-prone on incompatible trials, in which the presentation of the target stimulus does not correspond to the location of the assigned response, relative to compatible trials, in which the position of the target matches that of the response key. The target stimulus presented on one side of the screen may automatically trigger the activation of a motor response that corresponds to the location of that stimulus on the screen. This activation may clash with a more controlled process of mapping a different, possibly less salient, feature (direction of the arrow) onto the correct effector. The interference effect in the Simon arrow task is therefore commonly attributed to response selection processes (e.g., Lu & Proctor, 1995; Umilta & Nicoletti, 1990) while it avoids interference associated with perceptual conflict (Ridderinkhof, Van Den Wildenberg, Wijnen, & Burle, 2004; van den Wildenberg et al., 2010).

There is broad agreement that the anti-saccade task is a measure of inhibition of a prepotent motor response (Friedman & Miyake, 2004; Pettigrew & Martin, 2014; Stahl et al., 2014). Participants are asked to look either in the direction of a flashing cue presented to the left or right of a central fixation point in order to identify the target that will appear in the same location (pro-saccade condition) or away from the flashing cue so as to identify the target that will appear on the opposite side of the cue (anti-saccade condition). Participants thus have to stop an already initiated action (an incorrect eye saccade) rather than to select between two competing responses as in the Simon task (Munoz & Everling, 2004). Performance on anti-saccade tasks is therefore thought to reflect conflict resolution at the response execution level.

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[1] The Simon arrow task is also known in the literature as "non-verbal Stroop" or "spatial Stroop" task. We used the name "Simon arrow task" to distinguish it from the version in which words denoting direction (e.g. RIGHT, UP) rather than arrows are used as stimuli.

1.6 Types of interference and their resolution in lexical selection

With the concept of inhibition as a single cognitive function being called into question, it makes sense to differentiate between its various forms also in the linguistic context. Several authors have taken this deconstruction approach to investigate lexical selection, although it remains the exception rather than the norm.

To study the role of inhibition in object naming, Shao, Roelofs, & Meyer (2012), for example, adopted the distinction made by Forstmann et al. (2008) between selective and non-selective inhibition. According to these authors, selective inhibition is applied to an externally induced competing response option that is irrelevant in the current context. Non-selective inhibition refers to the suppression of any response option that has been pre-planned and is currently being executed. It is the former type, rather than the latter, that has been implicated in standard object and action naming (Shao et al., 2012), in the resolution of lexical-semantic interference in picture word interference (Shao, Roelofs, & Meyer, 2013; Shao et al., 2015), picture naming with name agreement manipulation (Shao, Roelofs, Acheson, & Meyer, 2014) and semantic blocking tasks, but not in the Stroop task (Shao et al., 2015). A different conclusion was reached by Sikora et al. (2016), in whose study both selective and non-selective inhibition were involved in phrase production, although competition in the version of the task employed by the authors was likely to originate from multiple sources (hence, the authors speak of the *distractor effect* rather than the more widely accepted semantic interference effect).

A different classification is advocated by Snyder, Banich, & Munakata (2014) after Botvinick, Braver, Barch, Carter, & Cohen (2001), who distinguish between underdetermined and prepotent competition. In the case of the former, the speaker has to select a goal-appropriate response option from a set of equally plausible candidates. This may involve, for example, generating a verb to a noun (e.g., *ball*) that affords multiple optional verbs (e.g., *kick, throw, bounce*) as opposed to a noun (e.g., *scissors*) that collocates with relatively few verbs (e.g., *cut*) (Snyder et al., 2014). In prepotent competition, a task-inappropriate response option is activated prior to or more strongly than the target and must be overridden so that the speaker utters the correct word. The most commonly used paradigm to elicit this type of competition is the picture word interference task (Schriefers et al., 1990). Indirect evidence for the involvement of inhibition in the resolution of underdetermined competition comes from a study by Snyder et al. (2010), in which the administration of a gamma-Aminobutyric acid (GABA) agonist (midazolam) to healthy participants resulted in more efficient lexical selection in a verb generation task. Performance on the same language task was adversely affected by anxiety, which had been linked to reduced neural inhibition in previous studies.

Sometimes the type of inhibition remains unspecified, with interference effects from individual tasks (e.g. the Stroop effect) taken as stand-ins for global inhibition. For example, Wardlow (2013) found that speakers with superior inhibitory capacity (indexed by a smaller arrow flanker effect) refrained more effectively from producing modifiers that could be deemed redundant from the perspective of the listener (e.g., saying “the big circle” when two circles are visible to the speaker, but only one to the listener). Inhibitory capacity assessed by the elevator task with distraction (a subtest of the Test of Everyday Attention; Posner & Petersen, 1990) similarly predicted the use of referential expressions in younger (but not older) speakers (Long et al., 2018). By taking the Stroop effect to reflect a general inhibitory capacity, Crowther & Martin (2014) suggested that those with better inhibitory control deal more effectively with semantic interference in the semantic blocking task.

1.7 Types of interference and their resolution in syntactic selection

Despite the extra cognitive load associated with the arrangement of items into a meaningful and grammatically coherent whole, which may contribute to greater within-language competition, research into how neuro-typical speakers manage the online demands of monolingual utterance planning and execution is only beginning to emerge. Engelhardt, Nigg, , & Ferreira (2013) were the first to suggest a link between inhibition and sentence production. Using a latent variable approach, they found that inhibition accounted for one third of the variance in the production of utterance repairs. Those with reduced inhibitory control were more likely to select an incorrect syntactic structure (which in the majority of cases involved erroneous assignment of grammatical roles), and subsequently correct it on the fly. However, the correlation patterns revealed that it was primarily performance on the Stroop task and not that on other inhibitory control measures (self-reported impulsivity and stop-signal task scores) that was associated with the occurrence of repairs.

A significant correlation between Stroop-test assessed inhibition and the proportion of double-object dative structures produced by adult English speakers was more recently reported by Thothathiri, Evans, & Poudel (2017). The relationship was apparent only under "equipotent verb" conditions, but not when the speakers produced dative sentences featuring verbs with a bias toward a double-object (e.g., *Mike offered Carol the napkin*) or a prepositional-object (e.g., *Mike tossed the coin to Carol*) structure. Equipotent verbs occur equally often with double-object (e.g., *Mike gave Carol the book*) and prepositional-object (e.g., *Mike gave the book to Carol*) dative structures and hence are said to afford greater syntactic flexibility. The authors concluded that production of double-object datives in the context of equipotent verbs, when one can opt for a less cognitively taxing (as evidenced in shorter production times) structure of a *prepositional*-object dative requires additional resources such as inhibition, that will bias attention towards a less dominant representation and away from the more strongly activated default option.

At the time of writing, only two other studies have reported a relationship between inhibitory control and syntactic production. Veenstra, Antoniou, Katsos, & Kissine (2018) found that inhibition was a significant predictor of number agreement production in ten- to twelve-year-olds. Children who experienced greater interference in the inhibitory control tasks (the colour-shape switching and the fish flanker scores combined) had higher agreement error rates. In Nozari & Omaki (2018), susceptibility to interference explained one fifth of the variance in the production of agreement errors by adult speakers. Importantly, only the Go/No Go component loaded highly on the construct of inhibition, while the remaining inhibitory control scores (the fish flanker, picture Stroop and Simon tasks) made no significant contribution.

On the surface, there is thus some evidence that greater inhibitory control translates into more fluent and error-free utterance production. Where the findings appear to diverge, however, is in the type of inhibition that drives this relationship. In Engelhardt et al. (2013) and Thothathiri et al. (2017) greater accuracy in the Stroop task was linked to more fluent utterances, on the one hand, and to selection of less dominant (non-default) syntactic structures on the other. Given that the Stroop task is a non-syntactic inhibition measure but also, *de facto*, a word production task (Starreveld & La Heij, 2017) and that the association between Stroop performance and sentence production emerges only when syntactic interference is experimentally induced in the latter, it can be argued that incongruent colour naming and syntactic selection under increased competition demands are underpinned by a shared cognitive control mechanism, which extends beyond syntactic and non-syntactic domains, but whose operation is nonetheless restricted to the language domain.

The findings also appear to diverge on the extent to which various inhibitory control tasks can be considered as measures of a single construct. While in Veenstra et al. (2018), both the switch cost and the fish flanker effect loaded significantly on the factor of inhibition, in Nozari & Omaki (2018) only the Go/No Go component made a significant contribution, with the fish flanker, the picture Stroop and the Simon effects having no predicative capacity for number agreement problems.

1.8 The fate of rejected competitors – a look at the causal links between interference control and language production

Inferences about the role of inhibition in language production are based in great part on correlational evidence and are hence subject to alternative explanations. An experimental technique that can provide insight into whether inhibitory mechanisms are causally involved in the resolution of within-language interference is the negative priming (NP) paradigm.

Recent years have seen a renewed interest in the method, which is claimed to be the prevailing technique for the assessment of inhibitory processes and remains an important tool with which to investigate selection processes in cognitive psychology research (D’Angelo, Thomson, Tipper, & Milliken, 2016; Frings, Schneider, & Fox, 2015). It is based on the premise that target selection is a dual process, which operates on both attended and ignored information. Not only is the activation of the intended representations enhanced, but that of the irrelevant ones is also attenuated. So much so, that once inhibited, subsequent processing of these representations is visibly compromised – a phenomenon known as the negative priming effect. In a standard procedure, a to-be-attended stimulus (target) is presented with a to-be-ignored stimulus (distractor) on the *prime* trial; the same prime distractor reappears as the target on the subsequent *probe* trial. An increase in reaction time (RT) and often reduced accuracy are reported on probe trials in response to previously ignored, but now critical stimuli, relative to stimuli that did not serve as distractors on the preceding trials. These cognitive costs are accounted for by the need to overcome residual inhibition associated with the ignored item (but see Neill & Valdes, 1992 and Wood & Milliken, 1998).

Since the first publication by Tipper (1985), the technique has found application primarily in studies of visual selective attention (e.g., inhibition of return, IOR; Klein, 2000) and memory retrieval (e.g., Healey, Hasher, & Campbell, 2013; Marsh, Beaman, Hughes, & Jones, 2012). In addition to demonstrating identity negative priming (deteriorated processing of target stimuli that were previously displayed as distractors), the effect was extended to semantically related pairs of stimuli. Probe targets that shared the same semantic category as prime distractors (e.g., a picture of a *cat* as a prime distractor and that of a *dog* as a probe target) were processed more slowly than their unrelated counterparts (e.g., a picture of a *cat* as a prime distractor and that of a *trumpet* as a probe target) (Tipper, 1985; Tipper & Driver, 1988). Yet, since its first documentation (but only with the use of pictorial stimuli), the status of this “semantic” negative priming has remained elusive. Indeed, for each study in support of the effect (e.g., Fox, 1995, Exp. 3; Murray, 1995; Tipper, 1985, Exp. 3; Tipper & Driver, 1988; Yee, 1991), there appears to exist one that argues against it (Chiappe & Macleod, 1995; Dark, Johnston, Myles-Worsley, & Farah, 1985; Sullivan & Faust, 1993; Tipper & Driver, 1988; Yee, 1991, Exp.1; see Fox, 1995 for a review).

Despite the fact that the NP studies necessarily used verbal stimuli (instantiating the “mind in the mouth” problem; Bock, 1996), their findings served to answer questions directly relevant to attention, memory and motor control research. A group of studies that have employed the NP paradigm in the linguistic context did so mainly in the domain of language comprehension, and specifically to show how inhibitory processes may aid lexical ambiguity resolution. NP effects were observed for the unselected meaning of homographs (Nievas & Marí-Beffa, 2002; Simpson & Kang, 1994; Simpson & Kellas, 1989), homophones (Gernsbacher & Faust, 1991) and metaphors (Gernsbacher, Keysar, Robertson, & Werner, 2001; Rubio Fernandez, 2007). Namely, the meanings which were originally dispensed with but which were subsequently required on follow-up tasks elicited slower responses relative to baseline stimuli. These delays were interpreted as a result of active suppression of meaning-inconsistent information.

An analogous technique (without the use of external distractors) has been applied to production research. Increased error rates and delays in retrieving a probe target picture's name were observed when it was categorically related to the prime target name elicited by a definition (Vitkovitch et al., 2001; Wheeldon & Monsell, 1994), picture naming (Vitkovitch et al., 2001) and word naming (Tree & Hirsh, 2003). Based on these findings, preliminary conclusions have been made not only about the role of inhibitory processes in spoken word production, but also about its potential loci and the specific mechanisms through which inhibition may be implemented (e.g., lateral inhibition, self-inhibition).

By manipulating aspects of the negative priming paradigm or its analogous technique (variously referred to in the production literature as "inhibitory priming", "competitor priming", and "competitive priming") it is possible to make inferences about the role, types and the workings of inhibitory processes in language production.

1.9 Aims and organisation of the thesis

Despite a proliferation of research on the competitive nature of language production, the debate over whether selection of target words is hampered by co-activation of context-inappropriate representations continues. It appears that for every study in support of a competitive view of lexical selection, there exists one offering an alternative, non-competitive explanation. The first aim of the present work therefore was to synthesise evidence from studies utilising the picture-word interference paradigm (the prevailing method of investigating within-language interference) in order to address the question of whether competition, understood in its narrow sense, as a delay in production caused by co-activation of related but irrelevant representations, is an integral part of the language production process. Chapter 2 presents a systematic review study (**Study 1**) in which competitive and non-competitive accounts of lexical selection outlined in Chapter 1 are tested against the reviewed sets of PWI data.

With an increasing number of authors challenging the notion of inhibition as a single construct and in light of the systematic review findings that production delays may reflect mechanisms operating at distinct stages of the production process, the second aim of this research project was to examine the relative contributions of different forms of inhibitory control to single word production under increased competition demands. Chapter 3 describes an individual differences study (**Study 2**) in which performance on non-verbal inhibitory tasks tapping resolution of conflict at different levels of information processing is used to account for variation in object naming in the context of prepotent (when the competing candidates are context-inappropriate) and underdetermined (when the competing candidates fit with the context) competition.

Given that most everyday communication proceeds in sentences rather than isolated words, and that the extra cognitive load associated with the arrangement of lexical items into a meaningful and grammatically coherent whole creates additional scope for competition, the aim of **Study 3** was to investigate the link between different types of inhibitory control and multi-word utterance production. Chapter 4 describes an individual differences study that assesses the extent to which variability in the resolution of conflict arising at different stages of information processing has the potential to account for variability in syntactic processing under increased interference conditions.

The use of the negative priming paradigm (a method of investigating inhibitory processes) in the language production research has not been fully explored. The aim of **Study 4** was to investigate the extent to which inhibitory processes modulate accessibility of lexical items during object naming. Chapter 5 describes a negative priming study designed specifically to establish whether inhibition spreads down the pre-established (associative) pathways by analogy to spreading activation.

The thesis is organised in six chapters. Chapter 1 provides a theoretical background and the rationale for the conducted studies. Chapters 2 to 5 present the aims, methods, results, and the discussion of the findings of the four studies described in this thesis. Chapter 6 provides a general discussion of the results of the presented studies, with an evaluation of their limitations and suggestions for future research.

CHAPTER 2: A SYSTEMATIC REVIEW OF PICTURE-WORD INTERFERENCE STUDIES (STUDY 1)

2.1 Background, rationale and aims of Study 1

In the last forty years, the picture-word interference (PWI) paradigm has been the main experimental tool for investigating the competitive nature of word production. In the task, participants are asked to name the depicted object (e.g., horse) and ignore its accompanying distractor (typically a visually presented word). Responses are delayed and more error-prone when the distractor is categorically related (e.g., *mouse*) to the target than when it is unrelated (e.g., *table*). This decrement in performance is expressed as the picture-word interference effect and was originally attributed to co-activation of irrelevant representations (lemmas/lexemes) that hinder the selection of the target word (competition-based account of the PWI effect). However, an increasing number of observations of polarity reversals from interference to facilitation following various manipulations of the task parameters, has led to modifications of the original account and given rise to alternative, non-competitive hypotheses concerning the origins of the effects (see section 1.2.2).

To date, it is not entirely clear where in the process of recognising and naming a pictured object, accompanied by a distracting stimulus, interference (or facilitation) takes effect, or how such an effect comes about. The answers are hard to find because results are often conflicting, methodologies vary and the PWI literature is extensive. Several helpful reviews have been published to elucidate the origins of semantic context effects, and thus illuminate the cognitive processes involved in spoken word production, but these focus either on advancing (see Abdel Rahman & Melinger, 2019, for swinging lexical network hypothesis; see Mahon et al., 2007, for the response exclusion hypothesis) or challenging a particular account (e.g., see Mulatti & Coltheart, 2012 for a critique of the response exclusion hypothesis), or present a mere overview of selected methodologies, their respective findings and proposed interpretations (e.g., Spalek, Damian, & Bölte, 2013). No systematic review of PWI effects has been undertaken to date. Consequently, the current work synthesises evidence from studies which have employed the PWI paradigm to explore the “competitive” nature of language production. Specifically, it aims to identify the loci of semantic context effects and the mechanisms from which these effects emerge, in order to address the question of whether spoken word production can be seen as a competitive process. For the purpose of this review, the word "competitive" is used in its technical sense, i.e., as a delay in production caused by the activation of target-related, but context-irrelevant lexical representations. Individual accounts of the PWI effect and lexical selection as outlined in Section 1.2.2 are examined against the reviewed sets of data to determine whether the effect is genuinely due to lexical competition or resides outside the language system, being an epiphenomenon of task-specific processes.

2.2 Scope and organisation

Due to the extent of the PWI research, the selection criteria had to be narrowed considerably. Only chronometric studies with unimpaired adult native speakers were included in the review. Neuroscientific, neuropsychological, translation, and bilingual studies, as well as studies that used target stimuli other than pictures of objects were excluded. Detailed inclusion and exclusion criteria are provided in the *Methodology* section.

The review has been organised around the main sites of manipulation in the PWI task: the distractor, the task and the target-distractor relation (see Figure 2). Although the time course of the PWI effect, or the temporal relation between target and distractor, has also been systematically varied and analysed in previous studies, for space reasons, and due to extensive coverage elsewhere (e.g., Glaser & Düngelhoff, 1984; Schriefers et al., 1990), this was not included in the present review. Stimulus onset asynchrony (SOA) of 0 milliseconds (i.e., when target and distractor are presented simultaneously) serves as a default, but results are reported for other SOAs when relevant to the research question. The review presents findings of studies in which a single variable (pure effect, e.g., distractor frequency) as well as pairs or even triplets of phenomena (joint effect, e.g., distractor frequency and semantic relatedness) were concurrently manipulated.

2.3 Terminology and notation

A final note concerns terminology and notational conventions used in the current review. The word *target* refers to a stimulus to be named. The word *distractor* denotes a stimulus to be ignored. Occasionally, the word *distractor* is substituted by the more descriptive term "interfering stimulus", which is found in the literature along with other alternative terms, such as "context word/picture", “context object” and “context stimulus”. Target-distractor relation or relatedness between targets and distractors is understood in terms of similarity between the two types of stimuli with regards to a specific feature, for example, phonological overlap. The term *PWI effect* is used interchangeably with other terms mentioned in the introduction. This is dictated both by convention and by the lack of a more precise term. For although “context effect” seems to fit well in the context of PWI findings, it is also applied to other picture naming paradigms, such as semantic blocking and continuous naming tasks. The effect is expressed as a difference between the mean reaction time (RT) of an *unrelated* condition and the mean RT of the *related* condition; if the effect is positive (+) the distractor slows down naming and is said to produce *interference* or *an inhibitory effect*; when the effect is negative (-), the distractor speeds up naming, and thus results in *facilitation*. Stimulus onset asynchrony (SOA) refers to the point in time at which the distractor is presented relative to the target. If SOA is negative, for example, an SOA of -150 milliseconds, distractor presentation precedes the target onset by 150 milliseconds. If SOA is positive, for example, an SOA of +150 milliseconds, the distractor is displayed 150 milliseconds after the target onset; when SOA equals 0 milliseconds, target and distractor are presented simultaneously.

Concepts are given in upper case, and distractor words in lower case italics. Target answers appear in inverted commas.

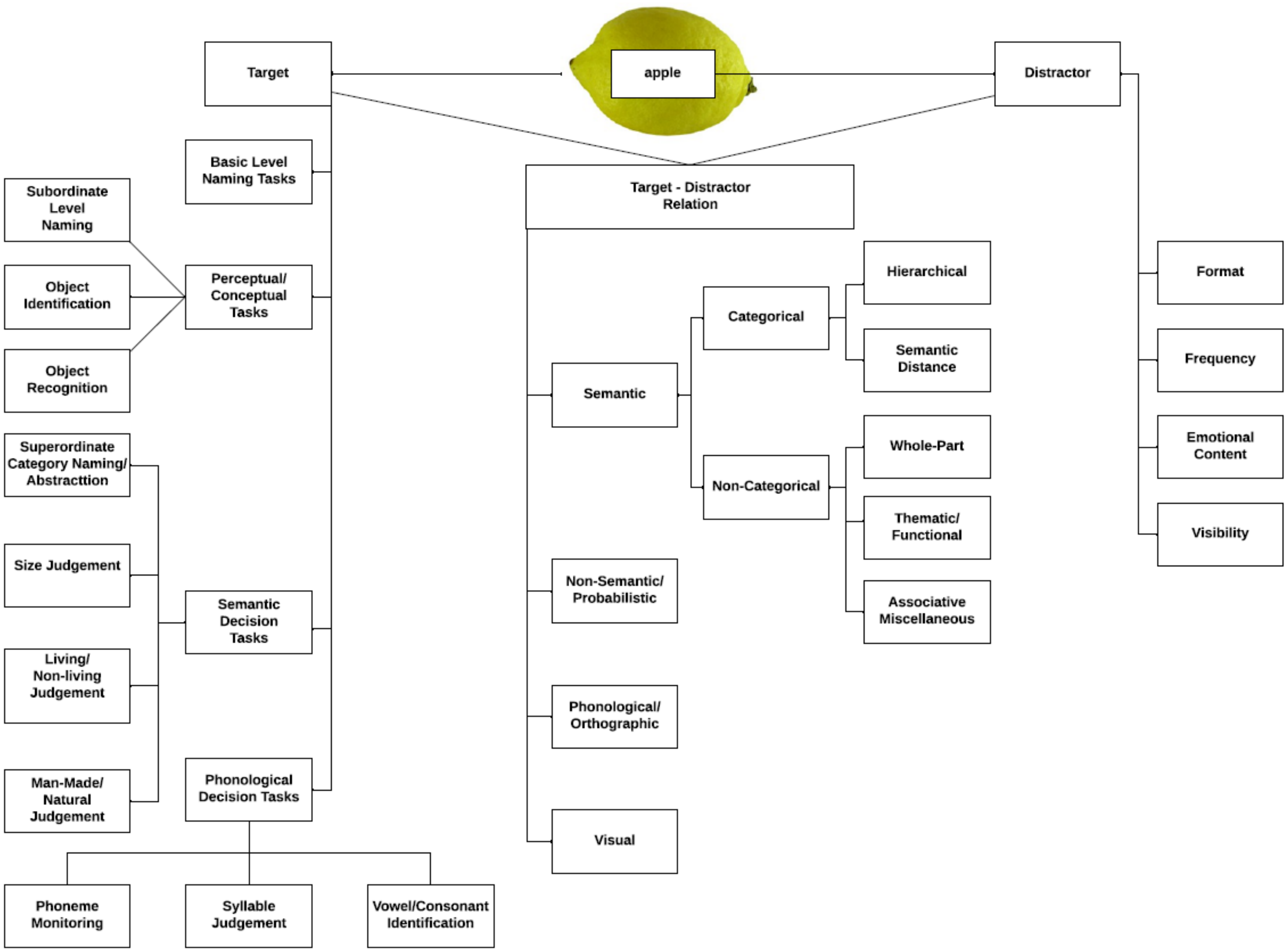


Figure 2. Main sites of manipulation in the picture word interference task

2.4 Methodology

2.4.1 Search details

Three electronic databases (PsychINFO, PubMed and Web of Science) were searched using the following combinations of keywords: "picture word interference" OR ("semantic interference" OR "context effect*" OR "semantic category" AND "picture naming") AND compet* NOT bilingual*. Additional records were identified by cross-checking the reference lists of core PWI articles to ensure all relevant papers were considered for review. The search covered the period up to July 2019. In total, 229 references were located by PsycINFO after the following filters were applied: peer-reviewed journal articles, adulthood (18 years and older), published in English, experimental studies. Web of Science generated 345 references, using the following filters: psychology experimental, articles, English, of which 184 were novel to PsycINFO. The search with PubMED generated 70 references (with English language as the sole filter), of which 22 were new. Nine additional articles were identified through manual search. For the detailed systematic review procedure, see the flowchart in Figure 3.

2.4.2 Study selection

Two raters (MK and PD) independently assessed the eligibility of the identified titles and abstracts for review. Full-text articles were retrieved when either reviewer decided that the article was potentially eligible. Studies were considered for review if they fulfilled the following inclusion criteria: (a) the studies presented original research written in English (i.e., reviews, book chapters, conference proceedings, commentaries were not accepted); (b) the participants were adult native speakers with no history of cognitive or neurological impairment (studies conducted in idiosyncratic languages, such as Chinese or sign language, were excluded); (c) the studies utilised the PWI paradigm to investigate competitive nature of single word production (i.e., studies using other tasks, such as the Stroop task or word reading, as well as studies investigating syntactic or morphological processing, such as grammatical gender, number, verb, modifier processing, were excluded) (d) studies that were based on behavioural data (i.e., studies using neuroscientific methods, such as electroencephalography, neuroimaging, transcranial direct current stimulation, etc., were excluded); (e) the studies used an experimental design with picture naming latency as the main dependent variable (i.e., studies based exclusively on correlational, distributional, or error analyses, or those incorporating computational models, were excluded). Any discrepancies between the raters were resolved through discussion and consensus.

Sixty articles met these criteria with a total of one hundred and seventeen studies. Note that because each selected article presents (often contradictory) findings from across a series of experiments, for practical reasons, each experiment has been treated as an independent study. The number of selected articles therefore does not match the number of reported studies.

2.4.3 Data extraction

The following data were extracted from the accepted articles: language in which the study was administered, number of participants, number of items, the task and the target answer, SOA, the findings, and the statistics reported.

2.4.4 Risk of bias assessment

Risk of bias in the included studies was assessed following the guidelines by the Cochrane Collaboration (Higgins and Green, 2011). Six domains were evaluated: sequence generation and allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome (data attrition bias), reporting bias (selective reporting) and other sources of bias (other bias). Since each domain addresses distinct issues which may be difficult to rate unambiguously, the risk of bias assessment was performed for individual entries within each domain. Furthermore, due to the specificity of psycholinguistic research, three separate entries were added to "other sources of bias". These were selective reporting of demographic information, verification of response accuracy and timing, and matching of item sets across experimental conditions. The risk of bias assessment was conducted by five independent raters. The first (MK) rated all the included studies. The remaining four raters rated one quarter of the included studies each. A judgement of low, high or unclear risk was made for each entry. Discrepancies in the ratings were resolved by discussion.

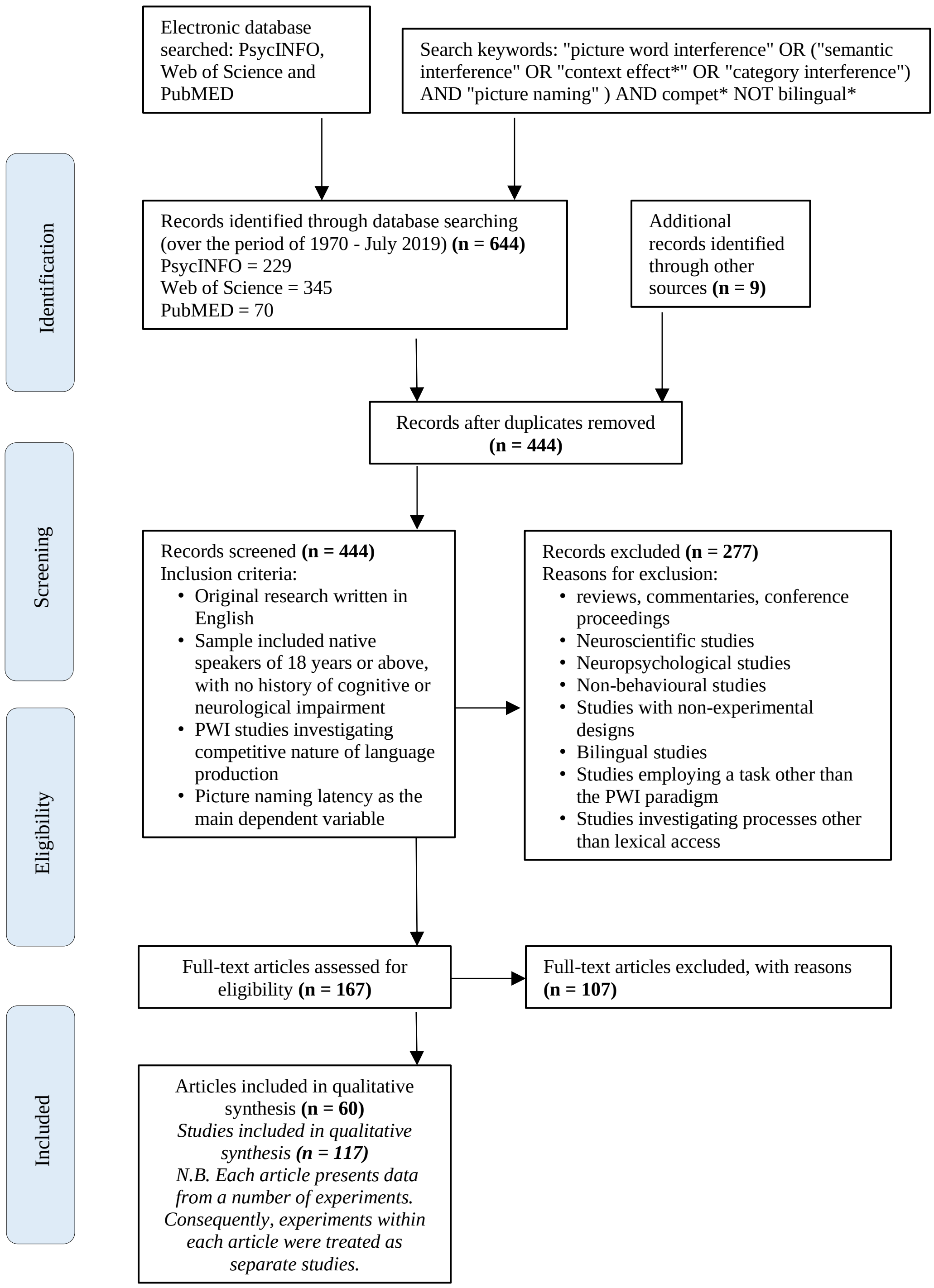


Figure 3. Flowchart of the systematic review procedure.

2.5 Results and discussion

2.5.1 SITE OF MANIPULATION: DISTRACTOR

2.5.1.1 Distractor format

Of the 18% (n = 21) studies which manipulated distractor format, 16 (76%), used pictures or photographs as distractors. These studies are hereafter referred to as the picture-picture interference (PPI) studies (see results in Table 1). Four (19%) studies utilised environmental sounds (Mädebach, Wöhner, Kieseler, & Jescheniak, 2017; Experiments 1, 2, 3, and 4), and one (5%) pseudo-words as distractors (Dhooge & Hartsuiker, 2012; Experiment 1). The main rationale for using pictures and environmental sounds rather than words as distractor stimuli is to challenge one of the REH's assumptions; namely, that distractor words access the articulatory buffer before a target picture's name is retrieved. It is reasonable to assume that if interference is obtained with categorically related distractors that are *non-verbal*, and therefore have *no* privileged access to the response buffer, the finding could be used against the REH hypothesis.

Only one (4.7%) study (La Heij, Heikoop, Akerboom, & Bloem, 2003, Experiment 2) reported facilitated picture naming in the presence of categorically related distractor pictures, a finding consistent with the REH. Besides being an isolated finding, however, its generality has been called into question because categorical relatedness of the stimuli was confounded with associative relations. That associative (non-categorical) relations can reverse the polarity of the effect, leading to facilitation rather than interference, has been well documented using both the picture-word and picture-picture interference paradigm (e.g., Bölte, Böhl, Dobel, & Zwitserlood, 2015, Experiment 1; Costa et al., 2005; Geng, Kirchgessner, & Schnur, 2013; Experiment 1; Mahon et al., 2007). Moreover, although La Heij et al. appeared to have resolved the issue of target uncertainty (confusability about which picture to name) by reducing the duration of distractor presentation to 50 milliseconds while keeping target presentation duration at 300 milliseconds, the very brief distractor exposure could have allowed for only a limited amount of distractor processing. If the distractor was indeed conceptually encoded, but its lexical representation was not sufficiently activated, the procedure could have well led to quicker target identification (through semantic priming), and thereby faster naming responses, an idea consistent both with the REH and SLNH.

In five (23%) studies (Bölte et al., 2015; Experiments 1 and 2; Damian & Bowers, 2003; Geng et al., 2013; Experiment 2; Navarrete & Costa, 2005; Experiment 1B) distractor pictures belonging to the same semantic category as target pictures showed no facilitation, but neither did they reliably interfere with picture naming. In addition, null results were reported in two (9%) studies (Mädebach et al., 2017; Experiment 4; Matushanskaya et al., 2016; Experiment 2) under specific task conditions: (1) when distractors were not included in the response set and (2) when their position or sequential order was highly predictable. The null results invite two possible interpretations. One, distractor pictures were effectively blocked at the outset, for example, by a perceptual reactive blocking mechanism (Roelofs, 2003), leaving no room for the processing of the interfering stimuli. Two, the null result reflects a trade-off between facilitation at the conceptual level (i.e., the distractor picture precipitates identification of the target concept through the spread of activation within the semantic network) and interference at the lexical level (i.e., the distractor's name enters into competition with the target's name, slowing down naming). That distractor pictures are conceptually encoded is reflected in the facilitation effects obtained both in semantic decision tasks and in studies employing associatively related stimuli. For example, classification of target pictures as either 'man-made' or 'natural' was quicker when they were accompanied by categorically related distractor pictures (e.g., APPLE-BANANA) than when they were presented with unrelated distractors (e.g., APPLE-SHIRT) (Damian & Bowers, 2003, but see the point in *Semantic decision tasks* section, 2.5.3.3 on a potential confound of response congruency which may have equally contributed to facilitation). Similarly, distractor objects that were associatively related to target pictures (i.e., loosely belong to the same semantic field as targets, e.g., SHOPPING BASKET-BARCODE) sped up naming compared to their unrelated controls (Bölte et al., 2015; Experiment 1 and 3). The evidence that distractor pictures are also lexically encoded is derived from studies in which facilitation was observed for distractor pictures that were morpho-phonologically related to targets (Bölte et al., 2015; Experiments 2 and 3). Without accessing the distractors' lexical codes, morpho-phonological facilitation would not have been possible because phonological processing depends on lexicalisation. The reason why no interference was obtained in the reviewed PPI studies despite evidence of lexical processing of distractors is that lexical activation in the PPI paradigm proceeds indirectly through conceptual encoding and may therefore be too weak to overshadow facilitation at the conceptual level. This idea is consistent with the SLNH and lexical selection by competition with a competition threshold.

In 57% of studies with distractor format manipulation (n = 12), categorically related items were found to interfere with picture naming (Aristei, Zwitserlood, & Rahman, 2012; Dean, Bub, & Masson, 2001; Glaser & Glaser, 1989; Experiment 6; Humphreys, Lloyd-Jones, & Fias, 1995; Experiments 1 and 4B; Jescheniak et al., 2014; La Heij et al., 2003; Experiment 1; Mädebach et al., 2017; Experiments 1, 2 and 3; Matushanskaya et al., 2016; Experiment 1). What these studies appear to have in common is that their experimental conditions allowed for enhanced activation of distractors at the lexical level. In other words, once the distractor's lexical node was adequately strengthened (possibly exceeding an activation threshold), the chances of it interfering with target naming increased. There are several ways in which to boost the lexical activation of non-verbal distractor stimuli. One is to include them in the response set (i.e., use them as targets). Indeed, studies in which the same stimuli routinely served as both targets and distractors (e.g., Dean et al., 2001; Experiment 1; Glaser & Glaser, 1989; Experiment 6; Humphreys et al., 1995; Experiment 1) or in which the response set membership was intentionally manipulated (e.g., Mädebach et al., 2017; Experiment 4), consistently reported interference. Naming of distractors when these appeared as targets in the task seemed to have primed their lexicalisation even when they had to be ignored. Inclusion of multiple exemplars from the same semantic category as experimental stimuli, using small item sets and repeated distractor naming (e.g., Glaser & Glaser, 1989; Experiment 6) can equally contribute to spontaneous activation of the distractor's name. Another factor that may inadvertently boost lexical activation of interfering stimuli is target uncertainty. In situations in which the signalling of the target is ambiguous, for example, the temporal succession of targets and distractors is so rapid that it makes target selection confusable for the speaker, lexical access may be initiated for all pictured concepts. Similarly, when task difficulty is high and cue onset prolonged (e.g., Humphreys et al., 1995), the speaker may strategically prepare verbal responses for both stimuli in advance of cue presentation. The speaker may also involuntarily lexicalise a distractor's concept when an expectation regarding either its spatial position (Jescheniak et al., 2014) or temporal order (Matushanskaya et al., 2016;

Experiment 1) is first induced but then violated (but note the temporal head start given to distractor pictures in both studies, with SOAs of -67 ms and -200 ms, which may equally allow for an alternative, REH-compatible interpretation). Finally, overtly naming both targets and distractors, which was made possible when novel compound nouns were produced to refer to the displayed objects in a study by Aristei et al. (2012) ensured distractors got a fair share of lexical input. To conclude, interference can be induced by categorically related *non-verbal* distractor stimuli under experimental conditions that promote their lexicalisation. These findings support the SLNH and lexical selection by competition with a competition threshold suggesting that the interference effect can be traced back to the lexical processing stage. One cannot rule out the possibility, however that the delay occurs partly or exclusively at a pre-lexical stage, when the concept activated by the distractor picture interferes with the recognition, identification and/or the process of conceptual-lexical mapping of the target picture, although the observation that the interference effect is not modulated by structural similarity between targets and distractors (Humphreys et al., 1995; Experiment 1) would argue against such an explanation.

The only study that used pseudo-words as distractors (Dhooge & Hartsuiker, 2012; Experiment 1) reported prolonged naming latencies in the context of unrelated distractor words (e.g., ASHTRAY-*flower*) relative to unrelated pseudo-words (e.g., ASHTRAY-*cromth*). Observation of interference in the absence of semantic relatedness between targets and distractors presents a challenge to the competitive view of lexical selection because it is unclear why *flower* should be a stronger competitor than *crompth* (neither is likely to be activated by ASHTRAY). The REH offers a plausible explanation of the results on the condition that pseudo-words reach the articulatory buffer before target picture names. If this is the case, they should be dismissed more quickly than real unrelated words (e.g., *flower*) because they do not fulfil the lexicality criterion (i.e., they are not legitimate words given the task instructions). This is in line with the interpretation proposed by Dhooge & Hartsuiker (2012), according to which the verbal-self monitor, being more sensitive to illegitimate words, intercepts and discards these more quickly than real words. Greater interference for legitimate words relative to pseudo-words could also be given an alternative explanation which places the locus of the effect at conceptual encoding (i.e., legitimate words supply semantic information which may interact with information about the target picture, unlike pseudo-words, which do not evoke any meaning). Finally, following the logic that high-frequency words (i.e., by virtue of being real, real words are more frequent and familiar than non-existent words) should have higher activation levels, contributing to greater interference, than low-frequency words (i.e., pseudo-words), a competitive account would also be well-founded. This is, however, not the case as discussed in the next section.

Interim summary

To sum up, there is no shortage of findings demonstrating semantic interference with categorically related *non-verbal* distractor stimuli. By contrast, facilitation with such stimuli appears to be a rare, and so far non-replicable observation (reported only in one study). Such a pattern of results supports competitive models of lexical selection and challenges the response exclusion hypothesis. The latter predicts facilitatory effects unless the articulatory buffer is blocked by a phonologically well-formed distractor response. Non-verbal distractors do not have the same articulatory advantage as words and so are unlikely to be processed ahead of target pictures. The null results are in line with the SLNH, which assumes facilitation at the level of conceptual encoding (the distractor concept primes the target concept) and interference at the level of lexical processing. If the distractor receives an additional lexical boost, the net result is inhibitory. Picture-induced interference under experimental conditions that promote lexical encoding of distractors is also in accordance with lexical selection by competition with a competition threshold. The interference effect should not be unambiguously attributed to competition at the lexical level, however because pre-lexical processing such as object recognition and conceptual encoding, especially in studies that did not control for visual similarity between the stimuli, may also be hindered by structural and/or conceptual information activated by non-verbal distractors. Given the facilitatory finding of pseudo-word distractors in the absence of semantic relatedness, the notion of a post-lexical criterion checking mechanism should not be completely abandoned.

Table 1. Distractor format manipulation

Authors (year); **study,** [language], *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target [type] – distractor [type, modality]	Finding	target [type] – distractor [type, modality]	Statistics
Geng et al., (2013); **Exp 2** [English], *PPI paradigm*	45	28	Name the green picture ("banana")	SOA = 0 ms	BANANA [green drawing] - STRAWBERRY [categorically related, red drawing]	> [2 ms]$^{ns/ns}$	BANANA [green drawing] - NEWSPAPER [unrelated, red drawing]	*ts* < 1
Bölte et al., (2015); **Exp 1** [German], *PPI paradigm with two distractors and longer cue onset*	38	15	Name the picture cued by an arrow ("lawn chair")	SOA = 0 ms; cue onset = 600 ms	LAWN CHAIR [photo] - OFFICE DESK [categorically related; photo] - SHOE RACK [categorically related, photo]	> [18 ms]^{ns}	LAWN CHAIR [photo] - TOOTH BRUSH [unrelated, photo] - BILLARD BALL [unrelated, photo]	*t*(37) = 1.045, *p* = .303
Bölte et al. (2015); **Exp 2** [German], *PPI paradigm with two distractors and shorter cue onset*	40	15	Name the picture cued by an arrow ("lawn chair")	SOA = 0 ms; cue onset = 200 ms	LAWN CHAIR [photo] - OFFICE DESK [categorically related; photo] - SHOE RACK [categorically related, photo]	> [4 ms]^{ns}	LAWN CHAIR [photo] - TOOTH BRUSH [unrelated, photo] - BILLARD BALL [unrelated, photo]	*t*(39) = 0.568, *p* = .287
Bölte et al. (2015); **Exp 3** [German] , *PPI paradigm with two distractors*	12	15	Name the picture that always appears second ("lawn chair")	SOA = -200 ms	LAWN CHAIR [photo] - OFFICE DESK [categorically related; photo] - SHOE RACK [categorically related, photo]	> [28 ms]*	LAWN CHAIR [photo] - TOOTH BRUSH [unrelated, photo] - BILLARD BALL [unrelated, photo]	*t*(19) = –2.535, *p* = .010; one-tailed t-test
Navarrete & Costa (2005); **Exp 1B** [Spanish], *PPI paradigm*	18	24	Name the green picture ("shirt")	SOA = 0 ms	SHIRT [green drawing] - HAT [categorically related; red drawing]	> [1 ms]^{ns}	SHIRT [green drawing] - PLANE [unrelated; red drawing]	*ts* < 1
Damian & Bowers (2003) [Dutch], *PPI paradigm*	28	18	Name the bigger picture ("apple")	SOA = -200 ms	APPLE [drawing] - BANANA [categorically related; embedded drawing]	< [2 ms]$^{ns/ns}$	APPLE [drawing] - SHIRT [unrelated; embedded drawing]	*ts* <= 1.1
				SOA = -100 ms	APPLE [drawing] - BANANA [categorically related; embedded drawing]	> [4 ms]$^{ns/ns}$	APPLE [drawing] - SHIRT unrelated; embedded drawing]	*ts* <= 1.1
				SOA = 0 ms	APPLE [drawing] - BANANA [categorically related; embedded drawing]	> [3 ms]$^{ns/ns}$	APPLE [drawing] - SHIRT [unrelated; embedded drawing]	*ts* <= 1.1
				SOA = +100 ms	APPLE [drawing] - BANANA [categorically related; embedded drawing]	< [2 ms]$^{ns/ns}$	APPLE [drawing] - SHIRT [unrelated; embedded drawing]	*ts* <= 1.1
La Heij, Heikoop, Akerboom, & Bloem (2003); **Exp 1** [Dutch], *replication of Glaser*	24	9	Name the picture that appears first/second [depending on SOA] ("table")	averaged SOAs [-300 ms, -50 ms, +50 ms, +100 ms]	TABLE [drawing] - BED [categorically related; drawing]	> [13 ms]$^{*/*}$	TABLE [drawing] - EYE [unrelated; drawing]	*F1*(1,23) = 4.3, *p* < .05; *F2*(1,8) = 5.65, *p* < .05.

& Glaser (1989), PPI paradigm								
La Heij, Heikoop, Akerboom, & Bloem (2003); **Exp 2** [Dutch] , *PPI paradigm*	24	40	Name the picture that appears first/second [depending on SOA] ("banana")	averaged SOAs [-300 ms, -50 ms, +50 ms, +100 ms]	BANANA [drawing] - APPLE [categorically related; drawing]	< [17 ms]*/*	BANANA [drawing] - GLASS [unrelated; drawing]	*F1*(1,23) = 27.3, *p* < .001; *F2*(1,39) = 9.4, *p* < .005.
Glaser & Glaser (1989); **Exp 6** [German], *PPI paradigm*	20	9	Name the picture that appears first/second [depending on SOA] ("cat")	averaged SOAs [from -300 ms to +300 ms]	CAT [drawing] - RABBIT[categorically related, drawing]	> [20 ms]*	CAT [drawing] - BED [unrelated, drawing]	SOA x semantic relatedness: *F*(27, 513) = 7.7, *MS* = 9,317, *p* < .05; significant for SOAs from -75 ms to +100 ms; *p* < .05;
Humphreys et al. (1995); **Exp 1** [English], *PPI paradigm; semantic relatedness as a between-subject variable*	41	49	Name the picture cued by the colour word ("tiger")	SOA = 0 ms; post-cue onset: 500 ms; RTs averaged over structurally similar and dissimilar pairs	TIGER [green drawing] - HORSE [categorically related, red drawing]	> [98 ms]*/*	TIGER [green drawing] - LEMON [unrelated, red drawing]	Semantic relatedness: *F1*(1, 40) = 4.08, *p* = .05, *MSE* = 168,507; *F2*(1, 48) = 17.90, *p* < .0001, *MS*E = 48,690; semantic relatedness x post-cue onset x structural similarity, *ps* > .05;
				SOA = 0 ms; post-cue onset: 2000 ms; RTs averaged over structurally similar and dissimilar pairs	TIGER [green drawing] - HORSE [categorically related, red drawing]	> [71 ms]*/*	TIGER [green drawing] - LEMON [unrelated, red drawing]	Semantic relatedness: *F1*(1, 40) = 4.08, *p* = .05, *MSE* = 168,507; *F*2(1, 48) = 17.90, *p* < .0001, *MSE* = 48,690; semantic relatedness x post-cue onset x structural similarity, *ps* > .05;
Humphreys et al. (1995); **Exp 4B** [English]; *PPI paradigm semantic relatedness as a within-subjects variable*	12	48	Name the picture cued by the location word (“chair”)	SOA = 0 ms; post-cue onset: 500 ms	CHAIR [drawing] - BED [categorically related, drawing]	> [57 ms]*/ns	CHAIR [drawing] - APPLE [unrelated, drawing]	*F1*(1, 11) = 11.37, *p* < .01; *F2*(1, 47) = 3.30, *p* = .07
Dean et al. (2001); **Exp 1** [English], *PPI paradigm*	16	28	Name the picture cued by the colour word ("guitar")	SOA = 0 ms; post-cue onset: 500 ms	GUITAR [green drawing] - VIOLIN [categorically related, red drawing]	> [100 ms]*	GUITAR [green drawing] - CAMEL [unrelated, red drawing]	*F*(1,15) = 10.66, *p* < .05

Aristei et al. (2012) [German], *PPI paradigm with novel compound naming*	24	160	Produce a compound noun using the names of both pictures ("applepeach")	SOA = 0 ms	APPLE $_{\text{[drawing]}}$ - PEACH $_{\text{[categorically related, drawing]}}$	> [26 ms]$^{*/*}$	APPLE $_{\text{[drawing]}}$ - HARP $_{\text{[unrelated, drawing]}}$	*t1*(23) = 2.7, p = .01; *t2*(159) = 2.9, p = .004
Jescheniak et al. (2014) [German], *PPI paradigm with valid and invalid cues*	24	20	Name the blue picture ("monkey")	SOA = 0 ms	MONKEY $_{\text{[blue drawing]}}$ - PIG $_{\text{[categorically related, black drawing]}}$	> [19 ms]$^{*/*}$	MONKEY $_{\text{[blue drawing]}}$ - AIRPLANE $_{\text{[unrelated, black drawing]}}$	Invalid cues, *F1*(1, 23) = 15.91, p < .001, η_p^2 = .41; *F2*(1, 39) = 7.69, p < .01, η_p^2 = .17
Matushanskaya et al. (2016); **Exp 1** [German], *PPI paradigm with induction of expectations based on SOAs frequencies*	24	20	Name the blue picture ("monkey")	SOA = -67 ms (distractor first, most frequent SOA)	MONKEY $_{\text{[blue drawing]}}$ - PIG $_{\text{[categorically related, black drawing]}}$	> [16 ms]$^{*/*}$	MONKEY $_{\text{[blue drawing]}}$ - AIRPLANE $_{\text{[unrelated, black drawing]}}$	*F1*(1, 23) = 16.65, p < .001, η_p^2 = .42, *F2*(2, 78) = 9.59, p = .004, η_p^2 = .20
				SOA = 0 ms	MONKEY $_{\text{[blue drawing]}}$ - PIG $_{\text{[categorically related, black drawing]}}$	> [7 ms]$^{*/ns}$	MONKEY $_{\text{[blue drawing]}}$ - AIRPLANE $_{\text{[unrelated, black drawing]}}$	*F1*(1, 23) = 4.33, p = .049, η_p^2 = .16, *F2*(2, 78) = 1.96, p = .169, η_p^2 = .05.
				SOA = + 40 ms (target first)	MONKEY $_{\text{[blue drawing]}}$ - PIG $_{\text{[categorically related, black drawing]}}$	< [1 ms]$^{ns/ns}$	MONKEY $_{\text{[blue drawing]}}$ - AIRPLANE $_{\text{[unrelated, black drawing]}}$	*Fs* < 1
Matushanskaya et al. (2016); **Exp 2** [German], *PPI paradigm with no induction of expectations*	24	20	Name the blue picture ("monkey")	averaged SOAs [-67 ms, 0 ms, +40 ms]	MONKEY $_{\text{[blue drawing]}}$ - PIG $_{\text{[categorically related, black drawing]}}$	< [3 ms]$^{ns/ns}$	MONKEY $_{\text{[blue drawing]}}$ - AIRPLANE $_{\text{[unrelated, black drawing]}}$	Relatedness: *F1*(1, 23) = 1.04, p = .319, η_p^2 = .04, *F2* < 1; SOA: *Fs* < 1; relatedness x SOA: *Fs* < 1
Mädebach et al. (2017); **Exp 1** [German], *environmental sounds*	24	32	Name the picture ("horse")	SOA = -800 ms	HORSE $_{\text{[drawing]}}$ - barking $_{\text{[categorically related, sound]}}$	> [17 ms]*	HORSE $_{\text{[drawing]}}$ - drumming $_{\text{[unrelated, sound]}}$	β = 0.025; *SE* = 0.007; *t*(2762.6) = 3.40; p < .001
				SOA = -500 ms	HORSE $_{\text{[drawing]}}$ - barking $_{\text{[categorically related, sound]}}$	> [12 ms]^{ns}	HORSE $_{\text{[drawing]}}$ - drumming $_{\text{[unrelated, sound]}}$	β = 0.013; *SE* = 0.009 ; *t*(46.22) = 1.50, p = .140
				SOA = -200 ms	HORSE $_{\text{[drawing]}}$ - barking $_{\text{[categorically related, sound]}}$	> [28 ms]*	HORSE $_{\text{[drawing]}}$ - drumming $_{\text{[unrelated, sound]}}$	β = 0.037; *SE* = 0.011; t(35.19) = 3.43; p = .002
Mädebach et al. (2017); **Exp 2** [German], *environmental sounds*	24	32	Name the picture ("horse")	SOA = -200 ms	HORSE $_{\text{[drawing]}}$ - barking $_{\text{[categorically related, sound]}}$	> [28 ms]*	HORSE $_{\text{[drawing]}}$ - drumming $_{\text{[unrelated, sound]}}$	β = 0.035; *SE* = 0.010; *t*(36.56) = 3.54; p = .001

				SOA = -100 ms	HORSE $_{[drawing]}$ - barking [categorically related, sound]	> [20 ms]*	HORSE $_{[drawing]}$ - drumming [unrelated, sound]	*β* = 0.027; *SE* = 0.010; t(25.42) = 2.86; p = .008
				SOA = 0 ms	HORSE $_{[drawing]}$ - barking [categorically related, sound]	> [8 ms]^{ns}	HORSE $_{[drawing]}$ - drumming [unrelated, sound]	*β* = 0.011; *SE* = 0.008; *t*(33.29) = 1.30; *p* = .203
Mädebach et al. (2017); **Exp 3** [German], *environmental sounds* with *no familiarisation*	24	32	Name the picture ("horse")	SOA = -200 ms	HORSE $_{[drawing]}$ - barking [categorically related, sound]	> [15 ms]^{ns}	HORSE $_{[drawing]}$ - drumming [unrelated, sound]	Across all 3 blocks: *β* = 0.021, *SE* = 0.008, *t(*39) = 2.72, *p* = .010;
				SOA = -200 ms	HORSE $_{[drawing]}$ - barking [categorically related, sound]	> [19 ms]*	HORSE $_{[drawing]}$ - drumming [unrelated, sound]	First block: *β* = 0.026, SE = 0.010, *t*(32.06) = 2.50, *p* = .018
Mädebach et al. (2017); **Exp 4** [German], *environmental sound distractors not in the response set*	24	32	Name the picture ("horse")	SOA = -200 ms	HORSE $_{[drawing]}$ - barking [categorically related, sound]	> [5 ms]^{ns}	HORSE $_{[drawing]}$ - drumming [unrelated, sound]	Across 2 blocks: semantic relatedness: $X_2(1)$ = 0.22, *p* = .641, semantic relatedness x block: $X_2(1)$ = 0.09, *p* = .759.
Dhooge & Hartsuiker (2012); **Exp 1** [Dutch], *unrelated words vs pseudo-words*	20	50	Name the picture ("ashtray")	SOA = 0 ms	ASHTRAY $_{[drawing]}$ - *flower* [unelated word]	> [22 ms]*	ASHTRAY $_{[drawing]}$ - *cromth* [unelated pseudo-word]	*β* = 21.83; *SE* = 4.80; *t* = 4.55; *p* < .001

2.5.1.2 Distractor frequency

Lexical frequency was manipulated by 13 (11%) of the reviewed studies. While unrelated high-frequency distractor words (e.g., APPLE-*chair*) were previously shown to induce greater interference than their low-frequency counterparts (e.g., APPLE-*stool*; Klein, 1964), the reverse pattern, namely slower picture naming for unrelated low-frequency distractors, has since been replicated by six independent laboratories in 12 (92.3%) separate studies (Catling, Dent, Johnston, & Balding, 2010; Dhooge & Hartsuiker, 2010; Geng, Schnur, & Janssen, 2014; Hutson, Damian, & Spalek, 2013; Miozzo & Caramazza, 2003; Starreveld, La Heij, & Verdonschot, 2013). See Table 2 for results of distractor frequency manipulation.

Prolonged picture naming times observed in the PWI task with infrequently encountered distractor words, a phenomenon known in the literature as the *distractor frequency effect*, presents a challenge to competitive models of spoken word production because high-frequency words, by virtue of having higher activation levels (lower activation thresholds) should be stronger (or at the very least, not weaker) competitors than low-frequency words. The effect is, however compatible with the post-lexical REH account, which assumes that high-frequency words enter the articulatory buffer sooner and so can be "expelled" from it more quickly than low-frequency words (e.g., Miozzo & Caramazza, 2003; Finkbeiner & Caramazza, 2006; Mahon et al, 2007). An alternative account that can accommodate the counterintuitive finding of slower picture naming in the presence of unrelated low-frequency distractors entails a perceptual reactive blocking mechanism whose role is to discriminate between relevant and irrelevant information at the input level (Roelofs, 2003). As high-frequency words are recognised faster (e.g., McClelland & Rumelhart, 1981), the reactive blocking mechanism is engaged sooner, allowing for an earlier decision as to which stimulus to name, and which to ignore. It is also possible that the distractor frequency effect arises due to greater attentional capture by low-frequency distractors. Their infrequent use and thereby lower concept familiarity may make them "pop out", diverting resources away from the primary task of target picture naming. In the visual domain, low frequency distractors have indeed been shown to interfere more with visual search than their more frequent controls (e.g., Müller, Geyer, Zehetleitner, & Krummenacher, 2009). Relatedly, concept retrieval for low-frequency words can be proportionally slower because their semantic nodes are thought to be more widely dispersed compared to more focused, densely connected nodes of high-frequency words (e.g., Steyvers & Tenenbaum, 2005). Semantic information from low-frequency distractor words may therefore be extracted later than that supplied by high-frequency words, delaying target object identification and consequently slowing down naming.

Because the distractor frequency effect has several alternative explanations, determining the conditions under which it is no longer detectable would make a more informative approach. Such an approach has indeed been taken by a number of authors. Five studies found no traces of interference when distractor frequency was manipulated in combination with other variables (Dhooge & Hartsuiker, 2010, Experiments 2 and 3; Geng et al., 2014, Experiment 2; Miozzo & Caramazza, 2003, Experiment 7; Starreveld et al., 2013, Experiment 1). In one study, the distractor frequency effect was absent when the speed with which target pictures was processed was experimentally reduced (Geng et al., 2014; Experiment 2). This was achieved by including only four target pictures in the response set and increasing the number of target repetitions to twenty. The failure to observe interference for low-frequency distractor words under conditions of facilitated target naming appears to be in line with the late, post-lexical locus account of the effect. It is possible that with practice, the names of the few target pictures used in the experiment become so readily accessible that they reach the articulatory buffer before it is blocked by distractor words. Equally, the data do not fully discredit the role of an early attention mechanism because it is not certain whether target processing was sufficiently swift to pre-empt the adverse effect of distractors at the input level. In one study, the distractor frequency effect disappeared when targets and distractors were phonologically related (Miozzo & Caramazza, 2003; Experiment 7). The interaction between distractor frequency and phonological overlap suggests a common processing stage, namely that the delay occurs at the level at which phonological information is accessed; such a pattern of results again favours a late rather than an early locus account of the effect. Dhooge & Hartsuiker (2010; Experiment 2) failed to observe the distractor frequency effect under reduced visibility conditions. As the masking procedure is assumed to prevent phonologically well-formed distractor responses from entering the articulatory buffer, the absence of interference for masked low-frequency distractor words would indicate that distractor responses must indeed enter the post-lexical stage for the distractor frequency effect to be observed.

To further constrain hypotheses about the loci and mechanisms that give rise to the distractor frequency effect, distractor frequency was cross-manipulated with stimulus onset asynchrony (SOA) in three (23%) studies. The results were mixed. In two studies (Dhooge & Hartsuiker, 2010; Experiment 3; Starreveld et al., 2013; Experiment 1) the effect was absent at early SOAs, but got progressively larger with increasing distractor onset latencies. Direct comparisons and interpretation of data appear to be problematic, however, because one study stopped short of including late onset distractor latencies (SOAs > 0 ms) (Dhooge & Hartsuiker, 2010; Experiment 3); while in the other (Starreveld et al., 2013; Experiment 1), the significant interaction between the SOA and distractor frequency was not followed up with simple effect analyses. To complicate the picture further, a contradictory finding of no interaction between SOA and distractor frequency was reported by Miozzo & Caramazza (2003; Experiment 5). Here, the distractor frequency effect was equivalent in size at all SOAs (-100, 0 and +150 ms). So, although the distractor frequency effect would seem to mimic the time course of the phonological facilitation effect, and could thus be said to have a post-lexical basis, more research is needed to resolve the existing discrepancies.

Other studies in which distractor frequency was factorially crossed either with semantic relatedness (n = 2; 15%) or with the task the participant is given to perform (n = 2; 15%) also produced conflicting results. Even though the distractor frequency effect persisted when picture naming was replaced by manual phonological decision tasks (a finding which would argue against a post-lexical locus), the results were clear-cut for a syllable judgement task (Hutson et al., 2013; Experiment 1), but fell short of significance in a phoneme monitoring task (Hutson et al., 2013; Experiment 2). Low-frequency distractors produced interference of an equivalent size irrespective of whether they were semantically related or unrelated to the targets (Miozzo & Caramazza, 2003; Experiment 5), suggesting that the effects are driven by two separate processes, which would be at odds with the competitive account of lexical access. This is in contrast to a significant interaction between distractor frequency and semantic relatedness reported by Starreveld et al. (2013; Experiment 1). The distractor frequency effect was larger when distractors were categorically related than when they were unrelated to targets, a finding that suggests a shared processing mechanism in support of competitive lexical selection.

Interim summary

To sum up, while the distractor frequency effect (longer response latencies for low-frequency words than for high-frequency words) has been consistently demonstrated, its theoretical underpinnings are not fully understood. The available data do not differentiate between alternative explanations regarding the locus of the distractor frequency effect. Even when the results appear to favour one account over another, they are often based on complex assumptions (e.g., that the stage of pre-articulatory response preparation is effectively bypassed by distractor masking) that require further empirical support. Studies manipulating lexical frequency in combination with other task parameters (e.g., semantic relatedness, task instructions) are scarce and often present contradictory findings; in addition, interpretation of results is complicated by psycholinguistic confounds known to affect picture naming. For example, although substantial progress has been made with regards to previously largely uncontrolled factors known to affect picture naming latencies, such as age of acquisition (Catling et al., 2010), other lexical variables, such as concept familiarity or concreteness, have not been adequately controlled or indeed investigated. There is reason to believe that different psycholinguistic variables exert their effects at different loci of target processing, so manipulating intrinsic properties of distractors other than frequency of occurrence may provide new insights into the mechanisms that contribute to the effect. Similarly, there is a dearth of studies in which distractor frequency was manipulated concurrently with task instructions. For example, no study has so far investigated the joint effect of distractor frequency and semantic decision task even though interference at the level of conceptual encoding offers a plausible explanation of the effect. The above arguments however, do not change the fact that were the competitive account to remain defensible, additional assumptions (such as operation of early or late task-specific processes that jointly contribute to the net effect) are needed to explain the distractor frequency effect.

Table 2. Distractor frequency manipulation [LH = low frequency; HF = high frequency]

Authors (year); **study,** [language], *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target [type] - distractor [type, modality]	Finding	target [type] - distractor [type, modality]	Statistics
Miozzo & Caramazza (2003); **Exp 1 (List B)** [English]	20	20	Name the target "moon"	SOA = 0 ms	MOON [drawing] - *career* [HF word, visual]	< [19 ms]$^{*/*}$	MOON [drawing] - *choir* [LF word, visual]	*F1*(1, 19) = 12.6, *MSE* = 281.4, p < .01; *F2*(1, 19) = 4.5, *MSE* = 758.4, *p* < .05; *d* = .32.
Miozzo & Caramazza (2003); **Exp 5** [English], *distractor frequency x semantic relatedness*	16	19	Name the target "bench"	SOA = -100 ms	BENCH [drawing] - *rock* [HF unrelated word, visual]	< [24 ms]$^{*/*}$	BENCH [drawing] - *dune*[LF unrelated word, visual]	*ps* <= .01; *ds* = [.19 - .38]
	16	19	Name the target "bench"	SOA = 0 ms	BENCH [drawing] - *rock* [HF unrelated word, visual]	< [28 ms]$^{*/*}$	BENCH [drawing] - *dune*[LF unrelated word, visual]	*ps* <= .01; *ds* = [.19 - .38]
	16	19	Name the target "bench"	SOA = +100 ms	BENCH [drawing] - *rock* [HF unrelated word, visual]	< [24 ms]$^{*/*}$	BENCH [drawing] - *dune*[LF unrelated word, visual]	*ps* <= .01; *ds* = [.19 - .38]
	16	19	Name the target "bench"	SOA = -100 ms	BENCH [drawing] - *chair* [categorically related HF word, visual]	< [30 ms]$^{*/*}$	BENCH [drawing] - *stool* [categorically related LF word; visual]	*ps* < .01; *ds* = [.19 - .38]
	16	19	Name the target "bench"	SOA = 0 ms	BENCH [drawing] - *chair* [categorically related HF word, visual]	< [25 ms]$^{*/*}$	BENCH [drawing] - *stool* [categorically related LF word; visual]	*ps* < .01; *ds* = [.19 - .38]
	16	19	Name the target "bench"	SOA = +100 ms	BENCH [drawing] - *chair* [categorically related HF word, visual]	< [26 ms]$^{*/*}$	BENCH [drawing] - *stool* [categorically related LF word; visual]	*ps* < .01; *ds* = [.19 - .38]
Miozzo & Caramazza (2003); **Exp 7** [English], *distractor frequency x phonological relatedness*	19	23	Name the target "ball"	SOA = 0 ms	BALL [drawing] - *road* [phonologically unrelated HF word, visual]	< [29 ms]$^{*/*}$	BALL [drawing] - *flake* [phonologically unrelated LF word, visual]	*F1*(1, 19) = 24.6, *MSE* = 8,479.1, *p* < .0001; *F2*(1, 22) = 24.8, *MSE* = 10,290.0, *p* < .0001; *d* = .44
				SOA = 0 ms	BALL [drawing] - *wall* [phonologically related HF word, visual]	< [3 ms]$^{ns/ns}$	BENCH [drawing] - *shawl* [phonologically unrelated LF word; visual]	*Fs* < 1
Geng et al. (2014); **Exp 1a** [English]	24	80	Name the target	SOA = 0 ms	ANCHOR [drawing] - *paper* [high frequency word; visual]	< [28 ms]$^{*/*}$	ANCHOR [drawing] - *comet* [low frequency word; visual]	*t1* (23) = 3.91, *p* < .001; *t2* (78) = 3.28, *p* = .002

Geng et al. (2014); **Exp 2** [English], *small number of targets with multiple target repetition*	20	80	Name the target	SOA = 0 ms	CAR [drawing] - *night* [HF word; visual]	[0 ms]$^{ns/ns}$	CAR [drawing] - *marsh* [LF word; visual]	*ts* < 1
Geng et al. (2014); **Exp 4** [English]	24	80	Name the target	SOA = 0 ms	ANCHOR [drawing] - *paper* [HF word; visual]	< [19 ms]$^{*/*}$	ANCHOR [drawing] - *comet* [LF word; visual]	*p* < .05 (no other statistics reported)
Hutson, Damian, & Spalek (2013); **Exp 1** [English], *distractor frequency x task type*	28	60	Indicate if the target's name is mono- or disyllabic [manual response]	SOA = 0 ms	APPLE [drawing] - *husband* [HF word, visual]	< [20 ms]*	APPLE [drawing] - *sorrow* [LF word, visual]	β = 19.11, *t*(2894) = 2.17, *p* = .030.
Hutson, Damian, & Spalek (2013); **Exp 2** [English], *distractor frequency x task type*	28	60	Indicate if the target's name contains the phoneme seen on a previous trial [manual response]	SOA = 0 ms	APPLE [drawing] - *husband* [HF word, visual]	< [27 ms]^{ns}	APPLE [drawing] - *sorrow* [LF word, visual]	β = 17.93, *t*(2498) = 1.77, *p* = .077.
Starreveld et al. (2013); **Exp 1** [Dutch] *distractor frequency x semantic relatedness*	20	24	Name the target "bear"	averaged SOAs [-86, -43, 0, +43 and +86 ms]	BEAR [drawing] - *horse* [semantically related, HF word, visual]	< [28 ms]?	BEAR [drawing] - *goat* [semantically related, LF word, visual]	Semantic relatedness x distractor frequency: *F1*(1, 19) = 6.2, *MSE* = 1,090, *p* = .02; *F2*(1, 21) = 5.0, *MSE* = 1,472, *p* = .037. No simple effect analyses reported
			Name the target "bear"	averaged SOAs [-86, -43, 0, +43 and +86 ms]	BEAR [drawing] - *ship* [unrelated, HF word, visual]	< [12 ms]?	BEAR [drawing] - *purse* [unrelated LF word, visual]	Semantic relatedness x distractor frequency: *F1*(1, 19) = 6.2, *MSE* = 1,090, *p* = .02; *F2*(1, 21) = 5.0, *MSE* = 1,472, *p* = .037. No simple effect analyses reported
Dhooge & Hartsuiker (2010); **Exp 1** [Dutch]	20	30	Name the target "bomb"	SOA = 0 ms	BOMB [drawing] - desk [HF word, visual]	< [23 ms]$^{*/*}$	BOMB [drawing] - earring [LF word, visual]	*F1*(1, 19) =38.43, *MSE* = 5,388.02, *p* < .001, *F*2(1, 29) = 19.13, *MSE* = 8,423.45, *p* < .001.
Dhooge & Hartsuiker (2010); **Exp 2** [Dutch], *distractor frequency x visibility*	40	20	Name the target "bomb"	SOA = 0 ms	BOMB [drawing] - table [non-masked, HF word, visual]	< [25 ms]$^{*/*}$	BOMB [drawing] - teeth [non-masked, LF word, visual]	*t1*(39) = 6.23, *p* < .001; *t2*(19) = 3.73, *p* < .01

				SOA = 0 ms	BOMB [drawing] - table [masked, HF word, visual,]	> [3 ms]$^{ns/ns}$	BOMB [drawing] - teeth [masked, LF word, visual]	*t1*(39) = –0.49, *p* = .63; *t2*(19) = 0.15, *p* = .88
Dhooge & Hartsuiker (2010); **Exp 3** [Dutch], *distractor frequency x SOA*	24	20	Name the target "bomb"	SOA = -300 ms	BOMB [drawing] - table [HF word, visual]	< [3 ms]$^{ns/ns}$	BOMB [drawing] - teeth [LF word, visual]	*t1*(23) = .74, *p* = .47; *t2*(19) = .81, *p* = .43
				SOA = -200 ms	BOMB [drawing] - table [HF word, visual]	< [7 ms]$^{ns/ns}$	BOMB [drawing] - teeth [LF word, visual]	*t1*(23) = 1.89, *p* = .07; *t*2(19) = 1.44, *p* = .17
				SOA = -100 ms	BOMB [drawing] - table [HF word, visual]	< [12 ms]$^{*/*}$	BOMB [drawing] - teeth [LF word, visual]	*t1*(23) = 3.84, *p* < .01; *t*2(19) = 2.31, *p* < .05
				SOA = 0 ms	BOMB [drawing] - table [HF word, visual]	< [24 ms]$^{*/*}$	BOMB [drawing] - teeth [LF word, visual]	*t1*(23) = 4.90, *p* < .001; *t2*(19) = 3.84, *p* < .01
Catling et al. (2010); **Exp 1** [English]	20	48	Name the target	SOA = 0 ms	APPLE [drawing] - *husband* [HF word, visual]	< [39 ms]$^{*/*}$	APPLE [drawing] - *sorrow* [LF word, visual]	*F1* (1, 19) = 6.914, *p* < .05; *F2* (1, 46) = 9.21, *p* < .005

2.5.1.3 Distractor visibility

To better understand how and at what point in the process of naming a depicted object semantic context effects come about, 6% of the reviewed PWI studies have manipulated the distractors' visibility (see Table 3). This type of manipulation typically involves a masking procedure, in which the distractor is obscured by a forward (a string of symbols preceding the distractor, e.g., #####) and a backward mask (a string of symbols following the distractor, e.g., NGCFRLNHS). The distractor itself is displayed for a very brief duration, typically 53 ms. Most participants are unaware of subliminally presented primes as evidenced in subjective post-experimental reports, in which only a few declare seeing stimuli other than the target pictures themselves (e.g., Dhooge & Hartsuiker, 2010) as well as in more objective post-hoc visibility tests (e.g., Damian & Spalek, 2014), in which participants have to identify masked distractors on individual trials under the same masking conditions.

The rationale for using masked distractors in the PWI paradigm is based on the assumption that the masking procedure effectively strips the stimuli of their lexical privilege to enter the articulatory buffer before target responses, while preserving their potential to affect earlier processing stages (Finkbeiner & Caramazza, 2006). Because distractors are no longer consciously perceived, they do not trigger the formulation of covert verbal responses, which would otherwise block the articulatory buffer and which would need to be removed to give way to target responses. Masking thus eliminates the need to engage response-exclusion processes, which should result in facilitation (a categorically related distractor which is conceptually, but not phonetically encoded may help to activate the target concept through a process of spreading activation) or at the very least produce a null result.

Facilitation was indeed observed for subliminally presented categorically related distractors in three (43%) studies (Finkbeiner & Caramazza, 2006; Experiments 1 and 2; Dhooge and Hartsuiker, 2010; Experiment 2), inviting a post-lexical, REH-compatible explanation of the semantic context effect. Although polarity reversal (interference under visible conditions turned into facilitation under masked distractor conditions) was also noted by Damian & Spalek (2014), it failed to reach statistical significance.

In contrast, semantic interference effects of comparable magnitudes were obtained both under visible and masked distractor conditions in one study (Piai et al., 2012; Experiment 2). The absence of interaction between semantic relatedness and distractor visibility was interpreted in favour of lexical selection with a competition threshold (Piai et al., 2012). It appeared that despite their "invisibility", with sufficient activation at the lexical level (e.g., by using many exemplars from few semantic categories and including distractors in the response set), masked distractors are capable of interfering with the production process. The idea that interfering stimuli must exceed a competition threshold to exert their effects rather than being unavailable to conscious awareness was further supported by another study (Piai et al., 2012; Experiment 1), in which categorically related distractors that were masked not only failed to produce facilitation, but a facilitatory effect was obtained for the same type of distractors that were clearly visible.

Special attention should be given to the joint manipulation of the distractor's visibility and frequency, on the one hand, and the distractor's visibility and emotional content, on the other. Both the distractor frequency effect (see the previous section) and the taboo interference effect (see the section below), have been ascribed a post-lexical locus according to the REH. Here, the results diverge again. The distractor frequency effect disappeared when distractors were masked (Dhooge and Hartsuiker, 2010; Experiment 2), which is in accordance with the REH. The taboo interference effect, on the other hand, was preserved under masked distractor conditions (Hansen, McMahon, Burt, & de Zubicaray, 2017; Experiment 4). The lack of interaction between the emotional content of distractor words and distractor visibility would argue for two separate loci of the effects. If taboo interference is attributed to response exclusion processes operating post-lexically (e.g., Dhooge and Hartsuiker, 2010; 2012), then the persistence of the effect under masked condition would either question the validity of the masking procedure or suggest the effect has an earlier locus.

Interim summary

Overall, manipulations of distractor visibility have produced inconsistent results, allowing for two alternative interpretations of the semantic context effect and lexical selection alike. On the one hand, the polarity reversal (interference turned into facilitation when distractors become inaccessible to conscious awareness and presumably to pre-articulatory encoding) is in line with the REH predictions. On the other, observing facilitation when interference would normally be expected (for categorically related distractors under visible conditions) and interference when facilitation would be predicted by the REH supports competitive lexical selection with a competition threshold. It is worth noting that the "visibility" account (the suitability of the masking procedure as a tool to effectively prevent the formulation of articulatory codes) has been challenged on at least three counts: (1) the notion of low visibility could be replaced by the concept of low activation strength (masked distractors may simply be too weakly activated at the lexical level to enter into competition with target names). (2) Although there is clear behavioural and electrophysiological evidence that masked distractors are processed, the extent of this processing is less clear-cut. For example, according to Dehaene et al. (1998), the processing of subliminally presented primes extends all the way down to include the motor system. This cannot be easily reconciled with the claim made by Finkbeiner & Caramazza (2006) that masking successfully prevents formulation of phonological production-ready responses. Even if the stage of articulatory encoding is indeed effectively eliminated by the masking procedure, so could the stage of lexical processing – without distractor lexicalisation, interference would be hard, if impossible, to find. (3) In addition, the results of a post-hoc visibility test conducted by Damian & Spalek (2014) indicated marked variability in the subliminal prime detection rates; importantly, a follow-up regression analysis showed that this variability was not a reliable predictor of the polarity or the size of the interference effect, i.e. individuals who were efficient at detecting masked distractors in the post-experimental task did not necessarily experience greater interference in the original task, as envisaged by the REH.

Because the competition threshold hypothesis has not received nearly as much critique as the visibility account, it appears to be a stronger candidate to explain sematic context effects. Future research could use a factorial design, in which semantic relatedness, lexical activation strength of distractors and distractor visibility would be concurrently manipulated. If facilitation is indeed due to low activation strength of distractors and not to their masking, interference should be observed for categorically related distractors that have been given adequate lexical boost both under visible and masked distractor conditions. This was partly shown by Piai et al. (2012), but with a between-subject design, a limitation that could be addressed in future PWI studies.

Table 3. Manipulation of distractor visibility

Authors (year); **study,** [language], *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target [type] – distractor [type, modality]	Finding	target [type] – distractor [type, modality]	Statistics
Finkbeiner & Caramazza (2006); **Exp 1** [English]	18	46	Name the target (visible condition)	SOA = -53 ms	TARGET [drawing] - *distractor* [visible, related]	> [32 ms][*/*]	TARGET [drawing] - *distractor* [visible, unrelated]	*F1*(1, 16) = 5.74, *p* = .03; *F2*(1, 44) = 5.89, *p* = .02
			Name the target (masked condition)	SOA = -53 ms	TARGET [drawing] - *distractor* [masked, related]	< [32 ms][*/*]	TARGET [drawing] - *distractor* [masked, unrelated]	*F1*(1, 16) = 5.82, *p* = .02; *F2*(1, 44) = 6.15, *p* = .01
Finkbeiner & Caramazza (2006); **Exp 2** [English]	20	38	Name the target (visible condition)	SOA = -66 ms	TARGET [drawing] - *distractor* [visible, related]	> [39 ms][*/*]	TARGET [drawing] - *distractor* [visible, unrelated]	*F1*(1, 18) = 4.52, *p* = .04; *F2*(1, 36) = 4.73, *p* = .03
			Name the target (masked condition)	SOA = -66 ms	TARGET [drawing] - *distractor* [masked, related]	< [49 ms][*/*]	TARGET [drawing] - *distractor* [masked, unrelated]	*F1*(1, 18) = 4.52, *p* = .04; *F2*(1, 36) = 7.77, *p* < .01
Damian & Spalek (2014); [German]	48	20	Name the target (visible condition)	SOA = -53 ms	ORANGE [drawing] - *banana* [visible, related]	> [38 ms][*/*]	ORANGE [drawing] - *flute* [visible, unrelated]	*t1*(47) = 5.34, *p* < 0.001; *t2*(19) = 4.66, *p* < 0.001
			Name the target "orange" (masked condition)	SOA = -53 ms	ORANGE [drawing] - *banana* [masked, related]	< [11 ms][ns/ns]	ORANGE [drawing] - *flute* [masked, unrelated]	*t1*(47) = 1.91, *p* = 0.063; *t2*(19) = 1.79, *p* = 0.090; (two different t2 and p2 values are reported)
Dhooge and Hartsuiker (2010); **Exp. 2** [Dutch] , *distractor visibility x distractor frequency*	40	20	Name the target "bomb" (visible condition)	SOA = -53 ms	BOMB [drawing] - *table* [high frequency, unrelated word, visual,]	< [25 ms][*/*]	BOMB [drawing] - teeth [low frequency, unrelated word, visual]	*t1*(39) = 6.23, *p* < .001; *t2*(19) = 3.73, *p* < .01
			Name the target "bomb" (masked condition)	SOA = -53 ms	BOMB [drawing] - *table* [high frequency, unrelated word, visual,]	> [3 ms][ns/ns]	BOMB [drawing] - teeth [low frequency, unrelated word, visual]	*t1*(39) = –0.49, *p* = .63; *t2*(19) = 0.15, *p* = .88.
			Name the target "bomb" (visible condition)	SOA = -53 ms	BOMB [drawing] - *grenade* [related word, visual,]	> [15 ms][*/*]	BOMB [drawing] - *stand* [unrelated word, visual,]	*t1*(39) = –3.81, *p* < .001; *t2*(19) = –2.96, *p* < .01.
			Name the target "bomb" (masked condition)	SOA = -53 ms	BOMB [drawing] - *grenade* [related word, visual,]	< [12 ms][*/*]	BOMB [drawing] - *stand* [unrelated word, visual,]	*t1*(39) = 5.05, *p* < .001; *t2*(19) = 3.07, *p* < .01

Hansen at al. (2017); **Exp 4** [English], *distractor visibility x distractor emotional content*	25	25	Name the target "bin" (masked condition)	SOA = -66.7 ms	BIN [drawing] - *twat* [masked, taboo, visual]	> [34 ms]*/*	BIN [drawing] - *fame* [masked, neutral, visual]	*t1*(24) = −3.771, *p* = .001; *t2*(24) = −4.121, *p* < .001
Piai et al. (2012); **Exp 1** [Dutch], *low co-activation of distractors*	18	16	Name the target "guitar" (visible condition)	SOA = - 66 ms	GUITAR [drawing] - *trumpet* [visible, related]	< [15 ms]*/*	GUITAR [drawing] - *swing* [visible, unrelated]	*F1*(1, 17) = 23.47, *MSE* = 357, *p* < .001; *F2*(1, 15) = 13.20, *MSE* = 543, *p* = .002.
			Name the target "guitar" (masked condition)	SOA = - 66 ms	GUITAR [drawing] - *trumpet* [masked, related]	> [2 ms]ns/ns	GUITAR [drawing] - *swing* [masked, unrelated]	*Fs* < 1
Piai et al. (2012); **Exp 2** [Dutch], *high co-activation of distractors*	16	32	Name the target "rabbit" (visible condition)	SOA = - 66 ms	RABBIT [drawing] - *deer* [visible, related]	> [13 ms]*/*	RABBIT [drawing] - *arm* [visible, unrelated]	*F1*(1, 15) = 12.02, *MSE* = 1,156, *p* = .003; *F2*(1, 31) = 4.57, *MSE* = 6,722, *p* = .041. Semantic relatedness x visibility: *Fs* < 1. No statistics for post-hoc tests reported.
			Name the target "rabbit" (masked condition)	SOA = - 66 ms	RABBIT [drawing] - *deer* [masked, related]	> [17 ms]*/*	RABBIT [drawing] - *arm* [masked, unrelated]	*F1*(1, 15) = 12.02, *MSE* = 1,156, *p* = .003; *F2*(1, 31) = 4.57, *MSE* = 6,722, *p* = .041. Semantic relatedness x visibility: *Fs* < 1. No statistics for post-hoc tests reported.

2.5.1.4 Emotional content of distractors

Eleven per cent of the selected PWI studies (n = 13) have manipulated the emotional content of distractor words. Taboo words (e.g., *c*nt*) were employed in thirteen studies, four of which additionally utilised non-taboo negative (e.g., *maggot*) and two of which also used positive (e.g., *friend*) verbal stimuli (see Table 4).

Of these, 12 studies (92.3%) found a reliable taboo interference effect – picture naming latencies were substantially longer in the context of semantically unrelated obscene words (e.g., LEAF-*c*nt*) than when presented with their neutral counterparts (e.g., LEAF-*vest*) (Dhooge & Hartsuiker, 2011; Experiment 2; Hansen et al., 2017; Experiments 1, 2, 3 and 4; Mädebach, Markuske, & Jescheniak, 2018; Experiment 1; White, Abrams, Hsi, & Watkins, 2018; Experiments 1 and 2; White, Abrams, Koehler, & Collins, 2017; Experiments 1 and 2; White, Abrams, LaBat, & Rhynes, 2016; Experiments 1 and 2). The effect also generalised, although to a lesser degree, to negative distractor words (e.g., WEB-*demon*) in three studies (White et al., 2016; Experiment 2; White et al., 2018; Experiments 1 and 2), but was eliminated when target pictures were accompanied by positive distractor words (e.g., WEB-*blossom*) (White et al., 2016; Experiment 1 and 2). That taboo and negative distractor words delay picture naming compared with neutral distractor words has several interpretations. According to the competition threshold hypothesis (Piai et al., 2012), because of their highly arousing nature, emotional words are more likely to accumulate sufficient activation to compete with target names for selection. For the same reason, they may be harder to block by an early selective attention mechanism (Roelofs, 2003; Roelofs, Piai, & Schriefers, 2013). The interference effect for emotionally salient distractor words can equally reflect the operation of a post-lexical self-monitoring mechanism performing more stringent checks when the articulatory buffer is occupied by socially inappropriate words (Dhooge and Hartsuiker, 2011), although it is not clear how the mechanism would apply to negative words. The attentional capture account holds that the detection of arousing verbal stimuli involuntary shifts attention away from the primary task (picture naming), slowing preparation of target response at either or both the pre-lexical and lexical processing stages. While taboo interference can be readily accommodated by either one, or by a combination of the above accounts, the effect appears problematic for the REH hypothesis. This is for two reasons. One, by analogy to high frequency words (with their facilitated lexical access), taboo distractor words should reach the articulatory buffer sooner than their lexically matched controls. Two, taboo distractors do not satisfy the response relevance criterion of "social appropriateness" (i.e., the task is to name objects using neutral, socially appropriate labels), and so, theoretically, should be excluded from the buffer more easily than neutral words. In both cases, picture naming should be quicker for taboo than for neutral distractor words.

In two (15%) studies, discrepancies emerged in relation to the time course of the taboo interference effect, with the effect being present at early (SOA = -150 ms), simultaneous (SOA = 0 ms) and late distractor presentation (SOA = +150 ms) in one study (White et al., 2017; Experiment 2), but absent at a SOA of +150 ms in another (Hansen et al., 2017; Experiment 1). The persistence of the effect at a late distractor onset (150 milliseconds after target presentation) is difficult to reconcile with the post-lexical REH account, because it is unlikely that the distractor would occupy the output buffer given the target's temporal head start.

The taboo interference effect persisted under masked distractor conditions in one study (8%) (Hansen et al., 2017; Experiment 4) and was attenuated, but not eliminated or reversed as is typically found with semantically related distractors, under phonological overlap conditions in two studies (15%) (White et al., 2016; Experiment 1 and Hansen et al., 2017; Experiment 3). While the former argues against a post-lexical locus of the effect (insofar as the masking procedure effectively prevents the distractors from reaching the articulatory buffer), the latter allows for both pre- and post-lexical interpretation. The overall picture is obscured again by contradictory findings. Taboo distractors that were phonologically related to target pictures' names (e.g., BIN-*b*tch*) were named faster than their unrelated counterparts (e.g., BIN-*tw*t*). The phonological facilitation effect was equivalent in magnitude for taboo and for neutral words in one study (Hansen et al. 2017; Experiment 3), but significantly larger for taboo words than for neutral (or negative and positive) words in another (White et al., 2016; Experiment 1). The absence of interaction between phonological relatedness and emotional valence of distractors (additivity of the effects) suggests that the effects arise at two different processing stages within the language production system, and so is in line with an early locus of the effect. Significant interaction, on the other hand, suggests a single (post-lexical) source of the taboo interference effect.

Two studies (15%) investigated how emotional valence of distractors affects phonological and semantic decision making (Mädebach et al., 2018; Experiment 1 and 2). A taboo interference effect emerged when basic-level naming was replaced by a manual phoneme monitoring task (e.g., indicate whether the target's name starts with a *b* or a *k*) as well as by a size judgement task (e.g., indicate whether the displayed object is larger or smaller in real life than a shoe box), but only when the processing demand associated with target identification was high (degraded visual input). Since the emotional content of distractors had an adverse effect on decision times in both tasks, and neither of these were assumed to entail preparation of articulatory responses, it was concluded that the effect arose at the lexical processing stage and possibly also at the level of conceptual encoding (at least when the cognitive load associated with target recognition was high).

Interim summary

On balance, despite being a well-established phenomenon, it is not entirely clear what drives the taboo interference effect (prolonged naming times for taboo distractor relative to neutral distractors). The scant evidence derived from concurrent manipulations of the distractor's emotional content and other task parameters (SOA, phonological relatedness, task instructions) appears to be weighted in favour of early (pre-lexical and lexical) rather than late (post-lexical) mechanisms. This is supported by the findings of the diminishing effect (the later the distractor is presented, the smaller the interference effect), the habituation effect (the effect gradually diminishes with subsequent distractor block repetitions) and consistent correlations between the taboo interference effect and arousal, but not valence or offensiveness ratings of distractor words (Hansen et al., 2017). Although the reaction time data obtained for taboo distractor words could be explained entirely by early attentional mechanisms, they do not unambiguously contest the role of the monitoring mechanism: once the target lemma has been chosen and phonologically encoded it may still be inspected for social appropriateness. While the taboo interference effect alone and its persistence under masked distractor conditions challenge the REH hypothesis, its occurrence in phonological and semantic decision tasks points to lexical and conceptual processing stages. In most likelihood, the effect reflects the operation of a combination of mechanisms across multiple processing stages, with distractor competition threshold, reactive distractor blocking, attentional capture and self-monitoring being the most plausible candidates.

Table 4. Manipulation of emotional content of distractors

Authors (year); **study,** [language], *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target [type] – distractor [type, modality]	Finding	target [type] – distractor [type, modality]	Statistics
White et al. (2016); **Exp 1** [English]	48	16	Name the target "rock", "swing"	SOA = 0 ms	ROCK [drawing] - *slut* [taboo word, visual]	> [94 ms]$^{?/*}$	SWING [drawing] - *tank* [neutral word, visual]	*t2*(30) = 3.40, *p* < .002, η_p^2 = .28 (no statistics for *t1*);
			Name the target "lightbulb", "swing"	SOA = 0 ms	LIGHTBULB [drawing] - *corpse* [negative word, visual]	> [18 ms]$^{?/ns}$	SWING [drawing] - *tank* [neutral word, visual]	*t2* < 1 (no statistics for *t1*)
			Name the target "peach", "swing"	SOA = 0 ms	PEACH [drawing] - *friend* [positive word, visual]	< [18 ms]$^{?/ns}$	SWING [drawing] - *tank* [neutral word, visual]	*t2* < 1 (no statistics for *t1*)
			Name the target "duck"	SOA = 0 ms	DUCK [drawing] - dick [phonologically related taboo word, visual]	> [? ms]$^{*/*}$	DUCK [drawing] - tits [phonologically unrelated taboo word, visual]	*t1*(47) = 7.31, *p* < .001, η_p^2 = .53; *t2*(15) = 5, *p* < .001; η_p^2 = .63
White et al. (2016); **Exp 2** [English]	48	16	Name the target "web"	SOA = 0 ms	WEB [drawing] - *nipples* [taboo word, visual]	> [? ms]$^{*/*}$	WEB [drawing] - *locker* [neutral word, visual]	*t1*(47) = 8.21, *p* < .001, η_p^2 = .59; *t2*(30) = 6.75, *p* < .001; η_p^2 = .60
			Name the target "web"	SOA = 0 ms	WEB [drawing] - *demon* [negative word, visual]	> [? ms]$^{*/*}$	WEB [drawing] - *locker* [neutral word, visual]	*t1*(47) = 4.99, *p* < .001, η_p^2 = .35; *t2*(30) = 2.3, *p* < .03; η_p^2 = .15
			Name the target "web"	SOA = 0 ms	WEB [drawing] - *blossom* [positive word, visual]	[? ms]$^{ns/ns}$	WEB [drawing] - *locker* [neutral word, visual]	*t1*(47) = .09, *p* = .93; *t2*(30) = .44, *p* = .67
White et al. (2017); **Exp 1** [English], *max stimuli duration of 3000 ms*	40	27	Name the target "glove"	SOAs [-150 ms, 0 ms, + 150 ms]	GLOVE [drawing] - *dildo* [taboo word, visual]	> [135 ms]*	GLOVE [drawing] – *citrus* [neutral word, visual]	*t* = 2.43, p = .015
White et al. (2017); **Exp 2** [English], *max stimuli duration of 350 ms*	40	27	Name the target "glove"	SOAs [-150 ms, 0 ms, + 150 ms]	GLOVE [drawing] - *dildo* [taboo word, visual]	> [131 ms]*	GLOVE [drawing] – *citrus* [neutral word, visual]	*t* = 2.05, *p* = .04
White et al. (2018); **Exp 1** [English]	60	30	Name the target "leaf"	SOA = 0 ms	LEAF [drawing] - *whore* [taboo word, visual]	> [125 ms]$^{*/*}$	LEAF [drawing] - *vest* [neutral word, visual]	*ps* < .001 (no other post-hoc statistics available)

			Name the target "leaf"	SOA = 0 ms	LEAF [drawing] - *corpse* [negative word, visual]	> [38 ms]$^{*/*}$	LEAF [drawing] - *vest* [neutral word, visual]	*ps* < .001 (no other post-hoc statistics available)
White et al. (2018); **Exp 2** [English]	60	30	Name the target "leaf"	SOA = 0 ms	LEAF [drawing] - *whore* [taboo word, visual]	> [127 ms]$^{*/*}$	LEAF [drawing] - *vest* [neutral word, visual]	*ps* < .001 (no other post-hoc statistics available)
			Name the target "leaf"	SOA = 0 ms	LEAF [drawing] - *corpse* [negative word, visual]	> [45 ms]$^{*/*}$	LEAF [drawing] - *vest* [neutral word, visual]	*ps* < .001 (no other post-hoc statistics available)
Dhooge & Hartsuiker (2011); **Exp 2** [Dutch]	20	20	Name the target	SOA = 0 ms	TARGET [drawing] - *distractor* [taboo word, visual]	> [38 ms]*	TARGET [drawing] - *distractor* [neutral word, visual]	$\beta 1 = -36.78$, $SE = 8.37$, t = -4.40, $p < .001$, $d = 0.90$.
Hansen et al. (2017); **Exp 1** [English]	18	25	Name the target "bin"	SOA = -150	BIN [drawing] - *twat* [taboo word, visual]	> [94 ms]$^{*/*}$	BIN [drawing] - *fame* [neutral word, visual]	$t1(17) = 5.307$, $p < .001$, $d = 1.25$; $t2(24) = 6.926$, $p < .001$, $d = 1.39$
			Name the target "bin"	SOA = 0 ms	BIN [drawing] - *twat* [taboo word, visual]	> [25 ms]$^{*/ns}$	BIN [drawing] - *fame* [neutral word, visual]	$t1(17) = 2.264$, $p = .037$, $d = 0.53$, $t2(24) = 1.804$, $p = .084$, $d = 0.36$.
			Name the target "bin"	SOA = +150 ms	BIN [drawing] - *twat* [taboo word, visual]	< [2 ms]$^{ns/ns}$	BIN [drawing] - *fame* [neutral word, visual]	$t1(17) = -0.190$, $p = .851$, $d = 0.05$; $t2(24) = 0.069$, $p = .945$, $d = 0.01$
Hansen et al. (2017); **Exp 2** [English]	20	25	Name the target "bin"	SOA = 0 ms	BIN [drawing] - *twat* [taboo word, visual]	> [50 ms]$^{*/*}$	BIN [drawing] - *fame* [neutral word, visual]	$t1(19) = 2.173$, $p = .043$, $d = 0.49$; $t2(24) = -4.075$, $p < .001$, $d = 0.82$
			Name the target "bin"	SOA = 0 ms	BIN [drawing] - *bitch* [phonologically related taboo word, visual]	< [5 ms]$^{ns/ns}$	BIN [drawing] - *song* [neutral word, visual]	$t1(19) = 0.432$, $p = .671$, $d = 0.10$; $t2(24) = 0.652$, $p = .521$, $d = 0.1$
			Name the target "bin"	SOA = 0 ms	BIN [drawing] - *bitch* [phonologically related taboo word, visual]	< [55 ms]$^{*/*}$	BIN [drawing] - *twat* [taboo word, visual]	$t1(19) = 3.312$, $p = .004$, $d = 0.74$; $t2(24) = 3.668$, $p = .001$, $d = 0.73$
Hansen et al. (2017); **Exp 3** [English]	20	25	Name the target "bin"	SOA = 0 ms	BIN [drawing] - *twat* [taboo word, visual]	> [46 ms]$^{*/*}$	BIN [drawing] - *twig* [neutral word, visual]	$F1(1, 19) = 10.120$, $p = .005$, $MSE = 4775.321$, $\eta_p^2 = .35$; $F2(1, 24) = 47.362$, $p < .001$, $MSE = 1341.150$, $\eta_p^2 = .66$; distractor emotional content x phonological relatedness, $p > .05$;

			Name the target "bin"	SOA = 0 ms	BIN [drawing] - *bitch* [phonologically related taboo word, visual]	> [55 ms]*/*	BIN [drawing] - *bird* [phonologically related neutral word, visual]	*F1*(1, 19) = 10.120, *p* = .005, *MSE* = 4775.321, η_p^2= .35; *F*2(1, 24) = 47.362, *p* < .001, *MSE* = 1341.150, η_p^2 = .66; distractor emotional content x phonological relatedness, *p* > .05;
			Name the target "bin"	SOA = 0 ms	BIN [drawing] - *bitch* [phonologically related taboo word, visual]	< [56 ms]*/*	BIN [drawing] - *twat* [phonologically unrelated taboo word, visual]	*F1*(1, 19) = 36.544, *p* < .001, *MSE* = 2061.641, η_p^2 = .66; *F2* (1, 24) = 31.053, *p* < .001, MSE = 2851.121, η_p^2 = .56; distractor emotional content x phonological relatedness, *p* > .05;
Hansen at al. (2017); **Exp 4** [English*], taboo interference under masked conditions*	25	25	Name the target "bin" (masked condition)	SOA = -66.7 ms	BIN [drawing] - *twat* [masked, taboo, visual]	> [34 ms]*/*	BIN [drawing] - *fame* [masked, neutral, visual]	*t1*(24) = −3.771, *p* = .001; *t2*(24) = −4.121, *p* < .001
Mädebach et al. (2018); **Exp 1** [German]	24	32	Name the target "bank"	SOA = 0 ms	BANK [drawing] - *dildo* [taboo word, visual]	> [98 ms]*/*	BANK [drawing] - *jacket* [neutral word, visual]	*F1*(1, 23) = 85.76, *p* < .001; *F2*(1, 31) = 125.07, *p* < .001; BF_{10} > 1,000 (extreme evidence)
			Indicate if the target's name starts with a *b* or a *k* [manual response]	SOA = 0 ms	BANK [drawing] - *dildo* [taboo word, visual]	> [35 ms]*/*	BANK [drawing] - *jacket* [neutral word, visual]	*F1*(1, 23) = 15.71, *p* = .001; *F2*(1, 31) = 25.98, *p* < .001; BF_{10} > 900 (reported only for the first presentation block; very strong evidence)

			indicate if the target object is larger or smaller than a standard shoe box [manual response]	SOA = 0 ms	BANK $_{[drawing]}$ - *dildo* $_{[taboo\ word,\ visual]}$	> [4 ms]$^{ns/ns}$	BANK $_{[drawing]}$ - *jacket* $_{[neutral\ word,\ visual]}$	*F1* < 1, *F2*(1, 31) = 2.13, *p* = .154; valence x repetition of blocks: *F1*(1, 23) = 2.90, p = .102, *F2*(1, 31) = 4.62, *p* = .040; taboo interference effect for participants, BF_{10} = 0.4, for items BF_{10} = 0.9 (anecdotal evidence)
Mädebach et al. (2018); **Exp 2** [German], *degraded visual input*	24	32	Indicate if the target object is larger or smaller than a standard shoe box [manual response]	SOA = -200 ms	BANK $_{[drawing]}$ - *dildo* $_{[taboo\ word,\ visual]}$	> [6 ms]$^{*/ns}$	BANK $_{[drawing]}$ - *jacket* $_{[neutral\ word,\ visual]}$	*F1*(1, 23) = 4.53, *p* = .044; *F2*(1, 31) = 3.68, *p* = .064; Taboo interference for participants BF_{10} = 2.8, for items BF_{10} = 1.8.
			Indicate if the target object is larger or smaller than a standard shoe box [manual response]	SOA = 0 ms	BANK $_{[drawing]}$ - *dildo* $_{[taboo\ word,\ visual]}$	> [17 ms]$^{*/*}$	BANK $_{[drawing]}$ - *jacket* $_{[neutral\ word,\ visual]}$	*F1*(1, 23) = 8.86, *p* = .007; *F2*(1, 31) = 11.45, *p* = .002; taboo interference for participants, BF_{10} = 13.4, for items BF_{10} = 36.11

2.5.2 SITE OF MANIPULATION: TARGET-DISTRACTOR RELATIONS

An important, if not the main site of manipulation in the PWI paradigm, is the relationship between the target and the distractor. There are several ways in which targets and distractors can relate to each other. Semantic relatedness is the most obvious relation, followed by non-semantic (probabilistic), visual, phonological (orthographic), and temporal (stimulus onset asynchrony) relations. The present review covers the first three of these because manipulations of phonological overlap are not pertinent to the current research question, while manipulations of temporal relations have been widely discussed elsewhere (e.g., Glaser & Düngelhoff, 1984; Levelt, 1992; Schriefers et al., 1990).

2.5.2.1 SEMANTIC RELATIONS

PWI studies typically distinguish between categorical and non-categorical relations. In the former group, targets and distractors are members of the same semantic category (e.g., vehicles) and are usually co-ordinates, or co-hyponyms, (i.e., they are derived from the same level of specificity, e.g., CAR-*train*), but can also include hierarchical (hypernymic, e.g., CAR-*vehicle* versus hyponymic, e.g., CAR-*Audi*) and semantic distance relations (distant, e.g. HORSE-*squid* versus close HORSE-*donkey*). In the non-categorical group, the semantic relations are more heterogeneous and can include: whole-part (CAMEL-*hump*), thematic (BENCH-*park*), functional (BRUSH-*paint*) and other associative (miscellaneous) relations. Their definitions vary and individual relations may be difficult to disentangle.

2.5.2.1.1 Categorical relations

In a standard PWI task, distractors are normally derived from the same level of abstraction (or specificity) as targets, and the stimuli are said to be co-ordinates (co-hyponyms). Numerous studies have shown interference induced by categorically related co-ordinates and these constitute a backdrop against which other types of semantic relations are discussed. A group of studies have manipulated the hierarchical relations between targets and distractors, employing distractor stimuli drawn either from a superordinate or a subordinate level of representation. Their findings are presented in the first instance, followed by findings from a different set of studies with semantic distance manipulation.

2.5.2.1.1.1 Hierarchical relations (hypernymy and hyponymy)

In 8.5% of the reviewed PWI studies (n = 10) participants named objects with their preferred basic-level names (e.g., a picture of a CAR as "car") while ignoring distractor words drawn from a different level of abstraction (or specificity) than targets. Following Rosch, Mervis, Gray, Johnson, & Boyes-Braem (1976), Hantsch, Jescheniak, & Schriefers (2005) defined the basic level as a level of specificity between a category label used to refer to a collection of objects (e.g., vehicle) and a label denoting a specific instance of a member of such a category (e.g., Audi). Of the reviewed PWI studies, six (5%) used hyponyms, or subordinate-level names (e.g., FISH-*shark*), and four (3.5%) used hypernyms, or superordinate-level names (e.g., FISH-*animal*) as distractors. For results, see Table 5.

Of the four PWI studies with hypernymic distractor names, two (50%) studies (Costa et al., 2003; Experiments 3 & 4) reported interference for *unrelated* basic-level distractor names (e.g., BICYCLE-*horse*) relative to *unrelated* superordinate-level distractor names (e.g., BICYCLE-*weapon*). This "within-level interference" effect (i.e., distractor from within the same level of abstraction causing delay in production relative to distractors from a different level of abstraction than targets) was taken to reflect a decision process in which a relevant semantic representation is chosen for lexicalisation (the "semantic selection" account). According to this account, when a speaker is asked to produce a basic-level name, the selection system considers available basic-level semantic representations as possible candidates for lexicalisation, which delays naming. An alternative explanation to the "within-level interference" effect observed by Costa et al. would be the REH account, according to which both basic- and superordinate-level distractor words would occupy the articulatory buffer before the target name, but basic-level distractor words would be harder to reject as potential responses because they are more relevant to the task at hand (naming an object at the basic-level of abstraction). Two (50%) other studies (Kuipers, La Heij, & Costa, 2006, Experiment 1A; Roelofs, 1992) reported *no* effect of the level of specificity from which distractors are drawn, however. Contrary to Costa et al. (2003), naming times for target pictures with unrelated superordinate-level distractor names (e.g., DOG-*vehicle*) and for those with unrelated basic-level names (e.g., DOG-*tomato*) were indistinguishable. The source of these discrepancies is unknown.

In five (83%) of the six PWI studies utilising hypernymic distractor names, semantically related subordinate-level distractors (e.g. FISH-*shark*) resulted in slower naming times than their unrelated counterparts (e.g., FISH-*Barbie*), a finding which was constrained to early rather than late SOAs (the effect disappeared at SOAs of +200 and +300 ms) (Bölte, Dohmes, & Zwitserlood, 2013; Experiment 2; Hantsch et al. 2005; Experiments 1, 2 & 4; Hantsch, Jescheniak, & Mädebach, 2012; naming condition). This adds credibility to the claim that distractor words do not have to be drawn from the same level of specificity to interfere with picture naming. An effect in the opposite direction was reported in one study (Roelofs, 1992), however; when distractor words were presented before targets (SOA = -100 ms), semantically related subordinate-level distractors (CAR-*jeep*) induced facilitation relative to their unrelated counterparts (CAR-*dagger*). No clear effects were observed at SOAs of 0 and +100 milliseconds, which is in conflict with the vast majority of PWI studies utilising subordinate-level names as distractors. The reason for this discrepancy is not fully understood.

Interim summary

Overall, between-level interference, namely that distractors that bear hierarchical relations to targets (being drawn from either a subordinate or superordinate category) are capable of inducing interference as long as they are drawn from the same semantic category, appears to be a genuine effect. This does not allow differentiation between the rival accounts, however. Both the lexical selection-by-competition and the REH account are plausible candidates. Moreover, some discrepancies emerged which should ideally be resolved by future research. Interference for basic-level distractors relative to superordinate-level names in the absence of semantic relatedness was observed in two studies but discredited in two others. Interference for subordinate-level distractors that are semantically related to targets relative to their unrelated counterparts observed in several studies appeared as facilitation in another study. Furthermore, the lack of fully-crossed factorial designs in which semantic relatedness, SOA and level of specificity of distractors with all levels of abstraction (basic-, subordinate- and superordinate-level) were manipulated creates a need for more research. Although this was partially achieved by Kuipers et al. (2006), the manipulation was restricted to basic-level and superordinate-level names only. The emerging picture thus raises the question of whether the absence of interaction between semantic relatedness and level of specificity would extend to subordinate-level distractors and whether picture naming in the presence of subordinate-level distractors would differ from that in the presence of basic-level and superordinate-level distractors. Comparing picture naming performance for basic-, subordinate-, and superordinate-level distractors could have further implications for lexical selection accounts because each type is associated with different processes. For example, when comparing the following pairs, DOG-*animal* and DOG-*Spaniel*, the pictorial and semantic information supplied by both distractor words will interact differently with the pictorial and semantic information supplied by the targets – the superordinate category name *animal* should be rejected more quickly, in accordance with the CEH, because accepting a four-legged creature with a tail as an ANIMAL should take less time than deciding whether or not the picture depicts a SPANIEL.

Table 5. Manipulation of hierarchical target-distractor relations

Authors (year), **study** [language]	Subjects	Items	Task ("correct response")	SOA/ cue onset	target $_{[type]}$ – distractor $_{[type, modality]}$	Finding	target $_{[type]}$ – distractor $_{[type, modality]}$	Statistics
Costa et al., (2003); **Exp 3** [English] , *hypernymic distractors*	31	20	Name the target using a basic-level name ("bicycle")	SOA = 0 ms	BICYCLE$_{[drawing]}$ - horse $_{[unrelated, basic-level word, visual]}$	> [18 ms]$^{*/*}$	BICYCLE$_{[drawing]}$ - weapon $_{[unrelated, superordinate word, visual]}$	*t1*(30) = 2.41, *p* < .02; *t2*(19) = 2.09, *p* < .05.
Costa et al., (2003); **Exp 4; Group 3** [English], *hyperymic distractors*	32	15	Name the target using a basic-level name ("house")	SOA = 0 ms	HOUSE$_{[drawing]}$ - *apple* $_{[unrelated, basic-level word, visual]}$	> [17 ms]$^{*/*}$	HOUSE$_{[drawing]}$ - *fruit* $_{[unrelated, superordinate word, visual]}$	*t1*(31) = 2.75, *p* < .01; *t2*(14) = 3.01, *p* < .01.
Hantsch et al., (2005); **Exp 1** [German], *hyponymic distractors*	32	24	Name the target using a basic-level name ("monkey")	SOA = 0 ms	MONKEY$_{[drawing]}$ - *chimpanzee* $_{[related, subordinate word, auditory]}$	> [42 ms]$^{*/*}$	MONKEY$_{[drawing]}$ - *Porsche* $_{[unrelated, subordinate word, auditory]}$	*t1*(31) = 4.45, *p* < .001; *t2*(23) = 3.65, *p* < .01
				SOA = +100 ms	MONKEY$_{[drawing]}$ - *chimpanzee* $_{[related, subordinate word, auditory]}$	> [27 ms]$^{*/*}$	MONKEY$_{[drawing]}$ - *Porsche* $_{[unrelated, subordinate word, auditory]}$	*t1*(31) = 4.68, *p* < .001*;* *t2*(23) = 2.49, *p* < .05;
				SOA = +200 ms	MONKEY$_{[drawing]}$ - *chimpanzee* $_{[related, subordinate word, auditory]}$	> [3 ms]$^{ns/ns}$	MONKEY$_{[drawing]}$ - *Porsche* $_{[unrelated, subordinate word, auditory]}$	*ts* < 1 (no other statistics reported)
				SOA = +300 ms	MONKEY$_{[drawing]}$ - *chimpanzee* $_{[related, subordinate word, auditory]}$	[0 ms]	MONKEY$_{[drawing]}$ - *Porsche* $_{[unrelated, subordinate word, auditory]}$	*ts* < 1 (no other statistics reported)
Hantsch et al., (2005); **Exp 2** [German] *replication of Exp 1 but with one exemplar from each semantic category*	32	24	Name the target using a basic-level name ("monkey")	SOA = 0 ms	MONKEY$_{[drawing]}$ - *chimpanzee* $_{[related, subordinate word, auditory]}$	> [39 ms]$^{*/*}$	MONKEY$_{[drawing]}$ - *Porsche* $_{[unrelated, subordinate word, auditory]}$	*t1*(31) = 4.88, *p* < .001; *t2*(23) = 3.77, *p* < .001
				SOA = +100 ms	MONKEY$_{[drawing]}$ - *chimpanzee* $_{[related, subordinate word, auditory]}$	> [25 ms]$^{*/*}$	MONKEY$_{[drawing]}$ - *Porsche* $_{[unrelated, subordinate word, auditory]}$	*t1*(31) = 2.08, *p* < .05*;* *t2*(23) = 2.88, *p* < .01
				SOA = +200 ms	MONKEY$_{[drawing]}$ - *chimpanzee* $_{[related, subordinate word, auditory]}$	< [4 ms]$^{ns/ns}$	MONKEY$_{[drawing]}$ - *Porsche* $_{[unrelated, subordinate word, auditory]}$	*ts* < 1 (no other statistics reported)

				SOA = +300 ms	MONKEY$_{\text{[drawing]}}$ - *chimpanzee* $_{\text{[related, subordinate word, auditory]}}$	[0 ms]	MONKEY$_{\text{[drawing]}}$ - *Porsche* $_{\text{[unrelated, subordinate word, auditory]}}$	*ts* < 1 (no other statistics reported)
Hantsch et al., (2005); **Exp 4** [German], *hyponymic distractors*	32	20	Name the target using a basic-level name ("fish")	SOA = +80 ms	FISH$_{\text{[photo]}}$ - *shark* $_{\text{[related, subordinate word, auditory]}}$	> [42 ms]$^{*/*}$	FISH$_{\text{[photo]}}$ - *Barbie* $_{\text{[unrelated, subordinate word, auditory]}}$	$t1(31) = 7.22$, $p < .001$; $t2(19) = 4.22$, $p < .001$;
				SOA = +100 ms	FISH$_{\text{[photo]}}$ - *shark* $_{\text{[related, subordinate word, auditory]}}$	> [39 ms]$^{*/*}$	FISH$_{\text{[photo]}}$ - *Barbie* $_{\text{[unrelated, subordinate word, auditory]}}$	$t1(31) = 5.43$, $p < .001$; $t2(19) = 4.61$, $p < .001$;
				SOA = +200 ms	FISH$_{\text{[photo]}}$ - *shark* $_{\text{[related, subordinate word, auditory]}}$	> [3 ms]$^{ns/ns}$	FISH$_{\text{[photo]}}$ - *Barbie* $_{\text{[unrelated, subordinate word, auditory]}}$	*ts* < 1 (no other statistics reported)
				SOA = +300 ms	FISH$_{\text{[photo]}}$ - *shark* $_{\text{[related, subordinate word, auditory]}}$	< [2 ms]$^{ns/ns}$	FISH$_{\text{[photo]}}$ - *Barbie* $_{\text{[unrelated, subordinate word, auditory]}}$	*ts* < 1 (no other statistics reported)
Hantsch et al. (2012); **naming condition**; [German], *hyponymic distractors*	36	20	Name the target using a basic-level name ("dog") (basic-level names practiced during familiarisation phase)	SOA = -100 ms	POODLE$_{\text{[photo]}}$ - *poodle* $_{\text{[related, subordinate word, auditory]}}$	> [17 ms]$^{*/*}$	POODLE$_{\text{[photo]}}$ - *tulip*$_{\text{[unrelated, subordinate word, auditory]}}$	$F1(1, 35) = 14.85$, $MSE = 1{,}644.68$, $p < .001$; $F2(1, 19) = 7.32$, $MSE = 2{,}039.44$, $p < .05$; semantic relatedness x SOA: *Fs* < 1
				SOA = 0 ms	POODLE$_{\text{[photo]}}$ - *poodle* $_{\text{[related, subordinate word, auditory]}}$	> [22 ms]$^{*/*}$	POODLE$_{\text{[photo]}}$ - *tulip*$_{\text{[unrelated, subordinate word, auditory]}}$	$F1(1, 35) = 14.85$, $MSE = 1{,}644.68$, $p < .001$; $F2(1, 19) = 7.32$, $MSE = 2{,}039.44$, $p < .05$; semantic relatedness x SOA: *Fs* < 1
				SOA = +100 ms	POODLE$_{\text{[photo]}}$ - *poodle* $_{\text{[related, subordinate word, auditory]}}$	> [25 ms]$^{*/*}$	POODLE$_{\text{[photo]}}$ - *tulip*$_{\text{[unrelated, subordinate word, auditory]}}$	$F1(1, 35) = 14.85$, $MSE = 1{,}644.68$, p < .001; $F2(1, 19) = 7.32$, $MSE = 2{,}039.44$, $p < .05$; semantic relatedness x SOA: *Fs* < 1

Kuipers et al., (2006); **Exp 1A** [Dutch] , hypernymic distractors	18	30	Name the target using a basic-level name ("dog")	SOA = 0 ms	DOG$_{[picture]}$ - *cow* [related, basic-level word, visual]	> [32 ms]$^{*/*}$	DOG$_{[picture]}$ - *tomato* [unrelated, basic-level word, visual]	Semantic relatedness: *F1*(1, 17) = 33.1, *p* < .001; *F2*(1, 29) = 36.7, p < .001. Level of categorisation: *F1* < 1; F2 < 1. Semantic relatedness x level of categorisation: *F1* < 1; *F2* < 1.
				SOA = 0 ms	DOG$_{[picture]}$ - *animal* [related, superordinate word, visual]	> [32 ms]$^{*/*}$	DOG$_{[picture]}$ - *vehicle* [unrelated, superordinate word, visual]	
				SOA = 0 ms	DOG$_{[picture]}$ - *cow* [related, basic-level word, visual]	> [42 ms]$^{*/*}$	DOG$_{[picture]}$ - *vehicle* [unrelated, superordinate word, visual]	
				SOA = 0 ms	DOG$_{[picture]}$ - *animal* [related, superordinate word, visual]	> [22 ms]$^{*/*}$	DOG$_{[picture]}$ - *tomato* [unrelated, basic-level word, visual]	
				SOA = 0 ms	DOG$_{[picture]}$ - *cow* [related, basic-level word, visual]	> [10 ms]$^{ns/ns}$	DOG$_{[picture]}$ - *animal* [related, superordinate word, visual]	
				SOA = 0 ms	DOG$_{[picture]}$ - *tomato* [unrelated, basic-level word, visual]	> [10 ms]$^{ns/ns}$	DOG$_{[picture]}$ - *vehicle* [unrelated, superordinate word, visual]	
Bölte et al., (2013); **Exp 2** [German], *hyponymic distractors*	56	48	Name the target using a basic-level name ("guitar")	SOA = -100 ms	GUITAR$_{[picture]}$ - *mandolin* [related, subordinate word, visual]	> [35 ms]$^{*/*}$	GUITAR$_{[picture]}$ - *oleander* [unrelated, subordinate word, visual]	*F1*(1, 55) = 14.128, *MSE* = 4,605, *p* < .001; *F2*(1, 47) = 6.542, *MSE* = 8,956, *p* = .014,
				SOA = -100 ms	GUITAR$_{[picture]}$ - *trombone* [related, basic-level word, visual]	> [20 ms]$^{*/ns}$	GUITAR$_{[picture]}$ - *oleander* [unrelated, subordinate word, visual]	*F*1(1, 55) = 4.074, *MSE* = 5,355, *p* = .048; F2(1, 47) = 3.029, *MSE* = 6,858, *p* = .088,
				SOA = -100 ms	GUITAR$_{[picture]}$ - *mandolin* [related, subordinate word, visual]	> [14 ms]$^{ns/ns}$	GUITAR$_{[picture]}$ - *trombone* [related, basic-level word, visual]	*t1*(55) = 1.3, *p* = .194; *t2*(47) = 1.3, *p* = .187

Roelofs (1992) [Dutch], hypernymic and *hyponymic distractors*	18	9	Name the target using a basic-level name ("car")	SOA = -100 ms	CAR$_{\text{[picture]}}$ - *jeep* [related, subordinate word, visual]	< [29 ms]	CAR$_{\text{[picture]}}$ - *dagger* [unrelated, subordinate word, visual]	Level of abstraction: $F1(2,34) = 0.78$, $p > .4$; $F2(2,16) = 0.68$, $p > .5$). SOA x abstraction level: $F1(4,68) = 1.09$, $p > .3$; $F2(4,32) = 0.69$, $p > .6$; no other statistics provided;
				SOA = -100 ms	CAR$_{\text{[picture]}}$ - *vehicle* [related, superordinate word, visual]	< [8 ms]	CAR$_{\text{[picture]}}$ - *plant* [unrelated, superordinate word, visual]	No other statistics provided;
				SOA = -100 ms	CAR$_{\text{[picture]}}$ - *tractor* [related, basic-level word, visual]	< [21 ms]	CAR$_{\text{[picture]}}$ - *house* [unrelated, basic-level word, visual]	No other statistics provided;
				SOA = 0 ms	CAR$_{\text{[picture]}}$ - *jeep* [related, subordinate word, visual]	> [5 ms]	CAR$_{\text{[picture]}}$ - *dagger* [unrelated, subordinate word, visual]	No other statistics provided;
				SOA = 0 ms	CAR$_{\text{[picture]}}$ - *vehicle* [related, superordinate word, visual]	> [1 ms]	CAR$_{\text{[picture]}}$ - *plant* [unrelated, superordinate word, visual]	No other statistics provided;
				SOA = 0 ms	CAR$_{\text{[picture]}}$ - *tractor* [related, basic-level word, visual]	> [9 ms]$^{ns/ns}$	CAR$_{\text{[picture]}}$ - *house* [unrelated, basic-level word, visual]	$t1(17) = 0.99$, $p > .1$; $t2(8) = 1.44$, $p > .05$
				SOA = +100 ms	CAR$_{\text{[picture]}}$ - *jeep* [related, subordinate word, visual]	< [10 ms]	CAR$_{\text{[picture]}}$ - *dagger* [unrelated, subordinate word, visual]	No other statistics provided;
				SOA = +100 ms	CAR$_{\text{[picture]}}$ - *vehicle* [related, superordinate word, visual]	< [3 ms]	CAR$_{\text{[picture]}}$ - *plant* [unrelated, superordinate word, visual]	No other statistics provided;
				SOA = +100 ms	CAR$_{\text{[picture]}}$ - *tractor* [related, basic-level word, visual]	> [6 ms]	CAR$_{\text{[picture]}}$ - *house* [unrelated, basic-level word, visual]	No other statistics provided;

2.5.2.1.1.2 Semantic distance relations

Semantic distance (also referred to as semantic gradient or semantic similarity) between targets and distractors is another aspect of the target-distractor relationship that has been systematically varied to constrain hypotheses on the nature of lexical access. Semantic distance is the degree of semantic overlap between a pair of items, which can be measured using a variety of methods. Most PWI studies with semantic distance manipulation have gathered subjective semantic similarity ratings from subjects, who estimated the degree of relatedness between individual concepts (e.g., “SPIDER-FLY”, “HOUSE-SWAN”) using Likert-type scales. Some studies have drawn on published feature production norms (e.g., McRae, Cree, Seidenberg, & McNorgan, 2005; Vigliocco et al., 2004), which are derived from lists of attributes generated in response to a given concept (e.g. KNIFE “is sharp” “used for cutting” “found in the kitchen”). Others have employed more objective techniques, such as Latent Semantic Analysis (LSA; Landauer, Foltz, & Laham, 1998), with semantic similarity scores derived from large corpora of text, and the Normalized Google Distance (NGD; Cilibrasi & Vitányi, 2007), with semantic similarity values based on the number of hits returned by the *Google* search engine for a given set of words. Understanding which method was applied to a given stimulus set is crucial because it can determine the polarity of the PWI effect.

Thirteen (11%) of the reviewed PWI studies have directly manipulated the semantic distance between distractors and targets, producing contradictory findings (see Table 6).

Of the thirteen, four studies (31%) (Mahon et al. 2007; Experiments 5, 5b, 6, and 7) found that target-distractor pairs that were closely related (e.g., HORSE-*zebra*) interfered less with picture naming than distantly related pairs (e.g., HORSE-*whale*). The results were not always clear-cut, however with discrepancies emerging within and across the experiments. Facilitation was observed when targets and distractors were presented simultaneously (SOA = 0 ms) in Experiment 5, 5b and 6, but using the same SOA, null results were reported in Experiments 7 & 7b, with facilitation constrained to an early SOA (-160 ms) in Experiment 7. The method used (subjective semantic similarity ratings) allowed assessment of the effect of within-category semantic distance, but may have underestimated the role of distinctive features of items (e.g., stripes for *zebra*). For example, an examination of the semantically close target-distractor pairs (e.g., HORSE-*zebra*) in Experiment 5 revealed that the majority of them were characterised by distinguishing features, which could have driven the facilitatory effect. Other factors, such as proportion of related trials, may also have contributed to the ease with which pictures in the context of semantically close distractors were named. For example, when as many as half of the trials were related, the semantic distance effect emerged at the SOA of -160 milliseconds. Greater relatedness proportion increases the chances of strategy development and so presenting a semantically close distractor ahead of the target could have led to expectancy generation, facilitating naming. When the number of trials was reduced to 38% (Experiment 7b), and the relation between the stimuli became less predictable, no semantic distance effect was observed.

Facilitation for semantically close items is compatible with the REH account, which assumes larger conceptual priming for a greater degree of semantic overlap. Since both distractors are words (i.e., they enter the articulatory buffer ahead of the picture's name) and both are equally plausible as responses (the REH does not differentiate based on a semantic distance criterion, and so exclusion times should be identical), no interference ensues, and the net result is facilitation. The finding that picture naming is slowed when the semantic distance between targets and distractors increases is problematic for competitive accounts as well as the CEH hypothesis.

Four studies (31%) (Hutson & Damian, 2014; Experiments 1 & 2; Lupker, 1979; Experiment 3; Mahon et al., 2007; Experiment 7b) reported no effect of semantic distance; here too, however the studies were not free from methodological problems. In Lupker (1979), the matching of items on the psycholinguistic variables known to affect naming speed across the two semantic distance conditions, close or typical (e.g. BANANA-*peach*) and far, or atypical (e.g., BANANA-*lime*), and the size of the item set (n = 10) were less than optimal. Hutson & Damian (2014) failed to replicate the facilitation effect for semantically close distractors reported by Mahon et al. (2007) and the semantic gradient effect (decreased interference with increasing semantic distance) reported by Vigliocco et al., (2004; Experiment 3). Removing the more problematic items from the analysis did not affect the null results. Although there was an indication of interference for semantically close items when the NGD method was applied to the data (Hutson & Damian, 2014; Experiment 2), the lack of correlation between semantic distance scores computed with this method and LSA scores and subjective ratings of semantic similarity undermines its construct validity. The interpretation of data is complicated further by power issues, with power for a medium-effect size based on the number of participants and conditions being .38 in Experiment 1, and .88 in Experiment 2 (Hutson & Damian, 2014).

The null results are hard to reconcile with the predictions of the REH account, which assumes a facilitatory effect (facilitation due to semantic priming between distractors and targets, which is greater in the case of semantically close items) unless it is cancelled out by interference due to the response relevance confound. Since both semantically close and distant distractors satisfy the semantic response criterion (naming an animal), no such confound was present. Neither can the null results be explained easily by the selection-by-competition account because semantically close distractors are likely to be more strongly activated by the target picture than their semantically distant items. The SLNH also predicts a net inhibitory effect for semantically close distractors because these tend to activate smaller semantic cohorts with greater resonance within the lexical network and stronger activation of distractor words.

The finding that picture naming is increasingly delayed with diminishing semantic distance between targets and distractors was reported in five (38%) studies (Aristei & Abdel Rahman, 2013; Rose, Aristei, Melinger, & Abdel Rahman, 2019; Vieth, McMahon, & de Zubicaray, 2014a; Experiments 1 & 2; Vigliocco et al., 2004; Experiment 3). A significant linear trend was observed in Vigliocco et al. (2004; Experiment 3) at the SOA of -150 milliseconds, with shorter naming latencies for smaller feature overlap. It is not certain, however, if the trend would have persisted had the unrelated ("far") distractor items been removed from the analysis. The design of the study also suffers from several flaws, for example, unequal repetition of distractors within (e.g., *hatchet* repeated three times in the "close" condition) and across semantic distance conditions, with some pairs being associatively (e.g., TROUSERS-*belt*) and phonologically related (e.g., BANANA-*broom*). Vieth et al. (2014a; Experiment 1) reported the semantic distance effect, but only with an early distractor onset (SOA = -160 ms). Picture naming latencies decreased with diminishing conceptual feature overlap (Vieth et al., 2014a; Experiment 2). Semantic similarity was the most reliable predictor of picture naming latencies, when distractors were presented aurally (SOA = -100 ms), accounting not only for the effects of categorical relatedness, but also for the effects of response relevance (Aristei & Abdel Rahman, 2013). Rose et al. (2019) observed interference for within-category semantically close items at the SOA of 0 milliseconds despite a high relatedness proportion (67%) and with distractors included in the response set.

Interference observed in the presence of distractors that are semantically close to targets is consistent with the assumptions of competitive accounts of lexical selection, according to which the effect of semantically related words on lexical competition is enhanced by the strength of activation spread between concepts as a function of their semantic feature overlap. The finding is problematic for non-competitive accounts, which predict greater facilitation for greater feature overlap. The inhibitory effect could also potentially originate during pre-lexical stages, in support of the CEH account. For example, in the case of a close semantic pair, (ANT-*spider*) as opposed to a distant semantic pair (ANT-*beaver*), deciding whether one sees an ANT or a SPIDER would take longer than recognising the picture as an ANT with a structural or conceptual representation of BEAVER in one's mind. The fact that *interference* for semantically close pairs in the majority of studies was restricted to early SOAs would additionally argue for a pre-lexical (structural and/or conceptual) locus of the semantic distance effect.

Interim summary

Overall, the evidence for the semantic distance effect is inconclusive. Inconsistent results are compounded by methodological problems present in both groups of studies, those showing facilitation and those reporting interference. Consequently, until these problems and the discrepancies between individual studies are resolved, the semantic distance effect should be viewed with caution when discussing the competitive nature of spoken word production.

Table 6. Manipulation of the semantic distance between targets and distractors

Authors (year), **study,** [language], *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target $_{[type]}$ – distractor $_{[type, modality]}$	Finding	target $_{[type]}$ – distractor $_{[type, modality]}$	Statistics
Mahon et al., (2007); **Exp 5** [English]; *subjective ratings of semantic distance;*	20	20	Name the target picture ("horse")	SOA = 0 ms	HORSE $_{[drawing]}$ - *zebra* $_{[close, word, visual]}$	< [41 ms]$^{*/*}$	HORSE $_{[drawing]}$ - *whale* $_{[distant, word, visual]}$	$t1(19) = 5.5$, $p < .001$; $t2(19) = 4.9$, $p < .001$
Mahon et al., (2007); **Exp 5b** [English] *replication of Exp 5; subjective ratings of semantic distance;*	32	24	Name the target picture ("horse")	SOA = 0 ms	HORSE $_{[drawing]}$ - *zebra* $_{[close, word, visual]}$	< [20 ms]$^{*/*}$	HORSE $_{[drawing]}$ - *whale* $_{[distant, word, visual]}$	$t1(31) = 3.0$, $p < .006$; $t2(23) = 2.4$, $p < .03$
Mahon et al., (2007); **Exp 6** [English]	32	22	Name the target picture ("banjo")	SOA = 0 ms	BANJO $_{[drawing]}$ - *guitar* $_{[close, word, visual]}$	< [16 ms]$^{*/ns}$	BANJO $_{[drawing]}$ - *trumpet* $_{[distant, word, visual]}$	$F1(1, 31) = 5.5$, $p < .03$, $\eta_p^2 = .15$; $F2(1, 21) = 2.7$, $p = .11$, $\eta_p^2 = .12$.
Mahon et al., (2007); **Exp 7** [English]; *percentage of related trials 50%; norms of Cree & McRae (2003) and subjective ratings of semantic distance;*	16	36 x 3	Name the target picture ("carrot")	SOA = -160 ms	CARROT $_{[drawing]}$ - *yam* $_{[close, word, visual]}$	< [16 ms]$^{*/*}$	CARROT $_{[drawing]}$ - *spinach* $_{[distant, word, visual]}$	$p1 <. 02$, $\eta_p^2 = .34$; $p2 < .03$, $\eta_p^2 = .13$; no other statistic reported;
				SOA = 0 ms	CARROT $_{[drawing]}$ - *yam* $_{[close, word, visual]}$	> [4 ms]$^{ns/ns}$	CARROT $_{[drawing]}$ - *spinach* $_{[distant, word, visual]}$	*Fs* < 1; no other statistic reported;
				SOA = +160 ms	CARROT $_{[drawing]}$ - *yam* $_{[close, word, visual]}$	< [10 ms]$^{ns/ns}$	CARROT $_{[drawing]}$ - *spinach* $_{[distant, word, visual]}$	$p1 = .14$, $\eta_p^2 = .14$; $p2 = .20$, $\eta_p^2 = .05$; no other statistic reported;
Mahon et al., (2007); **Exp 7b** [English]; *replication of Exp 7 with relatedness proportion reduced to 38%;*	36	36	Name the target picture ("carrot")	SOA = 0 ms	CARROT $_{[drawing]}$ - *yam* $_{[close, word, visual]}$	[0 ms]	CARROT $_{[drawing]}$ - *spinach* $_{[distant, word, visual]}$	*ps* > .05; no other statistic reported;
Lupker (1979); **Exp 3** [English]; *typicality norms*	20	10	Name the target picture ("dog")	SOA = 0 ms	DOG $_{[drawing]}$ - *lion* $_{[close, word, visual]}$	< [6 ms]$^{ns/ns}$	DOG $_{[drawing]}$ - *beaver* $_{[distant, word, visual]}$	No relevant statistic provided;

Vigliocco et al., (2004); **Exp 3** [English] *FUSS norms*	36	24	Name the target picture ("camel")	SOA = -150 ms	CAMEL [drawing] – *zebra* [very close, word, visual]	> [14 ms]	SHEEP [drawing] - *mouse*[close, word, visual]	Trend analysis: *F*1(1,35) = 5.59, *p* = .024; *F2*(1,23) = 4.71, *p* = .041; no data for individual comparisons provided;
				SOA = -150 ms	CAMEL [drawing] – *zebra* [very close, word, visual]	> [23 ms]	SHEEP [drawing] - *swan*[medium close, word, visual]	No data for individual comparisons provided;
				SOA = -150 ms	CAMEL [drawing] – *zebra* [very close, word, visual]	> [29 ms]	SHEEP [drawing] - *sofa*[unrelated, word, visual]	No data for individual comparisons provided;
Hutson & Damian (2014); **Exp 1** [English]; *replication of Vigliocco et al. (2004; Exp 3) with minor procedural differences*	26	24	Name the target picture ("hat")	SOA = 0 ms	HAT [drawing] - *scarf*[very close, word, visual]	> [5 ms]$^{ns/ns}$	HAT [drawing] - *shoe*[close, word, visual]	*t1* ≥ .55, *p* ≤ .585; *t2* ≥ .33, *p* ≤ .743; no other statistics provided;
					HAT [drawing] - *scarf*[very close, word, visual]	> [2 ms]$^{ns/ns}$	HAT [drawing] - *belt*[medium, word, visual]	*t1* ≥ .55, *p* ≤ .585; *t2* ≥ .33, *p* ≤ .743; no other statistics provided;
Hutson & Damian (2014); **Exp 2** [English] *replication of Mahon et al. (2007) with minor procedural differences*	64	16	Name the target picture ("kettle")	SOA = 0 ms	KETTLE [drawing] - *pot* [close, word, visual]	> [4 ms]$^{ns/ns}$	KETTLE [drawing] - *spoon* [far, word, visual]	*t1* = .67, *p* = .503; *t2* = .48, *p* = .636.
Vieth et al. (2014a). **Exp 1** [English] ; *feature generation norms by McRae et al. (2005) ; with relatedness proportion of 50%*	16	36	Name the target picture ("bicycle")	SOA = -160 ms	BICYCLE [drawing] - *scooter* [close, word, visual]	> [19 ms]$^{*/*}$	BICYCLE [drawing] - *aeroplane* [far, word, visual]	*t1*(15) = 2.53, *p* < .05; *t2*(35) = 3.30, *p* < .05, 9
				SOA = 0 ms	BICYCLE [drawing] - *scooter* [close, word, visual]	> [12 ms]$^{ns/ns}$	BICYCLE [drawing] - *aeroplane* [far, word, visual]	*t2*(35) = 1.8, *p* = .08; does not report *t1* statistics as main effect of semantic distance at this SOA only marginally significant by subjects;

				SOA = +160 ms	BICYCLE [drawing] - *scooter* [close, word, visual]	[0 ms]	BICYCLE [drawing] - *aeroplane* [far, word, visual]	*F1*(2,30) = 0.29, *p* = .75; *F2*(2,70) = .091; *p* = .41
Vieth et al., (2014a). **Exp 2** [English]; *feature generation norms by McRae et al. (2005)*	64	36	Name the target picture ("ant")	SOA = -160 ms	ANT [drawing] - *spider* [very close, word, visual]	> [18 ms]	ANT [drawing] - *beetle* [close, word, visual]	Linear trend for related items, with RTs decreasing from very close to very far distractors: *F1*(1,55) = 7.3, *p* = .03, η_p^2 = .12; *F2*(1,35) = 5.97, *p* < .003, η_p^2 = .15
					ANT [drawing] - *spider* [very close, word, visual]	> [16 ms]	ANT [drawing] - *crab* [middle, word, visual]	No other statistics provided
					ANT [drawing] - *spider* [very close, word, visual]	> [16 ms]*/*	ANT [drawing] - *sparrow* [far, word, visual]	*t1*(63) = 3.08, *p*= .003; *t2*(35) = 1.68, *p*= .01
					ANT [drawing] - *spider* [very close, word, visual]	> [19 ms]	ANT [drawing] - *otter* [very far, word, visual]	No other statistics provided
Rose et al., (2019). [German]; *no ratings or norms reported;*	24	125	Name the target picture ("eagle")	SOA = 0 ms	EAGLE [photo] - *owl* [close, word, visual]	> [13 ms]*/*	EAGLE [photo] - *gorilla*[distant, word, visual]	*t1*(23) = 3.2, *p* = .003; *t2*(124) = 2.3, *p* = .023
Aristei & Abdel Rahman (2013). [German]; *semantic similarity ratings on a 5-point scal*e;	30	100	Name the target picture ("yacht")	SOA = -100 ms	YACHT [photo] - *galleon*[close, word, auditory]	N/A	YACHT [photo] - *carriage*[distant, word, auditory]	Model II: β = 8.839, *t* = 3.99; Model III: β = 6.977, *t* = 6.27 (t-values larger than 2 are considered significant)

2.5.2.1.2 Non-categorical relations

2.5.2.1.2.1 Miscellaneous associative relations

Associative target-distractor relations in PWI studies form a highly heterogeneous group and their operational definitions vary depending on source. For example, they may be understood in terms of the frequency of co-occurrence in language use (how often two words appear as close neighbours in written and/or spoken texts; e.g., Spence & Owens, 1990), or be determined through free association norms obtained from subjects' verbal associations generated to lexical cues (e.g., Alario, Segui, & Ferrand, 2000; Sailor, Brooks, Bruening, Seiger-Gardner, & Guterman, 2009). Two associatively related items may also be defined as loosely belonging to the same semantic field but being derived from different semantic categories (e.g., Abdel Rahman & Melinger, 2007). Due to the lack of a unanimous definition, the relations will be discussed further under the umbrella term of miscellaneous associative relations, as distinct from associative relations that reflect whole-part relations (e.g., SHIP-*anchor*) and functional/thematic relations (e.g., DESERT-*camel*).

Of the reviewed PWI studies, eighteen (15%) examined whether miscellaneous associates and non-associates exert different effects on picture naming, with mixed results (for results, see Table 7).

While there are practically no reports of interference induced by non-categorical associates (i.e., associatively related distractors from a different semantic category than targets, MOUSE-*cheese*), in five studies (28%), they were found neither to precipitate nor to delay picture naming (Alario et al., 2000; Experiment 1b; Bölte et al., 2015; Experiment 2; Cutting & Ferreira, 1999; Experiment 3A; non-homophone condition; Mahon et al., 2007; Experiment 6c; and Lupker, 1979; Experiment 1).

The null results are difficult to reconcile with the REH account, which predicts facilitation through semantic priming (e.g., CARROT primes RABBIT) unless it is offset by interference arising from the confound of response relevance. Both the associated distractor ("carrot") and its non-associated counterpart ("station") are equally implausible as responses in the task of naming an animal (RABBIT). The confound is therefore eliminated and facilitation should thus remain the dominant force. The null results find a reasonable explanation in the SLNH, however. The latter assumes no interference if the lexical activation of the associated distractor is stronger than that of its non-associated control, but not strong enough to outweigh facilitation at the conceptual level. In the case of associated distractors (RABBIT-*carrot*) the spread of activation is thought to be more widely dispersed, with relatively little recursion within the semantic and lexical networks, and therefore weaker lexical activation of interfering stimuli compared to categorical co-coordinates (RABBIT-*horse*). The failure to detect an effect can also be attributed to some procedural details. For example, associated distractors produced comparable effects to their unrelated controls but only under brief stimuli exposure (Alario et al., 2000; Experiment 1b; Bölte et al., 2015; Experiment 2). A facilitatory effect emerged in two other studies by the same authors (Alario et al., 2000; Experiment 2b; Bölte et al., 2015; Experiment 1) when the timing of stimuli exposure was prolonged. Methodological factors could also have played their part in one of the studies by Mahon et al. (2007; Experiment 6c), in which association norms were exceptionally obtained from a word association test rather than published free association norms. In three additional studies, associated distractors failed to induce any effects solely at later SOAs (0, +150, and +300 ms; Brooks, Seiger-Gardner, & Sailor, 2014; Experiment 1; Sailor et al., 2009; Experiment 1 & 2).

In two (11%) studies, adding associative strength to categorical relations conferred neither advantage nor disadvantage to picture naming (La Heij, Dirkx, & Kramer, 1990; Experiments 2; Lupker, 1979; Experiment 2). Naming reaction times in the strongly associated co-ordinate condition (e.g., HAND-*foot*) were equivalent to naming reaction times in the non-associated co-ordinate condition (e.g., HAND-*ankle*), indicating that the effect of associative relation was negligible. However, methodological flaws (e.g., inadequate matching of item sets, small item sets with repetitive naming of targets) and insufficient statistical power may have contributed to type II error.

In 66% of the studies utilising non-categorical associates as distractors, miscellaneous associative relations were shown to speed up naming relative to their unrelated controls, irrespective of their modality (visual or auditory), but primarily with early stimulus onset asynchronies (i.e., SOAs < 0 ms). Six (33%) studies reported faster picture naming for associated distractors when these were presented prior to target onset (Alario et al., 2000; Experiment 2b; Bölte et al., 2015; Experiment 3; Brooks et al., 2014, Experiment 1; La Heij et al., 1990; Experiment 2; and Sailor et al., 2009; Experiments 1 & 2). In six (33%) studies, facilitation was also observed when targets and distractors were presented simultaneously (SOA = 0 ms), however, this finding was restricted to analysis by subjects only in half of these studies (Sailor et al., 2009; Experiment 2; Bölte et al., 2015; Experiment 1; Brooks et al. 2014; Experiment 1, Damian & Spalek, 2014; Mahon et al. , 2007; Experiment 1, 2 & 2b).

Competitive and non-competitive views have furnished their own interpretations of these results. Facilitatory effects for associatively related distractors are in line with the SLNH and are thought to reflect the trade-off between conceptual priming and lexical competition. The net outcome is facilitatory because non-categorical associates in the activated cohort are more dispersed resulting in less recursion and weaker activation of the distractor at the lexical level. This is supported further by the changing polarity of the effect that is facilitatory for strongly associated co-ordinates (e.g., LEG-*arm*), but disappears for weakly associated co-ordinates (e.g., LEG-*head*) at early SOAs, and that is non-existent for strongly associated co-coordinates at SOA of 0 ms, reappearing as interference for weakly related co-ordinates. Facilitation for associatively related distractors is also consistent with the REH account because both associated and non-associated distractors fulfil the response relevance criterion to the same extent (both are nonviable responses), so they are cleared from the articulatory buffer at equivalent times, causing no delay. Facilitatory effects are neither at odds with the CEH account because structural information supplied by both types of distractors (associated and non-associated) should result in the same level of interference, which appears to be negligible, or at the very least insufficiently strong to cancel out facilitation due semantic priming.

Interim summary

Overall, there is only weak evidence to suggest that associative relations exert no effect on the speed with which pictures are named. The null results can reflect a trade-off between conceptual priming and lexical interference, in accordance with the SLNH, but more likely than not, they are a consequence of methodological variations and low statistical power. There is compelling evidence that associatively related distractors precipitate naming, particularly when presented prior to target onset. This observation finds an explanation in both competitive and non-competitive views of lexical selection, and so cannot be used to falsify either of the hypotheses.

Table 7. Manipulation of miscellaneous associative target-distractor relations

Authors (year), **study** [language]; *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target [type] – distractor [type, modality]	Finding	target [type] – distractor [type, modality]	Statistics
Lupker (1979); **Exp 1** [English] ; *with bidirectional associates that are from a different semantic category; published free association norms*	20	11	Name the target picture ("mouse")	SOA = 0 ms	MOUSE [drawing] – *cheese* [non-categorical associate, word, visual]	< [1 ms]^{ns}	MOUSE [drawing] - *hand* [unrelated, word, visual]	*p* > .05; no other statistics provided;
Lupker (1979); **Exp2** [English]; *with bidirectional associates that are from the same semantic category; published free association norms*	20	9	Name the target picture ("chair")	SOA = 0 ms	CHAIR [drawing] - *table* [categorical associate, word, visual]	> [29 ms]*	CHAIR [drawing] - *butter* [unrelated, word, visual]	*p* > .05; no other statistics provided;
					CHAIR [drawing] - *lamp* [categorical non-associate, word, visual]	> [29 ms]*	CHAIR [drawing] - *butter* [unrelated, word, visual]	*p* > .05; no other statistics provided;
Cutting & Ferreira (1999); **Exp 3A, non-homophone condition;** [English]; *related but from a different semantic category*	36	27	Name the target picture ("apple")	SOA = -150 ms	APPLE [drawing] - *pie* [associate, word, auditory]	> [19 ms]$^{ns/ns}$	APPLE [drawing] - *mail* [unrelated, word, auditory]	$F1(1,70) = 3.13$, $p < .09$; $F2(1, 52) = 1.42$, $p > .05$
Alario et al., (2000); **Exp 1b** [French]; *published association norms*	20	20	Name the target picture ("boat")	SOA = -114 ms	BOAT [drawing] - *anchor* [non-categorical associate, word, visual]	< [3 ms]$^{ns/ns}$	BOAT [drawing] - *control* [unrelated, word, visual]	*ts* < 1; no other statistics provided;
Alario et al., (2000); **Exp 2b** [French]; *published association norms*	20	22	Name the target picture ("boat")	SOA = -234 ms (duration of 100 ms)	BOAT [drawing] - *anchor* [non-categorical associate, word, visual]	< [28 ms]$^{*/*}$	BOAT [drawing] - *control* [unrelated, word, visual]	$F1(1,38) = 6.6$, $p < .01$; $F2(1,19) = 15.4$, $p < .01$; type of relation x distractor duration: *Fs* < 1; No other statistics provided;

				SOA = -234 ms (duration of 200 ms)	BOAT [drawing] - *anchor* [non-categorical associate, word, visual]	< [41 ms]$^{*/*}$	BOAT [drawing] - *control* [unrelated, word, visual]	$F1(1,38) = 6.6$, $p < .01$; $F2(1,19) = 15.4$, $p < .01$; type of relation x distractor duration: $Fs < 1$; No other statistics provided;
Bölte et al., (2015); **Exp 1** [German]; *PPI paradigm*	38	15	Name the picture cued by an arrow ("shopping basket")	SOA = 0 ms/ cue onset: 600 ms	SHOPPING BASKET [drawing] - *barcode* [non-categorical associate, word, visual]	< [26 ms]*	SHOPPING BASKET [drawing] - *phone receiver* [unrelated, word, visual]	$t(37) = –2.517$, p = .016
Bölte et al. (2015). **Exp 2** [German]; *PPI paradigm*	40	15	Name the picture cued by an arrow ("shopping basket")	SOA = 0 ms/ cue onset: 200 ms	SHOPPING BASKET [drawing] - *barcode* [non-categorical associate, word, visual]	< [8 ms]^{ns}	SHOPPING BASKET [drawing] - *phone receiver* [unrelated, word, visual]	$t(39) = –0.654$, $p = .259$
Bölte et al., (2015); **Exp 3** [German]; *PPI paradigm*	20	15	Name the picture cued by an arrow ("shopping basket")	SOA = -200 ms	SHOPPING BASKET [drawing] - *barcode* [non-categorical associate, word, visual]	< [45 ms]*	SHOPPING BASKET [drawing] - *phone receiver* [unrelated, word, visual]	$t(19) = –3.644$, $p = .001$
La Heij et al., (1990); **Exp 2** [Dutch]; *published and own association norms*	10	14	Name the target picture ("leg")	SOA = -400 ms	LEG [drawing] - *arm* [strong categorical associate, word, visual]	< [69 ms]*	LEG [drawing] - *spoon* [unrelated, word, visual]	$F(1,9) = 39.9$, $p <.001$
				SOA = -400 ms	LEG [drawing] - *head* [weak categorical associate, word, visual]	> [4 ms]^{ns}	LEG [drawing] - *spoon* [unrelated, word, visual]	$p > .05$; no other statistics provided;
				SOA = 0 ms	LEG [drawing] - *arm* [strong categorical associate, word, visual]	> [3 ms]^{ns}	LEG [drawing] - *spoon* [unrelated, word, visual]	$p > .05$; no other statistics provided;
				SOA = 0 ms	LEG [drawing] - *head* [categorical, weak associate, word, visual]	> [17 ms]*	LEG [drawing] - *spoon* [unrelated, word, visual]	$F(1,9) = 6.1$, $p < .04$
La Heij et al., (1990); **Exp 3** [Dutch]; *published and own association norms*	10	14	Name the target picture ("leg")	SOA = +75 ms	LEG [drawing] - *arm* [strong categorical associate, word, visual]	> [22 ms]*	LEG [drawing] - *spoon* [unrelated, word, visual]	$F(1,9) = 6.3$, $p < .05$;
				SOA = +75 ms	LEG [drawing] - *head* [weak categorical associate, word, visual]	> [16 ms]^{ns}	LEG [drawing] - *spoon* [unrelated, word, visual]	p > .05; no other statistics provided;

				SOA = +150 ms	LEG [drawing] - *arm* [strong categorical associate, word, visual]	[?]	LEG [drawing] - *spoon* [unrelated, word, visual]	*p* > .05; no other statistics provided;
				SOA = +150 ms	LEG [drawing] - *head* [weak categorical associate, word, visual]	> [29 ms]*	LEG [drawing] - *spoon* [unrelated, word, visual]	*F*(1,9) = 5.2, *p* <. 05;
Sailor et al., (2009); **Exp 1** [English]; *published association norms and subjective ratings of semantic similarity*	24	30	Name the target picture ("rabbit")	SOA = -450 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	< [26 ms]*/*	RABBIT [drawing] - *station* [unrelated, word, visual]	*F1*(1, 184) = 15.19, *MSE* = 8,533, *p* < .001; *F2*(1, 232) = 6.98, *MSE* = 7,140, *p* < .01
				SOA = -150 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	< [21 ms]*/*	RABBIT [drawing] - *station* [unrelated, word, visual]	*F1*(1, 184) = 9.20, *MSE* = 5,168, *p* <.01; *F2*(1, 232) = 7.08, *MSE* = 7,247, *p* < .01
				SOA = +150 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	< [7 ms]ns	RABBIT [drawing] - *station* [unrelated, word, visual]	*p* > .05; no other statistics provided;
Sailor et al., (2009); **Exp 2** [English]; *published association norms and subjective ratings of semantic similarity*	24	30	Name the target picture ("rabbit")	SOA = -300 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	< [25 ms]*/*	RABBIT [drawing] - *station* [unrelated, word, visual]	*F1*(1, 184) = 21.00, *MSE* = 7,148, *p* < .001; *F2*(1, 232) = 12.16, *MSE* =8,828, *p* < .001
				SOA = 0 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	< [15 ms]*/ns	RABBIT [drawing] - *station* [unrelated, word, visual]	*F1*(1, 184) = 8.62, *MSE* = 2,934, *p* < .01; *F2*(1, 232) < 1.
				SOA = +300 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	< [7 ms]ns	RABBIT [drawing] - *station* [unrelated, word, visual]	*p* > .05; no other statistics provided;
Damian & Spalek (2014); **non-masked condition** [German]; *pre- and post-hoc ratings of association strength*	48	20	Name the target picture ("orange")	SOA = 0 ms	ORANGE [drawing] - *juice* [non-categorical associate, word, visual]	< [15 ms]*/ns	ORANGE [drawing] - *shoe* [unrelated, word, visual]	*t1*(47) = 2.31, *p* = .025*;* *t2*(19) = 1.65, *p* = .116
				SOA = 0 ms	ORANGE [drawing] - *lemon* [categorical associate, word, visual]	> [25 ms]*/*	ORANGE [drawing] - *lung*[unrelated, word, visual]	*t*(47) = 2.64, *p* = .011; *t2*(19) = 2.12, *p* = .047

				SOA = 0 ms	ORANGE [drawing] - *banana* [categorical non-associate, word, visual]	> [38 ms]$^{*/*}$	ORANGE [drawing] - *star*[unrelated, word, visual]	*t1*(47) = 5.34, *p* < .001; *t2*(19) = 4.66, *p* < .001
Mahon et al., (2007); **Exp 1** [English]	29	30	Name the target picture ("bed")	SOA = 0 ms	BED [drawing] - *sleep* [categorical associate, word, visual]	< [18 ms]$^{*/ns}$	BED [drawing] - *shoot* [unrelated, word, visual]	*t1*(28) = 4.5, *p* < .001; *t2*(29) = 1.8, *p* = .08
Mahon et al., (2007); **Exp 2** [English]	60	20	Name the target picture ("pencil")	SOA = 0 ms	PENCIL [drawing] - *write* [associate, word, visual]	< [21 ms]$^{*/*}$	PENCIL [drawing] - *speak* [unrelated, word, visual]	*F1*(1, 59) = 12.72, *p* < .002, η_p^2 = .18; *F2*(1, 19) = 5.26, *p* < .04, η_p^2 = .22
Mahon et al., (2007); **Exp 2b** [English]	23	25	Name the target picture ("crane")	SOA = 0 ms	CRANE [drawing] - *lift* [associate, word, visual]	< [23 ms]$^{*/*}$	CRANE [drawing] - *protect* [unrelated, word, visual]	*t1*(22) = 3.3, *p* < .004; *t2*(24) = 3.0, *p* < .007
Mahon et al., (2007); **Exp 6c** [English]; *association strength based on word association test*	15	20	Name the target picture ("rake")	SOA = 0 ms	RAKE [drawing] - *leaf* [associate, word, visual]	> [2 ms]^{ns}	RAKE [drawing] - *pond*[associate, word, visual]	*Fs* < 1
Brooks et al., (2014); **Exp 1** [English]; *with auditory and visual distractors; published association norms*	22	24	Name the target picture ("rabbit")	SOA = -300 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	< [31 ms]$^{*/*}$	RABBIT [drawing] - *station* [unrelated, word, visual]	*F1*(1,252) = 29.62, *p* = .0001, *F2*(1,276) = 21.35, *p* = .0001
				SOA = -150 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	< [19 ms]$^{*/*}$	RABBIT [drawing] - *station* [unrelated, word, visual]	*F1*(1,252) = 7.29, *p* = .007; *F2*(1,276) = 7.40, *p* = .007
				SOA = 0 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	> [3 ms]$^{ns/*}$	RABBIT [drawing] - *station* [unrelated, word, visual]	*F1*(1,252) = 16.62, *p* = .0001; *F2*(1,276) = 4.60, *p* = .033
				SOA = +150 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, visual]	> [4 ms]$^{ns/*}$	RABBIT [drawing] - *station* [unrelated, word, visual]	*F1*(1,252) = 2.54, *p* = .112; *F2*(1,276) = 21.40, p = .0001
				SOA = -300 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, auditory]	< [38 ms]$^{*/*}$	RABBIT [drawing] - *station* [unrelated, word, auditory]	*F1*(1,252) = 23.82, *p* = .0001; F2(1,276) = 9.81, *p* = .002

SOA = -150 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, auditory]	< [27 ms]$^{*/*}$	RABBIT [drawing] - *station* [unrelated, word, auditory]	*F1*(1,252) = 19.73, *p* = .0001; *F2* (1,276) = 8.70, *p* = .003
SOA = 0 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, auditory]	< [4 ms]$^{ns/ns}$	RABBIT [drawing] - *station* [unrelated, word, auditory]	*ps* > .05; no other statistics reported
SOA = +150 ms	RABBIT [drawing] - *carrot* [non-categorical associate, word, auditory]	[0 ms]	RABBIT [drawing] - *station* [unrelated, word, auditory]	*ps* > .05; no other statistics reported

2.5.2.1.2.2 Whole-part relations (meronymy)

As shown by the examples in the previous section, the materials in PWI studies with associative relation manipulation typically contain a mixture of different types of associations. 8.5% of studies (n = 10) have taken a more systematic approach to stimuli selection, however examining the effects of solely whole-part relations (e.g., CAMEL-*hump*) on picture naming (Costa et al., 2005; Experiments 1 & 2; Muehlhaus et al., 2013; Experiments 1 & 2; Vieth, McMahon, & de Zubicaray, 2014b; Experiments 1, 2 & 3) (see Table 8). Whole-part relations can be understood as relationships in which the target represents a whole, and the distractor its part. The latter is either a constituent of the object (e.g., FISH-*gills*; Costa et al., 2005), or denotes the stuff from which the object is made (e.g., CANDLE-*wax*; Muehlhaus et al., 2013). Whole-part relations can thus be said to include "has-a", "is-part-of", and "consists-of" relationships.

Facilitation for distractor words denoting parts was observed in five (50%) studies. In Costa et al. (2005; Experiments 1 & 2) and Muehlhaus et al. (2013; Experiment 1), this was the case when targets and distractors were presented simultaneously (SOA = 0 ms), while in Sailor et al. (2014; Experiments 1 and 3), facilitatory effects were evident only at the SOA of -300 milliseconds, and at the SOA of -150 milliseconds when part terms were also strongly associated with targets (e.g., AMBULANCE-*siren*). Shorter response latencies reported by Costa et al. (2005) and Muehlhaus et al. (2013; Experiment 1) for distractors denoting parts could therefore be an epiphenomenon of strong association between the items. The distractor words in Muehlhaus et al. were indeed selected based on free association norms. While this was not explicitly stated in Costa et al., closer inspection of their materials suggests that distractors denoting parts were strong associates of their targets (e.g., PEN-*ink*; CHURCH-*pew*).

The facilitatory effect found in PWI studies with whole-part relation manipulation invites two interpretations. The results reported in Costa et al. (2005), at least in Experiment 1, find a ready explanation in the REH account, which assumes default facilitation (due to the automatic spread of activation at the conceptual level) unless it is counterbalanced by interference ascribed to the response relevance confound. The unrelated condition in Experiment 1 contained distractors which represented whole objects, in contrast to distractors in the related (whole-part) condition which included words denoting parts; according to the REH, in the task in which the implicit rule is to name a whole object, rejecting a distractor word denoting a part as a plausible response is easier and therefore less time-consuming than rejecting a distractor word denoting a whole. Even when both related and unrelated distractor words denote parts (e.g., Costa et al., 2005; Experiment 2), the REH can still account for faster picture naming in the context of part terms because these tend to prime targets, which in the absence of response relevance confound, should lead to facilitation. The results also fit well in the SLNH framework, which predicts a facilitatory effect if there is automatic spread of activation within the conceptual network and weak or non-existent activation within the lexical network. In the example of BOTTLE-*cork* versus BOTTLE-*gills*, it is conceivable that the concept of a CORK will evoke the concept of a BOTTLE, whereas the concept of GILLS will not. The lexical node of *cork* may receive some activation from the concept of BOTTLE, which will, however, remain dominated by conceptual facilitation (due to greater dispersion and limited recursion within the networks), resulting in faster naming.

In five (50%) studies, whole-part relations did not reliably differ from their unrelated controls (Sailor & Brooks, 2014; Experiments 1, 2 & 3; Vieth et al., 2014b; Experiments 2 & 3). This was the case in all five studies when distractors were presented concurrently with the target (SOA = 0 ms) or after the target onset. No clear effects were registered at these SOAs, irrespective of whether the parts denoted by distractor words were visible in target pictures or not (visibility as a co-variate in a post-hoc analysis by Sailor & Brooks did not change the result), or of whether they denoted distinctive or non-distinctive parts of objects (e.g., AMBULANCE-*dashboard*) (Sailor & Brooks, 2014; Experiment 3). An exception should, however, be noted in Vieth et al. (2014b; Experiment 3), in which distractors denoting *non-distinctive* parts which were also *visible* in target pictures induced *interference* at the SOA of -150 milliseconds. Eliminating the association from target-distractor pairs by employing words denoting non-distinctive parts produced null effects and even led to polarity reversal in Sailor & Brooks (2014; Experiment 3).

The null results undermine the assumption of the REH because facilitation should be observed irrespective of whether a distractor is an associate or not. The findings of no effect could, however, be accommodated by the SLNH, particularly in the case of distractors denoting non-distinctive parts (e.g., AMULANCE-*dashboard*) as opposed to distinctive parts denoting unique features of objects (AMBULANCE-*siren*). AMBULANCE and DASHBOARD are likely to send activation to related concepts such as FIRE ENGINE and the superordinate category node (VEHICLES) which may all converge on the lexical activation of *dashboard* making it a stronger lexical competitor capable of offsetting facilitation at the conceptual level. This kind of recursive activation is unlikely in the case of AMBULANCE-*siren* because the items will activate divergent concepts and different superordinate category nodes.

Interference in the presence of whole-part relations was observed in three studies (Sailor & Brooks, 2014; Experiments 1 & 3; Vieth et al., 2014b; Experiment 3), but it only emerged for parts denoting non-distinctive features (e.g., DOG-*nose*) and was present either at the SOA of 0 milliseconds (Sailor & Brooks, 2014; Experiments 1 and 3; in the latter, significant by items only) or at SOA of -150 milliseconds (Vieth et al., 2014b; Experiment 3; significant by subjects only). In Vieth et al. (2014b; Experiment 3) only *non-distinctive* (non-associated) part terms that were also visible in target pictures induced interference when they were presented ahead of the target (SOA = -150 ms); this is different to Experiment 2 in which exactly the same materials were used, but the parts denoted by distractor words were *not* visible in the target picture. The interpretations are twofold. An inhibitory effect for visible non-distinctive parts (e.g., CAMEL-*knee*) suggests little or no conceptual priming (KNEE is unlikely to activate CAMEL) in addition to interference which arises either due to pre-lexical processes (the visibility of KNEE in the picture creates temporary uncertainty as to what it is one has to name, in accordance with the CEH) or due to lexical competition (KNEE and CAMEL activate related concepts, e.g., HORSE, and a superordinate category node ANIMALS which are likely to converge on lexical activation of *knee* in accordance with the SLNH). Sailor & Brooks (2014) dismissed visibility of parts as a relevant factor, which undermines the CEH, leaving the competitive view unscathed.

Interim summary

Overall, the findings indicate that whole-part target-distractor relations facilitate naming particularly when distractors are presented before the target and when they denote distinctive features of the displayed object. In fact, if an associative relation is not involved, whole-part relations either produce effects that are indistinguishable from those of their unrelated controls or slow down naming. While the latter is a rare phenomenon (significant by subjects or by items only in two of the three studies) in need of further empirical support, the disappearing facilitatory effect with increasing SOAs or when distractors are stripped of their associative strength indicates the operation of distinct mechanisms at varied levels of intensity and at different levels of information processing. Activation strength appears to be a crucial factor not only at the lexical level, as claimed by Abdel Rahman & Melinger (2019) in the extension of their SLNH or Piai et al. (2012) in their lexical selection by competition with a competition threshold proposal, but also at the conceptual level.

Table 8. Manipulation of whole-part relations between targets and distractors

Authors (year), **study** [language]; *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target $_{[type]}$ – distractor $_{[type, modality]}$	Finding	target $_{[type]}$ – distractor $_{[type, modality]}$	Statistics
Costa et al., (2005); **Exp 1** [English]; *parts denoted by distractors were NOT visible in target pictures*	22	22	Name the target picture ("car")	SOA = 0 ms	CAR $_{[drawing]}$ - *bumper* $_{[part, word, visual]}$	< [23 ms]$^{*/*}$	CAR $_{[drawing]}$ - *parrot* $_{[unrelated, word, visual]}$	*F1*(1,21) = 15.1, *p* < .002; *F2*(1,21) = 5.6, *p* < .03
Costa et al., (2005); **Exp 2** [English]; *parts denoted by distractors were NOT visible in target pictures; proportion of related trials reduced to 25%;*	24	32	Name the target picture ("fish")	SOA = 0 ms	FISH $_{[drawing]}$ - *gills* $_{[part, word, visual]}$	< [15 ms]$^{*/*}$	FISH $_{[drawing]}$ - *cork* $_{[unrelated, word, visual]}$	*F1*(1,22) = 5.6, *p* < .027; *F2*(1,31) = 4.5, *p* < .042
Muehlhaus et al., (2013); **Exp 1** [German]	22	52	Name the target picture ("candle")	SOA = 0 ms	CANDLE $_{[drawing]}$ - *wax* $_{[part, word, visual]}$	< [47 ms]$^{*/*}$	CANDLE $_{[drawing]}$ - *oar* $_{[unrelated, word, visual]}$	*t*(21) = −5.55, *p* < .001
Sailor & Brooks (2014); **Exp 1** [English]; *parts denoted by distractors visible in most target pictures;*	52	30	Name the target picture ("dog")	SOA = -300 ms	DOG $_{[drawing]}$ - *tail* $_{[associated part, word, visual]}$	< [15 ms]$^{*/*}$	DOG $_{[drawing]}$ - *string* $_{[unrelated, word, visual]}$	*F1*(1,408) = 14.9, *p* < .001; *F2*(1,232) = 6.8, *p* = .01 [unclear df for planned comparisons]
				SOA = -300 ms	DOG $_{[drawing]}$ - *nose* $_{[non-associated part, word, visual]}$	> [7 ms]$^{ns/ns}$	DOG $_{[drawing]}$ - *wood* $_{[unrelated, word, visual]}$	*F1*(1,408) = 3.4, *p* = .07; *F2*(1,232) = 1.9, *p* = .17
				SOA = -150 ms	DOG $_{[drawing]}$ - *tail* $_{[associated part, word, visual]}$	< [3 ms]$^{ns/ns}$	DOG $_{[drawing]}$ - *string* $_{[unrelated, word, visual]}$	*F1* and *F2* <= 1.1, *ps* => .3
				SOA = -150 ms	DOG $_{[drawing]}$ - *nose* $_{[non-associated part, word, visual]}$	> [6 ms]$^{ns/ns}$	DOG $_{[drawing]}$ - *wood* $_{[unrelated, word, visual]}$	*F1*(1,408) = 2.6, *p* = .11; F2(1,232) = 1.4, *p* = .24
				SOA = 0 ms	DOG $_{[drawing]}$ - *tail* $_{[associated part, word, visual]}$	> [4 ms]$^{ns/ns}$	DOG $_{[drawing]}$ - *string* $_{[unrelated, word, visual]}$	*Fs* < 1
				SOA = 0 ms	DOG $_{[drawing]}$ - *nose* $_{[non-associated part, word, visual]}$	> [18 ms]$^{*/*}$	DOG $_{[drawing]}$ - *wood* $_{[unrelated, word, visual]}$	*F1*(1,408) = 19.6, *p* < .001; *F2*(1,232) = 13.8, *p* < .001

Sailor & Brooks (2014); **Exp2** [English]; *replication of Costa et al. (2005; Exp 2) with minor procedural differences (i.e., Block 1: stimuli displayed until response; Block 2: stimuli displayed for 300 ms);*	26	24	Name the target picture ("bird")	SOA = 0 ms [distractor visible until response]	BIRD [drawing] – *wings* [associated part, word, visual]	> [1 ms][ns/ns]	BIRD [drawing] – *core* [unrelated part, word, visual]	Distractor duration *F1*(1, 25) = 24.2, *p* < .001; *F2*(1, 31) =241.4, *p* < .001; distractor type: Fs < 1; distractor type x distractor duration: *Fs* < 1
				SOA = 0 ms [distractor visible for 300 ms]	BIRD [drawing] – *wings* [associated part, word, visual]	< [2 ms][ns/ns]	BIRD [drawing] – *core* [unrelated part, word, visual]	Distractor duration *F1*(1, 25) = 24.2, *p* < .001; *F2*(1, 31) =241.4, p < .001; distractor type: Fs < 1; distractor type x distractor duration: *Fs* < 1
Sailor & Brooks (2014); **Exp 3** [English]; *associated and non-associate part terms matched on LSA values (semantic relatedness) relative to the target; parts denoted by distractors visible in some target pictures*	28	24	Name the target picture ("ambulance")	SOA = -300 ms	AMBULANCE [drawing] – *siren* [associated part, word, visual]	< [34 ms][*/*]	AMBULANCE [drawing] – *thorn* [unrelated part, word, visual]	*F1*(1, 216) = 57.8, *p* < .001; *F2*(1, 184) = 34.5, *p* < .001
				SOA = -300 ms	AMBULANCE [drawing] - *dashboard* [non-associated part, word, visual]	< [5 ms][ns/ns]	AMBULANCE [drawing] – *scent* [unrelated part, word, visual]	*F1(*1, 216) = 1.6, *p* = .21; F2(1, 184) = 2.9, *p* = .088
				SOA = -150 ms	AMBULANCE [drawing] – *siren* [associated part, word, visual]	< [18 ms][*/*]	AMBULANCE [drawing] – *thorn* [unrelated part, word, visual]	*F1*(1, 216) = 17.1, *p* < .001*; F2*(1, 184) = 10.9, *p* = .001
				SOA = -150 ms	AMBULANCE [drawing] - *dashboard* [non-associated part, word, visual]	> [1 ms][ns/ns]	AMBULANCE [drawing] – *scent* [unrelated part, word, visual]	*Fs* < 1
				SOA = 0 ms	AMBULANCE [drawing] – *siren* [associated part, word, visual]	> [1 ms][ns/ns]	AMBULANCE [drawing] – *thorn* [unrelated part, word, visual]	*Fs* < 1
				SOA = 0 ms	AMBULANCE [drawing] - *dashboard* [non-associated part, word, visual]	> [6 ms][ns/*]	AMBULANCE [drawing] – *scent* [unrelated part, word, visual]	*F1*(1, 216) = 1.7, *p* =.197; *F2*(1, 184) = 4.0, *p* = .048

Vieth et al., (2014b) **Exp 2** [English]; *parts denoted by distractor words NOT visible in target pictures*	27	24	Name the target picture ("camel")	SOA = -150 ms	CAMEL [photo] - *hump* [distinctive part, word, visual]	> [1 ms]$^{ns/ns}$	CAMEL [photo] - *hole* [unrelated, word, visual]	Relation type: *F1*(1, 26) < 1, *p* = .705, η_p^2 = 0.01; *F2*(1, 23) < 1, *p* = .659, η_p^2 = 0.01; distinctiveness: *F1*(1, 26) < 1, *p* = .462, η_p^2 = 0.02; *F2*(1, 23) < 1, *p* = .438, η_p^2 = 03. ; SOA: *F1*(2, 52) = 1.88, *p* = .163, η_p^2 = 0.07; *F2*(2, 46) = 4.56, *p* = .016, η_p^2 = 0.17. No interactions present.
				SOA = -150 ms	CAMEL [photo] - *knee* [indistinctive part, word, visual]	> [4 ms]$^{ns/ns}$	CAMEL [photo] - *floor* [unrelated, word, visual]	No main effects and no interaction; see above;
				SOA = 0 ms	CAMEL [photo] - *hump* [distinctive part, word, visual]	[0 ms]	CAMEL [photo] - *hole* [unrelated, word, visual]	No main effects and no interaction; see above;
				SOA = 0 ms	CAMEL [photo] - *knee* [indistinctive part, word, visual]	> [4 ms]$^{ns/ns}$	CAMEL [photo] - *floor* [unrelated, word, visual]	No main effects and no interaction; see above;
				SOA = +150 ms	CAMEL [photo] - *hump* [distinctive part, word, visual]	> [2 ms]$^{ns/ns}$	CAMEL [photo] - *hole* [unrelated, word, visual]	No main effects and no interaction; see above;
				SOA = +150 ms	CAMEL [photo] - *knee* [indistinctive part, word, visual]	> [3 ms]$^{ns/ns}$	CAMEL [photo] - *floor* [unrelated, word, visual]	No main effects and no interaction; see above;
Vieth et al., (2014b); **Exp 3** [English]; *parts denoted by distractor words are visible in target pictures*	27	24	Name the target picture ("camel")	SOA = -150 ms	CAMEL [photo] - *hump* [distinctive part, word, visual]	> [1 ms]$^{ns/ns}$	CAMEL [photo] - *hole* [unrelated, word, visual]	No main effects and no interaction; see above;
				SOA = -150 ms	CAMEL [photo] - *knee* [indistinctive part, word, visual]	> [14 ms]$^{*/ns}$	CAMEL [photo] - *floor* [unrelated, word, visual]	*F1*(1, 26) = 8.46, *p* = .007, η_p^2= 0.25; *F2*(1, 23) = 3.77, *p* = .065, η_p^2 = 0.14
				SOA = 0 ms	CAMEL [photo] - *hump* [distinctive part, word, visual]	< [5 ms]$^{ns/ns}$	CAMEL [photo] - *hole* [unrelated, word, visual]	No main effects and no interaction; see above;
				SOA = 0 ms	CAMEL [photo] - *knee* [indistinctive part, word, visual]	> [3 ms]$^{ns/ns}$	CAMEL [photo] - *floor* [unrelated, word, visual]	No main effects and no interaction; see above;
				SOA = +150 ms	CAMEL [photo] - *hump* [distinctive part, word, visual]	> [5 ms]$^{ns/ns}$	CAMEL [photo] - *hole* [unrelated, word, visual]	No main effects and no interaction; see above;
				SOA = +150 ms	CAMEL [photo] - *knee* [indistinctive part, word, visual]	< [6 ms]$^{ns/ns}$	CAMEL [photo] - *floor* [unrelated, word, visual]	No main effects and no interaction; see above;

Table 9. Manipulation of thematic relations between targets and distractors

de Zubicaray et al., (2013); [English]	17	36	Name the target picture ("desert")	SOA = -150 ms	DESERT [drawing] - *camel* [thematically related word, visual]	< [16 ms]*	DESERT [drawing] - *queen* [unrelated word, visual]	*t*(16) = -1.91, *p* < .05, d = -0.46 ; [one-tailed t-test]
Abdel Rahman & Melinger, (2007); **Exp 3** [German]	30	25	Name the target picture ("turban")	SOA = -150 ms	TURBAN [photo] - *chickpeas* [thematically related word, auditory]	< [21 ms]$^{*/*}$	TURBAN [photo] - *American* [unrelated word, auditory]	*F1*(1, 29) = 11.8, *p* <.002; *F2*(1, 24) = 11.4, *p* < .002.
Muehlhaus et al., (2013); **Exp 1** [German]	22	44	Name the target picture ("bench")	SOA = 0 ms	BENCH [drawing] - *park* [thematically related word, visual]	< [29 ms]*	BENCH [drawing] - *plug* [unrelated word, visual]	*t*(21) = −2.57, *p* = .018

2.5.2.1.2.3 Thematic relations

2.5% of PWI studies (n = 3) have specifically investigated thematic relationships between targets and distractors (Abdel Rahman & Melinger, 2007; Experiment 3; de Zubicaray, Hansen, & McMahon, 2013; Muehlhaus et al., 2013; Experiment 3) (see Table 9). Two items are said to be thematically related if they perform complementary roles in the same context or event (Estes, Golonka, & Jones, 2011). For example, DOG and LEASH are related by a walking theme. Estes et al. (2011) differentiate further between thematic relations that are spatial (e.g., DESERT-CAMEL), temporal (e.g., SUMMER-HOLIDAY), causal (e.g., WIND-EROSION), functional (e.g., HAMMER-NAIL), possessive (SURGEON-SCALPEL) and productive (COW-MILK). All three PWI studies manipulating thematic relations between targets and distractors reported faster picture naming in the context of related stimuli. A facilitatory effect for thematically related distractors was observed at the SOA of 0 milliseconds in one study (Muehlhaus et al., 2013; Experiment 1) and with an early distractor onset (SOA = -150 ms) in two other studies (Abdel Rahman & Melinger, 2007; Experiment 3; de Zubicaray et al, 2013).

The findings cannot be used to differentiate between the rival accounts of lexical access, however, especially when association strength is involved. In both de Zubicaray et al. (2013) and Muehlhaus et al. (2013), thematically related pairs were also associated as confirmed by published association norms. Although this was not explicitly stated in Abdel Rahman & Melinger (2007), it is not hard to imagine that association strength (e.g., FRENCHMAN-*beret*) could have been driving the reported effect. Facilitation is predicted by the REH on condition that both related and unrelated distractors fulfil the response relevance criterion to the same extent, which they do in the case of thematically related distractors, i.e., the system does not differentiate between PARK and JUNGLE when the task is naming a picture of a bench. Facilitation is also the predicted net outcome of the SLNH; because the distractor and target share few, if any semantic features (BENCH and PARK do not share internal features that LION and TIGER do), and activate different superordinate category nodes, the spread of activation is more diffuse and therefore lexical activation of PARK may be insufficient to outweigh strong facilitation at the conceptual level. The CEH can also accommodate the reported data because structural and/or conceptual representations of PARK and JUNGLE should be equally easy/hard to exclude when one is looking at a picture of a long metal seat for several people.

2.5.2.2 PROBABILISTIC RELATIONS

As indicated in the previous section, whether facilitation or interference is observed in the PWI task may be strongly dependent on the association strength between targets and distractors and therefore the strength of activation within both conceptual and lexical networks. Associative relations are confounded by semantic relations, so measuring effects of pure association or the probability with which two items occur together, or two representations are co-activated, is not an easy task. The effect of purely associative relations on picture naming are an underexplored topic in the area of PWI research, but one that could provide additional insight into the processes underlying lexical selection. Research could utilise opaque compound nouns (e.g., HONEY-*moon*) or expressions that have entered parlance recently (e.g., FACE-*book*), which would potentially allow one to test for the effects of association strength independent of semantic relations as well as the effect of association directionality.

2.5.2.3 VISUAL SIMILARITY

The role of visual form overlap between targets and distractors in the PWI paradigm has until recently received little attention, with only four (3.4%) studies directly manipulating this type of relationship (de Zubicaray et al., 2018; Experiments 1 and 2; Humphreys et al., 1995; Experiment 1; Mahon et al., 2007; Experiment 6b) (see Table 10). Visual similarity between pairs of items (e.g., ORANGE-*ball*) was determined either by subjective similarity ratings (Mahon et al., 2007; de Zubicaray et al., 2018) or measures of partonomic features and the degree of overlap between the outline contours of size-normalised drawings of objects (Humphreys et al., 1995). Two studies (de Zubicaray et al., 2018; Experiment 1; Humphreys et al., 1995; Experiment 1) demonstrated a form-related interference effect in the absence of sematic relatedness, and one (Mahon et al., 2007) observed an effect in the same direction, which approached significance by subjects, but was non-significant by items. In the only two studies in which interference was reported, the same stimuli served as targets and distractors (i.e., they were members of the response set), which introduces a potential confound of covert lexicalisation. The distractors that were named on trials in which they functioned as targets may have inadvertently been lexicalised on trials in which they were to be ignored. In addition, as discussed in the *Distractor Format* section, in the PPI task used by Humphreys et al., participants may have strategically prepared verbal responses for both pictures so an appropriate name could quickly be retrieved upon cue onset. In effect, the delay observed in the context of similar looking items could be related either to temporary difficulty in object recognition/identification, implicating a pre-lexical locus of interference, in accordance with the CEH, or lexical competition due to a covert lexicalisation confound. Indeed, when the response set membership was manipulated (de Zubicaray et al., 2018; Experiment 2), visually similar distractors no longer exerted an effect on picture naming.

Interim summary

Based on the evidence gathered so far, no firm conclusions can be drawn about whether or not visual form overlap affects performance on the PWI task. This issue requires additional work to establish the origin and reliability of the visual similarity effect. This could be achieved, for example, by including a range of SOAs, particularly early ones, at which processes such as object recognition and identification have a better chance of manifestation, while using targets and distractors that do not share response set membership. It would also be interesting to broaden the spectrum of structural features of objects (e.g., colour, size, shape, texture) used to manipulate visual similarity between targets and distractors. Different statistical methods, such as multiple hierarchical regression analyses, could be employed to gauge the relative contribution of visual similarity to the net PWI effect, above and beyond other relevant variables such as semantic relatedness or semantic distance between targets and distractors.

Table 10. Manipulation of visual similarity between targets and distractors

Authors (year), **study** [language]; *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target [type] – distractor [type, modality]	Finding	target [type] – distractor [type, modality]	Statistics
Mahon et al. (2007); **Exp 6b** [English]; *subjective ratings of visual similarity*	16	20	Name the target picture ("orange")	SOA = 0 ms	ORANGE [drawing] - *ball* [visually similar, word]	> [12 ms]$^{ns/ns}$	ORANGE [drawing] - *cigarette* [visually dissimilar, word]	*F1*(1, 15) = 3.8, *p* = .069; η_p^2 = .20; *F2* (1, 19) = 1.0, *p* = .32; η_p^2 = .05.
de Zubicaray et al., (2018); **Exp 1** [English]; *subjective ratings of visual similarity; distractors are part of the response set;*	24	30	Name the target picture ("igloo")	SOA = -150 ms	IGLOO [drawing] – *turtle* [visually similar, word]	> [37 ms]$^{*/*}$	IGLOO [drawing] - *feather* [visually dissimilar, word]	*t1*(23) = 3.82, *p* = .001, *d* = .7; *t2*(29) = 3.86, *p* = .001, *d* = .7 [unclear dfs for item analysis when number of items = 15]
				SOA = 0 ms	IGLOO [drawing] – *turtle* [visually similar, word]	> [24 ms]$^{*/*}$	IGLOO [drawing] - *feather* [visually dissimilar, word]	*t1*(23) = 2.85, *p* = .009, *d* = .7; *t2*(29) = 3.06, *p* = .005, *d* = .6
				SOA = +150 ms	IGLOO [drawing] – *turtle* [visually similar, word]	> [3 ms]$^{ns/ns}$	IGLOO [drawing] - *feather* [visually dissimilar, word]	*t1*(23) = 0.38, *p* = .71; *t2*(29) = 0.8, *p* = .43).
de Zubicaray et al, (2018); **Exp 2** [English]; *manipulation of the response set*	24 (12 per response set condition)	60 (30 per response set)	Name the target picture ("igloo")	SOA = -150 ms	IGLOO [drawing] – *turtle* [visually similar, word]	> [3 ms]$^{ns/ns}$	IGLOO [drawing] - *feather* [visually dissimilar, word]	SOA: *F1*(2,46) = 16.56, *p* < .001; η_p^2 = .42; *F2*(2,58) = 36.57, *p* < .001, η_p^2 = .56; distractor type: *Fs* < 1, *p* > .3; SOA x distractor type: Fs < 1; *p* > .3;
				SOA = 0 ms	IGLOO [drawing] – *turtle* [visually similar, word]	> [4 ms]$^{ns/ns}$	IGLOO [drawing] - *feather* [visually dissimilar, word]	See above
				SOA = +150 ms	IGLOO [drawing] – *turtle* [visually similar, word]	< [2 ms]$^{ns/ns}$	IGLOO [drawing] - *feather* [visually dissimilar, word]	See above
Humphreys et al. (1995**); Exp 1** [English], *PPI paradigm*	24	56	Name the target picture ("tiger", "fridge")	SOA = 0 ms; cue onset: 500 ms	TIGER [drawing] - *HORSE*[related, visually similar, word]	> [80 ms]$^{?/?}$	FRIDGE [drawing] - *KETTLE*[related, visually dissimilar, word]	*F1*(1, 47) = 8.93, p < .005; *F2*(1, 54) = 7.17, *p* < .01; no separate analyses for semantically related and unrelated conditions

			SOA = 0 ms; cue onset: 2000 ms	TIGER [drawing] - *HORSE*[related, visually similar, word]	> [15 ms]$^{ns/ns}$	FRIDGE [drawing] - *KETTLE*[related, visually dissimilar, word]	*Fs* < 1
24	56	Name the target picture ("tiger", "fridge")	SOA = 0 ms; cue onset: 500 ms	TIGER [drawing] -??? [unrelated, visually similar, word]	> [64 ms]$^{?/?}$	FRIDGE [drawing] - *???* [unrelated, visually dissimilar, word]	*F1*(1, 47) = 8.93, *p* < .005; *F2*(1, 54) = 7.17, *p* < .01; no separate analyses for semantically related and unrelated conditions
			SOA = 0 ms; cue onset: 2000 ms	TIGER [drawing] - *???*[unrelated, visually similar, word]	> [6 ms]$^{ns/ns}$	FRIDGE [drawing] - *???* [unrelated, visually dissimilar, word]	*Fs* < 1

2.5.3 SITE OF MANIPULATION: TASK

The question of whether interference in the PWI task would persist if the cognitive load associated with a particular production stage (e.g., lexical selection) were to be reduced or shifted to a different processing stage (e.g., object recognition) has spurred some researchers into manipulating the task that the participant is given to perform. In 12% of the reviewed studies (n = 14), task instructions were changed from basic-level naming to a non-naming perceptual, semantic or phonological decision task. Additionally, in 7.7% of the selected studies (n = 9), basic-level naming was replaced with subordinate-level naming. Studies in which participants were required to name the pictured object with a subordinate-level name were included in this section because of the additional perceptual processing load associated with this task.

2.5.3.1 Perceptual-conceptual decision tasks

Perceptual tasks are primarily concerned with visual processing of objects and may involve object detection, discrimination, recognition and identification. Of the reviewed PWI studies with task instructions manipulation, three (13%) utilised tasks requiring some degree of perceptual analysis, although performance on these tasks may also hinge on semantic processing and/or the process of integrating perceptual and conceptual information (see Table 11). Two studies reported interference for semantically related distractors without the apparent involvement of lexical processes (Dean et al., 2001; Experiment 2; Lupker & Katz, 1981; Experiment 1) and one found no effect (Schriefers et al., 1990; Experiment 3). While interference in the colour and object recognition tasks (Dean et al. and Lupker & Katz respectively) was interpreted in favour of the pre-lexical locus of the PWI effect, its absence in the object recognition memory task (Schriefers et al., 1990) was argued to support a lexical basis. The conclusions in all three studies may however, be premature. It is uncertain whether the interference effect observed by Dean et al. and Lupker & Katz was genuinely due to a non-lexical process or an outcome of strategic covert lexicalisation. It is not clear either how much "visual" and how much "semantic" processing was involved in the task selected by Schriefers et al. If participants based their recognition decisions largely, or exclusively, on stored structural representations, responding "yes" when the same perceptual codes were activated at study and at test, and "no" otherwise, without consulting semantic information, then the absence of interference reported by the authors does not preclude a semantic basis of the effect.

2.5.3.2 Subordinate-level naming

The vast majority of PWI studies required participants to name the depicted objects at the basic level of abstraction (e.g., TROUT as "fish"). In nine (7.7%) studies, however the task was replaced by subordinate-level naming. Findings from PWI studies in which participants were instructed to use a specific (as opposed to a general) name for the depicted object (i.e., TROUT as "trout") are reviewed in this section because subordinate-level naming is associated with higher perceptual demands (see Table 12). Chronometric research has shown that objects are identified and named more slowly at the subordinate level than at the basic level of abstraction, even when controlling for potential lexical confounds, such as frequency of occurrence or word length of target names (e.g., Jolicoeur, Gluck, & Kosslyn, 1984; Lin, Murphy, & Shoben, 1997).

Two of the nine (22%) subordinate-level naming studies (Vitkovitch & Tyrrell, 1999; Experiments 1 and 3) observed interference for related subordinate-level distractors (distractors representing the same semantic category and belonging to the same level of abstraction as targets) relative to their unrelated controls. Naming a picture of a MINI as "mini" was slower when it was accompanied by a semantically related distractor (e.g., *jaguar*) than when it was presented with an unrelated word (e.g., *tulip*). Such within-level interference is compatible with both competitive and non-competitive views of lexical selection. According to the lexical-selection-by-competition view, the target picture of MINI is likely to activate the superordinate category node of CAR as well as related exemplar nodes (e.g., JAGUAR, AUDI), which in turn activate their corresponding lexical nodes (i.e., *jaguar*, *audi*), rendering the related subordinate distractor (*jaguar*) a stronger competitor than an unrelated distractor (*tulip*). The CEH would entail greater difficulty for concept selection in the context of related subordinate-level distractors than unrelated ones, not so much because the cognitive system has access to information regarding the abstraction level of the distractors, as implied by Costa et al., (2005), which in this case is equivalent for both types of stimuli, but because the semantic and possibly structural information activated by the related distractor creates greater confusion about the target's identity than the information extracted from the unrelated distractor, thereby prolonging the time needed to select the correct concept for lexicalisation. The results can also be accommodated by the REH account because although both distractors should reach the articulatory output buffer at the same time, the related distractor (*jaguar*) is a more plausible response (satisfying some general response-relevant criteria, such as naming a car) and is therefore harder to exclude from the buffer than an unrelated word (*tulip*), also prolonging naming.

Seven (78%) subordinate-level naming studies used distractors denoting either the target object's basic-level name (identical basic distractors, e.g. MINI-*car*) or the target object's semantically related basic-level name (related basic distractors, e.g. MINI-*train*) versus their unrelated controls, with discrepant results reported both within- and across laboratories. Of the seven, two (28.5%) studies (Hantsch, Jescheniak, & Schriefers, 2009; Experiment 4; Vitkovitch & Tyrrell, 1999; Experiment 2) found between-level facilitation for identical basic-level distractors versus their unrelated controls. Naming a MINI as "mini" was faster when it was accompanied by a distractor word denoting the picture's basic-level name (i.e., car) than when it was presented with an unrelated basic-level distractor (e.g., flower). Facilitation for identical basic-level distractors relative to their unrelated controls cannot be explained by lexical competition alone because an opposite pattern of results would be expected. Similarly, the results appear to be in conflict with the REH, the predictions of which would entail either null results (due to conceptual priming and interference at the response level) or prolonged naming latencies for related basic-level distractors (e.g., the distractor *car* is more response relevant because the speaker must identify and name a specific type of car) which would be harder to exclude from the articulatory buffer than unrelated controls. The results are also problematic for the SLNH, which would predict an inhibitory net outcome, with facilitation at the conceptual level being outweighed by interference at the lexical level (the target MINI presumably activates the concept of a CAR, which in turn, activates its lexical node *car* making the distractor more competitive than its unrelated counterpart). There are at least two alternative accounts that are compatible with the facilitatory effect obtained for identical basic-level distractors, however.

One is the CEH account – the word *car* activates a corresponding concept and possibly a structural representation of CAR. The semantic (and pictorial) features of CAR converge onto the semantic and structural representation of MINI, making both processes of object recognition and target concept selection easier relative to unrelated basic-level distractors. Two, facilitation is due to the confound of “message congruency” (Kuipers et al., 2006). Conceptually, CAR is not incongruent with the target response; CAR leads to the same response as MINI because the latter must first be identified as a car. This explanation is supported by Hantsch et al. (2009; Experiment 4), showing that identical basic-level distractors lead to facilitation in subordinate-level naming if the proportion of response-congruent trials is high and if only one exemplar per basic-level category is used. Facilitation can thus be understood as a net effect of two opposing forces – inhibition either due to lexical competition (SLNH) or the confound of response relevance (REH) and facilitation due to the confound of message congruency – in this case the latter wins.

In four (57%) studies (Hantsch et al., 2005; Experiments 3 and 4; Hantsch et al., 2009; Experiments 1 and 2), the reverse pattern of results (that of interference) for identical basic-level distractors was reported, however. Here, identical basic-level distractors interfered with subordinate naming relative to unrelated distractors. This observation applied to both visually (Hantsch et al., 2005, Experiments 3 and 5) and auditorily presented distractors (Hantsch et al., 2009; Experiment 1 and 2) as well as a range of SOAs (from -100 ms to +300 ms). Interference was taken as evidence for the notion that basic-level names become lexically activated during subordinate-level naming and that these basic-level names compete for selection with the subordinate-level target words, in accordance with the SLNH. The REH explanation was given a similar amount of credit by the authors.

Although Hantsch et al. (2009) suggest a number of factors that may have led to discrepant results (facilitation in Vitkovitch & Tyrrell, 1999; Experiment 2, and Hantsch et al., 2005; Experiment 4, and interference in Hantsch et al.’s, 2009), such as distractor modality or the amount of pictorial information in the target picture, the authors fail to mention an important aspect of the experimental set-up, which may have effectively altered the nature of the task. Leaving statistical significance aside (e.g., in Hantsch et al., 2005; 2009, some comparisons would not have survived post-hoc corrections and some tests produced significant differences only by subjects), one major procedural difference between the studies by Vitkovitch & Tyrrell (1999, Experiment 2) and Hantsch et al. concerns the familiarisation phase. While participants in Hantsch et al. were extensively trained on subordinate-level names of the experimental stimuli, in Vitkovitch & Tyrrell they were only familiarised with the task structure, without being pre-exposed to the experimental materials themselves. It is therefore reasonable to assume that in Vitkovitch & Tyrrell, the task was more likely to involve additional perceptual processing (with the focus on recognition and identification), whereas in Hantsch et al. because of participants' familiarity with the target pictures, perceptual load was significantly reduced, if not eliminated, with greater demand placed on correct name retrieval.

Two studies (28.6%) reported null results with subordinate-level naming (Vitkovitch & Tyrrell, 1999; Experiment 2, condition with alternative basic-level distractors; Hantsch et al., 2009; Experiment 3). Null findings find a ready explanation in at least three rival accounts. The effect could reflect an interplay of a facilitatory component due to semantic priming (e.g., in MINI-*train*, TRAIN primes CAR which primes MINI), on the one hand, and an interfering component, on the other. The latter may stem from either lexical competition (e.g., convergent activation on the lexical node of *train*), in accordance with the SLNH, interference at the pre-conceptual level (i.e., perceptual/semantic disambiguation) or interference at the post-lexical level (the REH account).

Interim summary

In summary, PWI studies utilising both perceptual-conceptual tasks and subordinate-level naming tasks present contradictory findings, with a range of effects. In addition, each can be challenged on methodological or conceptual grounds, such as implicit lexicalisation, selection of tasks in which individual processing demands are not fully understood, or inadvertent use of procedures that can alter the nature of the task from perceptually- to lexically-based. There is therefore scope for more research utilising purely perceptual tasks, but where task relevance of distractors is preserved. It is easy to imagine a perceptual task, such as orientation judgement task, in which participants decide whether a target object is upright or tilted, and in which performance is not confounded by semantic or lexical processing, but which may be of little use because information supplied by the distractor (be it semantic or structural) is not relevant to the task at hand. Use of fully crossed factorial designs, for example, comparing PWI performance with identical basic-level distractors to that with alternative basic-level distractors in addition to concurrent manipulation of semantic relatedness or the level of abstraction from which distractors are drawn, would also be an advantage; as would elimination of potential confounds, such as familiarisation with experimental materials and message congruency.

Table 11. Perceptual-conceptual decision tasks

Authors (year), **study** [language]; *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target [type] – distractor [type, modality]	Finding	target [type] – distractor [type, modality]	Statistics
Dean et al. (2001); **Exp 2** [English]; *PPI paradigm with colour post-cuing*	16	28	Categorise the target picture according to its colour [manual "red"/"green" response]	SOA = 0 ms; cue onset: 500 ms	GUITAR [drawing] - VIOLIN [related, drawing]	> [177 ms]*	GUITAR [drawing] - CAMEL [unrelated, drawing]	*F*(1,15) = 16.39, *p* = .001
Lupker & Katz (1981); **Exp1** [English]	20	10	Categorise the target picture as to whether it is a DOG or not [*manual* "yes"/"no" response]	SOA = 0 ms	DOG [drawing] - *bear* [related word, visual]	> [30 ms]*	DOG [drawing] - *hammer* [unrelated word, visual]	*p* < .01 (no other statistics reported)
	20	10	Categorise the target picture as to whether it is a DOG or not [*vocal* "yes"/"no" response]	SOA = 0 ms	DOG [drawing] - *bear* [related word, visual]	> [17 ms]*	DOG [drawing] - *hammer* [unrelated word, visual]]	*p* < .01 (no other statistics reported)
Schriefers et al. (1990); **Exp 3** [Dutch]	20	16	Categorise the target picture as previously seen or new [manual response]	SOA = -150 ms	RADIO [drawing] - *TV set* [related word, auditory]	< [5 ms]$^{ns/ns}$	RADIO [drawing] - *church* [unrelated word, auditory]	*F1*(1,18) = 1.3, *MS*, = 14263; *F2* < 1; *ps* > .05

Table 12. Subordinate-level naming

Vitkovitch & Tyrrell (1999); **Exp 1** [English]	15	10	Name the target picture using a subordinate-level name ("mini")	SOA = 0 ms	MINI [drawing] - *jaguar* [related subordinate, visual]	> [33 ms]*	MINI [drawing] - *tulip* [unrelated subordinate, visual]	*p* <. 05 (no other statistics reported)
Vitkovitch & Tyrrell (1999); **Exp 2** [English]; *with identical basic-level distractors*	15	10	Name the target picture using a subordinate-level name ("mini")	SOA = 0 ms	MINI [drawing] - *car* [identical basic, visual]	< [47 ms]*	MINI [drawing] - *flower* [unrelated basic, visual]	*p* <. 01 (no other statistics reported)

Vitkovitch & Tyrrell (1999); **Exp 2** [English]; *with related basic-level distractors*	15	10	Name the target picture using a subordinate-level name ("mini")	SOA = 0 ms	MINI [drawing] - *train* [related basic, visual]	< [17 ms]^{ns}	MINI [drawing] - *flower* [unrelated basic, visual]	*Fs* < 1 (no other statistics reported)
Vitkovitch & Tyrrell (1999); **Exp 3** [English]	20	10	Name the target picture using a subordinate-level name ("glider")	SOA = 0 ms	GLIDER [drawing] - *yacht* [related subordinate, visual]	> [50 ms]*	GLIDER [drawing] - *koala* [unrelated subordinate, visual]	*p* <. 05 (no other statistics reported)
Hantsch et al. (2005); **Exp 3** [German]; *pictures with their preferred names at basic level*	32	24	Name the target picture using a subordinate-level name ("baboon")	SOA = 0 ms	BABOON [drawing] - *ape* [identical basic, visual]	> [28 ms]$^{*/*}$	BABOON [drawing] - *house* [unrelated basic, visual]	Semantic relatedness: *F1*(1,31) = 22.76, *p* <.001; *F2*(1,23) = 38.84, *p* < .001]; SOA: *F1*(3,93) = 2.87, *p* < .05, *F2*(3,69) = 10.70, *p* < .001; SOA x semantic relatedness: *ps* > .05;
				SOA = +100 ms	BABOON [drawing] - *ape* [identical basic, visual]	> [27 ms]$^{*/*}$	BABOON [drawing] - *house* [unrelated basic, visual]	As above
				SOA = +200 ms	BABOON [drawing] - *ape* [identical basic, visual]	> [17 ms]$^{*/ns}$	BABOON [drawing] - *house* [unrelated basic, visual]	As above
				SOA = +300 ms	BABOON [drawing] - *ape* [identical basic, visual]	> [10 ms]$^{ns/ns}$	BABOON [drawing] - *house* [unrelated basic, visual]	As above* [does not appear to be in line with no interaction]
Hantsch et al. (2005), **Exp 5** [German]; *photos with their preferred names at subordinate level;*	32	20	Name the target picture using a subordinate-level name ("shark")	SOA = +80 ms	SHARK [photo] - *fish* [identical basic, visual]	> [15 ms]$^{*/*}$	SHARK [photo] - *tree* [unrelated basic, visual]	*t1*(31) = 2.55, *p* < .05; t*2*(19) = 2.14, *p* < .05
				SOA = +100 ms	SHARK [photo] - *fish* [identical basic, visual]	> [16 ms]$^{*/*}$	SHARK [photo] - *tree* [unrelated basic, visual]	*t1*(31) = 3.14, *p* < .01; *t2*(19) = 2.22, *p* < .05
				SOA = +200 ms	SHARK [photo] - *fish* [identical basic, visual]	> [9 ms]$^{ns/*}$	SHARK [photo] - *tree* [unrelated basic, visual]	*t1*(31) =-1.43, *p* > .10; *t2*(19) =-2.10, *p* = .05
				SOA = +300 ms	SHARK [photo] - *fish* [identical basic, visual]	[0 ms]	SHARK [photo] - *tree* [unrelated basic, visual]	*ts* < 1 (no other statistics reported)
Hantsch et al. (2009), **Exp 1** [German]; *two exemplars from each semantic category*	32	24	Name the target picture using a subordinate-level name ("baboon")	SOA = -200 ms	BABOON [drawing] - *ape* [identical basic, auditory]	> [9 ms]$^{ns/ns}$	BABOON [drawing] - *house* [unrelated basic, auditory]	*ps* > .05 (no other statistics reported)
				SOA = -100 ms	BABOON [drawing] - *ape* [identical basic, auditory]	> [14 ms]$^{*/ns}$	BABOON [drawing] - *house* [unrelated basic, auditory]	*p1* < .05; *p2* > .05 (no other statistics reported)

				SOA = 0 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ auditory]}$	> [18 ms]$^{*/ns}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ auditory]}$	*p1* < .05; *p2* < .1 (no other statistics reported)
				SOA = +100 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ auditory]}$	> [18 ms]$^{*/*}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ auditory]}$	*ps* < .05 (no other statistics reported)
Hantsch et al. (2009); **Exp 2** [German]; *one exemplar from each semantic category*	32	12	Name the target picture using a subordinate-level name ("baboon")	SOA = -200 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ auditory]}$	> [10 ms]$^{ns/ns}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ auditory]}$	*ts* < 1 (no other statistics reported)
				SOA = -100 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ auditory]}$	> [4 ms]$^{ns/ns}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ auditory]}$	*ts* < 1 (no other statistics reported)
				SOA = 0 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ auditory]}$	> [25 ms]$^{*/*}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ auditory]}$	*p1* < .001; *p2* < .01 (no other statistics reported)
				SOA = +100 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ auditory]}$	> [30 ms]$^{*/*}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ auditory]}$	*p1* < .001; *p2* < .01 (no other statistics reported)
Hantsch et al. (2009), **Exp 3** [German]; *replication of Exp 1, with visual distractors*	32	24	Name the target picture using a subordinate-level name ("baboon")	SOA = -200 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ visual]}$	< [12 ms]$^{ns/ns}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ visual]}$	*p1* < .1, *p2* > .05 (no other statistics reported)
				SOA = -100 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ visual]}$	> [2 ms]$^{ns/ns}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ visual]}$	*ps* > .05 (no other statistics reported)
				SOA = 0 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ visual]}$	> [2 ms]$^{ns/ns}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ visual]}$	*ps* > .05 (no other statistics reported)
				SOA = +100 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ visual]}$	> [9 ms]$^{ns/ns}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ visual]}$	*ps* > .05 (no other statistics reported)
Hantsch et al. (2009); **Exp 4** [German]; *replication of Exp 2, with visual distractors*	32	12	Name the target picture using a subordinate-level name ("baboon")	SOA = -200 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ visual]}$	< [52 ms]$^{*/*}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ visual]}$	*ps* < .001 (no other statistics reported)
				SOA = -100 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ visual]}$	< [33 ms]$^{*/*}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ visual]}$	*p1* < .01, *p2* < .001 (no other statistics reported)
				SOA = 0 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ visual]}$	< [14 ms]$^{*/ns}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ visual]}$	*p1* < .05, *p2* < .1 (no other statistics reported)
				SOA = +100 ms	BABOON $_{[drawing]}$ - *ape* $_{[identical\ basic,\ visual]}$	< [1 ms]$^{ns/ns}$	BABOON $_{[drawing]}$ - *house* $_{[unrelated\ basic,\ visual]}$	*ps* > .05 (no other statistics reported)

2.5.3.3 Semantic decision tasks

Eleven (9.4%) PWI studies employed a semantic decision task in place of basic-level naming (see Table 13). Semantic decision tasks make overt demands on retrieval of semantic knowledge and in the PWI studies reviewed in the current work have ranged from superordinate classification (i.e., making a binary decision as to whether an object belongs to a specific superordinate category), superordinate naming (i.e., naming the target's higher-level category), through size judgement (i.e., deciding whether the depicted object is larger or smaller in real life than a predefined object), to living/non-living or natural/man-made classification.

Of the four (36%) PWI studies employing non-abstraction tasks, one found facilitation for semantically related distractor pictures (Damian & Bowers, 2003), and one reported null results (Humphreys et al., 1995; Experiment 3B). In one, size judgement latencies were comparable across taboo and unrelated neutral distractor conditions (Mädebach et al., 2018; Experiment 1), and in another, taboo distractors interfered more with the non-lexical size decision performance than their neutral controls but only when targets were visually degraded (Mädebach et al., 2018; Experiment 2). Although the absence of interference in a task that does not specifically require lexicalisation could be interpreted as support for the lexical locus of the PWI effect, lack of adequate controls undermines the validity of at least two findings. The results in Damian & Bowers could have been unduly influenced by message congruency, with semantically related pairs (e.g., SHIRT-*skirt*) in the man-made/natural decision task being always response congruent (both the target and distractor are classified as man-made), and unrelated pairs (e.g., SHIRT-*banana*) being at least sometimes response incongruent (the target is classified as man-made but the distractor as natural, which leads to conflict at the response output level). The same problem concerns Humpreys et al., in which covert verbalisation (due to task difficulty) could have resulted in interference, whereas response congruency during living/non-living decision making may have led to facilitation, with the two cancelling each other out. The results reported by Mädebach et al. demonstrate that interference in the PWI task is possible without overt lexicalisation and that it may arise relatively early in the process of spoken word production, when unwanted representations (such as emotionally charged words) divert attention away from semantic processing, consequently prolonging naming response times.

By far the most numerous group of studies (64%) employing semantic decision tasks (n = 7) have utilised a form of an abstraction task (Costa et al., 2003; Experiment 1; Hantsch et al. 2012; Humphreys et al. 1995; Experiment 3A; Glaser & Glaser, 1989; Experiment 6; Glaser & Düngelhoff, 1984 Experiment 2; Smith & Magee, 1980; Lupker & Katz, 1981; Experiment 2). In four (57.1%) studies, basic-level naming was replaced by superordinate category naming (e.g., naming a picture of a house as "building"). In two (28.6%) studies, subjects were instructed to name target objects with a higher category name (i.e., naming a picture of a poodle as "dog"). One (14.3%) study required subjects to make a binary decision as to whether a depicted object belonged to a specific superordinate category (e.g., is DOG an animal?).

Four (57%) of the PWI studies employing an abstraction task reported facilitation when target pictures had to be assigned to a higher-level category in the context of semantically related distractors relative to when they were paired with unrelated distractors (Costa et al., 2003; Glaser & Glaser, 1989; Experiment 6; Glaser & Düngelhoff, 1984; Experiment 2; Hantsch et al., 2012). The effect emerged both for distractors denoting the target picture's name (identical distractor words, e.g., HOUSE-*house*), and for those derived from the same semantic category as targets (alternative distractor words, e.g., HOUSE-*church*), although some discrepancies were observed for different SOAs. For example, while in Glaser & Glaser (1989; Experiment 6), facilitation was observed for all SOAs spanning a range of -300 ms to +75 ms, in Glaser & Düngelhoff (1984; Experiment 2) reliable facilitation was only found with long pre-exposure times (i.e., SOAs -400 ms and -300 ms). Even if the name *rose* competes with the correct response *flower* when one is categorising DAISY, this interference is overshadowed by strong facilitation, which presumably has two sources. At the conceptual level, the distractor *tulip* is likely to activate the superordinate category node *FLOWER* (semantic priming). Similarly, the structural information supplied by the distractor does not conflict with the information extracted from the target picture in a task in which participants need to classify the object to a higher-level category. At the response level, both distractor (e.g., *rose*) and target (e.g., *daisy*) lead to the same response (i.e., "flower"), which again speeds up categorisation relative to the unrelated condition, in which the stimuli (*daisy* versus *jeep*) map onto divergent response codes (message congruency).

Three (43%) studies showed no difference in picture categorisation between related and unrelated conditions (Humphreys et al., 1995; Experiment 3A; Lupker & Katz, 1981; Experiment 2; Smith & Magee, 1980; Experiment 1); however, also here the studies do not remain without criticism. For example, in the PPI task used by Humphreys et al., the decision to categorise the colour-cued target picture is preceded by at least two processes – a decision of whether to name or to categorise (i.e., name when red, categorise when green), and a recollection of which picture was displayed in which colour. Due to high processing demands, a strategy may be adopted, according to which, the green picture is covertly labelled with a category name, while the red picture is covertly labelled with a basic-level name in anticipation of the cue onset. Smith & Magee (1980) provide no descriptive or inferential statistics, simply claiming that words "[…] do not cause nearly as much interference when the task is changed to picture categorisation" (p. 379-380); however, graphically, the targets in the 100% congruent condition, in which all items were semantically related (e.g., SHOE-*dress*), appeared to be classified faster than those in the 0% congruent condition (SHOE-*frog*). Finally, in Lupker & Katz, the related distractors denoting targets' names (CAR-*car*) as well as those denoting names of some other exemplars from the same semantic category (CAR-*train*) showed facilitation, which nevertheless fell short of statistical significance.

Interim summary

On balance, a range of effects has been reported with the few PWI studies employing non-abstraction semantic decision tasks (i.e., living/non-living, natural/made-made and size classification). When the task was changed to higher-level category naming (abstraction task), categorisation was generally faster in the context of semantically related distractors than their unrelated controls. Interpretation of results in both groups of semantic decision studies however, is complicated by the confound of response congruency (response congruent targets and distractors leading to facilitation). Mixed evidence is compounded by the dearth of studies in which task (semantic decision versus basic-level naming) and semantic relatedness have been concurrently manipulated.

Table 13. Semantic decision tasks

Authors (year), **study** [language]; *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target [type] -distractor [type, modality]	Finding	target [type] -distractor [type, modality]	Statistics
Damian & Bowers (2003); post-hoc control experiment [Dutch]; *PPI paradigm with man-made/ natural classification*	12	22	Categorise the target object as man-made or natural [manual response] ("natural")	SOA = 0 ms	APPLE [drawing] - BANANA [related, embedded drawing]	< [42 ms]*/*	APPLE [drawing] - SHIRT [unrelated, embedded drawing]	*ps* < .05 (no other statistics provided)
Humphreys et al. (1995); **Exp 3B** [English]; *PPI task with living/non-living classification*	16	56	Categorise the target object as living or non-living [vocal response] ("living")	SOA = 0 ms; post-cue: 500 ms	TIGER [red drawing] - HORSE [related, green drawing]	< [33 ms]ns/ns	TIGER [red drawing] - LEMON [unrelated, green drawing]	*Fs* < 1 (no other statistics provided)
Mädebach et al. (2018); **Exp 1** [German]; *size judgement with distractor emotional content manipulation*	48	32	Classify the target object as larger or smaller than a standard shoe box [manual response] ("smaller")	SOA = 0 ms	GLASSES [drawing] - *anus* [taboo word, visual]	> [4 ms]ns/ns	GLASSES [drawing] - *seagull* [neutral word, visual]	*F1* < 1, *F2*(1, 31) = 2.13, *p* = .154, η_p^2 = .064
Mädebach et al. (2018); **Exp 2** [German]; *size judgement with target visibility and distractor emotional content manipulation*	24	32	Classify the target object as larger or smaller than a standard shoe box [manual response] ("smaller")	SOA = -200 ms	GLASSES [drawing] - *anus* [taboo word, visual]	> [6 ms]*/ns	GLASSES [drawing] - *seagull* [neutral word, visual]	*F1*(1, 23) = 4.53, *p* = .044, η2 = .165, *F2*(1, 31) = 3.68, *p* = .064, η_p^2 = .106. Bayesian t-tests: for participants BF_{10} = 2.8; for items BF_{10} = 1.8.
	24	32	Classify the target object as larger or smaller than a standard box [manual response] ("smaller")	SOA = 0 ms	GLASSES [visually degraded drawing] - *anus* [taboo word, visual]	> [17 ms]*/*	GLASSES [visually degraded drawing] - *seagull* [neutral word, visual]	*F1*(1, 23) = 8.86, *p* = .007, η_p^2 = .278, *F2*(1, 31) = 11.45, p = .002, η_p^2 = .270. Bayesian t-tests: for participants BF_{10} = 13.4, for items BF_{10} = 36.11.
Costa et al. (2003); **Exp 1** [English]; *higher category naming*	16	22	Name the target picture with a higher category name ("flower")	SOA = 0 ms	DAISY [drawing] - *rose* [related word, visual]	< [57 ms]*/*	DAISY [drawing] - *shirt* [unrelated word, visual]	*t1*(15) = 3.647; *p* < .01, *t2*(21) = 3.096, *p* < .01
Hantsch et al. (2012); [German] *higher category naming;*	36	20	Name the target picture with a	SOA = -100 ms	POODLE [photo] - *poodle* [identical, word, audio]	< [24 ms]*/ns	POODLE [photo] - *tulip* [unrelated, word, audio]	Semantic relatedness: *F1*(1, 35) = 7.97, *p* < .01; *F2*(1, 19) =

subordinate-level names learnt during practice phase			higher category name ("dog")					2.03, p = .17. Semantic relatedness x SOA: Fs < 1.
				SOA = 0 ms	POODLE [photo] - *poodle* [identical, word, audio]	< [7 ms]$^{*/ns}$	POODLE [photo] - *tulip* [unrelated, word, audio]	As above
				SOA = +100 ms	POODLE [photo] - *poodle* [identical, word, audio]	< [19 ms]$^{*/ns}$	POODLE [photo] - *tulip* [unrelated, word, audio]	As above
Glaser & Glaser (1989); **Exp 6** [German]; *superordinate-level naming*	20	9	Name the target picture with a superordinate category name ("animal")	SOAs [- 300 ms to +300 ms]	CAT [drawing] - *rabbit* [related, word, visual]	< [37 ms]*	CAT [drawing] - *bed* [unrelated, word, visual]	p < .05 (no other statistics reported);
				SOAs [- 300 ms to +300 ms]	CAT [drawing] - *cat* [identical, word, visual]	< [65 ms]*	CAT [drawing] - *bed* [unrelated, word, visual]	p < .05 (no other statistics reported);
Glaser & Düngelhoff (1984); **Exp 2** [German] *superordinate-level naming*	18	36	Name the target picture with a superordinate category name ("building")	SOA = -400 ms	HOUSE [drawing] - *church* [related, word, visual]	< [83 ms]*	HOUSE [drawing] -*car* [unrelated, word, visual]	ps < .05 (no other statistics reported)
				SOA = -300 ms	HOUSE [drawing] - *church* [related, word, visual]	< [78 ms]*	HOUSE [drawing] - *car* [unrelated, word, visual]	ps < .05 (no other statistics reported)
				SOA = -200 ms	HOUSE [drawing] - *church* [related, word, visual]	< [14 ms]^{ns}	HOUSE [drawing] - *car* [unrelated, word, visual]	ps > .05 (no other statistics reported)
				SOA = -100 ms	HOUSE [drawing] - *church* [related, word, visual]	< [29 ms]^{ns}	HOUSE [drawing] - *car* [unrelated, word, visual]	ps > .05 (no other statistics reported)
				SOA = 0 ms	HOUSE [drawing] - *church* [related, word, visual]	[0 ms]^{ns}	HOUSE [drawing] - *car* [unrelated, word, visual]	ps > .05 (no other statistics reported)
				SOA = -400 ms	HOUSE [drawing] - *house* [identical, word, visual]	< [88 ms]*	HOUSE [drawing] - *car* [unrelated, word, visual]	ps < .05 (no other statistics reported)
				SOA = -300 ms	HOUSE [drawing] - *house* [identical, word, visual]	< [53 ms]*	HOUSE [drawing] - *car* [unrelated, word, visual]	ps < .05 (no other statistics reported)
				SOA = -200 ms	HOUSE [drawing] - *house* [identical, word, visual]	< [30 ms]^{ns}	HOUSE [drawing] - *car* [unrelated, word, visual]	ps > .05 (no other statistics reported)
				SOA = -100 ms	HOUSE [drawing] - *house* [identical, word, visual]	< [4 ms]^{ns}	HOUSE [drawing] - *car* [unrelated, word, visual]	ps > .05 (no other statistics reported)
				SOA = 0 ms	HOUSE [drawing] - *house* [identical, word, visual]	> [16 ms]^{ns}	HOUSE [drawing] - *car* [unrelated, word, visual]	ps > .05 (no other statistics reported)

Humphreys et al. (1995); **Exp 3A** [English]; *PPI with basic-level and superordinate-level naming depending on cue colour*	20	56	Name the target picture with a superordinate category name when the cue is green ("animal")	SOA = 0 ms; post-cue onset: 500 ms	TIGER [red drawing] - *HORSE* [related, green drawing]	> [82 ms]$^{ns/ns}$	TIGER [red drawing] - *LEMON* [unrelated, green drawing]	*ps* > .05 (no other statistics reported)
Lupker & Katz (1981); **Exp 2** [English]; *superordinate-level naming*	18	20	Name the target picture with a superordinate category name ("vehicle")	SOA = 0 ms	CAR [drawing] - *car* [identical, word, visual]	< [13 ms]^{ns}	CAR [drawing] -*knife* [unrelated, word, visual]	*p* > .05 (no other statistics reported)
				SOA = 0 ms	CAR [drawing] - *train* [related, word, visual]	< [11 ms]^{ns}	CAR [drawing] - *knife* [unrelated, word, visual]	*p* > .05 (no other statistics reported)
Smith & Magee (1980); **Exp 1** [English]; *Superordinate categorisation*	16	24	Indicate if the target object belongs to the given category, e.g., CLOTHING? [vocal yes/no response] ("yes")	SOA = 0 ms	SHOE [drawing] - *dress* [related, word, visual]	< [?]^{ns}	SHOE [drawing] - *frog* [unrelated, word, visual]	Graphical facilitation for 100% related pairs relative to 50% related pairs or 0% related pairs, but no descriptive or inferential statistics reported

2.5.3.4 Phonological decision tasks

Of the studies reviewed, four (3.4%) employed a phonological decision task in place of basic-level naming. Phonological decision tasks used in combination with the PWI paradigm have included phoneme monitoring (or phoneme detection), syllable judgement and vowel/consonant identification. In the phoneme monitoring task, a target picture's name is mentally scanned for the presence of a particular phoneme. The latter can be pre-defined via task instructions (e.g., indicate whether the target picture name begins with a /b/ or a /k/), or specified on a trial-by-trial basis (e.g., indicate whether the target picture's name contains the phoneme seen in a previous trial). The syllable judgement task involves making a decision as to the number of syllables in the target picture's name (e.g., is ANCHOR mono- or disyllabic?). In the vowel/consonant identification task, participants make a judgement as to whether the final segment of a target picture's name is a vowel or a consonant. There is compelling evidence that tasks which require a decision based on either segmental information (i.e., individual segments, their order in a word) or metrical information (i.e., number of syllables, stress patterns) of the target picture's name involve conceptual, lexical and morpho-phonological access, but do not engage articulatory processes (e.g., Oppenheim & Dell, 2008; Wheeldon & Levelt, 1995). If the PWI effect survives the elimination of articulatory preparation, this would suggest that the effect has a pre-articulatory basis. Four studies employed a phonological decision task to test this prediction (Abdel Rahman & Aristei, 2010; Hutson et al., 2013; Experiments 1 and 2; Mädebach et al., 2018; Experiment 1).

In the vowel/consonant identification task (Abdel Rahman & Aristei, 2010), participants took longer to manually classify the final letter of the target picture's name in the presence of categorically related distractors than when targets were accompanied by unrelated distractors. The persistence of the semantic interference effect in the absence of overt articulation was taken as evidence against the REH account, according to which interference should only be obtained in tasks in which the articulatory output buffer is occupied by a production-ready representation which must be cleared for the target name to be produced. Also at odds with the REH account is the finding by Hutson, Damian, & Spalek (2013; Experiments 1 & 2), who reported no interaction between task (naming versus phonological decision) and distractor frequency, which together with the fact that the phonological decision task involved manual responses, indicates a locus outside the articulatory output buffer (but note a marginally significant effect in Experiment 2). Similarly, a delay in phoneme detection was reported for taboo distractor words relative to their neutral counterparts (Mädebach et al., 2018; Experiment 1). Since the manual phoneme detection task assumes no preparation of articulatory codes, the locus is again placed before the articulatory output buffer. In addition, the taboo interference effect appeared to be attenuated in the phoneme detection task relative to the naming task, which would suggest that the two are underpinned by the same process. This however cannot be confirmed without an interaction between task (naming versus phonological decision) and emotional content of distractors being subjected to a statistical analysis.

Interim summary

There is thus fairly consistent, albeit scant, evidence that the interference effect is preserved even if the task does not explicitly require generation of articulatory codes. The findings undermine the role of response-competition as well as self-monitoring processes as a single source of interference. The data are not incompatible, however with accounts that place the locus of interference at an early, pre-lexical stage. For example, the presence of the distractor frequency effect in phonological decision tasks could be explained by an "attentional capture" account, according to which low frequency words (by virtue of being rare) in comparison to high frequency words attract additional cognitive resources, diverting attention away from target processing. Similarly, although Abdel Rahman & Aristei (2010) argued for interference to arise at the level of lexical selection as the most parsimonious account of the semantic interference effect in the absence of overt articulation, the results do not rule out the possibility that the effect resides outside the lexical selection stage, being an epiphenomenon of concept selection (due to competing conceptual representations) or concept rejection (with a conflict detection mechanism intercepting and possibly blocking conceptual representations that have been wrongly selected).

Table 14. Phonological decision tasks

Authors (year), **study** [language], *notes*	Subjects	Items	Task ("correct response")	SOA/ cue onset	target [type] – distractor [type, modality]	Finding	target [type] – distractor [type, modality]	Statistics
Abdel Rahman & Aristei (2010). [German]; *semantic relatedness manipulation*	22	120	Indicate if the target's name ends with a vowel or with a consonant [manual response] ("consonant")	SOA = 0 ms	CAR [drawing] - *ship* [related, word, visual]	> [17 ms]$^{*/*}$	CAR [drawing] - *worm* [unrelated, word, visual]	$t1(21) = 2.12$, $p = .046$; $t2(119) = 2.04$, $p = .044$
			Name the target picture ("car")	SOA = 0 ms	CAR [drawing] - *ship* [related, word, visual]	> [23 ms]$^{*/*}$	CAR [drawing] - *worm* [unrelated, word, visual]	$t1(21) = 3.93$, $p < .001$; $t2(119) = 3.65$, $p < .001$
Hutson, Damian, & Spalek (2011); **Exp 1** [English]; *distractor frequency manipulation*	28	60	Indicate if the target's name is mono- or disyllabic [manual response] ("disyllabic")	SOA = 0 ms	APPLE [drawing] - *sorrow* [low frequency, word, visual]	> [20 ms]*	APPLE [drawing] - *husband* [high frequency, word, visual]	$\beta = 19.11$, $t(2894) = 2.17$, $p = .030$
			Name the target picture ("apple")	SOA = 0 ms	APPLE [drawing] - *sorrow* [low frequency, word, visual]	> [24 ms]*	APPLE [drawing] - *husband* [high frequency, word, visual]	$\beta = 24.73$, $t(3002) = 4.53$, $p < .001$
Hutson, Damian, & Spalek (2011); **Exp 2** [English]; *distractor frequency manipulation*	28	60	Indicate if the target's name contains the phoneme seen in a previous trial [manual response]	SOA = 0 ms	APPLE [drawing] - *sorrow* [low frequency, word, visual]	> [27 ms]^{ns}	APPLE [drawing] - *husband* [high frequency, word, visual]	$\beta = 17.93$, $t(2498) = 1.77$, $p = .077$
			Name the target picture ("apple")	SOA = 0 ms	APPLE [drawing] - *sorrow* [low frequency, word, visual]	> [28 ms]*	APPLE [drawing] - *husband* [high frequency, word, visual]	$\beta = 29.85$, $t(2779) = 5.09$, $p < .001$
Mädebach, Markuske, & Jescheniak (2018); **Exp1** [German]*; distractor emotional content manipulation*	24	32	Indicate if the target's name starts with a /*b*/or a /*k*/ [manual response] ("b")	SOA = 0 ms	BROOM [drawing] - *cunt* [taboo, word, visual]	> [35 ms]$^{*/*}$	BROOM [drawing] – *chest* [neutral, word, visual]	$F1(1, 23) = 15.71$, $p = .001$, $\eta_p^2 = .406$; $F2(1, 31) = 25.98$, $p < .001$, $\eta_p^2 = .456$
			Name the target picture ("broom")	SOA = 0 ms	BROOM [drawing] - *cunt* [taboo, word, visual]	> [98 ms]$^{*/*}$	BROOM [drawing] – *chest* [neutral, word, visual]	$F1(1, 23) = 85.76$, $p < .001$, $\eta_p^2 = .789$; $F2(1, 31) = 125.07$, $p < .001$, $\eta_p^2 = .801$

2.5.6 RISK OF BIAS ASSESSMENT RESULTS

The proportion of studies with each of the judgements ('high', 'low' and 'unclear' risk of bias) for individual domains is presented in the risk of bias graph (Figure 3). All of the judgements in a cross-tabulation of studies by domain are presented in the risk of bias summary graph (Figure 4).

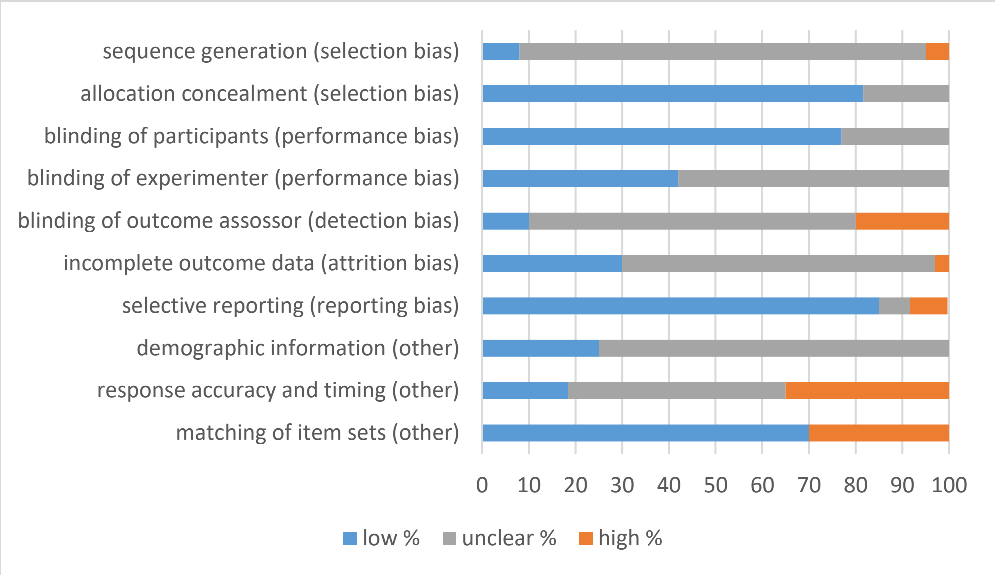


Figure 3. Risk of bias graph. Percentage of PWI studies with each of the judgements of the risk of bias.

Random sequence generation

In studies with a between-subjects design, the risk of bias associated with the sequence generation domain was judged as low if assignment of participants to individual conditions was randomised. A rating of low risk was also given to within-subjects or mixed design studies in which both the generated sequence of blocks/conditions was counterbalanced across participants (e.g., using a Latin square design) and participants were allocated to each block/condition sequence by a random process. It was also applied to those studies in which a sequence of trials (and thereby conditions) was randomised separately for each participant. Only five (8%) studies met these criteria. The domain received a high risk judgement if a non-random method of sequence allocation was used. This was the case in three studies (5%), in which participants were allocated to a block/condition sequence based on their time of arrival in the laboratory. The method of sequence generation and/or condition or sequence allocation was unreported in 44 of the 60 included studies, and hence their risk of bias was marked as unclear. Risk of bias was also deemed unclear if the sequence of blocks/conditions was unevenly distributed across participants. This was the case in seven studies (12%), in which the number of participants did not correspond to the number of generated block sequences. In three studies, allocation of keys to the right and left hand response was not counterbalanced (all were identified as unclear bias studies).

Allocation concealment

The risk of selection bias due to inadequate allocation concealment refers to the extent to which knowledge of condition or sequence allocation can influence participant selection. The majority of studies (82%) employed a within-subjects design, and were therefore considered to have a low risk of bias in this particular domain. Where a between-subjects design was employed (18%) and no adequate measures were taken to conceal allocation, awareness of the forthcoming assignment could in principle have enabled the experimenter to delay the testing of a participant until the next "appropriate" assignment based on some prognostic factors (e.g., a young male participant might do better on a manual decision task) or to alter the allocation altogether. Since the risk of bias could not be ruled out in those studies and none of them reported whether or how allocation was concealed, their risk of bias was marked as unclear.

Blinding of participants

In most studies, including those with between-subjects designs, participants' awareness of condition allocation (e.g., whether someone is asked to name a picture or make a size judgement of a pictured object) is in itself unlikely to lead to performance bias. However, in rare cases, blinding of participants may be undermined by the blocking or full randomisation of conditions. For example, when emotional content of distractors is manipulated as a within-subject variable and taboo and neutral distractor conditions are blocked, participants can develop strategies to optimise their performance in that particular condition. Even when conditions are intermixed but their order is fully randomised, it is possible that trials from the same condition (e.g., related one) would appear in succession, allowing participants to generate expectancies and affecting their processing of subsequent stimuli. Studies in which such designs were employed and in which information on participant blinding was omitted were considered to have an unclear risk of bias (23%). In the remaining studies, the risk of bias was judged as low because participants' awareness of condition allocation was either unlikely to affect their performance or it was minimised by adequate randomisation of conditions.

Blinding of experimenter

Blinding of experimenter pertains to a situation in which the person conducting an experiment remains unaware of condition allocation throughout the duration of the experiment. Knowledge of condition allocation may affect an experimenter's attitude towards participants, leading to performance bias. Although none of the assessed studies explicitly stated whether or not the experimenter was blinded to condition allocation, this was unlikely to pose a risk in 42% of the assessed studies due to randomisation of conditions. Inadequate blinding of experimenter could have been a source of performance bias in the remaining studies in which a between-subjects or a blocked within-subjects design was used, and hence their risk of bias was marked as unclear.

Blinding of outcome assessor

Risk of bias due to inadequate blinding of outcome assessor refers to the extent to which measurement of an outcome is influenced by an assessor's knowledge of condition allocation. In the context of PWI studies, this pertains primarily to measurement of participants' vocal responses, which, unlike the recording of manual responses, allows some room for judgement (e.g., was the participant's response correct, was the voice key triggered prematurely by a non-speech sound). None of the studies reported whether or not the person coding participants' responses was blinded to condition allocation. Their risk of detection bias was judged as low, however if the study used a randomised within-subjects design and if response coding in that study was verified offline with an audio-recording (10% of studies). If no information was given about how participants' responses were evaluated, or a within-subjects design with intermixed conditions was used but offline response accuracy checking remained unspecified, the risk of bias was judged as unclear (70% of studies). Assessment of participants' responses was at a high risk of bias in studies which used between-subjects designs or within-subjects designs with condition blocking, in which the experimenter registered participant's responses online (i.e., while the experiment was in progress), and in which no objective record (e.g., an audio recording) was described to verify the accuracy of the experimenter's judgement (20% of studies).

Incomplete outcome data

In the context of PWI studies, incomplete outcome data handling pertains to identification of errors and reaction time outliers, their exclusion from data analysis and subsequent justification of that exclusion. Outlier measurement, exclusion of problematic data points and reasons for their exclusion were adequately reported in one quarter of the assessed studies. In the overwhelming majority of studies (67%), which were considered to have an unclear risk of bias, at least two flaws of incomplete outcome data handling were identified. These include lack of clarity on outlier identification (e.g., whether RT outliers were calculated using global mean across all participants and conditions or individual conditional mean), clustering of all error types (e.g., incorrect responses, premature voice key triggering, voice key malfunction, disfluencies) into one category, and provision of a global percentage of excluded data without breakdown per condition. When there was no evidence of data screening, the risk of bias was marked as high (3%).

Selective reporting

Bias may also be introduced through the selective use and reporting of statistical tests. Risk of bias appeared to be high in 8% of studies in which either no descriptive and inferential statistics were provided, a post-hoc test was performed but no post-hoc statistics were reported, or in which the reported effect would not have survived post-hoc corrections had those been applied. In 85% of studies, all pre-specified outcomes were reported with adequate detail. A small number of studies (7%) received an unclear risk of bias judgement due to apparent discrepancies between descriptive and inferential statistics (e.g., where descriptive data would suggest an interaction, no statistically significant interaction was reported).

Other bias: selective reporting of demographic information

Only one quarter of the assessed studies provided adequate detail on age, gender and the first language of participants. The vast majority (75%) neglected to report either one, a combination of two, or all of the variables. Hence their risk of bias was marked as unclear.

Other bias: verification of response accuracy and timing

Even with adequate blinding of outcome assessment, the procedure used to register participants' vocal responses is not error-proof. Often, the experimenter evaluates responses in real time, during a brief (typically a one- or two-second-long) interval before the onset of the next trial. This was a standard procedure in 35% of the assessed studies, which were marked as high risk. In 47% of studies, there was no indication of how responses were evaluated or whether or not their accuracy and timing were rechecked offline, and hence their risk of bias was deemed unclear. Verification of response accuracy and timing based on audio-recordings was reported only in 18% of studies. These were therefore judged to be at a low risk of bias.

Other bias: matching of item sets

The validity of findings also becomes questionable when the stimuli sets between conditions are not matched on relevant psycholinguistic properties. For example, distractor words across low- and high-frequency conditions may be matched on length, but not on other variables known to affect processing speed, such as age of acquisition or imageability. The standard procedure to avoid complications due to inadequate matching of items sets is to re-combine pictures and distractors from the related condition into unrelated pairs of items. In studies in which this was possible and in those in which adequate matching was realized (70%), risk of bias was judged as low. Matching was not realized in 30% of studies, and these were judged to be at a high risk of bias.

	Sequence generation	Allocation concealment	Blinding of participants	Blinding of experimenter	Blinding of outcome assessor	Incomplete outcome data	Selective outcome reporting	Demographic information	Response accuracy and timing	Matching of item sets
Abdel Rahman & Aristei (2010)	?	+	+	?	?	?	+	+	-	+
Abdel Rahman & Melinger (2007)	?	+	?	+	?	?	+	?	-	+
Alario et al., (2000)	-	+	?	+	?	?	-	?	-	+
Aristei & Abdel Rahman (2013)	?	+	+	?	-	?	?	+	-	+
Aristei et al., (2012)	?	+	?	+	?	+	+	?	?	+
Bölte et al., (2013)	?	+	+	+	?	?	+	?	?	-
Bölte et al., (2015)	?	+	?	?	?	?	-	?	-	-
Brooks et al., (2014)	?	?	+	?	?	+	+	+	+	+
Catling et al. (2010)	?	+	+	+	?	?	+	?	?	+
Costa et al. (2003)	?	+	+	+	?	?	+	?	?	+
Costa et al., (2005)	?	+	+	+	?	?	+	?	?	-
Cutting & Ferreira (1999)	?	+	?	+	?	?	+	?	-	+
Damian & Bowers (2003)	?	+	+	?	-	+	+	?	-	+
Damian & Spalek (2014)	?	+	+	?	?	+	+	?	?	+
de Zubicaray et al., (2013)	?	+	+	+	+	?	?	+	+	+
de Zubicaray et al., (2018)	?	+	+	?	?	+	+	?	?	+
Dean et al. (2001)	?	+	?	+	?	?	+	?	-	+
Dhooge & Hartsuiker (2010)	?	+	+	+	?	?	+	+	-	-
Dhooge & Hartsuiker (2011)	?	+	+	+	?	?	+	?	-	-
Finkbeiner & Caramazza (2006)	-	+	+	?	?	?	+	?	?	+
Geng et al. (2014)	?	?	+	?	-	?	+	?	-	-
Geng et al., (2013)	?	+	+	+	?	?	+	?	?	+
Glaser & Düngelhoff (1984)	?	?	+	?	-	+	-	?	-	+
Glaser & Glaser (1989)	-	?	?	?	-	?	+	?	-	+
Hansen et al. (2017)	?	+	+	?	?	+	-	+	?	+
Hantsch et al., (2009)	?	+	+	?	?	?	?	?	?	+
Hantsch et al., (2012)	?	+	+	?	?	+	+	?	?	+
Hantsch et al., (2005)	?	+	+	?	?	?	+	?	?	+
Hantsch & Mädebach (2013)	?	+	+	?	?	+	+	?	?	+
Humphreys et al. (1995)	?	?	+	?	?	+	-	?	?	+
Hutson & Damian (2014)	?	+	+	+	+	?	+	?	+	-
Hutson, Damian, & Spalek (2011)	?	+	+	?	+	+	+	?	+	-
Jescheniak et al., (2014)	?	+	+	+	+	?	+	?	+	+
Kuipers et al., (2006)	+	+	+	+	?	?	+	?	-	-
La Heij et al., (1990)	?	?	?	?	-	+	-	?	?	+
La Heij, Heikoop, Akerboom, & Bloem (2003)	?	+	+	?	-	?	-	?	-	+
Lupker & Katz (1981)	?	?	?	?	-	?	-	?	-	-
Lupker (1979)	+	+	?	+	?	?	-	?	-	-
Mädebach et al., (2017)	?	+	+	?	-	?	+	+	-	+
Mädebach et al., (2018)	?	?	+	?	?	?	+	+	?	+
Mahon et al., (2007)	?	+	+	+	?	?	+	?	?	+
Matushanskaya et al. (2017)	?	+	+	+	+	+	+	?	+	+
Miozzo & Caramazza (2003)	?	+	+	+	?	?	+	?	-	-
Muehlhaus et al., (2013)	?	+	?	+	+	?	-	+	+	+
Navarrete & Costa (2005)	?	+	+	+	?	?	+	?	?	+
Piai et al. (2012)	+	+	+	?	-	?	+	?	-	+
Roelofs (1992)	?	+	+	?	-	+	?	?	-	+
Rose et al., (2019)	+	+	+	+	?	-	+	+	?	+
Sailor & Brooks (2014)	?	+	+	?	?	?	+	+	?	+
Sailor et al., (2009)	?	+	+	?	?	?	+	+	?	+
Schriefers et al. (1990)	?	?	+	?	?	?	-	?	?	-
Smith & Magee (1980)	?	+	+	?	?	-	-	?	+	+
Starreveld et al. (2013)	?	+	+	?	?	?	-	?	?	-
Vieth et al. (2014a)	?	?	+	?	?	+	-	?	?	+
Vieth et al., (2014b)	?	+	+	+	?	+	+	?	?	+
Vigliocco et al., (2004)	?	+	+	+	?	+	?	?	?	-
Vitkovitch & Tyrrell (1999)	+	?	?	?	-	+	+	?	?	+
White et al. (2016)	?	+	?	?	?	?	-	+	+	-
White et al. (2017)	?	+	?	?	?	?	-	+	+	-
White et al. (2018)	?	+	+	?	?	?	?	+	+	+

Figure 4. Risk of bias summary. Judgement of risk of bias for each domain for the reviewed PWI studies. "+" low risk, "-" high risk, "?" unclear risk

Recommendations

Based on the risk of bias assessment, the following recommendations can be made about the design and conduct of future PWI studies.

Many authors neglect to report how sequences of trials, blocks, and conditions were generated and whether or not participants were allocated to each sequence by a random process. Investigators should not only minimise selection bias by ensuring that participants are allocated to a generated sequence based on a method that includes an element of chance and that the generated sequences are adequately counterbalanced in blocked designs (i.e., an equal ratio of participants is allocated to each sequence, assignment of keys/buttons to responses is counterbalanced in manual tasks), but also communicate these efforts to the reader.

The risk of performance bias arising from inadequate blinding of participants can be reduced by the choice of a within-subjects design in which the conditions of interest are intermixed rather than blocked, by inclusion of filler trials (especially when relatedness proportion is high, in some cases reaching 67%), and by the use of pseudo-random rather than fully randomised sequences. These efforts can be complemented by the use of post-test awareness probes to gauge participants' awareness of any regularities or interdependencies in the performed tasks.

More clarity should be given of experimenter and outcome assessor blinding, especially when knowledge of condition allocation poses a genuine risk of performance or detection bias. Ideally, experiments should be conducted and participants' vocal responses evaluated by a person who is naïve to the aims of the study. If this is not feasible, future studies should incorporate within-subjects designs in which conditions are intermixed rather than blocked. Since evaluation of participants' vocal responses in real time is not fully objective or error-proof, an audio-recording should be obtained of the experimental session for an off-line checking of response accuracy

Information about how and why the data were trimmed and about the amount of data removed from statistical analyses should be adequately reported. This includes provision of percentages of errors and RT outliers *per condition*, description of RT outlier identification (i.e., if absolute or standard deviation cut-offs were adopted; if the latter, whether these were calculated from global or individual condition means), and differentiation between error types (e.g., incorrect responses should be separated from voice key malfunction). Data analysts should ideally be blinded to the conditions of interest, so that the risk of “inconvenient” data suppression or manipulation is minimised.

There is also a need for a more thorough reporting of descriptive and inferential statistics. It is not uncommon for authors to omit measures of variability or post-hoc statistics. Where multiple comparisons have been made, post-hoc corrections should be applied.

The risk of bias assessment has indicated persistent poor reporting of demographic details. Appropriate background information such as age, gender and first language of participants should be clearly stated.

Relying entirely on the automatic detection of response onset times by a voice key may introduce error (Protopapas, Archonti, & Skaloumbakas, 2007). Specialised software can be used to visually inspect a waveform for premature triggering of the voice key (e.g., by non-speech sounds and movement) and for voice key activation failures (e.g., due to insufficiently loud responses).

Matching of stimuli sets across experimental conditions on variables known to affect item processing should be optimised where re-assignment of pairs is not possible. Careful consideration should be given to factors affecting the speed with which both words (e.g., lexical frequency, age of acquisition, length, imageability) and pictures (e.g., complexity, name agreement, concept familiarity) are processed.

2.6 Summary of main findings

This work has systematically reviewed the findings of PWI studies investigating the competitive nature of spoken word production. Competition in this context refers to the narrow sense of the term as a delay in target name selection caused by co-activation of non-target lexical representations. Various parameters of the PWI task have been manipulated in these studies (e.g., distractor format, target-distractor relationship, task demands) to establish how and when in the process of recognising and naming a pictured object semantic context effects come about. Below is a summary of the findings from individual manipulations as well as their implications for the proposed accounts of lexical selection.

Evidence from distractor format manipulation

Contrary to popular assertions that categorically related distractor pictures facilitate naming, the majority of the reviewed studies have shown the opposite – that pictorial distractors belonging to the same semantic category as targets interfere more with picture naming than their unrelated controls. A similar observation was made for distractors in the form of environmental sounds. This was apparent under conditions which promoted lexical encoding of the non-verbal interfering stimuli. The fact that pictorial and environmental sound distractors produced interference, despite having no articulatory advantage over target picture names, presents a challenge to the REH account. There is also the possibility, in accordance with the CEH, that the structural and/or conceptual information activated by non-verbal distractors introduces temporary uncertainty about what it is that one sees (object recognition) and/or what it is that one needs to name (concept selection). On the other hand, if that were the only source of interference, an inhibitory effect would be obtained irrespective of whether or not pictorial (or environmental sound) distractors were adequately lexicalised. The evidence obtained from distractor format manipulation thus appears to favour a competitive view of lexical selection, with early decision processes potentially also contributing to the effect.

The only study that utilised pseudo-words as distractors reported facilitated picture naming in the context of unrelated illegitimate words compared to unrelated real words. Although this observation was originally explained in terms of a self-monitoring mechanism that is fine-tuned to detect and eliminate meaningless words more quickly than real words (lexicality bias), it also fits well with alternative competitive accounts (SLNH and selection-by-competition with competition threshold) and non-competitive (REH and CEH) accounts of semantic context effects.

Evidence from distractor frequency manipulation

The evidence produced by studies with distractor frequency manipulation does not allow for strong conclusions to be drawn about the locus of semantic context effects or the mechanisms from which they emerge. Although the distractor frequency effect has been replicated in multiple studies, it is open to several interpretations (REH, CEH, perceptual reactive blocking, attentional capture). Joint manipulations of distractor frequency and other variables such as SOA, distractor visibility, or emotional content of distractors, have produced mixed results. Their interpretation is further complicated by questionable presuppositions on which predictions have been made (e.g., the efficacy and extent of masking; the locus of taboo interference). Distractor frequency has been extensively studied within the PWI paradigm, while other intrinsic properties of distractors (e.g., imageability, concept familiarity) remain underexplored. Examining psycholinguistic variables known to exert their effects at different stages of information processing could provide further insight into the processes underlying semantic context effects. This line of PWI research would also benefit from more empirical data derived from cross-factorial designs in which both distractor characteristics and task demands are manipulated. Although some attempts have been made to address this, the results of how the distractor frequency effect is modulated by phonological decisions, for example, were not clear-cut. Other tasks in which perceptual or semantic processing load is increased could also be employed.

Evidence from distractor visibility manipulation

Manipulations designed to prevent phonological responses from entering an articulatory buffer using a masking procedure have produced limited and equivocal evidence. The prediction that interference would turn into facilitation if the need for articulatory buffer clearing was eliminated was confirmed by just a handful of studies. However, other studies have either failed to replicate the polarity reversal or demonstrated interference irrespective of whether the distractors were masked or visible. The validity of the masking procedure was further called into question, as it is not clear what stages are effectively “turned off” under reduced visibility conditions. Facilitation should not be at all surprising if the processing of subliminally presented distractor words was restricted to their conceptual encoding. It was proposed that the notion of conscious perception of distractors be replaced with the concept of distractor activation strength.

Evidence from manipulations of emotional content of distractors

Although the taboo interference effect is a robust phenomenon, its origins are not fully understood. The evidence obtained from concurrent manipulations of the emotional content of distractors and other variables such as SOA and phonological relatedness is inconclusive. There is compelling, albeit scant evidence from studies in which emotional content of distractors was factorially crossed with task demands, suggesting that the taboo interference effect is driven by early lexical (competition from co-activated lexical representations) and/or pre-lexical (attentional modulation) processes. Persistent interference in the absence of articulatory preparation (phonological decision task) undermined the role of the articulatory buffer clearing mechanism as the main driving force of the effect. The pre-lexical basis of the taboo interference effect could not be ruled out because the effect was preserved in the absence of lexical encoding (semantic decision task), although this was only observed under degraded input conditions. The taboo interference effect also runs contrary to the REH account because unrelated, socially inappropriate distractor words should be eliminated from the articulatory buffer sooner than unrelated neutral distractor words following the response relevance logic (taboo words do not fulfil an implicit criterion of producing speech that is socially appropriate). By analogy to pseudo-words, socially inappropriate words should also be more easily detected and eliminated by the verbal self-monitor, leading to facilitation. The opposite pattern of results (i.e., greater interference for taboo words) was explained by more conservative checking of offensive, potentially embarrassing responses by the self-monitor, an activity which takes time. In either case, the lines of reasoning used to explain pseudo-word facilitation and taboo interference appear to contradict one another. It is also unclear how a self-monitoring system can account for the findings of interference for negative distractor words.

Evidence from hierarchical relations manipulations

Hierarchically related distractors (i.e., those drawn from different levels of specificity than targets) were generally found to induce interference, although the evidence was less clear-cut for hypernymic distractors. Even when the evidence appears to be more consistent, as in the case of subordinate-level distractors, it leads to opposing interpretations; selection-by-competition, REH and CEH all offer a plausible explanation of the results. This line of research is in need of more empirical data derived from cross-factorial designs, which would include distractors from all levels of specificity.

Evidence from semantic distance manipulations

It is too early to draw any strong conclusions about the robustness of the semantic distance effect. Roughly an equal number of studies have produced an inhibitory, facilitatory or no effect for semantically close distractors relative to their more distant controls. Direct comparisons are problematic because of the different measures used to operationalise semantic distance, in addition to potentially confounding variables such as relatedness proportion or inadequate matching of stimulus sets across experimental conditions.

Evidence from manipulations of associative (miscellaneous) and thematic relations

The facilitatory effect for associatively and thematically related distractor words relative to their unrelated controls is a fairly well-established phenomenon, particularly at early SOAs. However, due to the miscellaneous nature of the associative relations, facilitatory effects find plausible explanations in both competitive and non-competitive accounts. Future research could examine the effect of purely associative (probabilistic) relations on the speed of naming in the absence of semantic relatedness.

Evidence from manipulations of whole-part relations

Based on the evidence from manipulations of whole-part relations in the PWI paradigm, two critical factors appear to determine the direction of the semantic interference effect: distinctiveness and visibility of distractor-denoted parts in target pictures. Distinctiveness (or strong association between items) appears to be the driving force of the facilitatory effect, which can reflect the interplay either between strong semantic priming and weak lexical interference (in accordance with the SLNH), or strong semantic priming and lack of interference due to articulatory buffer clearing (in accordance with the REH). Distractors denoting non-distinctive features of targets either have no effect on picture naming or interfere with production when presented after target onset. While the null results could be due to the absence of semantic priming, interference could be explained by lexical competition. Pre-lexical decision processes (e.g., uncertainty about what one needs to name) could also contribute to the net inhibitory effect, especially with distractors denoting parts that are visible in target pictures. This claim found support in one study which specifically manipulated the visibility of distractor-denoted parts in target pictures, but was discredited in a post-hoc analysis of another study, leaving the issue unresolved.

Evidence from manipulations of visual similarity

Despite an indication that visual similarity between targets and distractors in the absence of semantic relatedness contributes to the net inhibitory effect observed in the PWI task, its robustness is far from settled. More empirical data are needed with studies tapping a broader range of structural features of objects such as size, shape and colour as well as eliminating the confound of response membership.

Evidence from manipulations of task demands

PWI studies with task demand manipulations have not furnished any clear answers about the mechanisms that drive semantic context effects or the loci at which these effects emerge. This is for several reasons. Evidence derived from “perceptual” tasks appears to be inconclusive because of the dubious nature of the tasks themselves (e.g., it is unclear how much perceptual processing is involved in the task) as well as minor procedural variations (e.g., familiarisation with experimental stimuli) which may unwittingly alter the nature of the task.

A range of effects has been reported by studies utilising semantic decision tasks, signalling a need for more research that could resolve the existing discrepancies. Even though facilitation was a fairly consistent finding in superordinate category naming tasks, the results were likely influenced by the confound of response congruency.

There is fairly consistent, albeit weak evidence against an articulatory locus of the semantic context effect produced by studies utilising phonological decision tasks. Only one study examined how the PWI effect is modulated when the task involves a pre-articulatory phonological decision, with the remaining handful of studies investigating the joint effects of phonological decisions and frequency or emotional content of distractors. Since the origins of these effects remain unexplained and the differences in performance are marginal, any conclusions about the source and the mechanisms underlying the PWI effect based on the results of these manipulations would be premature.

Overall

To address the main research question of whether or not spoken word production is a "competitive" process (in the narrow sense of the word), none of the reviewed findings has directly refuted the claim that the speed with which a target word is selected depends on co-activation of non-target representations. A range of effects from interference, through null effects, to facilitation that have been reported in the context of the PWI task can be plausibly explained both with the SLNH and the selection-by-competition with a competition threshold account. In fact, the semantic context effect may no longer be viewed as an all-or-nothing phenomenon; instead, its gradient may change depending on the interaction of a number of forces operating at different stages of information processing and at various levels of intensity. Competition from unwanted lexical representations is just one such viable force.

Various sites of the PWI paradigm have been manipulated, with each manipulation enabling more precise inferences to be made about the cognitive processes involved in spoken word production. Many discrepancies remain unresolved; some arguments will need to be substantiated with more empirical data. Two developments have proved particularly useful in advancing the debate on the nature of lexical selection, however. One, interference from non-verbal distractors (pictures and environmental sounds) has been confirmed to be a genuine effect dependent on adequate lexicalisation of interfering stimuli. This has undermined the REH, but left the CEH largely unchallenged. Two, manipulations of whole-part relations have highlighted the role of association strength (distinctiveness) and visibility of distractor-denoted parts in target pictures as important determinants of the speed of naming. In particular, the polarity reversal of the PWI effect (from facilitation to interference) when non-distinctive but picture-visible parts of objects are used as distractors would suggest a lexical (in accordance with competitive views of lexical selection) or a pre-lexical locus (in accordance with the CEH) of the effect.

The REH and the self-monitoring account in their current form lack sufficient explanatory power to account for all of the reviewed findings. The REH account has been challenged by findings from studies that have employed manipulations of distractor format, distractor emotional content and task demands, among others. The lines of reasoning proposed by the self-monitoring hypothesis to account for pseudo-word facilitation (lexicality bias) on the one hand, and taboo interference (bias towards socially inappropriate words) on the other, appear to be contradictory. Observations of interference for negatively connoting words or for non-distinctive parts in studies manipulating whole-part relations also appear difficult to accommodate within the self-monitoring framework. These findings should not be taken to contest the existence of a monitoring system as such, but to challenge its role as the sole contributor to the PWI effect. A general criterion checking mechanism of some sort is conceivable. Not being restricted to the post-lexical stage, such a mechanism could integrate contextual information from a number of sources, from the more global context of task demands or social appropriateness to the more local contextual information inherent in the task (e.g., when one is naming an object, a verb distractor should be more easily rejected than a noun distractor), determining if the selected representation (structural, conceptual, lexical, phonological) should be processed further. The issue of multi-functionality of the system should also be addressed. The monitor in its current form performs the role of a detector (it intercepts errors), eliminator (it excludes a response), and editor (it corrects the error) at the same time. Extra consideration should be given to other processes such as a suppression mechanism, which could be mobilised by the monitor.

The CEH account has not been given adequate consideration, even though early processes associated with picture naming could potentially be influenced by structural and semantic information supplied by the distractor. Several studies have implicated the pre-lexical stage as a potential locus of the PWI effect, but except for studies manipulating the visual similarity between targets and distractors, its contribution to the net semantic interference effect has not been directly assessed. It therefore remains a viable determinant of the speed with which pictures are named in the PWI task.

CHAPTER 3: TYPES OF INTERFERENCE AND THEIR RESOLUTION IN LEXICAL SELECTION (STUDY 2)

3.1 Background, rationale and aims of Study 2

As outlined in the introductory chapter (Section 1.3.3), there is some support for the claim that inhibitory control underlies normal language production and this can be observed across several linguistic contexts: in object and action naming, in the selection of syntactic structures and in pragmatic language use. Nevertheless, the findings pose several interpretation problems. In a number of studies, inhibitory control is treated as part of an "executive" package, being studied alongside other cognitive functions, such as working memory and mental set shifting; as a result, it is usually measured with a single task, with little rationale for why a particular task was chosen (e.g. Long, Horton, Rohde, & Sorace, 2018; Wardlow, 2013). In addition, it is often unclear what type of inhibition contributes to the efficacy of language production. When a distinction is made (for example, selective vs non-selective inhibition), the evidence with regards to the proposed types is either inconclusive, conclusions are based on indirect proxies for the construct of interest or the proposed classification may not be warranted. For example, the literature presents inconsistent results for the involvement of selective and non-selective inhibition in resolving lexical competition, e.g., see Crowther & Martin (2014) and Shao et al. (2015). Interpretation of findings may further be complicated by the use of indirect proxies for inhibition rather than more direct methods of measurement. Both Shao et al. (2015, p.1816) and de la Vega et al. (2014, p.3) recognise the use of statistical (the interference effects quantified as the slope of the slowest delta segment in distributional RT delta plots analysis) and behavioural (anxiety and pharmacological manipulation) proxies for inhibition as a limitation of their work, urging the application of "more direct" or "independent behavioural" measures in future research. Moreover, the proposed classification system is not always justifiable. The distinction between selective and non-selective inhibition as adopted by Shao et al. (2015), for example, seems to confound the type (e.g. inhibiting a prepotent response) and the locus of interference (e.g., inhibition at the response stage).

Given that inhibitory control is not a unitary construct, as demonstrated by previous theoretical work and recent empirical findings (Section 1.3.2), the aim of Study 2 was to assess the unique contribution of different types of non-verbal inhibitory control to object naming under increased within-language competition. Resolution of conflict at different stages of information processing was measured with the anti-saccade task, the arrow flanker task, and the Simon arrow task (Section 1.3.2). In addition, two object naming tasks were employed that reflect different inhibitory demands associated with target word selection: picture word interference (PWI) and picture naming with name agreement manipulation (henceforth, NA task). For a detailed description of the PWI paradigm, see Section 1.2.2. In contrast to the PWI task, which is associated with prepotent competition (the activated competitors are context-irrelevant), the competition in the NA is said to be underdetermined because the activated lexical candidates are equally viable responses (e.g., Snyder et al., 2014).

The NA task draws on the observation that low name agreement objects that are associated with multiple names (e.g., COINS could be labelled as “coins”, “money”, “pennies”, etc.) are named more slowly than high name agreement objects with one dominant name (e.g., TOMATO is usually labelled as “tomato”). This observation holds after controlling for other psycholinguistic variables known to affect picture naming, such as frequency of occurrence and age of acquisition (e.g., Alario et al., 2004). Prolonged naming latencies in low name agreement versus high name agreement trials (the NA effect) are thought to reflect the activation of more than one lexical representation, which creates greater selection demands and potentially necessitates recruitment of cognitive resources involved in conflict resolution (e.g., Alario et al., 2004; Bose & Schafer, 2017; Hartsuiker, & Notebaert, 2009). The origins of the effect can be traced to lexical encoding but only for objects with low name agreement due to the availability of alternative names and not visual or conceptual ambiguity (Britt, Ferrara, & Mirman, 2016; Vitkovitch & Tyrrell, 1995).

In addition to using different non-verbal inhibitory control measures and spoken word production tasks reflecting distinct inhibitory demands, individual variation in lexical knowledge was assessed with the vocabulary subtest of the Wechsler Adult Intelligence Scale III, WAIS-III (Wechsler, 1997). The inclusion of this measure in the statistical analysis was motivated by the premise that both the PWI and NA effects are contingent on spreading activation, which varies among individuals. Activation in individuals with larger vocabularies (more robust semantic-lexical networks; Mainz, Shao, Brysbaert, & Meyer, 2017) may spread to a greater number of neighbouring representations, inducing more competition and thereby creating an increased need for inhibitory control, than activation in individuals with smaller vocabularies. By including the WAIS vocabulary measure as a control variable it was possible to assess the role of inhibitory control independent of the degree to which within-language competition is induced in speakers with different vocabulary sizes.

In sum, the study extends previous work examining the relationship between inhibitory control and lexical selection in three ways: 1) it utilises behavioural measures of non-verbal inhibitory control, rather than statistical or behavioural proxies, each capturing resolution of conflict at different stages of information processing; 2) it examines the unique contribution of these three different inhibitory processes to the production of words in the context of prepotent and underdetermined competition; 3) it controls for vocabulary knowledge and general processing speed.

We hypothesised that performance assessed with the standard inhibitory control tasks should predict the magnitude of interference effects in the object naming tasks, if some form of conflict is indeed involved in spoken word production under prepotent and underdetermined competition. In addition, as each non-verbal inhibitory control task captures resolution of conflict at different points in the information flow, performance on these tasks may uniquely contribute to the speed with which objects are named in the two production tasks. Because the analysis is largely exploratory, we did not specify which inhibitory component would make the strongest contribution to object naming under prepotent or underdetermined competition, although it may be speculated based on the rival accounts of the PWI effects that the flanker and/or the anti-saccade effect can reliably predict the magnitude of interference in the PWI task, with the anti-saccade effect having a negligent role in the NA task (due to the absence of an external word distractor that could potentially block the articulatory buffer).

3.2 Method

3.2.1 Participants

Ninety-seven native English speakers (N_{males}=26; M_{age}=21.9 years, $range_{age}$ 18-44 years), recruited from Middlesex University, took part in the study. All participants reported English to be their dominant language, but only those who were born in the UK or arrived in the country by the age of five years were included in the final analysis. All had normal or corrected-to-normal vision and reported no cognitive deficits and no history of neurological impairment. Eight participants were excluded from the analysis for either failing to meet the inclusion criteria, scoring below chance in the anti-saccade task or failing to complete all parts of the experiment. The final sample comprised eighty-nine participants.

3.2.2 General procedure

Participants were tested individually in a sound-attenuated room. After signing the consent form and completing a short demographic and language background questionnaire, participants performed three non-verbal inhibitory control tasks (anti-saccade task and arrow flanker task with an embedded Simon arrow task), two object naming tasks (PWI and NA) and the WAIS vocabulary test. The order of the non-verbal inhibitory control and object naming tasks was counterbalanced across participants. The WAIS vocabulary test was always administered last. All tasks except for the WAIS vocabulary test were run on a computer using E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA). Responses from the non-verbal inhibitory control tasks and the object naming tasks were collected using the same software. All vocal responses were audio-recorded for later scoring. Speech onset latencies in the object naming tasks were registered online via a voice key. In addition, they were coded manually using Audacity ® 2.2.1 recording and editing software to avoid unnecessary data loss (e.g. failure of the voice key to detect a response) and to correct for inaccuracies (the voice key being triggered by irrelevant noises, or being unable to detect voiceless consonants). The testing session lasted approximately 45 minutes.

3.2.2.1 Materials, design and procedure for individual tasks

To assess non-verbal inhibitory control, we utilised three tasks: the anti-saccade task and the arrow flanker task with an embedded Simon arrow task. For visual presentation of the low and high interference conditions across these three tasks, see Figure 5.

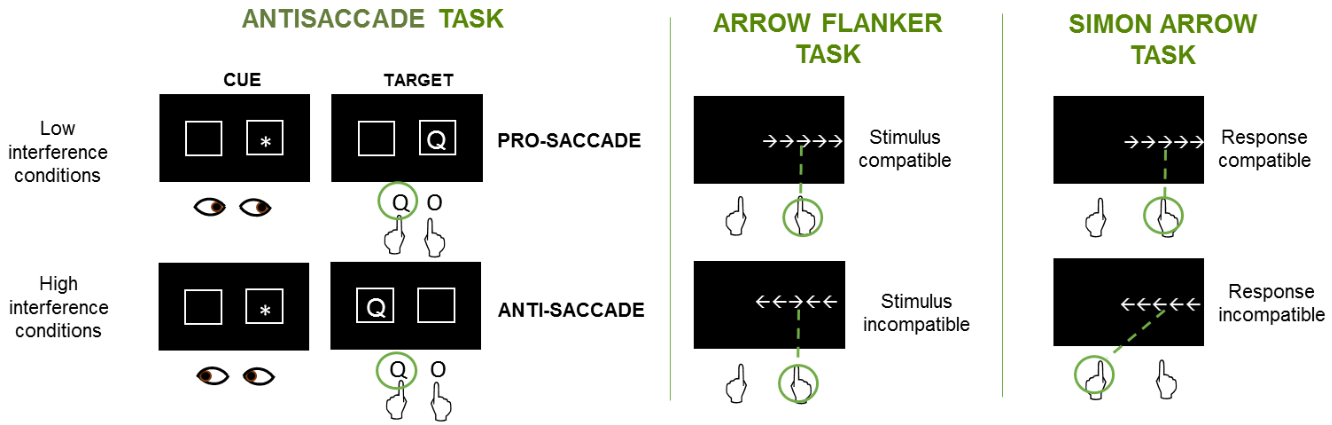


Figure 5. Low and high interference conditions across the anti-saccade, the arrow flanker and the Simon arrow tasks.

Anti-saccade task

Materials, procedure and design

We used the version of the anti-saccade task from Ortells, Noguera, Álvarez, Carmona, & Houghton (2016) consisting of two blocks: pro-saccade and anti-saccade. In the pro-saccade block, participants must look in the direction of a peripheral stimulus (an asterisk that flashes either to the right or left of the fixation point) in order to identify the target letter (Q or O) that appears briefly in the same location. In the anti-saccade block, participants must look away from the peripheral stimulus as quickly as possible, since the target letter appears on the opposite side of the asterisk. Participants pressed the designated keys ("B" and "N") on the keyboard using their index and middle fingers of the dominant hand. Both speed and accuracy were emphasised. All participants received 12 practice trials per block, with online feedback for incorrect responses. If a participant's accuracy in the practice trials was lower than 50%, an additional practice block was administered. There were 96 trials in total: 48 in the anti-saccade block and 48 in the pro-saccade block. The order of the blocks was counterbalanced across participants: half received the pro-saccade block first, while half received this second. The position of the response keys was also counterbalanced across participants.

The design and the timing of trials was identical to Ortells et al. (2016) and is presented in Figure 6.

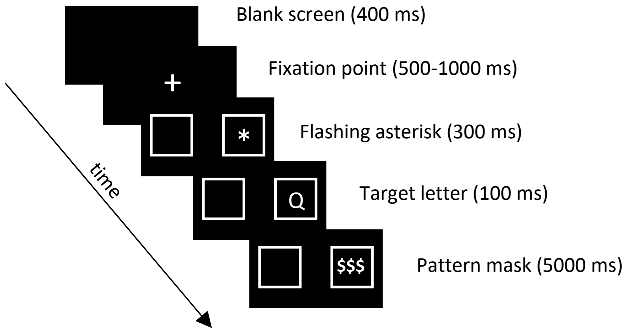


Figure 6. Presentation order and timing of trials in the anti-saccade task.

Data analysis and screening

Only correct responses were included in the analysis of response latencies (24.3% of trials were removed). In addition, responses shorter than 200 ms and longer than 1700 ms and those 3 SD beyond individuals' means were discarded

(2.6% of the trials). The two main dependent variables were the anti-saccade effects quantified as 1) mean reaction time (RT) in the anti-saccade block minus mean RT in the pro-saccade block and 2) mean error rate (ER) in the anti-saccade block minus mean ER in the pro-saccade block. Larger interference effects indicate poorer inhibitory control.

Flanker arrow with an embedded Simon arrow task

Materials, procedure and design

A arrow-based version of the Simon task (Simon, 1990) was embedded within an arrow version of the Eriksen flanker task (Eriksen & Eriksen, 1974). Participants were instructed to identify the direction of a target arrow flanked on each side by two irrelevant stimuli (flankers). The flankers could either be squares (neutral condition), arrows facing in the same direction as the target (stimulus-compatible) or arrows facing the opposite direction to the target (stimulus-incompatible). The stimuli could be presented in the centre of the screen (neutral condition), on the same side as the response key (response-compatible) or on the opposite side to the response key (response-incompatible). Participants were instructed to use both hands to press a designated key (“L”) on the right when the central target arrow pointed to the right and a designated key (“A”) on the left when the central target arrow pointed to the left. They were told to respond as quickly as possible without sacrificing accuracy.

There were five conditions containing 40 trials each: 1) neutral; 2) stimulus-compatible, response-compatible; 3) stimulus-incompatible, response-compatible; 4) stimulus-compatible, response-incompatible; and 5) stimulus-incompatible, response-incompatible. The trials and conditions were intermixed in a random order. The 200 trials were divided into four blocks of 50 trials each, separated by three short breaks. There were 20 practice trials with all conditions represented equally. Online feedback for incorrect (“INCORRECT”) and undetected (“FASTER”) responses was provided during practice.

Each trial began with a 100 ms blank screen followed by a fixation point for a varied duration of 500-1400 ms. The targets and flankers were presented in 22-point, bold white font against a black background, with the spatial separation of the symbols identical to the spacing of symbols in a printed word (0.16 cm), and remained on the screen for the duration of 1700 ms or until the participant's response.

Data analysis

Only correct responses were included in the analysis of response latencies (7.5% of the data were removed). There were two dependent measures: 1) the arrow flanker effect expressed as the difference in mean RTs between the stimulus-incongruent, response-congruent condition and the stimulus-congruent, response-congruent condition and 2) the Simon arrow effect expressed as the mean RT difference between stimulus-congruent, response-incongruent and stimulus-congruent, response-congruent conditions. Mean error rates were also calculated for these tasks. Larger effects denoted poorer inhibitory control.

3.2.2.2 Word production measures

Picture word interference (PWI) task

Materials

Sixty-two high quality colour images of objects and their normative data were taken from the Bank of Standardized Stimuli, BOSS (Brodeur, Guérard, & Bouras, 2014). Eight images were used for practice. Twenty-seven served as target images and twenty-seven as filler images. The latter were used to increase the proportion of no-distractor trials to minimise participants' strategy use. All the images were scaled to 300 x 300 pixels and were presented in the centre of the screen on a white background.

In addition, sixty-two distractor words were selected from the labels of BOSS objects and from the MRC Psycholinguistic Database (Coltheart, 1981), eight to serve as distractor words for the practice trials and fifty four to serve as distractor words in the experiment. They were either categorically related to the target images or unrelated (associatively, semantically or phonologically). Association norms were obtained from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 2004) and the Edinburgh Associative Thesaurus (Wilson, 1988). The two sets of distractor words were matched on the frequency of occurrence (CELEX), length (syllables, phonemes and letters), familiarity, imageability and association strength. These norms were obtained with the N-Watch program (Davis, 2005) and are presented in *Table 15*. The pairings of the target images and the distractor words are presented in Appendix A. The distractor words were superimposed centrally on the images on a white background such that they did not obscure the images themselves. They were printed in lower case in black bold 28 Arial font.

Table 15. Word frequency, familiarity, length (in syllables, phonemes and letters) and imageability norms for distractor words in the related and unrelated conditions of the picture word interference task.

	Relationship between target picture and distractor word	*M*	*SD*	*SE*	*t*	*p*
Word frequency (CELEX)	related	32.86	46.84	9.01	-1	.32
	unrelated	51.67	85.88	16.53		
Familiarity	related	502.96	156.16	30.05	-.58	.56
	unrelated	525.11	121.78	23.44		
Length (syllables)	related	1.48	.58	.11	0	1
	unrelated	1.48	.58	.11		
Length (phonemes)	related	3.96	.81	.16	.52	.61
	unrelated	3.85	.77	.15		
Length (letters)	related	5.00	.68	.13	-.2	.85
	unrelated	5.04	.71	.14		
Imageability	related	557.26	163.23	31.41	.41	.74
	unrelated	570.44	120.08	23.11		

Procedure

Participants were required to name the displayed images using a single name as quickly and as accurately as possible, while ignoring a distractor word when one was present. Before testing, participants completed a familiarisation phase during which all the images and their names were presented on the computer screen in a randomised order with the object's name displayed below the image. Participants were asked to read the names aloud; they then received eight practice trials containing practice images with superimposed practice distractor words. Correct feedback was provided on the computer screen if the participant produced the wrong name.

During the experimental phase, stimuli were presented in three blocks of 36 trials each, separated by two short breaks. Each block contained 9 categorically related trials, 9 unrelated trials, 9 no distractor trials and 9 filler images. Every target image appeared three times in the experiment (with categorically related distractors, with unrelated distractors and with no distractors), but only once per block. The presentation order of blocks was counterbalanced across participants, as was order of conditions across blocks. Trial presentation was pseudorandomised such that the same condition did not occur more than twice in a row and items that were semantically or phonologically related did not appear in succession.

Each trial began with a blank screen for 500 ms, followed by a fixation point with a varied duration of 500-1000 ms. The target was then presented for 3000 ms or until the voice key was triggered by the participant's response. A tone lasting 380 ms occurred prior to the onset of the target image. The trials are presented in Figure 7.

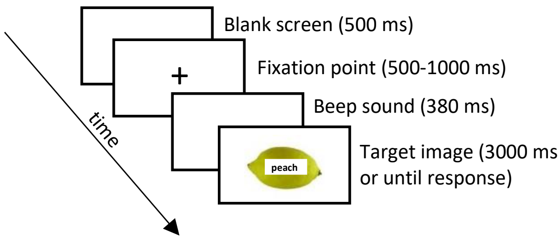


Figure 7. Presentation and timing of trials in the picture word interference task.

Data analysis

Reaction times and accuracy were measured manually using Audacity ® 2.2.1 recording and editing software. The analysis of naming latencies was based only on correct responses (2.4% of the data were removed due to errors). Responses shorter than 250 ms and longer than 3000 ms as well as those falling 3 SD beyond individual means were excluded (2.2% of the data). To measure speech onset latency, a cursor was placed at 380 ms from the onset of the tone and moved across to the onset of the correct name produced by the participant as demonstrated in Figure 8. The naming RT difference between the categorically related and unrelated conditions was used to index the size of the PWI effect. Larger effect sizes indicate less efficient resolution of within-language interference and thus reflect poorer inhibition.

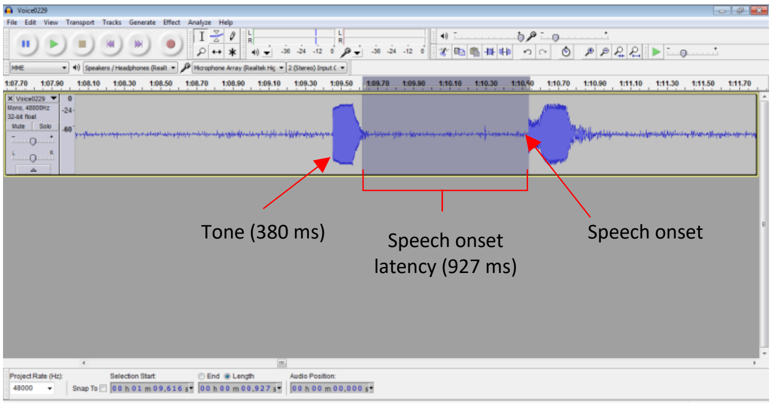


Figure 8. An example of speech onset latency measurement in Audacity ® 2.2.1.

Name Agreement (NA) task

Materials and design

Fifty two high quality colour images and their normative data were obtained from the BOSS database (Brodeur et al., 2014). These were different from those used in the PWI task. Four images served as practice and forty-eight as experimental stimuli. All images were scaled to 300 x 300 pixels and were presented in the centre of the screen on a white background. There were 24 images of low NA and 24 images of high NA (Appendix B). The grouping was based on the percentage of individuals who produced the same name for a given picture as reported in Brodeur et al. (2014). The low and high NA images were matched on a number of psycholinguistic variables known to affect naming speed. For means, standard deviations and *p*-statistics for picture name agreement and psycholinguistic variables on which the two sets of images were matched, see Table 16.

Table 16. Name agreement and psycholinguistic variable statistics for objects with high and low name agreement.

	NA group	*M*	*SD*	*SE*	*t*	*p*
Name agreement (%)*	low	44	11	2	-22.76	<.001
	high	98	3	1		
Word frequency (CELEX)	low	26.54	27.52	5.62	1.6	.11
	high	15.25	19.91	4.06		
AOA	low	138.00	131.09	27.33	1.3	.22
	high	89.92	133.58	27.27		
Familiarity	low	4.30	.37	.08	-1.4	.19
	high	4.43	.27	.05		
Visual complexity	low	2.44	.44	.09	1.6	.12
	high	2.25	.38	.08		
Object agreement	low	3.94	.44	.10	-1.4	.17
	high	4.14	.47	.10		

*Name agreement (%) is the percentage of individuals who produced the same name for a given picture.

Images appeared on a computer screen one at a time and participants were instructed to name the displayed item using one word as quickly and as accurately as possible. Before testing, participants received four practice trials displaying images that were not part of the experimental set. The experimental phase consisted of two blocks of 24 intermixed (both low and high NA) images each; a short break was provided between blocks. Order of blocks was counterbalanced across participants and order of trials was pseudorandomised such that consecutive trials were not semantically or phonologically related. A trial consisted of a blank screen (500 ms), followed by a fixation point for a varied duration between 500 ms and 1000 ms, and a target image, which remained on-screen for 3000 ms or until the voice key was triggered. Each item was preceded by a 380 ms tone to indicate the start of the trial.

Data analysis

Naming latencies were coded manually using Audacity ® 2.2.1 recording and editing software. Only correct names and their alternatives were included in the analysis of naming latencies (12.2% of the data were removed due to errors). Incorrect names, e.g. “screwdriver” or “nail” for SCREW were discarded. Semantically viable alternatives (e.g. “scale” for RULER, “ciggie” for CIGARETTE) were accepted as correct. In addition, naming latencies shorter than 250 ms and longer than 3000 ms as well as those falling 3 SD beyond individual means were discarded (1.4% of the data). Latencies included the time from the end of the tone to the onset of the participant’s response, including hesitations and repairs prior to the correct response word. The NA effect was calculated as mean RT difference between low NA and high NA conditions. The larger the effect size, the less efficient the resolution of within-language competition (i.e., poorer inhibition).

3.2.2.3 Control measures

WAIS-III Vocabulary Subtest

In the vocabulary subtest of WAIS-III (Wechsler, 1997) participants must provide definitions to a list of words (e.g. “Tell me what *consume* means”). The original list was shortened to 26 items as the first seven items were not discriminating enough for a group of students (Tan, Martin, & Van Dyke, 2017). Participants were told that the task was not a speeded task and that there were no penalties for wrong answers. They were allowed to skip any word that was unknown. Responses were audio-recorded and scored according to the WAIS manual, with 2 points awarded for a correct and complete answer, 1 point for a correct but incomplete answer and 0 points for an incorrect or no answer. The maximum score was 52 points.

Processing speed

Processing speed was calculated as an average RT score of the neutral condition in the arrow flanker task.

3.3 Results

Results are reported in three stages. First, we analysed the non-verbal inhibitory and object naming tasks in terms of their interference effects. Second, we examined the correlational patterns of all the tasks. Third, we investigated the relations between individual tasks using hierarchical multiple regression analyses.

Interference effects

Data from the non-verbal inhibitory control tasks and tasks of object naming with interference manipulation were analysed to determine the impact of interference on both response times and accuracy. Mean reaction times and error rates per condition are presented in Table 17. See also Figure 9 below.

Table 17. Mean reaction times (in milliseconds) and mean error rates (in percent) per condition for the Anti-saccade, Arrow flanker, Simon arrow, picture word interference and name agreement tasks.

		Reaction time (ms)		Error rate (%)	
Task	Condition	*M*	*SD*	*M*	*SD*
Anti-saccade	Pro-saccade	460	111	7.9	9.6
	Anti-saccade	527	130	16.4	11.4
Arrow flanker	Stimulus compatible	620	70	.55	1.4
	Stimulus incompatible	820	112	5.5	6.6
Simon arrow	Response compatible	620	70	.55	1.4
	Response incompatible	642	76	1.5	2.6
PWI	Related	604	120	1.4	2.7
	Unrelated	548	83	1	2.7
NA	High	769	122	5.9	5.5
	Low	938	176	6.3	5.7

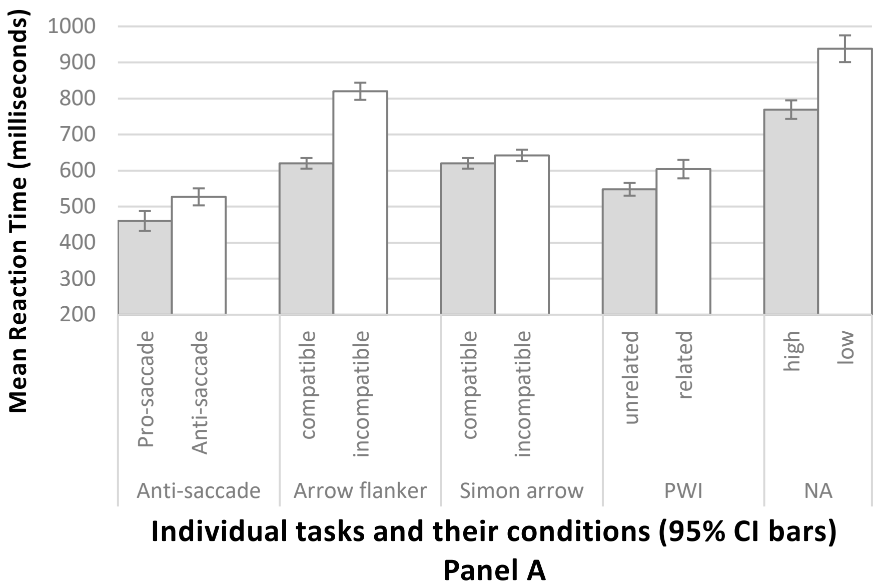
A paired-sample t-test showed that responses had lower error rates (ERs) in the pro-saccade (M = 7.9%, SD = 9.6%) than in the anti-saccade block (M = 16.4%, SD = 11.4%), $t(88) = -7.0$, $p < .001$, $d = 0.74$. Participants were on average 70 ms slower in the anti-saccade (*M* = 527 ms, *SD* = 130 ms) than in the pro-saccade block (*M* = 460 ms, *SD* = 111 ms), *t*(88) = -6.2, *p* < .001, *d* = 0.65.

Paired-sample t-tests showed typical arrow flanker and Simon arrow interference effects, both in terms of RT and ER. Participants made fewer errors on stimulus compatible (*M* = .6%, *SD* = 1.4%) than on stimulus incompatible trials (*M* = 5.5%, *SD* = 6.6%), *t*(88) = -7.2, *p* < .001, *d* = .76. They were also 200 ms quicker to identify the direction of the target arrow when it was facing in the same direction as the flankers (*M* = 620 ms, *SD* = 70 ms) than when it was facing in the opposite direction (*M* = 820 ms, *SD* = 112 ms), t(88) = -22.4, *p* < .001, *d* = 2.3. The percentage of incorrect responses was higher when the stimuli appeared on the opposite side of the response key (*M* = 1.5%, *SD* = 2.6%) than when they were presented on the same side as the response key (*M*= .6%, *SD* =1.4%), *t*(88) = 3.5, *p* = .001, *d* = .38. Responses were also faster to stimuli presented on the same side as the response key (*M* = 620 ms, *SD* = 70 ms) than when they were presented on the opposite side (*M* = 642 ms, *SD* = 76 ms), *t*(88) = 6.5, *p* < .001, *d* = .69.

The results from the PWI task showed a significant semantic interference effect, but only in terms of response latencies. Error rates were comparable across the categorically related (*M* = 1.4%, *SD* = 2.7%) and unrelated (*M* = 1%, *SD* = 2.7%) conditions, *t*(88)= 1.5 , *p* = .12. However, on correct trials, participants were on average 60 ms slower to name images with categorically related distractors (*M* = 604 ms, *S*D = 120 ms) than images with unrelated distractors (*M* = 548 ms, *SD* = 83 ms), *t*(88) = -7.9, *p* < .001, *d* = .83.

Similarly, a significant NA effect was obtained only for the RT analysis. The percentage of invalid responses was comparable across the low (*M* = 6.3%, *SD* = 5.7%) and high (*M* = 5.9%, *SD* = 5.5%) name agreement conditions, *t*(88) = .69, *p* = .49. However, on correct trials, participants were on average 170 ms faster to name objects in the high NA (*M* = 769 ms, *SD* = 122 ms) than in the low NA (*M* = 938 ms, *SD* = 176 ms) condition, *t*(88) = 14.99, *p* < .001, *d* = 1.59.

Taken together, the present experiments succeeded in replicating the interference effects typically observed in these tasks.



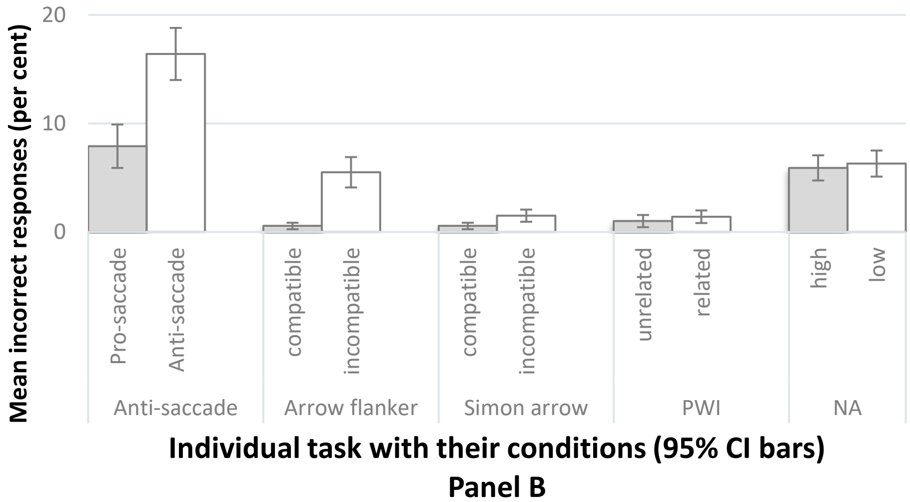


Figure 9. Mean response latencies (panel A) and mean error rates (panel B) per condition in the anti-saccade, arrow flanker, Simon arrow, picture word interference (PWI) and name agreement (NA) tasks.

Correlational patterns

Next, we examined the relations between non-verbal inhibitory control measures and measures of within-language interference resolution and whether these relations would remain after controlling for vocabulary and processing speed. Bivariate and partial Pearson's correlations between these measures are presented in Table 18.

Table 18. Pearson's bivariate and partial correlation coefficients for WAIS vocabulary scores, global processing speed, interference effects obtained in the non-verbal inhibitory control tasks and in the object naming tasks

Bivariate correlations between individual measures

	1	2	3	4	5	6	7	8	9	10
1. WAIS vocabulary	1	-.332**	.046	-.070	-.072	-.100	-.167	-.081	-.291**	-.060
2. Processing speed		1	-.178	.170	.178	.171	.144	.138	-.086	.067
3. Antisaccade effect (RT)			1	.153	-.067	.044	.041	.119	.039	-.052
4. Antisaccade effect (ER)				1	.041	-.157	-.134	-.031	-.124	.076
5. Arrow flanker effect (RT)					1	.309**	.482**	-.002	.226*	-.002
6. Arrow flanker effect (ER)						1	.400**	.215*	-.008	-.113
7. Simon arrow effect (RT)							1	.184	.156	.134
8. Simon arrow effect (ER)								1	.118	.041
9. PWI effect (RT)									1	.184
10. NA effect (RT)										1

Partial correlations controlling for vocabulary and processing speed

	1	2	3	4	5	6	7	8
1. Antisaccade effect (RT)	1.000	.189	-.037	.077	.068	.147	.021	-.042
2. Antisaccade effect (ER)		1.000	.011	-.192	-.166	-.057	-.124	.065
3. Arrow flanker effect (RT)			1.000	.287**	.471**	-.028	.257*	-.015
4. Arrow flanker effect (ER)				1.000	.383**	.195	-.009	-.128
5. Simon arrow effect (RT)					1.000	.164	.137	.122
6. Simon arrow effect (ER)						1.000	.126	.030
7. PWI effect (RT)							1.000	.189
8. NA effect (RT)								1.000

RT = reaction time
ER = error rate
Note. For interference resolution tasks, higher scores indicate larger interference effects and thereby poorer inhibition.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Regression analyses

Two hierarchical multiple regression analyses were performed, with the PWI and NA effect scores as criterion variables, and the WAIS vocabulary, processing speed, anti-saccade, arrow flanker, and Simon arrow effects (both RT and ER) as predictor variables. The assumptions for multiple regression were satisfied, with none of individual cases unduly influencing the model. To ensure that neither WAIS vocabulary nor processing speed score explains away the entire association between the ability to resolve within-language interference and the ability to resolve interference in the non-verbal domain, both control variables were entered into the model first using the forced entry method. The anti-saccade, arrow flanker and Simon arrow effects were entered into the second block using the same method.

Both models, vocabulary knowledge with processing speed (model 1), and vocabulary knowledge, processing speed plus non-verbal inhibitory control measures (model 2) significantly predicted the resolution of within-language interference in the PWI task , F_1 (2,86) = 5.99, p = .002 ; F_2 (8,80) = 2.97, p =.006 respectively. Nearly 12% of the variability in the PWI effect scores was accounted for by the WAIS vocabulary and processing speed scores (adjusted R^2 =.102). This increased to 23% (adjusted R^2 =.152) when non-verbal inhibitory control measures were added to the model. Out of the non-verbal inhibitory control measures, arrow flanker effect (RT) was the only significant predictor of the PWI effect (β = .298, t = 2.55, p = .013) above and beyond vocabulary knowledge, processing speed, the Anti-saccade and the Simon arrow effects.

A separate analysis was conducted for the NA effect as a criterion variable. However, neither vocabulary knowledge, processing speed nor any of the non-verbal inhibitory control measures predicted competition resolution in the NA task. The unstandardized beta (*b*), standardised beta (*β)* scores and their standard errors (*SE b*) as well as the associated *t* and *p* values are displayed in Table 19.

Table 19. Hierarchical multiple regression analyses of variables predicting within-language interference resolution in the object naming tasks (final models)

	b	*SE b*	*Beta*	*t*	*p*
(a) PWI effect as the criterion					
WAIS vocabulary	-2.654	.777	-.359	-3.41	.001
Processing speed	-.171	.088	-.216	-1.94	.056
Anti-saccade effect (RT)	.034	.069	.051	.49	.624
Anti-saccade effect (ER)	-.892	.616	-.153	-1.45	.151
Arrow flanker effect (RT)	.239	.094	.298	2.55	.013
Arrow flanker effect (ER)	-1.631	1.185	-.154	-1.38	.172
Simon arrow effect (RT)	-.007	.261	-.003	-.03	.979
Simon arrow effect (ER)	3.940	2.866	.142	1.37	.173
(b) NA effect as the criterion					
WAIS vocabulary	-.214	1.341	-.018	-.16	.874
Processing speed	.048	.152	.039	.32	.751
Anti-saccade effect (RT)	-.072	.119	-.070	-.61	.544
Anti-saccade effect (ER)	.796	1.062	.087	.75	.456
Arrow flanker effect (RT)	-.100	.162	-.079	-.61	.540
Arrow flanker effect (ER)	-3.099	2.045	-.187	-1.52	.134
Simon arrow effect (RT)	.827	.451	.245	1.83	.070
Simon arrow effect (ER)	1.738	4.946	.040	.35	.726

[a]*Note*. N = 89. R = .48, R^2=.23, adjusted R^2= .15, SE = 62.5
[b]*Note*. N = 89. R= .26, R^2 = .07, adjusted R^2 = .02, SE = 107.9

3.4 Discussion

This study examined the unique contribution of different types of non-verbal inhibitory control to the production of words in the context of prepotent and underdetermined within-language competition. To this end we used three standard measures of inhibitory control (the anti-saccade task, the arrow flanker task and the Simon arrow task) and two object naming tasks (the picture word interference task, PWI, and name agreement task, NA) within which level of interference was manipulated. We also measured participants' vocabulary knowledge and processing speed, and used these as control variables.

Vocabulary size was a significant predictor of PWI performance, with marginal contribution of processing speed. Out of the three non-verbal inhibitory control measures, only performance on the arrow flanker task predicted the speed with which PWI interference was resolved. Object naming under prepotent competition was slower for speakers with greater flanker effects than for those with smaller flanker effects. This relationship remained significant after accounting for vocabulary knowledge, processing speed and the contribution of other non-verbal inhibitory control measures. Neither the anti-saccade nor the Simon effect explained any variance in the PWI effect. Nor was there any evidence of a relationship between NA performance and conflict resolution in any of the non-verbal inhibitory control tasks.

To the extent that the flanker effect reflects inhibitory processes and the PWI effect captures the resolution of interference as occurring in natural language production, the results suggest that inhibitory control facilitates word selection in the face of prepotent competition. As such, the data provide support for the involvement of inhibition in monolingual word production as demonstrated by Shao et al. (2013; 2015) and Sikora et al. (2016), albeit using different classification and assessment methods; while both Shao et al. and Sikora et al. relied on statistical proxies to imply that selective inhibition (indexed with the slope of the slowest delta segment in the PWI task) is engaged in the resolution of prepotent competition, we did so using independent behavioural measures.

The reason for an absence of correlation between the anti-saccade and the Simon effects on the one hand, and the PWI effect, on the other, is that these tasks reflect different interference-resolution demands. Interference is argued to arise and be resolved at different loci between stimulus detection and response generation (Egner, Delano, & Hirsch, 2007; Milham et al., 2001; Nee et al., 2007). The anti-saccade task is primarily a motor response-execution paradigm (Munoz & Everling, 2004). The Simon effect is considered to be primarily a response selection phenomenon, independent of stimulus-identification or response-execution processes (Lu & Proctor, 1995; van den Wildenberg et al., 2010). The flanker task, in turn, is commonly thought to tap resolution of representational conflict. The unique contribution of the flanker effect to PWI performance, above and beyond the anti-saccade or the Simon effects, indicates that inhibitory mechanisms might be recruited in response to conflict occurring at a specific point in the information processing stream, one that in the context of the PWI task, happened to be most prominent at the representational level of stimulus processing.

This pattern of results corroborates the findings of Study 1 and places them more in line with the competitive theories of spoken word production than the non-competitive ones. Although the locus of interference observed in the PWI task appears to be constrained to early rather than late, post-lexical stages, the current evidence does not allow to establish whether it is lexically or conceptually based. It is conceivable that the flanker task, which involves resolution of conflict between representations of non-verbal stimuli (arrows), also engages a language component. The arrow stimuli are not completely arbitrary and thereby can potentially activate lexical representations associated with the concept of direction (LEFT and RIGHT). Conversely, as discussed in the previous chapter, it cannot be ruled out that at least part of the PWI effect may be attributed to perceptual or conceptual interference. Until this uncertainty is resolved, it cannot be fully confirmed that the source of interference as observed during object naming in the PWI task is strictly lexical.

A possible explanation for the lack of correlation between the PWI effect and the Simon effect, leaving aside a much smaller effect size, is that the Simon effect is taken to reflect resolution of conflict associated with the activation of two incompatible response codes. The location of the target stimuli induces the participant to press the key that is located on the side compatible with the effector (the hand pressing the key) but the meaning derived from the arrow leads to the activation of the effector on the opposite side. This is analogous to the situation in which an automatic reading response code is activated by the distractor word in the PWI task but the target demands a more controlled action of naming the pictured object. However, since the PWI effect indexes a difference in mean response times between the related and unrelated conditions, both of which present distractor words, the response selection effect is cancelled out.

The current study also examined the contribution of different inhibitory control mechanisms to the resolution of underdetermined competition during object naming. However, none of the three inhibitory control measures predicted the NA effect. This is in contrast to Shao et al. (2014), who reported a significant correlation between the slope of the slowest delta segment in the NA task (indicative of selective inhibition) and the NA effect. There were two major differences between the two studies, however. Shao et al. assumed the slope of the slowest delta segment to be a reliable index of selective inhibition; we used independent behavioural methods to assess different inhibitory processes. Second, unlike the present study, the procedure in Shao et al. included a familiarisation phase. This may be problematic as it is unclear whether the NA effect obtained in their study reflected the time needed to manage the co-activation of multiple lexical entries or the time needed to retrieve a specific lexical item practiced during the familiarisation phase.

The fact that there was no relationship between the PWI and NA effects, on the one hand, and the non-verbal inhibitory control measures and the NA effect, on the other, may suggest that these tasks capture different forms of interference and thereby are associated with distinct cognitive control mechanisms. Following Snyder et al. (2014), selecting from a set of co-activated entries where no one entry is more legitimate or compelling than the other (underdetermined competition) imposes different control demands compared to selecting a lexical candidate in the presence of a stronger but illegitimate candidate (prepotent competition). Since the NA effect reflects underdetermined competition, unlike the non-verbal inhibitory control measures used in the current study, the reason why we have failed to observe any relationship between these measures can indeed suggest dissociable conflict-control processes.

Alternatively, it could be argued that selection in the NA task is governed by processes other than inhibition. As pointed out by Paivio, Clark, Digdon, & Bons

(1989), the delays in the naming of objects with low name agreement (items associated with multiple names as opposed to one dominant name) may either reflect lateral inhibition, where the activated representations inhibit one another delaying the selection of the target one, or diffuse activation, where concept-to-lemma mappings are spread over several pathways making the activation of each individual pathway weaker compared to the activation of a single concept-to-lemma pathway in case of object with high name agreement. The idea that alternative names compete for selection (in the sense of Levelt et al.'s, 1999) has been recently questioned by Oppenheim et al (2017; in prep). In their norming study, pictures with stronger secondary names were named faster than pictures with weaker secondary names, after accounting for more dominant names, when an opposite pattern would be expected by a competitive hypothesis.

Of course, another consideration is that the non-verbal tasks can, by their nature, only index abilities that are either fully domain-general or at least closely yoked across domains. If lexical selection were dependent on language-specific inhibitory abilities, then nonverbal measures may not predict their strength, so this evidence could not address that possibility. This explanation, is however less likely given the association between the flanker and the PWI effects.

Taken together, to the extent that the flanker effect is a valid index of the ability to resolve representational conflict and the PWI effect reflects competition as occurring in natural spoken word production, the current study provides evidence for the involvement of inhibitory processes during object naming under prepotent, but not underdetermined competition. Until the pre-lexical source of interference in the PWI task is ruled out, however, this remains a tentative conclusion.

CHAPTER 4: TYPES OF INTERFERENCE AND THEIR RESOLUTION IN SYNTACTIC SELECTION (STUDY 3)

4.1 Background, rationale and aims of Study 3

As outlined in Chapter 1 (section 1.3.3), there is accumulating evidence that speakers recruit inhibitory control when selecting among competing representations during object naming and when inhibiting alternative competing terms in referential language use. There is also a growing body of research showing the importance of inhibition in sentence comprehension (e.g., Hsu, Jaeggi, & Novick, 2017; Thothathiri, Asaro, Hsu, & Novick, 2018; Vandierendonck, Loncke, Hartsuiker, & Desmet, 2017). However, it is less clear whether similar control processes are engaged during *production* of *longer* utterances. Given that communication is rarely an exchange of isolated words, investigating the mechanisms that underlie the construction of multiword utterances is a necessary step towards understanding the production of language at large. This research contributes to this understanding by examining whether selection of syntactic structures is regulated by different types of non-verbal inhibitory control.

There are good reasons to believe that generating a sentence provides greater scope for competition and thereby an increased need for cognitive control than single word retrieval. While a speaker's mental dictionary is largely finite (containing an estimated 42,000 entries; Brysbaert et al., 2016), the same speaker is capable of generating an infinite number of sentences. As linguistic choices abound, settling on one particular structure or arrangement of items may become increasingly effortful and time consuming (Ferreira & Engelhardt, 2006; Hwang & Kaiser, 2014; Myachykov, Thompson, Scheepers, & Garrod, 2011). Importantly, online construction of a sentence requires a greater deal of computation than production of a single word (see section 1.1.3).

Given the scarcity of evidence on the role of inhibition in grammatical encoding and the lack of clarity about which inhibitory mechanisms may be recruited during syntactic processing, as outlined in section 1.3.4, Study 3 assessed independent contribution of specific forms of non-verbal inhibition to the selection of distinct syntactic structures under increased interference conditions. To this end, three inhibitory control tasks were selected (the anti-saccade, arrow flanker and Simon arrow tasks), each tapping resolution of non-verbal conflict at a different stage of information processing. Their predictive capacity was gauged in relation to two core syntactic processes in English: grammatical voice selection and number agreement computation. The rationale for why these processes were selected for the purpose of this study is provided below.

Grammatical voice selection

Whether a speaker commits to an active (e.g., *The pirate ate the cheese*) or a passive (e.g., *The cheese was eaten by the pirate*) voice structure depends on a combination of factors. Speakers usually opt for structures that are less complex and more familiar. In English, there is a strong bias towards active sentences because these are relatively more frequent and less complex than passives (Dick & Elman, 2001). At the same time, the choice of one sentence structure over another appears to be constrained by communicative context (e.g., passive voice may be the preferred structure in academic writing) and syntactic priming (recent experience of a specific structure; Altmann & Kemper, 2006). Subject animacy and the accessibility of noun and verb lemmas have been similarly documented to play a role in sentence structure selection (e.g., Bock, 1987; Ferreira & Engelhardt, 2006; Ferreira & Dell, 2000). Speakers are biased in favour of animate objects and will insert these in the sentence subject position by default. Similarly, noun lemmas that are activated first are assigned a nominative role assuming the sentence subject position, with those that are less readily available accommodated later.

The grammatical voice elicitation task created for the purpose of this study exploits four types of constraints to induce syntactic interference. The main factor that constrains the selection of a grammatical voice structure is task instructions. Speakers are specifically asked to use the given past (e.g., *ate*) or past participle verb form (e.g., *eaten*) when constructing a meaningful, grammatical sentence with the names of the displayed objects (animate and inanimate). This external verb form constraint may conflict with other endogenous constraints such as animacy (speakers generally prefer animate-subject sentences to inanimate-subject sentences), order of noun lemma activation (information that is accessible first tends to be mentioned first, i.e., becomes the sentence subject), and probability (active voice is the default structure in English). Speakers therefore may need to override an inclination to assign a nominative role to an object that is both cued (more readily accessible) and animate as dictated by context.

Number agreement computation

Number agreement is a core syntactic process in English, in which the verb has to agree in number with the sentence subject (usually the head noun). In *The key to the cabinets was rusty* the verb (*was*) matches the singular number of the sentence subject (*The key*). This process is sometimes disrupted when the sentence contains more than one noun phrase that does not match in number with the subject noun phrase. In this situation, it is not uncommon to observe agreement errors (e.g., *The key to the cabinets were rusty**); the local noun in the proximity of the verb (*cabinets*) affects its number computation, and the speaker erroneously produces a plural verb. It is reasonable to assume that activation of a mismatched local noun has to be inhibited in order for correct agreement relations to be computed.

To date, most accounts of number attraction view it primarily as a syntactic process (e.g., Eberhard, Cutting, & Bock, 2005; Vigliocco & Nicol, 1998). More recent work, however suggests a role for extra-linguistic factors such as cognitive control. Haskell & MacDonald (2003), for example attribute number agreement errors to "partial activation of both singular and plural verb forms" (p. 765), with competition between the two forms taking some time to resolve. According to the retrieval-based account (Badecker & Kuminiak, 2007), the retrieval of the agreement controller is susceptible to interference from other items in memory. Veenstra et al., (2018) suggest that because of the recency effect the local noun has higher activation than the head noun and that inhibitory control may be needed to draw attention towards the less active but appropriate representation (head noun) and away from the incorrect representation (local noun). Nozari & Omaki (2018) propose a similar role for inhibitory control processes.

Methodological improvements

The study has implemented several methodological improvements relative to previous studies. Performance on syntactic selection tasks has thus far been indexed either by error rates alone (Veenstra et al., 2018), by disfluencies alone (Engelhardt et al., 2013), or by a combination of error rates and disfluencies (Nozari & Omaki, 2018). It is important to note, however that temporary difficulties with syntactic interference resolution may surface in speech not only as errors or disfluencies, but also as delays in production. Speakers who adopt a more cautious response style, for example, may commit no errors and produce fluent speech, even when their performance has been affected by syntactic conflict manipulations (e.g., Rabbitt, 1979; Staub, 2009). To better capture individual variation in utterance production and to address the problem of speed-accuracy trade-off, this study provides response latency as well as error rate analyses for both non-verbal inhibitory control tasks and sentence production tasks in addition to disfluency-type analyses in the grammatical voice production task.

While previous studies have included single measures of syntactic selection, this study offers a within-subject analysis of two different syntactic processes: grammatical voice selection and number agreement computation. It is possible that specific types of non-verbal inhibitory control may be relevant to the selection of one syntactic form, but not to that of the other.

It is not clear whether estimates provided by the latent variable analysis are superior to inferences based on less complex models. Although the method allows for extraction of the variance common to the inhibitory control tasks used in a study and partialling out of the variance due to task-specific processes, thus providing a "purer" measure of the construct of interest, the observed differences in individual component loadings (Nozari & Omaki, 2018; Veenstra et al., 2018) and the modest or non-existent inter-correlations between individual manifest variables (Engelhardt et al., 2013) invite caution in the interpretation of these results. The rationale for including these different inhibition measures as indicators of a single construct may not be theoretically or empirically justified. As outlined in the introductory chapter (section 1.3.2), recent findings suggest that the various tasks used to assess inhibition reflect distinct functions and that the concept of inhibition as a construct should be abandoned (e.g., Chuderski et al., 2012; Pettigrew & Martin, 2014). With these arguments in mind, this study focuses on diversity rather than unity of the inhibitory control function, analysing the data at the task level.

It is worth noting that difficulties in syntactic selection may result not only from deficient cognitive control mechanisms, but also from insufficient language exposure or gaps in one's syntactic knowledge. Vocabulary size was therefore used as a control measure. It was taken as a proxy for language competence, which is vital in lexical and grammatical processing.

4.2 Method

4.2.1 Participants

Ninety-six participants (N_{female}=78; M_{age}=20.7 years, SD=3.4) were recruited at Middlesex University. All reported English to be their dominant language, but only those who were born in the UK or arrived in the country by the age of five years were included in the final analysis. All had normal or corrected-to-normal vision, with no history of neurological impairment and no cognitive deficits. Three participants had medical conditions that precluded them from completing all the tasks. Two had missing data in one of the tasks. Four performed at least one of the tasks below the specified level and were therefore excluded. The final sample consisted of eighty-seven participants (N_{female}=70; M_{age}=20.6 years, SD=3.6).

4.2.2 General procedure

Participants were tested individually in a sound-attenuated room. After informed consent was obtained, participants completed a brief demographic and language background questionnaire and then performed the non-verbal inhibitory tasks, utterance production tasks and the WAIS-III vocabulary test. The order of non-verbal inhibitory tasks and utterance production tasks was counterbalanced across participants according to the incomplete Latin square design with the constraint that the verbal and non-verbal tasks alternated. The WAIS-III vocabulary test was always administered last. Participants were assigned to each order on a random basis. Participants received both oral and written instructions which put equal emphasis on speed and accuracy of responding. Each experimental task was preceded by practice trials and an opportunity to ask questions for clarification. All the tasks except for the WAIS-III vocabulary test were administered on a computer using E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA). Responses from the non-verbal tasks and from the number attraction task were collected using E-Prime. Responses from the grammatical voice elicitation task and the WAIS-III vocabulary test were audio-recorded for later scoring.

4.2.3 Materials, design and procedure for individual tasks

Non-verbal inhibitory tasks

The three non-verbal inhibitory control tasks (anti-saccade, arrow flanker and Simon arrow) were identical to those used in Study 2. For materials, design, procedure and scoring see Chapter 3.

Sentence production tasks

Grammatical voice elicitation task

Materials

The grammatical voice elicitation task was adapted from Altmann & Kemper, (2006). Participants were required to produce a simple, meaningful and grammatical sentence containing the names of the stimuli presented on the screen. Participants could use auxiliary verbs such as “was” and “were”, but were told not to use the verbs “has”, “have”, or “had”. The stimuli were presented in random corners of the computer display and included two pictures of objects differing in animacy and one verb. The animate objects typically depicted a role (e.g., CLEANER, SOLDIER, BABY). The inanimate objects depicted concrete items (e.g., KEY, BICYCLE, HOUSE). The pictures were colour photographs taken from the Bank of Standardized Stimuli, BOSS (Brodeur, Guérard, & Bouras, 2014) and the Internet. They were presented one after another, with a 1000-millisecond interval, and were followed by a verb. The latter could be either an irregular past form (*ate*, *shook*, *grew*) requiring animate objects in the subject position or an irregular past participle form (*eaten*, *shaken*, *grown*) requiring inanimate objects in the subject position. Because the aim of the task was to elicit either an active or a passive grammatical voice and the design of the task allowed for production of alternative syntactic forms (e.g., active perfective), participants were reminded to avoid using “has”, “have”, and “had” before each block. An additional set of pictures depicting animate (e.g., GARDENER) and inanimate (e.g., ICE CREAM) objects as well as a set of intransitive verbs in the past participle form (*melted*) were used as fillers. All stimuli are presented in Appendix C.

Design

There were 96 trials in total divided across four experimental blocks, each containing 12 experimental and 12 filler trials. The order of trials was pseudo-randomised with the constraint that the experimental and filler trials alternated. The order of blocks was counterbalanced across participants. The conditions were spread evenly across blocks, with six low-interference trials (3 active and 3 passive) and six high-interference trials (3 active and 3 passive) in each block.

Procedure

Before the experiment began, participants were familiarised with the structure of the task and the experimental stimuli. Two examples of correct utterances were demonstrated by the experimenter. This was followed by a practice block in which ten practice trials, two of each condition, were randomly presented. The pictures and the verbs used in the practice block were not included in the experimental materials. Before each experimental block, participants were shown the experimental pictures (animate and inanimate objects) that would appear in that block and were asked to name them. Participants were corrected only when they used a name that would not fit in the experimental context. The picture naming practice was followed by an experimental block. The blocks were separated by short breaks.

On half of the experimental trials, animate objects were presented first, followed by inanimate objects and a verb; on the other half, the order of object presentation was reversed; the order of presentation was counterbalanced between subjects; the verb was always presented last together with a beep sound. Participants were asked to speak as soon as possible upon hearing the beep.

The stimuli (two pictures and one verb in the experimental trials and one picture and one verb in filler trials) were presented one after another in random corners of the computer display. The sequence was as follows. First, a blank screen appeared for the duration of 700 milliseconds, followed by a fixation cross of a jittered duration (500 to 1000 milliseconds). Immediately after that the first object appeared, followed by the second object and then the verb with the beep sound. The stimuli succeeded one after another with 1000-millsecond intervals. All remained on the screen until a vocal response was recorded. Presentation and timing of the trials are presented in Figures 10 and 11.

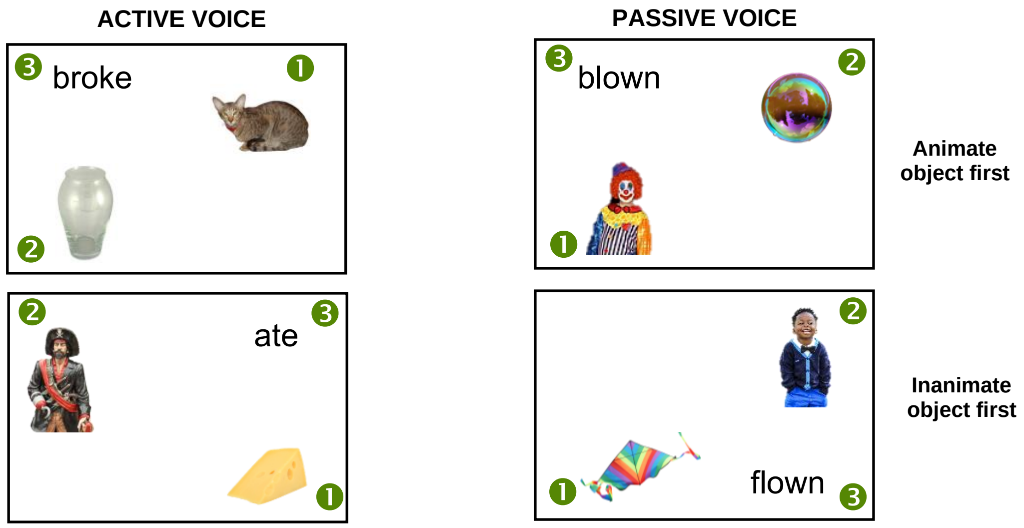


Figure 10. Grammatical voice elicitation task. Upon hearing a beep, participants produce a sentence with the presented stimuli. The stimuli appear on the screen one by one, with 1000-millisecond intervals. Numbers ❶❷❸ indicate the order of stimulus presentation. Participants are allowed to insert *was* and *were*, but are not allowed to use *has/have/had*.

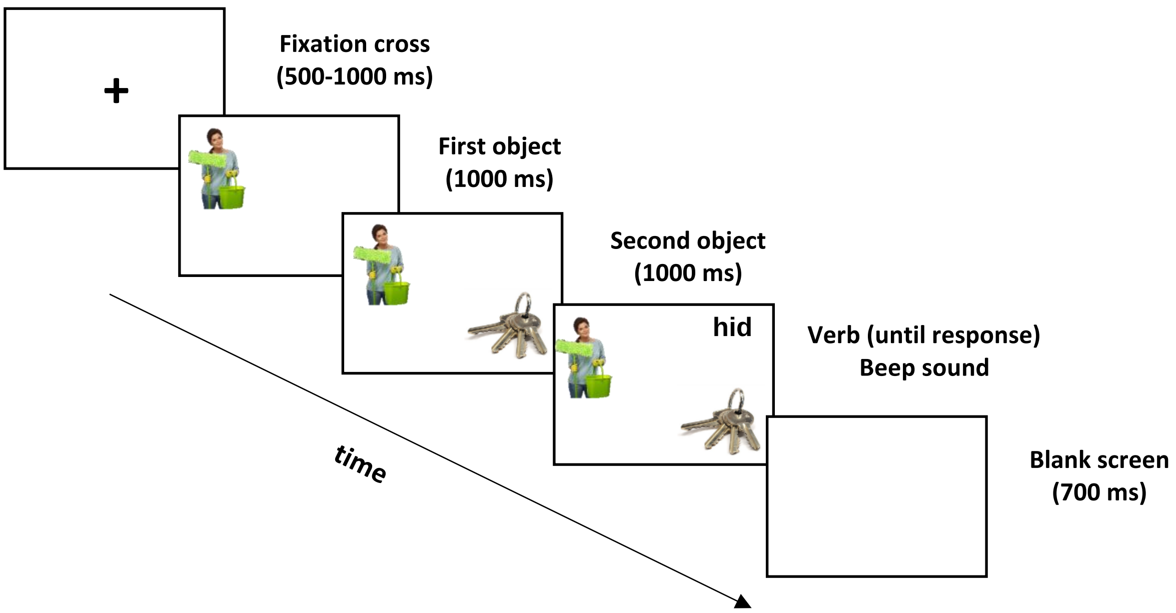


Figure 11. The sequence and timing of trials in the grammatical voice elicitation task.

Scoring and data preparation

Participant's responses were audio-recorded. Sentences containing errors, disfluencies and silent pauses longer than 250 milliseconds were transcribed verbatim and coded for disfluency types. These included repairs (e.g., *the cat broke… the vase was broken by the cat*), prolongations (e.g., *theee… farmer*), hesitations (e.g., *ehm… the grass*..), and repetitions (*the boy.. the boy saw the ghost*).

Incorrect responses such as utterances containing *has*, *have* or *had* (e.g., *the clown had blown a bubble*) or ungrammatical structures (e.g., *the clown blown a bubble*) as well as responses that were initiated before the beep sound were discarded.

Latency to begin speaking was measured manually using Audacity ® 2.2.1 recording and editing software. The cursor was placed at the beginning of the beep sound and the distance was measured to the correct mention of the subject phrase. Response with speech onset latencies longer than 6000 milliseconds were excluded from the analyses.

Number agreement task

Materials

The number agreement task was adapted from Staub et al. (2009). Participants were asked to read a fragment of a sentence presented one word at a time at a constant rate (i.e., rapid serial visual presentation) and then to choose one of the two possible grammatical continuations of the sentence.

Forty-eight experimental fragments were created by adapting items from various materials previously used to assess number agreement (Bock, Nicol, & Cutting, 1999; Haskell & MacDonald, 2003; Humphreys & Bock, 2005; Staub 2009). Each fragment began with the definite article and a noun (e.g., *The light*), followed by a prepositional phrase which contained a local noun (e.g., *in the rooms*…). The fragments were always five words in length. The continuation of the sentence contained a verb phrase with an inflected auxiliary verb "to be" and either an adjective (e.g., *…were bright*) or a past participle (e.g., *…was fixed*). The verb could be used either in simple present or in simple past tense. Tenses and complement types were proportionately represented across the experimental conditions. An additional forty-eight fragments were created to serve as fillers. These were in the form of object-extracted relative clauses (e.g., *The roof that the builder*…) and were employed to ensure participants read all the words in the fragments instead of focusing on the sentential subject alone. All items are presented in Appendix D.

Design

Half of the items were assigned to a low-interference condition in which the head noun and the local noun shared the number feature (e.g., *The stains on the walls…; The roof that the builder…*). In the other half of the items (high-interference condition) the head noun and the local noun did not match in number (e.g., *The stains on the wall…; The roof that the builders…*). Half of the items required a singular predicate (e.g., *The defect in the cars was corrected; The rumours that the worker was spreading*), and half a plural predicate (e.g., *The defects in the car were corrected; The rumour that the workers were spreading*).

The 96 trials were organised into four blocks with three short breaks in between. Each block contained 12 experimental and 12 filler trials, with three items per condition. The trials within each block were randomised for each participant and the order of the blocks was counterbalanced across participants.

Procedure

Participants received ten practice trials with two items per condition. The practice materials were different from those used in the experiment. Each trial consisted of the following sequence of events. A fixation cross appeared in the centre of the screen for the duration of 500 milliseconds, and was followed by a blank screen (250 ms). The words of the sentence fragments were presented in 18-point bold Arial font, in the centre of the screen, one at a time, for the duration of 250 milliseconds each and with an inter-stimulus interval of 150 milliseconds. After the final word, two possible continuations of the fragment appeared on the screen. The verbs were presented in uppercase letters on either side of the screen (e.g., F. WAS fixed K. WERE fixed). Participants indicated by pressing either the “F” or the “K” on the keyboard which of the sentence endings was the correct one. The possible continuations of the fragments remained on screen for the maximum duration of

5000 milliseconds. After the participant had selected a response, a prompt appeared to press the spacebar to move to the next trial.

Control measures

The vocabulary subtest of WAIS-III (Wechsler, 1997) was the same as the one used in Study 2. For a detailed description, see Chapter 3.

General processing speed was indexed by a mean RT obtained from the neutral condition of the arrow flanker task.

4.3 Results

Results are reported in three stages. Results from task-level analyses are presented first. This is followed by correlational and hierarchical multiple regression analyses.

Task-level analyses

Anti-saccade task

Trials in which subjects made errors were removed from the RT analysis (6.6% in pro-saccade and 18.3% in anti-saccade condition). RTs lower than 200 milliseconds or higher than 1700 milliseconds were also excluded as were RTs exceeding 3 SDs above each subject's mean per condition. This impacted 2.3 % of the data in the pro-saccade and 2.9% of the data in the anti-saccade condition. A paired-sample t-test revealed a significant difference between the anti-saccade and the pro-saccade conditions both in terms of error rates [$t(86) = 8.57$, $p <.001$, $d = .92$] and response latency [$t(86) = -6.60$, $p < .001$, $d = .71$]. In the pro-saccade condition, participants correctly identified the target letter in 93% (*SD* = 8%) of the trials while in the anti-saccade condition this accuracy dropped to 82% (*SD* = 12%). The average speed to detect the target letter in the pro-saccade condition was 458 milliseconds (*SD* = 102 ms), with response latencies significantly slower in the anti-saccade condition (*M* = 548 ms, *SD* = 147 ms). See Table 20 and Figures 12 and 13.

Table 20. Mean reaction times (in milliseconds) and mean error rate (in percent) per condition for the anti-saccade, arrow flanker, Simon arrow, number agreement and grammatical voice elicitation tasks.

		Reaction time (ms)		Error rate (%)	
Task	Condition	*M*	*SD*	*M*	*SD*
Anti-saccade	Pro-saccade	458	102	6.6	8
	Anti-saccade	548	147	18	12
Arrow flanker	Stimulus compatible	616	70	.94	2
	Stimulus incompatible	817	117	7.5	11
Simon arrow	Response compatible	616	70	.94	2.1
	Response incompatible	641	78	1.8	3.1
Number agreement (PPs)	Low singular	1564	378	11	12
	High singular	1804	505	44	23
	Low plural	1619	398	17	15
	High plural	1702	445	24	19
Number agreement (OERCs)	Low singular	1641	361	11	12
	High singular	1817	463	36	17
	Low plural	1540	382	12	11
	High plural	1743	389	18	13
				Occurrence (%)	
Voice elicitation (repairs)	Low active	-	-	2.7	4.7
	High active	-	-	4.2	6.1
	Low passive	-	-	19.6	1.7
	High passive	-	-	23.8	2.1
Voice elicitation (pauses)	Low active	-	-	5.1	9.8
	High active	-	-	8.5	13.8
	Low passive	-	-	4.9	7.7
	High passive	-	-	6.6	11.8
Voice elicitation (other disfluencies)	Low active	-	-	5.8	8.9
	High active	-	-	11.9	14.3
	Low passive	-	-	11.7	13.3
	High passive	-	-	10.26	14.4
Voice elicitation (speech onset)	Low active	1393	358	-	-
	High active	1647	445	-	-
	Low passive	2147	638	-	-
	High passive	2341	696	-	-

PPs = prepositional phrases
OERCs = object extracted relative clauses

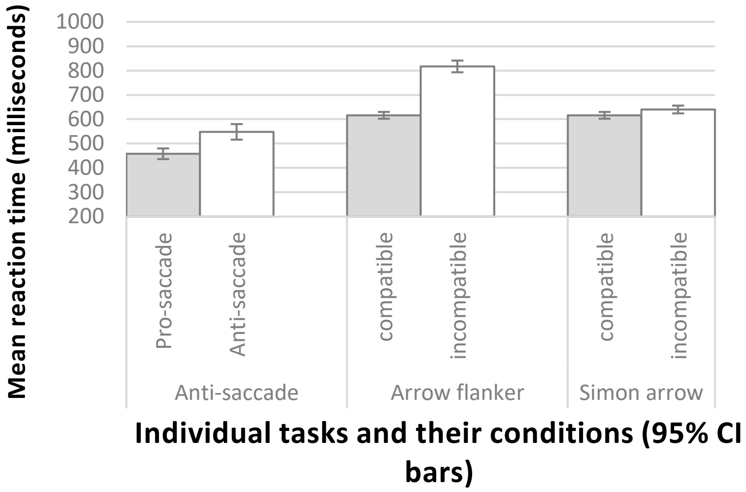


Figure 12. Response latencies in the non-verbal inhibitory control tasks across the low- and high-interference conditions.

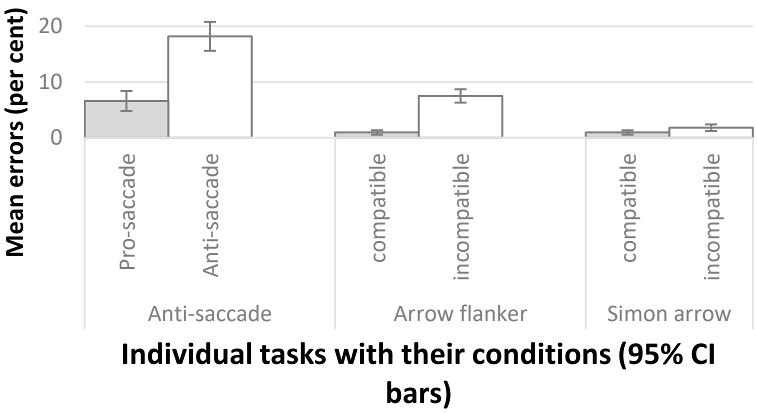


Figure 13. Error rates in the non-verbal inhibitory control tasks across the low- and high-interference conditions.

Arrow flanker task

Participants made significantly more errors in the incompatible condition (*M* = 7.53%, *SD* = 11%) than in the compatible condition (*M* = .94%, *SD* = 2.1%), $t(86) = -5.78$, $p < .001$, $d = .63$. They were also significantly slower to respond on trials in which the target and the flanking arrows were facing in the opposite direction (*M*= 817 ms; *SD* = 117 ms) than when the arrows were all facing in the same direction (*M* = 616 ms; *SD* = 70 ms), $t(86) = -21.1$, $p < .001$, $d = 2.26$. See Table 20 and Figures 12 and 13.

Simon arrow task

Participants were more error-prone in incompatible trials (*M* = 1.8%, *SD* = 3.1%) than in compatible trials (*M* = .94%, *SD* = 2.1%), *t*(86) = 3.27, *p* = .002, *d* = .35. Participants were significantly slower when they had to identify the target on the ipsilateral side of the correct response key (*M* = 640 ms, *SD* = 78 ms) than when the target's location corresponded to the correct response key (*M* = 616 ms, *SD* = 69 ms), *t*(86) = - 7.1, *p* < .001, *d* = .78. See Table 20 and Figures 12 and 13.

Number agreement task

Because the critical trials in the number agreement task included prepositional phrase (PP) sentence fragments, whereas object extracted relative clause (OERC) sentence fragments were used as filler trials, inferential statistics are only reported for the former. Only correct responses were included in the RT analysis (see Table 20 for ERs across individual conditions). A 2 x 2 repeated measures ANOVA was conducted to assess the effect of interference (low *versus* high) and grammatical number (singular *versus* plural) on the accuracy and the speed of number agreement computation. See Table 20 for descriptive statistics and Figures 14 and 15 for main effects and interactions.

RT analysis for PP sentences

There was a main effect of interference, $F(1,86) = 33.97$, $p < .001$, $\eta_p^2 = .283$ as well as a significant interaction between grammatical number and interference, $F(1,86) = 7.95$, $p = .006$, $\eta_p^2 = .085$, but no effect of grammatical number on response latency, $F(1,86) = .63$, $p = .430$, $\eta_p^2 = .007$. Simple effects analyses with a Bonferroni correction showed that the computation of number agreement was slower for high interference trials (in which the head and the local noun mismatched in number) than for low interference trials (in which the head and the local noun matched in number) regardless of whether a singular ($p < .001$) or a plural predicate ($p = .018$) was required. The difference in the speed with which number agreement was computed between singular and plural predicate conditions was evident only under conditions of high interference ($p = .034$), but disappeared in the low interference condition ($p = .097$). This replicates the RT mismatch asymmetry observed in earlier studies (Haskell & MacDonald, 2003; Staub, 2009), according to which it takes longer to select a correct verb form when the local noun is plural rather than when it is singular.

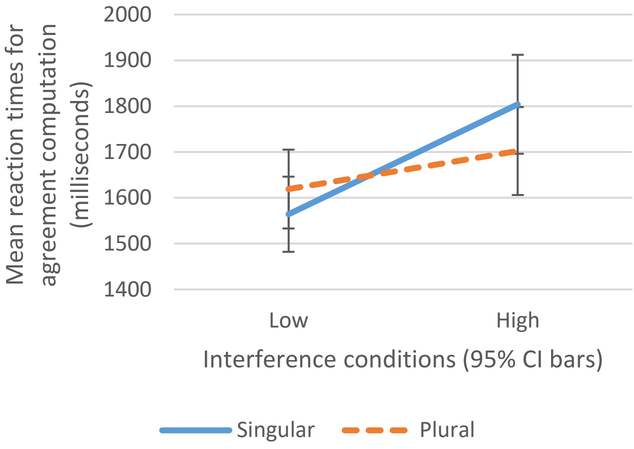


Figure 14. Response latencies for number agreement computation across high- and low-interference conditions for prepositional phrase sentence fragments which required either a singular or a plural predicate.

ER analysis for PP sentences

There was a main effect of number, $F(1,86) = 11.30$, $p = .001$, $\eta_p^2 = .111$, a main effect of interference, $F(1,86) = 142.98$, $p < .001$, $\eta_p^2 = .629$, and a significant interaction between these two variables, $F(1,86) = 111.94$, $p < .001$, $\eta_p^2 = .566$. Participants made more number agreement errors in the high interference condition than in the low interference condition irrespective of whether a singular (p < .001) or a plural (p = .001) predicate was required to complete the prepositional phrase sentence fragment; however, this difference was more pronounced for sentences in which a single predicate was required. This replicates the asymmetry phenomenon reported in earlier studies in which number agreement computation is harder when the head noun is singular and the local noun is plural (Bock & Eberhard, 1993; Eberhard, 1997; Staub, 2009).

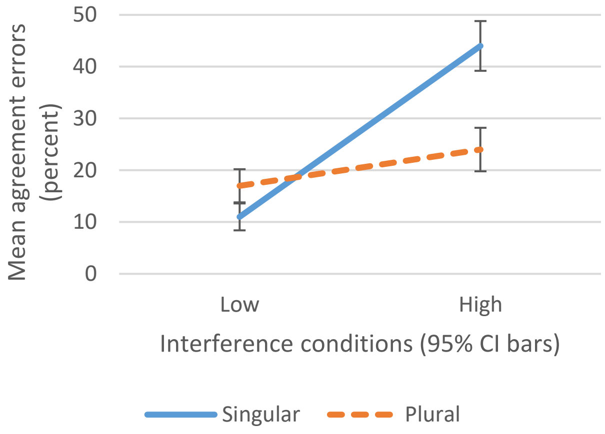


Figure 15. Number agreement errors across high- and low-interference conditions for prepositional phrase sentence fragments which required either a singular or a plural predicate.

Grammatical voice elicitation task

Responses containing errors, those initiated before the beep sound or those with speech onsets longer than 6000 milliseconds were excluded from analysis. This impacted 8.7 % of the data in low active, 6.1% of the data in high active, 9.9% of the data in low passive, and 11.1% of the data in high passive conditions.

Analysis of repairs

Mean repair occurrences were entered into a 2 x 2 repeated measures ANOVA with grammatical voice and interference as factors. There was a main effect of grammatical voice [$F(1,86) = 111.74$, $p < .001$, $\eta_p^2 = .579$] and a main effect of interference [$F(1,86) = 10.50$, $p = .002$, $\eta_p^2 = .109$], but no interaction [$F(1,86) = 1.9$, $p = .171$, $\eta_p^2 = .022$]. Speakers repaired their utterances more often when a passive voice was required ($M = 21.7\%$, $SE = 1.7\%$) compared to when an active voice ($M = 3.5\%$, $SE = .43\%$) was the correct structure. Importantly, the occurrence of repairs was significantly higher under high interference conditions ($M = 14\%$, $SE = 1.1\%$) relative to low interference conditions ($M = 11.2\%$, $SE = .9\%$). See Table 20 and Figure 16. This replicates the results by Engelhardt, Corley, Nigg, & Ferreira (2010), who reported a higher proportion of repairs for inanimate-first past participle trials.

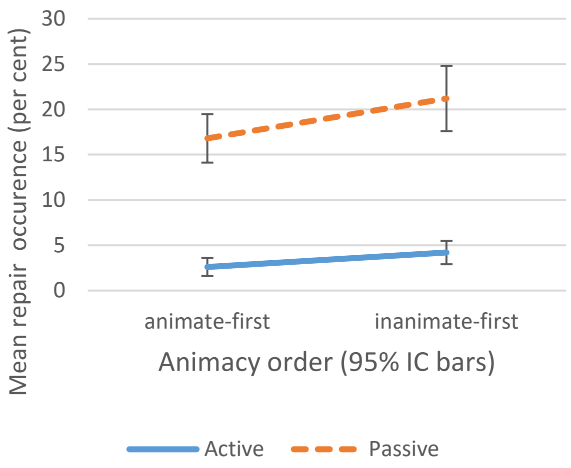


Figure 16. Occurrence of repairs in the grammatical voice elicitation task across the low- and high-interference conditions when either an active or a passive structure was required.

Analysis of silent pauses

There was a main effect of interference [$F(1,86) = 7.90$, $p = .006$, $\eta_p^2 = .084$], but no main effect of grammatical voice [$F(1,86) = .95$, $p = .332$, $\eta_p^2 = .011$], and no interaction [$F(1,86) = .88$, $p = .351$, $\eta_p^2 = .010$]. Speakers inserted on average more silent pauses under high interference ($M = 7.5\%$, $SE = 1.1\%$) than under low interference conditions ($M = 5\%$, $SE = .7\%$). See Table 20 and Figure 17.

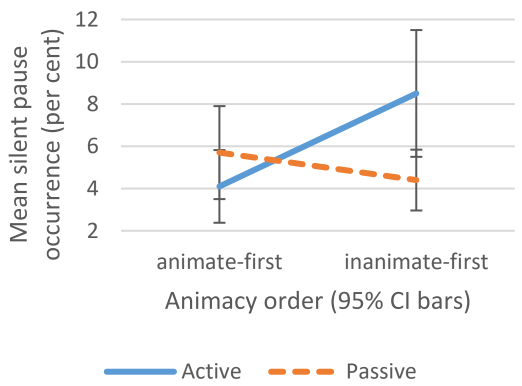


Figure 17. Occurrence of silent pauses in the grammatical voice elicitation task across the low- and high-interference conditions when either an active or a passive structure was required.

Analysis of other disfluencies (repetitions, prolongations and hesitations)

There was a main effect of grammatical voice [F(1,86) = 4.92, p = .029, η_p^2= .054], a main effect of animacy order [F(1,86) = 6.81, p = .011, η_p^2= .073], and a significant interaction [F(1,86) = 19.54, p < .001, η_p^2= .185]. More disfluencies were produced when an inanimate object was presented first (M = 11.93%, SE = 1.5%) than when an animate object appeared first (M = 5.78%, SE = .95%), but only when an active voice was required [F(1,86) = 21.36, p < .001, η_p^2= .199]. No such effect was observed for passive sentences [F(1,86) = 1.67, p = .200, η_p^2= .011]. When an animate object was presented first, more disfluencies were observed in passive sentences than in active sentences [F(1,86) = 26.32, p < .001, η_p^2= .234]. No difference in disfluencies was observed between the active and passive sentences for the inanimate-first condition [F(1,86) = 1.38, p = .244, η_p^2= .016]. See Table 20 and Figure 18.

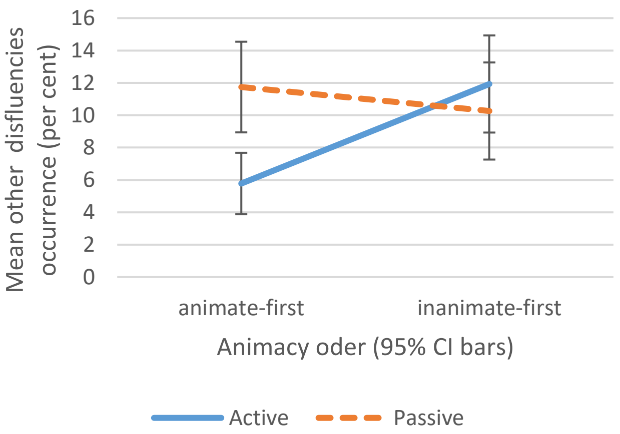


Figure 18. Occurrence of other disfluencies (repetitions, hesitations and prolongations combined) in the grammatical voice elicitation task across the animate-object-first- and inanimate-object-first conditions when either an active or a passive structure was required.

Analysis of speech onset latencies

There was a main effect of grammatical voice [F(1,86) = 172.11, p < .001, η_p^2= .667], a main effect of interference [F(1,86) = 66.06, p < .001, η_p^2= .434], but no significant interaction [$F(1,86) = .1.08$, $p = .301$, $\eta_p^2 = .012$]. Participants began to speak with a greater delay when a passive structure (M = 2244 ms, SE = 67) was required than when an active structure (M = 1520 ms, SE = 41) was the correct answer. Importantly, speech onset latencies were on average 200 milliseconds longer under high interference (inanimate-first) (M = 1994 ms , SE = 52) than low interference (animate-first) (M = 1770 ms, SE = 48) conditions. See Table 20 and Figure 19.

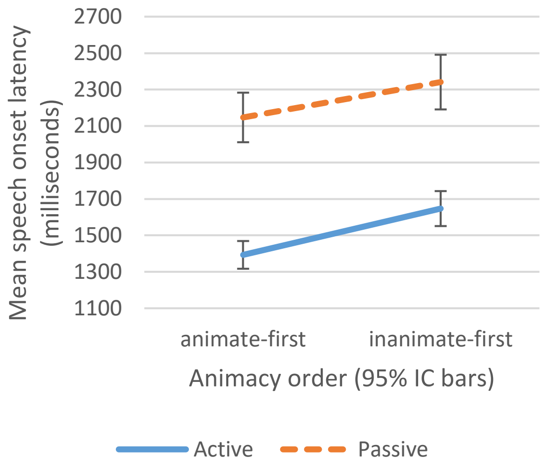


Figure 19. Mean speech onset latencies in the grammatical voice elicitation task across the low- and high-interference conditions when either an active or a passive structure was required.

Correlational analyses

Pearson's bivariate correlations between the WAIS vocabulary score, processing speed and interference effects across the inhibitory control and sentence production tasks are presented in Table 21. Pearson's bivariate correlations are also presented for the WAIS vocabulary score, processing speed, interference effect of the inhibitory control tasks and high interference conditions of the sentence production tasks (Table 22).

Hierarchical multiple regression analyses

Six hierarchical multiple regression analyses were carried out to assess the relative contributions of non-verbal inhibition to syntactic selection under high interference conditions after controlling for language knowledge (WAIS score) and processing speed (mean RT on neutral arrow flanker trials). Control variables were entered into the first block. The six non-verbal inhibitory control measures were entered into the second block.

Table 21. Pearson's bivariate correlations between WAIS vocabulary score, processing speed and interference effects across inhibitory control and sentence production tasks

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. WAIS vocabulary	.005	-.104	.050	-.177	-.058	-.124	-.198	-.209	-.224*	.024	-.025	-.145	-.265*	.056	.034	.069	.028	-.278**	-.049
2. Processing speed		-.056	.074	-.108	.057	.398**	.230*	.139	-.068	-.078	.004	.213*	-.036	.026	.164	-.097	-.004	-.013	.062
3. Antisaccade effect (ER)			.264*	.080	.199	-.085	-.011	.194	.037	-.058	-.189	-.202	.092	.178	-.068	-.176	.154	.128	.060
4. Antisaccade effect (RT)				.081	.099	.072	.236*	.024	.134	.030	.156	-.060	.080	.176	.147	-.056	-.022	-.087	.095
5. Flanker effect (ER)					.370**	.177	.227*	-.077	.093	-.312**	.114	-.066	.153	-.269*	.031	.031	-.275**	.119	-.226*
6. Flanker effect (RT)						-.037	.228*	.016	.011	-.268*	-.063	.045	-.106	.004	.156	.108	-.088	.089	-.029
7. Simon effect (ER)							.434**	-.064	.063	.015	.039	.185	.010	-.078	-.082	-.240*	-.114	.152	-.044
8. Simon effect (RT)								-.041	.223*	-.044	.256*	.102	.010	-.013	-.039	-.043	-.139	.083	-.034
9. Number effect singular (ER)									.287**	.110	.083	-.023	.071	-.052	.224*	-.062	.022	-.062	.071
10. Number effect plural (ER)										.159	.228*	.066	.019	-.111	.146	-.084	.054	.080	-.063
11. Number effect singular (RT)											-.002	.037	-.084	-.117	.042	-.008	.037	.114	.084
12. Number effect plural (RT)												.178	.032	.140	-.011	.001	-.114	-.047	-.075
13. Active repairs effect													-.207	.034	.085	-.027	.019	.090	-.054
14. Passive repairs effect														-.114	-.248*	-.127	-.186	.035	.426**
15. Active pauses effect															-.048	.034	.102	.099	.162
16. Passive pauses effect																.042	.092	.057	-.204
17. Active other disfluencies effect																	.035	.225*	-.126
18. Passive other disfluencies effect																		.229*	.128
19. Active speech onset effect																			-.058
20. Passive speech onset effect																			

Correlation is significant at the 0.05 level (2-tailed).

Correlation is significant at the 0.01 level (2-tailed).

Table. 22 Pearson's bivariate correlations between WAIS vocabulary score, processing speed, interference effects of inhibitory control tasks and individual high interference conditions of sentence production tasks

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. WAIS vocabulary	.005	-.104	.050	-.177	-.058	-.124	-.198	-.196	-.125	-.360**	-.245*	-.318**	-.314**	.042	.075	-.025	.031	-.311**	-.372**
2. Processing speed		-.056	.074	-.108	.057	.398**	.230*	.032	.227*	-.033	.098	-.019	.037	.042	-.029	.005	-.013	.130	.058
3. Antisaccade effect (ER)			.264*	.080	.199	-.085	-.011	.076	-.012	.170	.014	.173	-.148	-.084	.136	-.105	-.186	.126	.117
4. Antisaccade effect (RT)				.081	.099	.072	.236*	.007	.159	.055	.259*	.311**	-.040	.107	.199	.028	-.033	.233*	.016
5. Flanker effect (ER)					.370**	.177	.227*	-.316**	-.098	.113	.138	.331**	.070	-.047	.015	-.014	.064	.128	.109
6. Flanker effect (RT)						-.037	.228*	-.193	-.072	.070	-.025	.026	.041	-.035	.080	.006	.041	.197	.136
7. Simon effect (ER)							.434**	-.039	.071	-.043	.171	.029	.142	-.028	-.056	-.105	-.193	.119	.146
8. Simon effect (RT)								-.049	.243*	-.051	.326**	.111	.079	-.004	-.001	-.052	-.028	.223*	.181
9. Number mismatch singular (RT)									.579**	.178	.162	.009	.022	.054	-.007	-.033	-.090	.260*	.217*
10. Number mismatch plural (RT)										.111	.441**	.183	-.023	.118	.155	.002	.048	.220*	.228*
11. Number mismatch singular (ER)											.199	.302**	.189	-.014	-.039	.010	.051	.302**	.224*
12. Number mismatch plural (ER)												.365**	.054	.107	.047	-.046	-.188	.249*	.139
13. Passive inanimate first repairs													.015	.068	.139	.064	-.104	.511**	-.030
14. Active inanimate first repairs														.063	.072	.057	.105	-.103	.203
15. Passive inanimate first pauses															.349**	.060	.032	.028	.035
16. Active inanimate first pauses																-.041	.128	.220*	.177
17. Passive inanimate first other dis																	.573**	.024	-.060
18. Active inanimate first other dis																		-.135	.019
19. Passive inanimate first RT																			.433**
20. Active inanimate first RT																			

Correlation is significant at the 0.05 level (2-tailed).

Correlation is significant at the 0.01 level (2-tailed).

Voice elicitation task

Four outcome variables were derived from performance on high interference passive voice trials (animate second-order condition)[2]: repairs, pauses, other disfluencies (repetition, hesitations and prolongation combined) and speech onset latency.

Repairs

Both models (Model I and II) predicted the occurrence of repairs in the high interference passive voice condition significantly well [Model I: $F(2,84) = 4.75$, $p = .011$; Model II: $F(8,78) = 4.34$, $p < .001$]. The final model accounted for 31% of the variance in the number of repairs produced. Language knowledge made a unique contribution to the model predicting 8% of the variance in repairs. Those with higher WAIS scores (better language knowledge) made fewer repairs. Importantly, the anti-saccade effect (indexed by RT) and the flanker effect (indexed by ER) contributed to the model above and beyond other variables each explaining 9% of the variance in the prediction of utterance repairs each. The results for both models are shown in Table 23.

Pauses

Neither Model I [$F(2,84) = .15$, $p = .863$] nor Model II [$F(8,78) = .34$, $p = .957$] was able to reliably predict the percentage of silent pauses inserted in passive voice utterances under high competition conditions.

Other disfluencies

Neither Model I nor Model II was able to reliably predict the percentage of silent pauses inserted in passive voice utterances under high interference conditions . Model I: $F(2,78) = .03$, $p = .974$; Model II: $F(8,78) = .37$, $p = .932$.

Speech onset latencies

[2] Repairs were more numerous and speech onset latencies longer in the animate-second- than animate-first-order condition of the passive voice trials (in which an irregular past participle verb form is required in the sentence), but the effect that emerged may have been too small to be reliably predicted by the inhibitory control measures. Raw measures (percent of repairs and mean RTs) rather than the difference scores were therefore included in the hierarchical multiple regression analyses.

Both models predicted speech onset latency in high interference passive voice trials significantly well [Model I: F(2,84) = 5.41, p = .006; Model II (8,78) = 2.41, p = .022]. Model II accounted for 20% of the variance in the speed with which a correct utterance was initiated, with the WAIS scores explaining nearly 8% of the unique variance in speech onset latencies. The anti-saccade effect (indexed by RT) explained 4% of the unique variance in speech onset latencies, however, this contribution did not survive corrections for multiple comparisons.

Table 23. Hierarchical multiple regression of variables predicting proportion of repairs, silent pauses, other disfluencies and speech onset latency in the grammatical voice elicitation task

		B	*SE*	*β*	*t*	*p*
(a) Repairs as an outcome variable						
Model I	(Constant)	47.71	16.15		2.95	.004
	WAIS	-.68	.22	-.32	-3.08	.003
	Processing speed	.00	.03	-.02	-.17	.863
Model II	(Constant)	32.93	16.31		2.02	.047
	WAIS	-.63	.21	-.29	-2.99	.004
	Processing speed	.02	.03	.07	.62	.535
	Anti-saccade ER	.06	.14	.04	.41	.683
	Anti-saccade RT	.04	.01	.32	3.12	.003
	Arrow flanker ER	.56	.17	.35	3.25	.002
	Arrow flanker RT	-.03	.02	-.14	-1.37	.175
	Simon arrow ER	-.73	.78	-.11	-.94	.351
	Simon arrow RT	-.02	.06	-.04	-.31	.754
(b) Pauses as an outcome variable						
Model I	(Constant)	1.00	6.65		.15	.880
	WAIS	.03	.09	.04	.39	.701
	Processing speed	.00	.01	.04	.38	.704
Model II	(Constant)	2.39	7.54		.32	.752
	WAIS	.01	.10	.01	.06	.956
	Processing speed	.00	.01	.05	.37	.714
	Anti-saccade ER	-.06	.06	-.12	-.98	.331
	Anti-saccade RT	.01	.01	.14	1.20	.233
	Arrow flanker ER	-.02	.08	-.03	-.22	.824
	Arrow flanker RT	.00	.01	-.02	-.14	.890
	Simon arrow ER	-.14	.36	-.05	-.40	.692

	Simon arrow RT	.00	.03	-.01	-.11	.915
(c) Other disfluencies as an outcome variable						
Model I	(Constant)	11.24	14.26		.79	.433
	WAIS	-.04	.19	-.02	-.23	.821
	Processing speed	.00	.02	.01	.05	.962
Model II	(Constant)	9.25	16.11		.57	.568
	WAIS	-.12	.21	-.07	-.57	.570
	Processing speed	.01	.03	.06	.47	.640
	Anti-saccade ER	-.17	.14	-.15	-1.25	.216
	Anti-saccade RT	.01	.01	.08	.70	.485
	Arrow flanker ER	.03	.17	.02	.20	.845
	Arrow flanker RT	.00	.02	.02	.15	.885
	Simon arrow ER	-.77	.77	-.14	-1.00	.319
	Simon arrow RT	-.02	.06	-.05	-.38	.708
(d) Speech onset latency as an outcome variable						
Model I	(Constant)	2570	650		3.96	.000
	WAIS	-.03	.01	-.31	-3.04	.003
	Processing speed	.00	.00	.13	1.28	.204
Model II	(Constant)	2350	710		3.30	.001
	WAIS	-.03	.01	-.30	-2.79	.007
	Processing speed	.00	.00	.10	.84	.401
	Anti-saccade ER	.00	.01	.02	.16	.870
	Anti-saccade RT	.00	.00	.21	1.90	.061
	Arrow flanker ER	.00	.01	.02	.21	.834
	Arrow flanker RT	.00	.00	.13	1.14	.257
	Simon arrow ER	.00	.03	.01	.05	.963
	Simon arrow RT	.00	.00	.06	.45	.652

[a]*Note*. **Model I:** Multiple *R* = .32, R^2 = .10; adjusted R^2 = .08; *SE* = 16.46; **Model II:** Multiple *R* = .56, R^2 = .31; adjusted R^2 = .24, *SE* = 15;
[b]*Note*. **Model I:** Multiple *R* = .06, R^2 = .004, adjusted R^2 = -.02, *SE* = 6.77; **Model II:** Multiple *R* = .18, R^2 = .03; adjusted R^2 = -.07, *SE* = 6.93;
[c]*Note*. **Model I:** Multiple *R* = .03, R^2 = .001, adjusted R^2 = -.06, *SE* = 14.53; **Model II:** Multiple *R* = .19, R^2 = .04; adjusted R^2 = -.06, *SE* = 14.81;
[d]*Note*. **Model I:** Multiple *R* = .34, R^2 = .11, adjusted R^2 = -.09, *SE* = 663; **Model II:** Multiple *R* = .45, R^2 = .20; adjusted R^2 = -.15, *SE* = 654;

Number agreement production

High interference singular predicate trials (ERs)

The proportion of errors made in the high interference prepositional phrase trials in which a singular predicate was required (*The key to the cabinets…*) was the primary outcome variable. Vocabulary size was the only reliable predictor of number agreement errors, $F(2, 84) = 6.31$, $p = .003$, accounting for 13% of the variance in their proportion, with higher WAIS scores predicting fewer number agreement errors. Adding the non-verbal inhibitory control measures to the final model (Model II) failed to improve its predictive capacity, $F_{\text{change}}(6, 78) = .69$, $p = .656$. The results for both models are shown in Table 24.

High interference singular predicate trials (RTs)

The second outcome variable that was of interest in this study was the response latency in the number mismatching trials with a singular predicate requirement (*The key to the cabinets…*). Neither vocabulary size nor processing speed reliably predicted the speed with which subject-verb agreement was computed under increased competition conditions; however, adding the non-verbal inhibitory control measures to the final model (Model II) significantly increased its predictive capacity, $F_{change}(6,78) = 2.28$, $p = .044$. The flanker effect (indexed by ER) was the only significant predictor of the number agreement response latency, accounting for 8% of its unique variance. However, the direction of the relationship was unexpected. Those with higher error rates in the arrow flanker task (higher values reflecting poorer resolution of representational conflict) needed less time to compute the correct subject-verb agreement. Such a pattern of results does not allow for a straightforward interpretation other than that reflecting the speed accuracy trade-off.

Table 24. Hierarchical multiple regression of variables predicting proportion of errors and response latency in the number agreement task

		B	*SE*	*β*	*t*	*p*
(e) Number agreement errors as an outcome variable						
Model I	(Constant)	85.87	20.86		4.12	.000
	WAIS	-1.00	.28	-.36	-3.54	.001
	Processing speed	-.01	.03	-.03	-.31	.757
Model II	(Constant)	74.00	23.38		3.16	.002
	WAIS	-1.05	.30	-.38	-3.48	.001
	Processing speed	.01	.04	.03	.24	.809
	Anti-saccade ER	.16	.20	.09	.83	.411
	Anti-saccade RT	.01	.02	.08	.71	.479
	Arrow flanker ER	.15	.25	.07	.61	.545
	Arrow flanker RT	.01	.03	.03	.26	.792
	Simon arrow ER	-.39	1.12	-.04	-.35	.727
	Simon arrow RT	-.11	.09	-.15	-1.24	.220
(f) Number agreement response latencies as an outcome variable						
Model I	(Constant)	2109.94	491.09		4.30	.000
	WAIS	-12.28	6.68	-.20	-1.84	.070
	Processing speed	.24	.76	.03	.31	.758
Model II	(Constant)	2540.63	521.14		4.88	.000
	WAIS	-15.94	6.70	-.26	-2.38	.020
	Processing speed	.03	.83	.00	.04	.968
	Anti-saccade ER	4.16	4.41	.10	.94	.349
	Anti-saccade RT	.11	.44	.03	.24	.807
	Arrow flanker ER	-15.45	5.55	-.33	-2.78	.007
	Arrow flanker RT	-.71	.65	-.12	-1.08	.282
	Simon arrow ER	-1.72	24.99	-.01	-.07	.945
	Simon arrow RT	.00	1.93	.00	.00	.999

[e]*Note*. **Model I:** Multiple R = .36, R^2 = .13; adjusted R^2 = .11; *SE* = 21; **Model II:** Multiple R = .42, R^2 = .18; adjusted R^2 = .09, *SE* = 21.5;
[f]*Note*. **Model I:** Multiple R = .20, R^2 = .04; adjusted R^2 = .02, *SE* = 500; **Model II:** Multiple R = .43, R^2 = .18; adjusted R^2 = .10, *SE* = 479;

4.4 Discussion

This study was designed to evaluate the relative contributions of three types of inhibitory control, operating at different stages of information processing, to syntactic selection under increased interference conditions. The core syntactic processes examined were grammatical function assignment (the grammatical voice elicitation task) and grammatical number assignment (the number agreement task). Two hypotheses were tested: (1) inhibitory control measures should predict the ease with which a target syntactic structure is selected under high competition demands, and (2) the three types of inhibitory control may differentially contribute to performance in the two utterance production tasks.

A series of regression analyses provided some support for the link between non-verbal inhibitory control and grammatical function assignment under increased competition. Specifically, two forms of non-verbal inhibition, one at the motor output level (expressed as the anti-saccade RT effect) and one at the level of representation activation (expressed as the flanker ER effect), were related to the occurrence of repairs in high interference passive voice trials, with better inhibitory abilities predicting fewer utterance repairs. Neither speech onset latency nor other types of disfluencies (i.e., silent pauses or hesitations, repetitions and prolongations combined) were reliably predicted by inhibitory control measures. This pattern of results corroborates the involvement of inhibition in the production of repairs as demonstrated by Engelhardt et al. (2013), but also extends their findings in that both suppression of a motor output response and resolution of representational conflict appear to be relevant to the smooth production of utterances when an incorrect grammatical function assignment is experimentally induced.

The positive relationship between inhibition at the response execution level and the production of utterance repairs above and beyond language knowledge and other forms of inhibition permits the following interpretation. Inhibitory control abilities may be most critical when a highly activated lemma (which in the case of high interference passive voice trials appeared to be an animate, second order object) is wrongly assigned the nominative role, reaches the output buffer and is either suppressed or articulated leading to an overt error and its subsequent repair. The results suggest that those who are faster to suppress an incorrect motor response (a saccade towards an irrelevant cue) may well halt their speech sufficiently early to avoid uttering and then repairing an incorrect phrase.

The contribution of the flanker effect to the production of utterance repairs when the effects of language knowledge and other types of non-verbal inhibition have been controlled for suggests that interference can also arise and be resolved at a more abstract, representational level. Higher error rates in the arrow flanker task are taken to reflect poorer resolution of stimulus-level conflict that arises due to a mismatch between representations of the target (the middle arrow) and those of distractors (the flanking arrows). It could be that the co-activation of visual or conceptual representations of the flanking arrows dominates the activation of the middle arrow representation, delaying its selection. By analogy, assignment of the nominative role to the most active but context-inappropriate lexical representation (i.e., automatically placing a dominant lemma in the subject position when the given verb form dictates otherwise) may slow down correct function assignment. From the current data, it is not possible to determine how selection is accomplished, but it is reasonable to assume that some kind of interference resolution mechanism is in operation that facilitates the selection of the intended grammatical structure at representations (intermediate) level of processing. The evidence obtained in this study, however, does not allow for specific conclusions to be made with regards to whether the conflict is conceptual (at the pre-lexical stage) or lexical (lexical stage) in nature.

Alternatively, even though the non-verbal inhibitory tasks are routinely used as tests of inhibition, they may also tap into non-inhibitory processes such as conflict detection or action monitoring. It is possible that despite having selected an incorrect response code, those who scrutinise their covert behaviour more closely may well detect and correct the erroneous response before it is executed. Efficient monitoring abilities would thus translate into fewer overt corrections. Chevalier, Chatham, & Munakata (2014) have recently highlighted the importance of monitoring for contextual cues in inhibiting an ongoing action. Their data revealed that practicing monitoring was more beneficial to response stopping than training stopping itself.

The examination of number agreement computation in the present study has produced a less clear picture in relation to non-verbal inhibitory control. The latter had no obvious relationship with the proportion of number agreement errors or the speed with which the correct verb form was selected in the high interference singular predicate condition. The results, although seemingly incompatible with previous findings, can nonetheless be explained by conceptual and procedural differences. For instance, despite demonstrating that better inhibitory control was related to reduced error rates in the subject-agreement computation task, inhibition in Veenstra et al. (2018) was treated as a latent variable representing shared variance in performance on two executive control tasks: the fish flanker task (a children's analogue to the arrow flanker task) and the colour-shape task thought to tap into switching ability. The latent variable explained 80% of the variance in the colour-shape task and only 20% of the variance in the fish flanker task; hence it is unclear to what extent the factor truly reflected an inhibitory component and to what degree it represented a different process common to both tasks. In the colour-shape task, participants decide the colour or the shape of the target object based on the changing perceptual features of the cue. While response inhibition may underlie this decision process (the response code associated with the previous cue must be inhibited), the task also requires reconfiguration of one's response to the new cue (Monsell, 2003). The construct of inhibition examined by Veenstra et al. may therefore better reflect the ability to monitor contextual cues than inhibition *per se*. Similarly, despite the conclusion reached by Nozari & Omaki (2018) that production of correct subject-verb agreement in situations of high competition demands is predicted by individuals' performance on general inhibitory control tasks, only the No-go scores were truly predictive of number agreement errors, while the flanker and the Simon effects were not. In addition, because a perceptual cueing technique was used in their task, the positive correlation between no-go scores and attraction errors may have reflected suppression of irrelevant perceptual cues at the input level, as opposed to true suppression of syntactic information.

The lack of a clear connection between non-verbal inhibitory control and subject-verb agreement computation in the present study has at least two interpretations. One, even though the selection of the correct verb form may be affected by the co-activation of a non-intended representation, the process which mediates this selection is domain-specific. Two, grammatical number computation may not involve competition between the two activated verb forms, as claimed by

Haskell & MacDonald (2003), with errors and delays in production reflecting other non-competitive processes such as memory retrieval difficulties (e.g., Badecker & Kuminiak, 2007). The activation of a local noun may lead to temporary uncertainty as to which of the two nouns is the legitimate subject in control of verb number assignment. Alternatively, the more recently (and presumably more strongly) activated local noun and its number feature overwrites the activation of the head noun; re-activation of its memory trace, and specifically retrieval of its number feature is likely to take time and be error-prone.

The null result reported in the current study for the link between non-verbal inhibitory control and subject-verb agreement computation must be viewed with caution, as it does not necessarily offer evidence against the relationship between the constructs in question. For example, the absence of a relationship may be partly explained by task characteristics. While in both Veenstra et al. and Nozari & Omaki the stimuli remained on screen until the participant's response, thereby minimising memory load, the RSVP format used in the present study may have created an extra demand on memory processes.

In sum, the findings obtained in Study 3 imply that there are at least two sources of interference during online passive voice construction. One appears to originate at the intermediate stage of processing and is presumably concerned with overcoming (either primed or/and default) assignment of nominative function to the animate object noun lemma when the past participle verb requires an inanimate object in the subject position, although the role of conceptual interference (i.e., deciding who is the agent and who the patient) cannot be ruled out. The other can be traced to the response output stage, where an animate object noun representation that has been wrongly assigned the nominative function (placed in the subject position) reaches the output buffer and may either be suppressed in time to prevent articulation, or articulated, leading to an error and its subsequent repair. Also in this case, it is unclear to what extent production of repairs is driven by inhibitory processes and how much variability, if any, in the occurrence of repairs can be explained by monitoring abilities.

CHAPTER 5: NEGATIVE PRIMING WITH NOVEL ASSOCIATIONS (STUDY 4)

5.1 Background, rationale and aims of Study 4

As outlined in the Introduction (section 1.4), the "semantic" negative priming (NP) effect has been observed by some authors, but not by others. A possible source of these conflicting results, as acknowledged by several authors (Abad, Noguera, & Ortells, 2003; Damian, 2000; Fox,1995; Hutchison, 2002; MacLeod, Chiappe, & Fox, 2002), could be the specific nature and by that the strength of the relationship between ignored prime distractors and attended probe target stimuli (also referred to as prime-target pairs). According to these authors, the majority of the studies that showed a reliable "semantic" NP effect used stimuli that were both categorically and associatively related across the prime and probe trials (e.g., *cat-dog*). Such pairs form relatively strong associates compared to just categorically (e.g., *giraffe-mouse*) or just associatively (e.g., *brain-wave*) related pairs. Therefore depending on the experimental materials, disparate results may have been obtained in different experiments.

For example, Yee (1991) found that during a lexical decision task (LDT) probe target words that were highly associated (according to a variety of published word association norms) to one of the two distractor words presented above and below geometrical shapes that served as targets on prime trials were processed more slowly than control stimuli. It is difficult to specify the nature or the strength of the relationship between the critical stimuli and establish whether they ultimately had any role to play in obtaining a significant effect as the paper does not include the full list of prime-target word pairs. In Fox (1996), bilingual speakers had to categorise as even or odd focally presented numbers while ignoring flanking words on prime trials. This was followed by a LDT on probe trials, in which the word targets were highly associated to the previously ignored flanking words. The latter produced cross-language "semantic" NP only when the flankers appeared in L1, possibly inducing greater interference on prime trials than flankers in L2 (but see replication failure by Duscherer & Holender, 2002). It is worth noting that despite the claim that the pairs were highly associated, the experimental materials in Fox (1996) contained a mixture of categorically and associatively related words (e.g. *doctor-nurse*) as well as associatively but non-categorically related words (e.g. *blue-sky*; *brain-wave*), with different types of semantic relations between them, which, again, complicates the interpretation of findings.

Damian (2000) compared NP performance on picture categorisation and two versions of picture naming tasks (with and without visual overlap) in which targets were preceded by either identical, unrelated, or categorically but weakly associated distractors. While NP was obtained for identical items across prime and probe trials (identity NP), "semantic" NP in the magnitude of -25 milliseconds was only evident in the categorisation task. No "semantic" NP was observed in either of the naming tasks, even in the presence of visual overlap between categorically related pictures. Despite a reliable finding in the categorisation task, Damian (2000) argued against "semantic" NP on the whole, reasoning that the effect may have arisen spuriously as a result of "response repetition". Because the same type of response was required on both the prime and probe trials, delayed responses to probe targets that were categorically related to prime distractors may not have been the result of inhibition spread but the need to reinstate a response that had been previously suppressed. Although Damian (2000) concluded that NP does not extend to categorically related stimuli, it cannot be ruled out, as conceded by the author himself, that the null results obtained in the naming tasks could also be explained by the absence of strong associations between prime-target pairs. For although the author does not provide the exact matching of prime-target pairs, he does reiterate in the discussion that the picture stimuli belonged to the same semantic category but were only weakly associated.

In a study by Ortells, Abad, Noguera, & Lupianez (2001), strongly associated ignored prime words caused a reliable "semantic" NP effect but only at a 600-ms stimulus onset asynchrony (SOA) (Experiments 1,2,3,8) and at both a 600ms SOA (Exp. 8) and 1000 ms SOA when neutral as opposed to valid target cues were used (Exps. 4-6) on prime trials. Neutral cues were thought to increase target unpredictability and thus hamper its selection (and presumably contributed to greater interference on prime trials relative to valid cues). Although Ortells et al., (2001) used strongly associated prime-target pairs according to published word association norms (e.g. *orange-lemon*), they provide neither the full list nor the mean association strength of their prime-target pairs. A reliable "semantic" NP was also obtained by Hutchison (2002). Strongly associated pairs (e.g. *stork-baby*), with the mean association strength of 0.26, according to a variety of published word association norms, produced significant “semantic” NP (-35 ms). Here the stimuli chosen were more homogenous, with only associatively related words (e.g. *path-road*; *puppet-string*), albeit exemplifying a variety of semantic relations (e.g. functional, synonymic, collocational). A significant “semantic” NP effect of a similar magnitude to Hutchison (2002) was most recently demonstrated in a study on individual differences by Ortells et al. (2016), but only for those with high working memory capacity (WMC). The responses to semantically related probe target words in a LDT in that particular group was on average 30 ms slower than processing neutral stimuli. Ortells et al., (2016) concluded that the high WMC group has the ability to suppress the spread of activation through the semantic network. The association strength of prime-target pairs was confirmed with published word association norms; yet the experimental materials included pairs that were highly heterogeneous, with some both categorically and associatively related (*lion-tiger*), some categorically related but of low association strength (*ray-thunder*), others associatively but non-categorically related (*cream-strawberry*), with the association strength ranging from 39.1% to 96.5%. Because of the heterogeneity of the experimental stimuli, it is difficult to assess whether the type or strength of the relationship between prime-probe word pairings contributed to the observed effect. WMC was the main variable of interest and it proved critical in determining “semantic” NP; however, it remains unclear whether high WMC is a sufficient condition for observing the effect and whether other variables, such as the type or strength of the relationship between prime-probe target stimuli are equally important.

Studies using the inhibitory priming technique (a method analogous to negative priming but without external distractors) have demonstrated reliable interference for probe targets that were non-associated category co-ordinates (e.g., LEOPARD-*tiger*) (Tree & Hirsh, 2003; Vitkovitch et al., 2001; Wheeldon & Monsell, 1994) and a facilitatory effect for associatively related non-coordinates (e.g., *stork-baby*) (Tree & Hirsh, 2003).

The assumption that “semantic” NP may rely on there being a strong association between words has been directly tested by two separate research groups (MacLeod et al., 2002; Abad et al., 2003), albeit with opposing conclusions. MacLeod et al. (2002) assessed three types of prime-target relationships: identical, unrelated and related. The latter included prime-target word pairs that were either categorically related (where the ignored prime word belonged to the same semantic category as the target probe word, e.g., *banjo-fiddle),* or associatively related (where the probe target was strongly associated to the prime distractor but belonged to a different semantic category, e.g., *cradle-baby*). While the authors found a robust NP for identical words, there was no evidence of "semantic" NP. There are a few potential problems with MacLeod's et al. (2002) study, however. First, only 20 words in total were used in the experiment. Although such a small number of items were justified with the evidence that smaller sets typically yield greater NP effects, it has also been argued that repeated exposure to the same stimuli and over-familiarisation with the words may negatively influence semantic processing, which may be crucial to obtaining "semantic" NP (Neill, 1992). Second, the prime and probe tasks both involved reading aloud target words, while ignoring distractor words. Reading aloud may not activate semantic representations to the extent that other tasks do (e.g., semantic categorisation, object naming, real size judgement). Although the authors refer the reader to the null results in Chiappe & MacLeod's (1995) study, in which a categorisation task was used, their argument is refuted by Abad et al. (2003) who argue that the failure to obtain a "semantic" NP effect in Chiappe & MacLeod (1995) could equally be attributed to the lack of a strong association between the ignored prime words and probe target words (weak categorical relations e.g. *couch-dresser*). Third, if the association strength is indeed critical for the detection of "semantic" NP, the failure by MacLeod et al (2002) to demonstrate a reliable effect could be accounted for by the use of only weak (categorical) and moderate (associatively related but belonging to two different semantic categories) associates as prime-probe target pairs.

It is possible that strongly associated words, but not weakly (categorically only) or moderately (associatively only) related ones yield "semantic" NP – a hypothesis directly tested by Abad et al., (2003). The latter compared NP performance across two semantic conditions in which prime-target pairs were either categorically related, but of low association strength (e.g. *cow-lion*) or both categorically and associatively related (e.g. *tiger-lion*), exemplifying the strongest association strength due to a "triple overlap", in semantics (category), in structure (sharing a number of physical features) and in lexis (often encountered in close lexical proximity). A significant “semantic” NP effect (Exp.1: -30 ms; Exp.2: -53 ms) from the ignored words that were spatially pre-cued on prime trials was obtained in a LDT probe task, but only for “associative and categorical”, and not for “categorical only” pairs. Abad et al., (2003) concluded that the mere presence of a categorical relationship between prime-target words is not sufficient to produce the effect. Although Abad et al. (2003) made some progress with regards to whether the “semantic” NP effect depends on the kind and strength of the relationship between prime-probe word pairings, their experimental stimuli necessarily contained pairs that were always meaningfully related. The authors themselves pointed out that future research could separate meaning from lexical co-occurrence to show what effect the latter, in its pure form, has on “semantic” NP (p. 292).

This was indeed the first aim of the current study. Specifying the nature of the relationship between words that gives rise to “semantic” NP could help delineate conditions under which the effect (with its elusive character) is likely to occur. Resolving the question as to whether the effect is dependent on their being a meaningful relationship between previously ignored but now salient information would also contribute to the debate on the locus of inhibition and its potential spread. For delayed responses to probe targets that are semantically related to ignored prime distractors was originally taken as evidence that distracting stimuli are processed to an abstract level of representation and that inhibition spreads from directly supressed items to their semantic neighbours (by analogy to spreading activation, see Collins & Loftus, 1975; Neely, 1977). This has remained, however, a contentious issue, with some supporting the central locus of “semantic” NP (e.g. May, Kane & Hasher, 1995), others advocating a more peripheral view (e.g., de Zubicaray, McMahon, Eastburn, & Pringle, 2008).

De Zubicaray et al. (2008), for example, pointed out that obtaining a “semantic” NP effect with categorically related prime-target pairs does not necessarily reflect access to semantic representations. Many of the pairs belonging to the same semantic category are also structurally similar (e.g. *cat-dog, belt-tie*). The effect may therefore be due to a high degree of visual overlap between items, indicating perceptual and not semantic processing. This reasoning found support in their behavioural and neuroimaging data. De Zubicaray et al. (2008) reported that NP performance in a naming task in which prime distractors and probe targets were categorically related was associated with the activation of brain regions (fusiform and insular-opercular cortices) other than those typically engaged in semantic processing (e.g. anterolateral temporal cortex). Crucially, both response latencies and the activity of the fusiform cortex were affected by the degree of structural similarity between prime-probe object pairings, increasing with the number of shared features.

Obtaining a reliable “semantic” NP effect in the absence of semantic relatedness, with purely associative prime-probe object pairings, would not only indicate that a meaningful relation is not a necessary condition for observing the effect, but also argue against conceptual processing. Frequency of lexical co-occurrence, and not semantic association, could be a critical factor that decides whether or not the effect is likely to emerge. In addition, if a reliable “semantic” NP effect is obtained with semantically unrelated items, it would indicate that inhibition is applied not only to the immediately interfering information, but also to its related nodes in an associative network.

Given observational and experimental evidence which suggests that language production is a competitive process, what is the fate of the activated, but unselected representations? What is suppressed – the directly competing representation alone or the interfering information together with its associated nodes? Down what type of network does inhibition spread and how far-flung is its inhibitory reach? Demonstrating “semantic” NP in the absence of semantic relatedness would not only promote the view that language production is a dual selection process (in which excitatory and inhibitory mechanisms complement each other) and that inhibition operates in a manner analogous to spreading activation, but also help to address the question as to what types of elements in a language network it possibly subsumes.

To address the inconsistency surrounding the “semantic” negative priming (NP) effect and specifically the question of whether inhibition applied to the most highly activated competitor spreads to its other associatively related nodes, Study 4 utilised the negative priming paradigm with purely associative relations between prime and probe items. For this purpose, novel associations between words (prime interfering stimuli) and pictures (probe target stimuli) were first learnt to a fixed criterion. In the experimental task participants first named the depicted target object while ignoring the interfering word in prime trials (the PWI paradigm) and subsequently named the depicted target object that was associated to the just-ignored word in probe trials (picture naming task). It was predicted that response times to the associated probe target stimuli would be longer than to non-associated probe target stimuli.

5.2 Method

5.2.1 Participants

Thirty three participants were recruited from Middlesex University ($N_{females}$ = 19; M_{age} = 25.3 years, SD_{age}= 6.5 years), with English as their first language. The majority participated in the study for course credit. Three participants' data were excluded from the analysis due to poor recall performance on the paired associate learning task (PALT; less than 50% of the total picture-word pairs). Participants completed a demographic and language background questionnaire. All the participants signed a consent form and were debriefed. All had normal or corrected-to-normal vision.

5.2.2 Materials

The experimental stimuli included 108 black-and-white line drawings and 27 English common nouns (see Appendix E). The pictures were selected from Szekely et al. (2004) and presented common, concrete objects. They were 300 x 300 pixels in size, displayed on white background. 54 pictures served as critical stimuli and 54 were used as fillers. Out of the 54 critical stimuli, 27 were combined with the word stimuli to form 27 word-picture pairs in the PALT task. The pairs were carefully matched so that they were not semantically, phonologically or otherwise associatively related. This was confirmed independently by three experimenters. The remaining 27 pictures served as prime target stimuli in the experimental negative priming (NP) task. They were presented with superimposed distractor words, the same that formed paired associates in the PALT task. The target pictures and the superimposed distractor words were semantically related to maximise interference on prime trials. The remaining 54 pictures served as fillers. They formed prime-probe target pairs in the NP task and were used to minimise expectancy generation by increasing the ratio of distractor to no-distractor prime trials.

5.2.3 Procedure

Participants were tested individually in a sound-proof testing room. They sat comfortably in front of a computer screen and a keyboard. A microphone was attached to a pair of headphones that the participants were asked to wear throughout the experiment. After filling in the demographic and language background questionnaire, the participants performed two tasks: a study task (PALT) and an experimental task (the NP task) (see a detailed description of each task below). Each task was administered in 3 blocks. In the PALT task, there were 27 study pairs in total, 9 per block. In the NP task, there were 81 prime and 81 probe trials, 27 of each per block. On the critical probe trials, the target pictures were either associated to the prime distractor words from the PALT task (intact condition), or were associated to a different word from the PALT task (recombined condition). In the filler condition, the probe target pictures were not studied in the PALT task, but were only seen during the familiarisation phase preceding the PALT task. The purpose of the filler condition was to create a good proportion of distractor to no-distractor prime trials, which should lead to greater interference.

Stimuli in both tasks were presented electronically using the E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Similarly, all responses were recorded with the software using a voice key. The entire session lasted about 40 minutes.

Paired-associate learning task (PALT)

Before each study phase, participants were familiarised with a set of pictures and their names (36 per block) presented on a sheet of paper. This was to avoid unnecessary data loss due to hesitations and naming errors during the experimental task (Meyer & Damian, 2007). Pictures were then randomly presented on a computer screen and participants were asked to name the depicted objects by using the correct name. Naming errors were corrected by the experimenter.

The PALT task comprised a presentation phase and a retrieval practice phase (Figure 20). During the presentation phase, participants were shown 9 pairs of unrelated words and pictures. Each pair appeared on the computer screen for 5 seconds and was followed by a blank screen for 2 seconds. Word-picture pairs were presented in a random order. Participants were asked to remember the pairs for a future cued recall test. To help them remember the pairs better, participants were encouraged to form an association between the two items. Participants were then asked to perform a cued recall test, where they were to retrieve the associated picture to the cued word.

This was repeated three times (Figure 21). The word presentation order was randomised. Following the response, the correct pair was displayed on the screen for 2 seconds to further consolidate the new word-picture pairings.

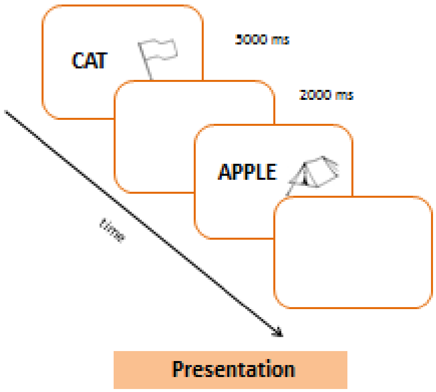


Figure 20. Presentation phase in the PALT task.

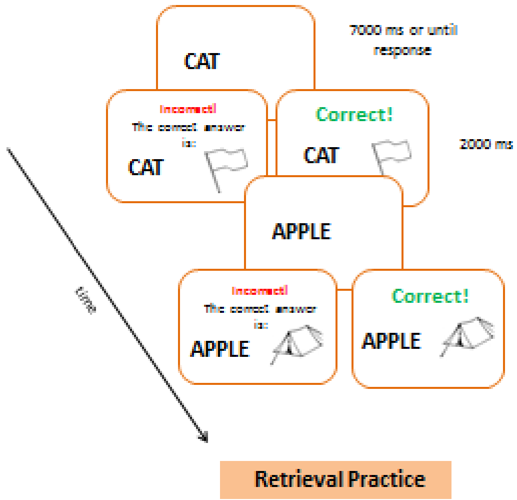


Figure 21. Retrieval practice phase with feedback in the PALT task.

Negative Priming (NP) task

Participants received 10 practice trials before the actual task. They were told to name the displayed pictures as quickly and as accurately as possible, while ignoring distractors when these were present (Figure 22). Each couplet trial began with a prime trial (4000 ms or until response was given), which was followed by a fixation point that appeared on the screen for 500 ms before the onset of a probe trial lasting 4000 ms or until the voice key was triggered by a verbal response. The prime-probe trial couplets were separated with an inter-stimulus interval that was set to vary in length between 1500 ms and 2000 ms. This, together with a randomised presentation of prime-probe target pairs and a relatively low proportion of distractor to no-distractor prime trials, was aimed at reducing participants' preparation and anticipation of each stimulus.

The NP task consisted of 162 prime and probe trials in total. There were 81 probe trials in total (27 intact, 27 recombined and 27 fillers). On the prime trial, a to-be-named target picture was presented with or without a superimposed distractor word seen during the study phase. It was followed by a probe trial where the to-be-named target picture was seen during the study phase and was associated to the distractor word (intact condition), was seen during the study phase but was associated with a different word (recombined condition), or was only seen during the familiarisation phase, but not the study phase and was preceded by a no-distractor prime trial (filler condition).

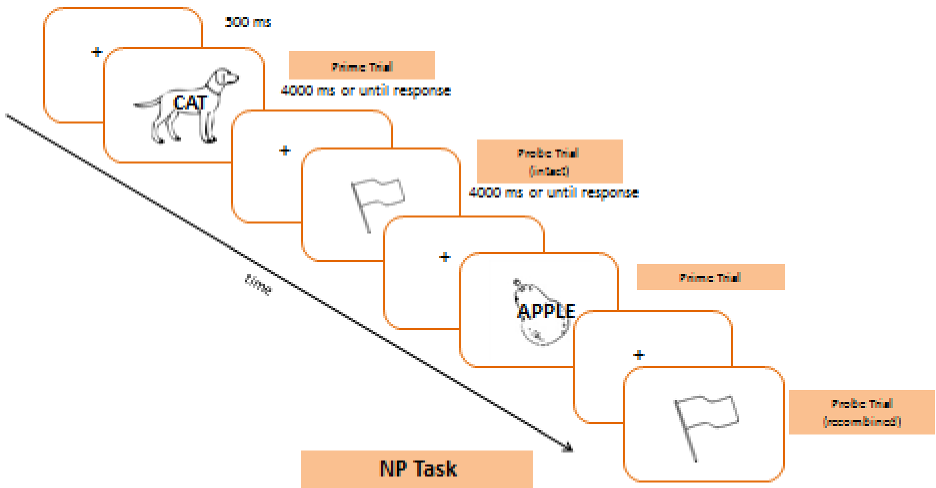


Figure 22. Negative priming task

5.3 Results

PALT task

Only correct responses were included in the analysis. RTs larger than 4000 ms and smaller than 500 ms were removed. In addition, RTs larger or smaller than

2SD within each participant’s individual mean were excluded. In total, 13.3% trials were excluded from the analysis.

To determine whether recall performance improves with retrieval practice (number of cued recall tests), two one-way repeated measures analyses of variance (ANOVA) were conducted, with the speed of recall (RT) and recall accuracy as dependent variables and retrieval practice (Recall 1, Recall 2 and Recall 3) as an independent variable. As the assumption of sphericity for the RTs has been violated [$W(2) = .78$, $p = .025$], the Greenhouse-Geisser correction was used in the analyses.

There was a main effect of study (retrieval practice) on recall performance both in terms of RT [$F(1.6,47.1) = 47.2$, $p < .001$, $\eta_p^2 = .62$] and accuracy [$F(2,58) = 33.9$, $p < .001$, $\eta_p^2 = .54$] (Table 25).

Table 25. Means and standard deviations response latencies (RT) and accuracy on the PALT task

	Recall 1 Mean (SD)	Recall 2 Mean (SD)	Recall 3 Mean (SD)	*F*	*P*	*η2*
RT (ms)	1560 (392)	1345 (390)	1181 (256)	47.2	<.001	.62
Accuracy (%)	77.6 (16)	86 (15)	92.1(9)	33.9	<.001	.54

Post-hoc comparisons

Post-hoc comparisons were carried out using a Bonferroni adjustment for multiple comparisons. These revealed significant differences between the three retrieval attempts, both in terms of response latency and accuracy (Figures 23 & 24). Participants were on average 215 ms [SE = 30; p < .001] quicker to recall the items on second retrieval attempt relative to the first and 379 ms [SE = 47; p < .001] quicker on the third retrieval attempt relative to the immediate recall. There was also a small gain in the retrieval speed between the second and the third attempt in the magnitude of 163 ms [SE = 39; p < .001]. In terms of the number of correctly recalled items, participants remembered ca. 8% [SE =1.6; p < .001] more pairs on the second attempt relative to the first, and 14% [SE = 1.9; p < .001] more items on the third relative to the first attempt. There was also a 6% [SE =1.7; p < .05] increase in accuracy between the second and the final recall.

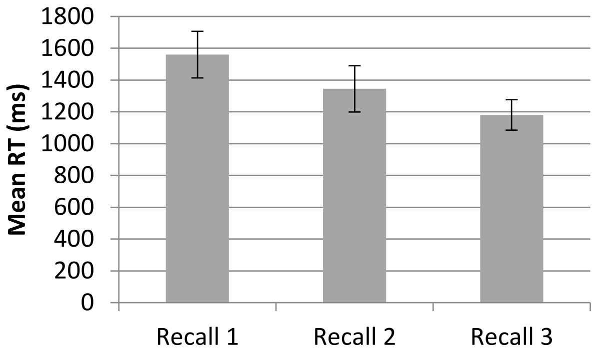


Figure 23. Effect of trainging on recall
95% CI error bars

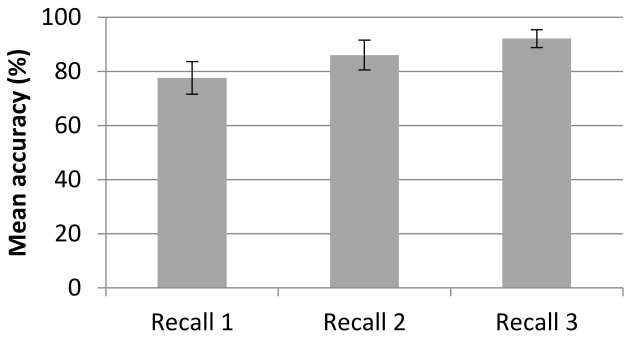


Figure 24. Effect of training on recall
95% CI error bars

NP task

Only correct probe responses were considered for the RT analysis. Responses longer than 2000 ms and shorter than 500 ms were discarded as were the data points outside the 2SD of individual participants' means. In addition, only those word-picture pairings that were correctly recalled on two out of three retrieval attempts were subjected to further analyses. This resulted in the total exclusion of 22% data.

A reliable NP effect is typically illustrated by significantly longer naming times to distractor-target probes than to control probes. Thus in our analysis we relied on planned comparisons involving direct comparison of intact trials with recombined. The analysis (paired-samples t-test) revealed no significant difference between responses on intact and recombined probe trials, [$t(29) = .074$, $p > .05$; $M_{intact} = 704.9$, $M_{recomb} = 704.3$].

5.4 Discussion

"Semantic" NP is a label for an empirical effect of decrement in performance (reduced speed and often an increase in errors) when processing items that are "semantically" related to the ones that had been previously ignored (suppressed). The attribute "semantic" is an umbrella term that subsumes different types of relationships between prime-probe target pairs including categorical (items belonging to the same semantic category e.g. animals), associative (items that frequently occur together in natural language) and a combination of the two. Associative relations themselves may represent thematic, functional, synonymic, whole-part and any other types of relations that could be used to define the core meaning of the word. Precisely because of such heterogeneity and the standard practice of many researchers to select stimuli on an intuitive, ad-hoc basis, it has been difficult to pinpoint the true cause of "semantic" NP. Although some progress has been made in establishing that category membership is not sufficient to produce the effect, it could not be ruled out that is not a necessary condition either.

The current study was designed in response to a direct call by Abad et al. (2003, p.292) for an investigation that would assess the contribution of pure associative relations (in the absence of semantic relatedness) between prime-probe target stimuli towards "semantic" NP, and in part in response to previous general calls for research on the role of the type and strength of the relationship between critical stimuli in "semantic" NP (e.g. Fox, 1995). In order to separate meaning from lexical co-occurrence, this study employed a paired-associate learning task (PALT) in which participants had to learn new, unrelated word-picture pairs (e.g. *apple*-TENT, *cat*-FLAG). The pairs were subsequently embedded within an experimental NP task, where the word from the PALT task served as a distractor (e.g. *apple* superimposed on the picture of a PEAR) on the prime trial and its associated picture as target (TENT) on the probe trial. It was expected that by suppressing the word distractor (*apple*) on the prime trial, inhibition would spread automatically to its immediate associate (TENT) and so naming of the associated picture on the probe trial would take relatively longer than naming of a non-associated picture (FLAG). This prediction did not find support in the present data, however.

The failure to demonstrate "semantic" NP with purely associatively related prime-probe target items could indicate that a semantic element has to be present in one form or another for the effect to emerge. An extreme position would be to echo MacLeod et al. (2002), who have cast doubt on the existence of NP for semantically related stimuli as a whole. There are, however, alternative ways to explain the null results obtained in the present study.

A plausible explanation for the absence of "semantic" NP for pure associative relations is that of diminishing NP effects. The "semantic" NP effect is typically smaller (~30 ms) than that obtained on identity NP tasks (~50 ms), where the prime distractor is the same as the probe target (Fox, 1995). The effect could have been further attenuated by the relative strength of experimentally induced associations – these may not have been powerful enough to cause the spread of inhibition; because of these limiting steps, the "semantic" NP effect may be diluted to the extent that it is no longer detectable at the behavioural level. A solution could be either to use an extensive study protocol where the new, semantically unrelated pairs are practiced until they are well integrated with the existing knowledge or to capitalise on phrasal associates that have been in circulation for some time (e.g. *face-book*) and that form fairly strong associates, as in Coane & Balota (2010).

A caveat to consider when interpreting the current results is the absence of distractors on probe trials. The present study was designed with distractors appearing exclusively on prime trials. A typical negative priming (NP) paradigm will have distractors on both types of trials (D'Angelo et al. 2016). Several authors have, in fact, suggested that NP is only observed when the probe target is accompanied by a distractor. In contrast, if no such distracting stimuli are present on probe trials, the NP effect is eliminated or even reversed to positive priming (D'Angelo & Milliken, 2012; Milliken, Thomson, Bleile, MacLellan, & Giammarco, 2012; Moore, 1994; Tipper & Cranston, 1985). Recent publications have, however, questioned the dependence of NP effect on probe distractors (Frings & Spence, 2011; Frings & Wentura, 2006), leaving the dispute unresolved. In addition, in some of the reported studies that produced reliable "semantic" NP, the probe displays contained a single stimulus. It can be concluded therefore that the presence of a distractor is not a necessary condition for the phenomenon to occur. Rather a different type of requirement needs to be satisfied. Frings & Spence (2011) argue the effect may rely more on the processing difficulty rather than the presence of a probe distractor *per se*, with the likelihood of observing the NP effect increasing with the time it takes to respond to the probe trial. Lack of the NP effect in the current study could be explained with a relatively low processing difficulty of the probe task (i.e. naming the presented picture) compared to others tasks that are more cognitively demanding (e.g. semantic categorisation or size judgement tasks).

It cannot be ruled out that other variables have influenced the outcome of the present study. “Semantic” NP as the standard identity NP is generally thought to be sensitive to the timing between the presentation of a prime distractor and the onset of a probe target (stimulus onset asynchrony, SOA). For example, inhibition of return in visual selective attention research is only observed with a certain delay (Klein, 2000). Inhibition needs time to accrue, but it also dissipates after a period of time. There is therefore a fine balance between allowing it to develop and preventing it from losing its potency. “Semantic” NP has been most commonly observed under an SOA of 600 ms (Abad et al., 2003; Ortells et al., 2001; Ortells et al., 2016; Yee, 1991), but a reliable finding of under an SOA greater than 1000 ms has not been unheard of (e.g. Marí-Beffa, Estévez, & Danziger, 2000; Hutchison, 2002; Richards, 1999). In the current study, the prime and probe displays were separated with a fixation point lasting 500-ms; however since both types of trials required a naming response, the SOA could not be fixed at a particular value, and so oscillated around 1200 ms (allowing ~700 ms for the naming response).

Some authors have emphasised the importance of the nature of the probe task in obtaining reliable “semantic” NP. Generally, tasks that encourage semantic processing or a forced-choice binary decision, such as semantic categorisation and lexical decision task, have been shown to produce significant effects. Both Damian (2000) and Richards (1999) found significant “semantic” NP with the categorisation task, but not with word identification (Richards, 1999) or naming (Damian, 2000). On the other hand, MacLeod et al. (1995) failed to report reliable “semantic” NP with a categorisation task although their null results have been accounted for with an alternative explanation (see Abad et al., 2003). The naming task used in the current study is in principle a suitable task as there is compelling evidence that naming an object entails access to semantic information. Reliable “semantic” NP was also observed previously when participants had to name pictures while ignoring superimposed distractors (Tipper, 1985; Tipper & Driver, 1988), but perhaps low processing difficulty of naming probe target objects in those studies was compensated for by the presence of overlapping probe distractor pictures, an aspect that has not been implemented in the design of the current study.

Finally, Ortells et al., (2016) have identified working memory capacity (WMC) among the factors that may play a critical role in determining “semantic” NP. The effect was only evident in the high WMC group who was thought to have sufficient cognitive resources to suppress the distractors and their semantic associates. The ability to resolve interference from task-irrelevant information in individuals with low WMC may be too poor to observe a delay in responding on probe targets that are identical to prime distractors, let alone probe targets that are semantically related to prime distractors. As WMC was not measured in the current study, it cannot be ruled out that a lack of sufficiently strong high WMC group could have adversely affected the results.

In conclusion, “semantic” NP in previous studies has been obtained under limited conditions. Although extra care was taken to devise the current study, we could not factor in all the variables that have been shown to potentially affect the phenomenon. Quotation marks were used throughout this paper to emphasise that the attribute *semantic* may be a misnomer, and that *associative NP* would be a more appropriate name as inhibition was hypothesised to spread down an associative type of network. Our prediction was not confirmed by the present data, however. Assuming that inhibition spreads down the semantic network, there is currently insufficient evidence to suggest it be the case. In most of the reported studies, “semantic” has been treated very narrowly, in terms of category co-membership, or very broadly, without proper care for systematic assessment of what types of relations (functional, script, whole-part, synonymic, hypernymic, etc.) specifically contribute to “semantic” NP. Therefore rather than dismissing the phenomenon itself based on null results, it would be worth investigating further whether and what kinds of prime-probe target relationships are responsible for the effect, while taking other potentially relevant variables (i.e. SOA, the nature of the response on the probe task, individual differences in WMC) that have been shown to affect “semantic” NP into account. This has already been done with other paradigms, e.g. picture word interference (PWI) task, where only target and distractors that belong to the same taxonomic category result in delayed responding, whereas other types of relationships, e.g. associative (Alario et al., 2000; La Heij et al., 1990), hypernymy-hyponymy (Kuipers & La Heij, 2008, but see Hantsch, Jescheniak & Schriefers, 2005), part-whole (Costa et al., 2005), and noun-verb (Mahon et al., 2007), produce facilitation effects.

CHAPTER 6: GENERAL DISCUSSION

The primary aim of this thesis was to characterise different types of interference and their control in monolingual language production. The systematic review of picture-word interference studies was conducted to trace the origins of semantic context effects in order to address the question of whether language production can be seen as a competitive process. Based on its findings and in light of recent empirical evidence for the separability of inhibitory control functions, further work assessed individual contributions of different types of conflict resolution mechanisms to production of words in the context of prepotent and underdetermined within-language interference. The notion of separability of inhibitory components was further applied to syntactic selection in a study assessing the extent to which resolution of different types of conflict is a source of variability in online grammatical production skills. Finally, a negative priming study investigated the potential spread of inhibition, and specifically whether it is applied to associatively related nodes within a language network. Chapter 6 provides a summary of the main findings of the four studies detailed in this thesis as well as their theoretical implications. Limitations of each study and directions for future research are subsequently discussed.

6.1 Summary of findings

6.1.1 Study 1: A systematic review of picture word interference studies

That multiple lexical candidates are activated during the production of even a single word is now widely accepted. Whether these candidates interfere with the selection of the target word, however, is the subject of an ongoing debate. Proponents of the competitive view of lexical access hold that the speed and ease with which a word is produced depends on the co-activation of non-target representations. The higher the activation of the competitors, the more time is needed and the harder it is to produce the sought-after word. Supporters of the non-competitive view argue that lexical retrieval proceeds independently of the level of activation of the unwanted candidates. A lexical item is selected once it has reached a certain activation threshold or the item with most activation gets selected after a certain time delay. The bulk of experimental evidence that has been generated in the course of this debate comes from picture-word interference (PWI) studies. The aim of Study 1 was to synthesise findings from various manipulations of the PWI task parameters in order to address the question of whether competition understood in its strict sense (e.g., that of Levelt et al.'s, 1999), as disruption of linguistic performance brought upon by the activation of non-target lexical items, is an integral part of the production process. Specifically, the study assessed the extent to which semantic context effects reflect competitive word retrieval and how much they are driven by non-competitive non-lexical processes specific to some aspects of the task.

Five main categories of findings have emerged from the reviewed sets of PWI data.

Several lines of PWI research have revealed contradictory findings. For instance, a range of effects (from facilitation, through null results, to interference) has been reported by studies manipulating semantic distance between targets and distractors. Discrepancies have also been noted across studies that have examined the effects of distractor masking on the speed of naming. The reliability of the visual similarity effect has not been firmly established. The findings furnished by studies manipulating the perceptual-conceptual processing demands, as well as those in which basic-level naming was replaced with subordinate-level naming have not been any more reliable. Inconsistent patterns of results have similarly been obtained by studies employing semantic decision tasks other than abstraction tasks. In many cases, the sources of these discrepancies remain unclear, but some procedural and conceptual differences have been acknowledged where possible.

A second group of findings is derived from manipulations which have produced robust semantic context effects but which nonetheless are unable to fully discriminate between the rival accounts. For instance, despite its successful replication across several different laboratories, the origins of the distractor frequency effect are not fully understood. The taboo interference effect has similarly been well documented but its theoretical underpinnings await further clarification. Manipulations of hierarchical relations between targets and distractors do not allow for an easy distinction between the alternative interpretations of PWI effects. Despite a fair degree of consistency, observations of facilitation with associative (miscellaneous) and thematically related distractors find plausible explanations in both competitive and non-competitive accounts.

The validity of some of the findings has been undermined by lack of adequate controls and complex presuppositions on which experimental hypotheses have been predicated. Response congruency has been a major source of confound, which may have unduly influenced results in subordinate-level naming and semantic decision studies. Inadequate matching of item sets across experimental conditions may have similarly distorted the observed effects. For example, several studies with distractor frequency manipulations have failed to control for potentially salient intrinsic properties of distractors such as concept familiarity, age of acquisition, and imageability. Only a small proportion of studies with semantic relatedness manipulation have matched target-distractor pairs across experimental conditions on the degree of visual overlap. A number of studies have failed to control for associative strength, allowing it to vary freely for different stimuli sets. Additionally, interpretation of findings for a number of manipulations is compounded by presuppositions that may require further scrutiny. This is particularly the case for distractor masking, distractor frequency and taboo interference effects.

For a number of manipulations, the available evidence is scant. Only a handful of PWI studies have explicitly manipulated the visual similarity between targets and distractors. There also appears to be a dearth of studies in which naming has been replaced with perceptual, semantic and phonological decision tasks. Intrinsic properties of distractors other than lexical frequency have not been sufficiently explored within the PWI paradigm. Equally, concurrent manipulations of these various aspects of the PWI task have not been fully exhausted.

The last group of findings pertains to manipulations that have generated reliable context effects, appear to be free from potential confounds and can be used to constrain the proposed accounts of lexical selection. Three types of manipulations have been particularly informative in elucidating the loci and the cognitive processes responsible for semantic context effects. Findings derived from these manipulations and their implication for the proposed accounts of lexical selection, and production models more broadly, are discussed below.

Despite the widely reported claims that non-verbal distractors lead to facilitatory effects, a reverse pattern (that of interference) has been repeatedly demonstrated. This was the case when lexical activation of distractors was incidentally or experimentally boosted (e.g., by including distractors in the response set; by overtly producing distractors' names in a compound noun production task). This pattern of results is in line with competitive (inhibitory) accounts of word production which assume that lexical access is impaired by activation of non-target lexical items (e.g., Levelt, 1989; Levelt et al., 1999; Roelofs, 1992; Schriefers et al., 1990; Starreveld & La Heij, 1995; Vigliocco et al., 2002). In particular, it is consistent with the selection-by-competition with a competition threshold hypothesis, which postulates that production is hindered by lexical competitors only if their activation level exceeds a certain threshold (Piai et al., 2012). Put differently, competing representations must be sufficiently activated at the lexical level in order to enter into competition with target words and delay their selection.

Whereas inhibitory effects for non-verbal distractors provide support for competitive accounts of lexical access, they present a challenge to non-competitive explanations, specifically to the response exclusion hypothesis, REH (Finkbeiner & Caramazza, 2006; Mahon et al., 2007; Miozzo & Caramazza, 2003). Observing interference in the absence of overt verbal distractors undermines one of its core assumptions, namely that the semantic inhibition effect is partly due to a phonologically well-formed and thus production ready distractor word occupying the articulatory buffer before the target object's name can be retrieved. Without verbal distractors, it is hard to see how the buffer would be obstructed and where else in the system other than at an early production stage a delay would occur. Similarly, the concept exclusion hypothesis (CEH), which attributes delays in naming to non-lexical factors at early stages of processing (visual and/or conceptual ambiguity of the target brought upon by incompatible visual/conceptual information activated by the distractor), would have difficulty explaining the lack of interference reported in studies in which distractor pictures did not receive a lexical activation boost. If structural and/or conceptual disambiguation was the sole contributor to the interference effect, it would have been observed regardless of whether distractor pictures' names were sufficiently activated.

With both of these alternative explanations for the semantic inhibition effects called into question, it is hard to see how the pattern of results would fit within a wider non-competitive framework of word production, for example, that of Dell's (1986) or Oppenheim et al.'s (2010). If no competition was assumed and a word was selected based on its activation level alone (Dell, 1986), naming should be speeded in the presence of categorically related pictorial/ environmental sound distractors because of semantic priming, or in the very least, it should be no different to performance in the unrelated distractor condition. While competitive incremental learning (increasing semantic-lexical connection weights for selected items and decreasing these weights for non-selected items), as proposed by Oppenheim et al. (2010), could potentially explain the findings in the picture-picture and picture-sound interference studies which used repeated naming episodes (e.g., when multiple exemplars of the same category served as targets), a different explanation would be required for interference effects observed in studies which did not involve incremental learning (i.e., those with single naming episodes).

Manipulations of associative (miscellaneous) and whole-part relations between targets and distractors have also been useful in furthering the debate on the origins of PWI effects, particularly when associative strength/distinctiveness was factored into the equation. Facilitatory effects for associative and whole-part relations were observed at early rather than later SOAs. Importantly, minimising the associative strength between targets and distractors or employing distractors denoting non-distinctive parts of target objects resulted in polarity reversal whereby facilitation was turned into interference. Such pattern of results can be predicted by competitive accounts of lexical access, in particular the swinging lexical network hypothesis, SLNH (Abdel Rahman & Melinger, 2009, 2019). Under this account, the net experimental effect reflects the interplay of distinct mechanisms operating at different stages of information processing (semantic facilitation and lexical competition) and with varied levels of intensity. A non-distinctive feature (a constituent part of an object), by definition, will induce weaker semantic priming (it is only weakly associated with the target) and greater lexical competition (due to recursive activation within the semantic network more concepts will converge on the lexical representation of the constituent part). Conversely, a distinctive feature is likely to induce greater semantic priming (it is more strongly associated with the target) and weaker lexical competition (due to more disperse activation within the semantic network, fewer concepts will converge on the lexical representation of the constituent part). Patterns of facilitation and interference observed with part-term and associative relations manipulation bear more broadly on the computational model of lexical selection proposed by Howard et al. (2006), and particularly on two of its core components: competition (activation of a competitor delays production of a target) and shared activation (activation spreading via related semantic nodes or via semantic features). In the absence of sufficiently strong competition at the lexical level, there is no mechanism that can offset facilitation due to shared activation at the semantic level. How competition is instantiated remains an open question. While competition in Howard et al.'s model can be implemented either through lateral inhibition (lexical representations inhibiting each other) or a decision criterion such as Luce choice ratio (the activation of the target must exceed the activation of all the competitors by a differential amount), Abdel Rahman & Malinger (2019) argue the latter mechanism to be more fit for their "swinging network" because inhibited lexical representations would potentially dampen the resonance within the semantic network.

Whereas the changing polarity of the effect that is facilitatory for strong associates or distinctive parts, particularly at early SOAs, but disappears for weak associates or non-distinctive parts, reappearing as interference at later SOAs can be accounted for by competitive accounts, it is problematic for the REH account. It is hard to see how a "buffer clearing" mechanism discriminates between response relevant and irrelevant distractors based on association strength alone (both associates and non-associates meet the response relevance criterion equally well). More broadly, inhibitory effects observed with part term and associative relations manipulations are difficult to explain without recourse to competition (e.g., Dell 1986; Oppenheim et al., 2010) as the tasks employed in these studies rely on single naming episodes, with potential competition thus constrained to the actual selection process.

It is no accident that semantic context effects are usually referred to in the plural form. A range of these effects (from facilitation, through null results, to interference) has been demonstrated with the various manipulations of the PWI task parameters. It transpires that inhibitory effects are not as rare an observation as is commonly reported in the literature, and should certainly not be considered an exception, as being constrained to categorically related distractor words derived from the same level of specificity as targets. Contrary to popular claims, interference has been reliably demonstrated for non-verbal (picture and environmental sound) distractors, for distractors denoting parts of target objects and for distractors drawn from a different level of specificity than targets.

PWI effects can be best characterised as graded rather than all-or-nothing. They reflect the interplay of distinct mechanisms operating at different stages of information processing and with varied levels of intensity. Lexical competition remains a viable force, which contributes to the overall PWI effect; ‘selection-by-competition with a competition threshold’ and SLNH remain tenable hypotheses, capable of explaining the majority of the reviewed findings, except for the distractor frequency effect (greater interference for low-frequency than high-frequency distractor words). To account for the latter and thus to uphold the claims of competitive word retrieval, additional non-lexical mechanisms must be assumed that can overrule the presumed interference from high-frequency distractors. Both the REH and the self-monitoring (Dgooge & Hartsuiker, 2010, 2012) accounts, as they currently stand, lack sufficient explanatory power. The REH account has been challenged by findings from studies with the following manipulations: distractor format, distractor emotional content, associative strength of part-term distractors and task demands. The explanations proposed by the self-monitoring account of the pseudo-word facilitation effect (lexicality bias) and the taboo interference effect appear to be based on contradictory logic. However, neither the REH nor the self-monitoring account should be discounted as additional explanations for variations in the speed with which objects are named in the context of interfering stimuli. Despite indications that interference may originate (at least partially) pre-lexically, before or around semantic access, the potential contribution of early processes (as stipulated in the CEH account) in the context of PWI has not been properly addressed. Manipulations of semantic distance, visual similarity and visibility of distractor-denoted parts in target objects, which could provide valuable insight into the role of competing pre-lexical representations, have either produced inconclusive evidence or have been insufficiently explored. Although lexical interference appears to be an important source of interference, the influence of non-lexical decision processes (e.g., structural or conceptual disambiguation) as determinants of the speed of naming cannot be ruled out.

To address the main research question of whether spoken production can be seen as a competitive process in the strict sense of the word, in light of the reviewed

PWI findings, the tentative answer is affirmatory. It is nevertheless only tentative, and for two reasons. One, although the competitive hypotheses of lexical access in the PWI task have not been directly refuted, relative contribution of pre-lexical processes to object naming remains to be determined. Two, the PWI paradigm is an experimental task involving object recognition, word comprehension and an interaction between the two, perhaps bearing little resemblance to word retrieval in everyday communication. Despite these artificial aspects of the task, it is conceivable that an endogenous form of competition is present in natural language production, be it in the form of a recently heard, frequently used or an emotionally charged word, the activation of which impedes the selection of the target word. Indeed, some authors (Dhooge & Hartsuiker, 2011; Starreveld, & La Heij, 1995) have shown that in a speeded PWI task, speakers often erroneously produce the distractor name instead of the picture name, a situation that simulates production of natural speech errors. It is also feasible, in accordance with the REH and the self-monitoring accounts, that an erroneously selected item can reach the output buffer where it can be suppressed before it is articulated and that this may proceed following some criterion checking process (the self-monitoring mechanism assessing the response for its social appropriateness, lexicality, audience design, and so on). In this sense, spoken word production is only metaphorically competitive since no other representations slow down target selection but potential recruitment of an inhibitory mechanism to stop the incorrect response does.

6.1.2 Study 2: Types of interference and their resolution in lexical selection

Study 2 investigated the relative contribution of different types of inhibitory control (measured by the anti-saccade task, the arrow flanker task and the Simon arrow task) to the resolution of within-language interference in two word production tasks: the picture-word interference (PWI) task, and a picture naming task with name agreement (NA) manipulation. Measures of individuals' vocabulary knowledge and general processing speed served as control variables. The PWI task was characterised to involve prepotent competition resolution, i.e., selecting a word from a cohort of co-activated, but context-irrelevant lexical representations; whereas the NA task was considered to be a measure of underdetermined competition resolution, i.e., selecting a word from a set of equally plausible lexical candidates. Hierarchical multiple regression analyses revealed that only performance on the flanker task predicted the magnitude of the PWI effect. Specifically, individuals who were quicker to resolve interference induced by incompatible stimuli in the arrow flanker task were also quicker to name objects accompanied by categorically related distractor words. This contribution remained significant after controlling for vocabulary knowledge and general processing speed as well as the other measures of inhibitory control. Neither the Simon effect nor the anti-saccade effect was a reliable predictor of the ability to resolve semantic interference in the PWI task. None of the inhibitory control measures correlated significantly with the NA effect.

The most straightforward interpretation of the relationship between the flanker and the PWI effect is that both measures reflect the ability to deal with conflict that arises as a result of concurrent activation of non-target representations and/or response codes. In the arrow flanker task, selection of a correct representation/ response code is thought to be hindered by the activation of the flanking arrows as demonstrated by prolonged response times and reduced accuracy on incompatible trials relative to the baseline. Similarly, interference in the PWI task can be said to originate from co-activation of representations/ articulatory codes that are irrelevant to the communicative goal. That a decrement in performance on both tasks reflects competitive selection rather than non-competitive processes is inferred from two premises. One, if competition was a superfluous notion and selection were to proceed regardless of the activation level of task-irrelevant items (e.g., Dell, 1986), manipulations of distractor activation strength should have no influence over the speed with which a target is selected. This is not the case, however. Changes in the saliency of distractors in the flanker task, for example, have been shown to modulate the interference effect (e.g., Miller, 1991). Raising the activation of distractors at the lexical level in picture-picture interference studies (e.g., Mädebach et al., 2017) and in picture naming studies with masked distractors (e.g., Piai et al., 2012) resulted in polarity reversals, such that facilitation for weakly activated distractors was changed to interference for strongly activated distractors. Two, while it is conceivable that conflict in the arrow flanker task accumulates in an incremental manner as a result of repeated presentation of the same stimuli by analogy with the incremental learning mechanism proposed by Oppenheim et al. (2010), whereby some stimulus-response associations are strengthened and others weakened, as reflected in trial-by-trial effect modulation, it is hard to see how the incremental learning logic could be applied to the current PWI data set. The PWI task used in Study 2 did not involve repeated naming, with only a few exemplars from the same semantic category employed as targets. It is thus not easy to find an explanation for the association between the flanker and the PWI effects within purely non-competitive models of selection.

More specifically, it can be argued that the two tasks share the requirement of managing conflict that is most prominent at the level of representation selection rather than at the level of perceptual encoding (e.g., Sanders & Lamers, 2002; Van't Ent, 2002) or response selection (e.g., Eriksen & Eriksen, 1974; Eriksen & Schultz, 1979). This is based on two premises. One, while the interference effect in the arrow flanker task can be taken to reflect the ability to proactively block irrelevant stimuli at the input stage (perceptual blocking mechanism), whereby the participant strategically ignores the flanking arrows so as to attend solely to the middle arrow, the adoption of a similar strategy would be unlikely in the case of the PWI task. The distractor stimuli in both the categorically related and unrelated conditions of the PWI task used in the current study were equally salient in terms of their perceptual and psycholinguistic properties (both were words matched on a number of variables that affect processing speed), so if a speaker were to proactively filter out distractor words while focusing on target pictures alone, the effect would have been cancelled out. Two, in line with dual-route information processing models developed to explain the findings in classic conflict paradigms (e.g., the activation-suppression model proposed by Ridderinkhof et al., 2004), conflict in the arrow flanker task could also stem from activation of incompatible response pathways, such that the flankers trigger a more potent but irrelevant response code (fast, 'direct' route) whereas the target induces a weaker but correct response code (slower, 'indirect' route). By analogy, the distractor word in the PWI task, being phonologically well-formed and production-ready could be said to activate an articulatory code via the 'direct' route before the target picture's name is retrieved via the slower, more deliberate route, in line with one of the assumptions of the REH hypothesis. The unique contribution of the flanker effect to the magnitude of semantic interference above and beyond other inhibitory control measures, i.e., the Simon effect (measure of conflict resolution at the level of response selection) and the anti-saccade effect (measure of motor response blocking) however, can be taken as evidence against the late-stage response-based conflict as the main driving force of the effects. This leaves the option of conflict between incompatible representations as the most plausible explanation for the relationship between the flanker and the PWI effects. It is possible that the flanking arrows activate a conceptual representation of direction that is incompatible with that of the target arrow. That a lexical representation of direction is also activated and interferes with the selection process is less likely, but should not be readily dismissed. In the PWI task, spreading activation within the semantic network leads to activation of related semantic nodes and their corresponding lexical units (or the overlap in semantic features activates multiple lexical candidates), which together with the presentation of the distractor word makes it a strong enough competitor to frustrate the retrieval of the target name. There is, of course, a possibility that conflict in the PWI task is primarily conceptual rather than lexical in nature, with delays and errors in naming on incompatible trials reflecting problems with object identification. It is for future research to assess how much of the variance in the PWI effect can be accounted for by non-lexical factors.

It is evident from the current data that individuals vary in their ability to minimise interference effects in order to optimise performance on inhibitory control and word production tasks, although the mechanisms by which this is achieved are only speculative. For example, the conflict paradigm literature suggests that conflict is resolved either by amplification of the correct representation, suppression of task-irrelevant information/ motor output, or a combination of these processes (Egner, 2008; Egner, Delano & Hirsch, 2006). In the language production literature, a top-down biasing mechanism has been proposed that either boosts the activation of the correct representation or lowers the activation of an incorrect one based on some contextual information (e.g., Belke & Stielow, 2013; Roelofs, 1992). For example, in the computational word production model (WEAVER++) proposed by Roelofs (1992), the system uses procedural knowledge ("action-based rules") to bias the flow of activation in favour of the target lemma. The biasing mechanism is analogous to the response relevance checking mechanism as stipulated by the REH hypothesis, (Mahon et al., 2007) and the monitoring system posited by Dhooge & Hartsuiker (2010; 2012) that evaluates the selected representation in terms of its relevance to the communicative context (e.g., when naming an object, a distractor denoting an action is implausible as an answer, and can therefore be rejected more quickly than a distractor denoting an object), except that the locus at which it is assumed to operate is not constrained to the articulatory buffer. Instead, it may be engaged sooner than at the response selection stage. For example, in Roelofs' (1992) model, it is the lexical selection process that performs the checking. Although the current study did not assess how selection occurs, the observed association between the flanker and the PWI effect suggests that a top-down biasing mechanism is not necessarily a procedural artefact specific to the PWI task, but a more general process that mediates conflict resolution under broader circumstances.

Although the contribution of the flanker effect to semantic interference resolution in the PWI task after partialling out the variance associated with response-based conflict (Simon effect) has been interpreted in favour of the intermediate (representation) rather than late (response selection) locus of interference resolution, some caution is warranted. It could be that the size of the Simon effect was too small for the association between performance on the arrow flanker task and the PWI task to be affected. Compared to standard arrow-based Simon effects in paradigms that use single arrows as targets rather than multiple arrows as in the current version of the Simon task, the Simon effect was indeed visibly reduced (cf., Luo & Proctor, 2017; Experiment 3). The role for the type of conflict that arises and is resolved at the response selection stage in spoken word production cannot therefore be fully discounted.

The lack of a clear relationship between the PWI effect and the Simon or the anti-saccade effects should not be taken as evidence against the role of late-stage conflict resolution mechanisms in spoken word production. It could be that each is independently engaged at a different production stage. For example, unsuccessful resolution of lexical conflict could result in automatic activation of two incompatible response codes leading to response-based conflict. Inefficient resolution of the latter could in turn provide scope for response blocking (resolution of conflict at the response execution stage) to be put into action. However, with multiple predictors, the power of the study may have not allowed for the detection of clear relationships between these variables.

The null findings for the relationship between inhibitory control measures and the NA effect again are no grounds for dismissing the role of interference resolution mechanisms in the naming of objects with low name agreement. Future studies could use a bigger sample or employ experimental methods to investigate if processes other than competition could be responsible for the NA effects. Moreover, the inhibitory control tasks used in the current study may not have been adequate to be applied in the context of underdetermined competition by which the NA task is characterised. The inhibitory measures are best thought of as assessing prepotent competition, i.e., strong interference from incompatible representations, response codes or execution ready responses, which could partly explain why no significant associations were observed between the variables in question.

6.1.3 Study 3: Types of interference and their resolution in syntactic selection

Study 3 examined the relative contribution of three types of inhibitory control (measured with the anti-saccade task, the arrow flanker task and the Simon arrow task) to grammatical encoding in two sentence production tasks (grammatical voice elicitation and number agreement computation), while also controlling for language competence (WAIS vocabulary score) and general processing speed (mean RT in the neutral condition of the arrow flanker task). Multiple hierarchical regression analyses demonstrated that WAIS vocabulary score was a reliable predictor of the occurrence of repairs and speech onset latencies in the high interference passive voice condition of the grammatical voice elicitation task. Language competence also predicted subject-verb agreement errors and (marginally) response latencies in the high interference singular predicate condition of the number agreement computation task. Importantly, the inhibitory control measures explained some of the unique variance in performance on the grammatical voice elicitation task, but not on the number agreement computation task. In particular, the flanker and the anti-saccade effects turned out to be significant predictors of utterance repairs. Under experimental conditions that were aimed at inducing incorrect grammatical role assignment, individuals with larger flanker and anti-saccade effects self-corrected more often.

Studies have only recently begun to explore the role of inhibition (competition) in sentence production (Engelhardt et al., 2013; Nozari & Omaki, 2018; Veenstra et al., 2018). Relating the current results to any particular model of grammatical encoding that explains how words are selected and ordered in a sentence while also addressing the question of inhibition (competition) is therefore difficult because such models have not been fully developed. The existing lexico-syntactic models either focus on grammatical encoding to account for non-inhibitory effects (e.g., the structural priming model discussed by Dell, Chang, & Griffin, 1999) or account for inhibitory effects but in the context of language comprehension (e.g., Vosse & Kempen, 2000; MacDonald, Pearlmutter & Seidenberg, 1994). The current findings are therefore discussed with reference to the origin of interference (how it potentially arises), the locus of interference (where in the system it potentially arises) and resolution of interference (how it is potentially resolved) as explicated in models of lexical access.

The flanker effect was found to be a reliable predictor of passive voice utterance repairs, above and beyond language competence and the two other inhibitory control measures. Individuals with larger flanker effects (indicative of poorer inhibition) were more likely to repair their utterances online, i.e., the speaker would produce an unintended grammatical structure but immediately replace it with the correct target one. Clearly, sentence production was temporarily impaired and this impairment could be related to interference of some sort. It is important to note that repairs in the current study (e.g., saying *The pirate… the cheese was eaten by the pirate*) reflect incorrect assignment and subsequent re-assignment of grammatical roles (nominative and accusative) to the verb's arguments (animate and inanimate noun lemmas). In most cases, the speaker would mistakenly assign the nominative role to an animate noun lemma, subsequently inserting it in the subject position, even though the to-be-used irregular past participle verb form would require an inanimate noun lemma to be encoded as a sentential subject. What could potentially interfere with the assignment of grammatical roles to the verb's arguments that would result in overt errors and their immediate corrections?

Although utterance repairs were more numerous in the animate-second- than animate-first-order condition of the passive voice trials (in which an irregular past participle verb form is required in the sentence), replicating the results reported by Engelhardt et al. (2010), the effect that emerged may have been too small to be reliably predicted by the inhibitory control measures. Instead, the flanker and the anti-saccade effects predicted repairs in both animate-first- and animate-second-order passive voice trials, suggesting that the presence of an animate object itself, regardless of whether it was presented as the first or second item in the display, is sufficient to induce conflict during passive voice construction. This observation is consistent with Altmann & Kemper (2006), who concluded that the order of activation of noun lemmas is not the main determinant of sentence structure, with animacy of the verb’s arguments (“animate-subject constraint”) having greater influence over syntactic form selection. Due to their conceptual prominence and consequently higher level of activation, animate noun lemmas tend to be assigned to higher-level grammatical roles (animate nouns have faster activation rates than inanimate nouns; McDonald, Bock, & Kelly, 1993). Because they are more highly activated, animate noun lemmas are accommodated early in the sentence, usurping the position of inanimate noun lemmas, and thus disrupting the process of correct syntactic form selection. In this sense, the process of grammatical encoding could be said to be competitive.

Interference in both animate-first- and animate-second-order conditions of the passive voice trials could also be traced to a strong preference of English speakers for active sentences (e.g., Bates & Devescovi, 1989). Although the strong bias towards the active voice often overlaps with the animacy constraint, in some cases the propensity for active grammatical structures is overruled by the affinity of animate noun lemmas for higher-order grammatical roles. For example, in the sentence *The man was hit by a car*, the animacy constraint trumps the “active-voice-as-default” constraint, resulting in the animate noun being tagged with the nominative case and inserted in the subject position, while the speaker opts for the passive voice structure. It is possible that in the current study the two constraints converged however, additionally increasing the activation of animate noun lemmas and making them more likely to be accommodated early in the sentence. If the active voice was indeed used as a default syntactic option, a competitive incremental learning mechanism with associated weight changes, analogous to the one proposed by Oppenheim et al. (2010), may therefore also explain the obtained pattern of results. It is conceivable that by tagging animate noun lemmas with the nominative case, the connections between selected animate noun lemmas and the nominative role are strengthened while those between the unselected inanimate noun lemmas and the nominative role are weakened. When it comes to selection therefore, the inanimate noun lemma is already in a disadvantaged position.

Based on the unique contribution of the flanker effect to the occurrence of repairs during passive voice construction, what could be said about the potential locus of interference and its resolution? Although part of the variance in the flanker effect could be accounted for by perceptual conflict, interference occurring at this stage of processing is unlikely in the voice elicitation task in which the items in the display were equally salient and separated from one another. Conflict at the representational stage of information processing is a likely candidate to explain the pattern of results. Although the flanker effect made a unique contribution to the occurrence of repairs during passive voice construction, after controlling for the Simon and the anti-saccade effects, the size of the Simon effect and the insufficient power of the study may not have allowed for the emergence of significant relationships between these measures. The unique contribution of the anti-saccade effect to the production of repairs implies that interference can also be traced to the response output stage, where an animate object noun representation that has been wrongly assigned the nominative role (and subsequently placed in the subject position) reaches the output buffer and may either be suppressed in time to prevent articulation, or articulated, leading to an error and its subsequent repair. Here, individuals who were quicker to suppress incorrect saccades (as indexed by smaller anti-saccade effects), were also less likely to produce overt errors and their repairs. A blocking mechanism at the response execution stage may therefore be the last gating mechanism which can reduce the chances of articulating an incorrect syntactic structure.

The final point concerns the mechanisms by which syntactic interference could be resolved. It is clear that individuals differ in the ability to deal with conflict as reflected in different rates of utterance repairs. How do speakers optimise their language performance? By analogy with accounts of interference resolution in lexical selection (e.g., Belke & Stielow, 2013; Roelofs, 1992), speakers may rely on some top-down biasing mechanism, whereby they use contextual information (i.e., the presented verb form) to bias the flow of activation either away from the more highly activated (animate) noun lemma or towards the less highly activated (inanimate) noun lemma when constructing passive sentences.

There was no obvious relationship between either of the types of non-verbal inhibitory control and the selection of a correct verb form in the high interference singular predicate condition of the grammatical number computation task. This was unexpected in view of recent findings according to which inhibitory control (understood as a latent construct) was predictive of subject-verb agreement errors in both adults (Nozari & Omaki, 2018) and children (Veenstra et al., 2018). Closer examination of the task characteristics and individual inhibitory control measures used in these studies revealed that the shared variance derived from the individual tasks may have reflected the construct of interest (inhibition) but it may equally have represented non-inhibitory processes that were common to the tasks used (e.g., conflict detection, working memory).

Two possible explanations were provided to account for the lack of an association between inhibitory control tasks and number agreement computation under conditions of high interference. It is possible that competition and inhibition were present but were not observed in high interference trials because they were masked by comprehension or working memory retrieval difficulties (the task involving the RSVP format and a comprehension element). Nonetheless, this explanation can be salvaged, because the same demands applied to the high and low interference conditions, which should cancel each other out, and because both number attraction and mismatch asymmetry effects as reported by Nozari & Omaki (2018) and Veenstra et al. (2018) as well as previous studies (e.g., Eberhard, 1997) were replicated with this paradigm.

The fact that inhibitory measures did not explain any variance in the number agreement computation task also allows for the possibility that the standard number attraction and mismatch asymmetry effects observed in subject-verb agreement computation do not involve competition. Instead, both errors and delays reflect temporary uncertainty about which noun is the sentence's subject (i.e., a comprehension problem) or a retrieval difficulty, since to select the correct verb form it may be crucial to retrieve the subject's grammatical number from working memory. It remains to be established whether competition is part of the subject-verb agreement computation, and if so, what competes with what (e.g., whether the local noun automatically activates a matching verb, which delays the selection of a subject-compatible verb).

6.1.4 Study 4: Negative priming with novel associations

Study 4 was designed to address the inconsistency surrounding the "semantic" negative priming (NP) effect and specifically the question of whether inhibition applied to the most highly activated competitor spreads to its other associated nodes. Previous studies had suggested that the difficulty in obtaining a reliable semantic NP effect might be due to the heterogeneous nature of experimental materials used. The prime-probe stimuli pairs employed often reflect a range of semantic relationships with varied association strength. To circumvent the problem of heterogeneity and possible contamination from association strength, Study 4 utilised the negative priming paradigm with purely associative relations between prime and probe items. For this purpose, novel associations between words (prime interfering stimuli) and pictures (probe target stimuli) were first taught to a fixed criterion. In the experimental task participants first named the depicted target object while ignoring the interfering word in prime trials and subsequently named the depicted target object that was associated to the just-ignored word in probe trials. It was predicted that response times to the associated probe target stimuli would be longer than to non-associated probe target stimuli, a hypothesis which was not confirmed by the data.

Observing associative NP could inform our understanding of the type of biasing mechanism which has been implicated in competitive lexical selection. It is currently unknown whether such a mechanism would operate by enhancing the activation of the target word (e.g., Roelofs, 1992), or by dampening the activation of co-activated but goal-irrelevant representations, or both. In the model of lexical access proposed by Roelofs (1992) for example, the system uses "condition-action rules" to determine which node meets the task relevance criteria specified in working memory and selectively boosts the activation of that node. An analogous mechanism that lowers the activation of non-target nodes could also mediate the selection of the sought-after word although such a mechanism has not been implemented in the model yet. The absence of an associative NP effect in Study 4 could be interpreted in favour of such an inhibitory mechanism because if the distractor in the prime trial was not actively suppressed, it should pre-activate its associated node in the probe trial (via spreading activation along the associative links) facilitating target object identification and its subsequent naming. That no improvement in performance was observed in response to probe targets that were associated to prime distractors could imply that the activation of the latter was indeed dampened in the course of prime trial selection. Alternatively, the associations between prime distractor and probe targets, being only recently formed and unconsolidated may have been too weak to result in spreading activation. The current results cannot discriminate between these alternative explanations.

The absence of an associative negative priming effect can be explained in several ways. Insufficient power is one limitation of the current study, which may not have allowed for the detection of the effect of the magnitude reported in the negative priming literature. While identity negative priming, which demonstrates a cognitive cost associated with probe targets that are *identical* to ignored prime distractors, is in the order of 50 milliseconds, “semantic” NP is typically half the size (Fox, 1995). This problem could be exacerbated by the newly formed associative relationship between prime distractors and probe targets, with the result that the effect may simply have been too attenuated to be detected using the current sample size. The spread of inhibition may not have manifested because of the relatively low processing difficulty involved in probe trials (naming a target object without a distractor). Finally, there appears to be a specific time window during which the likelihood of observing the NP effect is maximised. Appropriate SOAs may therefore need to be used to allow inhibition to accrue but also to prevent it from dissipating too early. Another possibility is that inhibition was not present in the first place. A standard PWI task was used in prime trials so it is plausible that other non-inhibitory processes (e.g., incremental learning) were involved when the participant was naming the target object while ignoring the prime interfering stimulus, although this explanation is less likely in view of the findings obtained in studies 1 and 2.

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6.2 General findings

Overall, the studies reported in this work allow better characterisation of the origin of interference (how it potentially comes about), its locus (where it might originate) and its resolution (how a word or a phrase is ultimately selected) in single and multi-word utterance production.

The results of studies 1, 2 and 3 provide evidence for lexical and syntactic selection to be inherently competitive, in the sense that performance, at least on some language production tasks, is temporarily impaired and that this impairment can be attributed to co-activation of goal-irrelevant representations that delay the selection of the target word in the case of lexical retrieval and the assignment of a higher-order grammatical role to the correct verb's argument in the case of syntactic selection. Although the competitive accounts can accommodate the pattern of results in the reported studies, the findings of studies 3 and 4 do not completely rule out the role of non-competitive processes in the observed effects. The incremental learning mechanism proposed by Oppenheim et al. (2010) is a post-selection mechanism, whereby the production of a word (or a grammatical phrase) leads to the strengthening of connections between the activated semantic features and the selected lexical item (or between the highest-order grammatical role and the selected animate lemma) and the weakening of the connections between the activated semantic features and co-activated but unselected lemmas (the highest-order grammatical role and the unselected inanimate lemma), a process which leaves the previously activated but unselected items at a disadvantage for selection. The question of how competition is instantiated has not been addressed in the current work, but two mechanisms are the likely contributors to the observed inhibitory effects: lateral inhibition (lexical units inhibiting each other with the most strongly activated unit prevailing over its competitors; e.g., Schade, 1992; Stemberger, 1985) and critical difference criterion (a target node becomes available for selection if its activation exceeds the activation of all its competitors by a certain amount; e.g., Roelofs, 1992). It is for future research to investigate the underlying mechanisms of within-language competition.

The findings of studies 1, 2 and 3 support the multi-loci view of inhibition. Conflict can arise and be resolved relatively early in the flow of information, at the representational level, or late at the response execution stage, with a blocking mechanism at the motor output level as the last gating mechanism that can reduce the chances of articulating an incorrectly selected representation and preventing overt errors. Where in the system interference is most prominent and how soon it is resolved may depend on task demands. Task complexity, for example, may explain the discrepancies both between the studies described in this work (engagement of a response blocking mechanism during passive voice construction, but not in the PWI task) and those reported in the literature (involvement of non-selective inhibition as measured with the stop-signal task in noun phrase production in Sikora et al. 2016, but no evidence of a similar mechanism in the PWI or the blocked cyclic naming task in Shao et al., 2015). An unresolved question is how much of the variance in the reported effects, when they are attributed to representational conflict, is lexical and how much conceptual.

The final point concerns the mechanisms that mediate the resolution of interference. Although this was not directly assessed in the current work, the pattern of results suggests that there may be at least two dissociable mechanisms responsible for individual differences in performance on language production tasks. One is an intelligent checking system that evaluates an activated representation (response option) against some contextual criteria (is it socially appropriate, does it make sense, etc.), whose operation is not restricted to the articulatory buffer. The other is a biasing mechanism, which either enhances the activation of target nodes or suppresses the activation of the non-target ones. The current results do not differentiate between these mechanisms, for although the inhibitory control tasks employed in studies 2 and 3 are commonly used as measures of inhibition (in both experimental research and clinical assessment) they are likely to conflate both processes.

6.3 Limitations and future directions

Probably the single most important limitation of the systematic review study (Study 1) is the PWI paradigm itself. Due to the extent of the literature, the inclusion criteria allowed for evaluation of the most prominent accounts of lexical selection in light of the findings based exclusively on the PWI task. Findings from studies utilising other word production tasks which make no demands on word reading (in the case of written distractors) or word comprehension (auditory distractors) and their interaction with the process of object recognition, including continuous naming (e.g., Belke & Stielow, 2013), blocked cyclic naming (e.g., Navarrete et al., 2014), or picture Stroop task (Nozari & Omaki, 2018), could also be taken into account to inform the debate on the nature of lexical selection. As could other response-time paradigms for studying the role of prepotent (e.g., dual-task paradigms, Ferreira & Pashler, 2002; translation; Navarrete & Costa, 2005; inhibitory priming; Vitkovitch et al., 2001; Wheeldon & Monsell, 1994) and underdetermined competition in word production (tasks with low and high contextual constraints, such as object naming with name agreement manipulation, (e.g., Britt et al., 2016), or verb generation task, (e.g., Snyder & Munakata, 2008); however, these were beyond the scope of this work.

Furthermore, the findings included in the systematic review are constrained to reaction time analyses performed independently from analyses of errors. Errors are important not only to account for the speed-accuracy trade-off, but also because, based on their assessment, unique inferences can be made about the loci of PWI effects (e.g., fewer errors were noted with taboo words than with neutral words in support of a late monitoring mechanism; Dhooge & Hartsuiker, 2011).

Based on the systematic review findings, three additional suggestions can be made for future explorations of semantic context effects and spoken word production alike. One, several areas have been identified whose exploration may contribute to a better understanding of the inhibitory processes affecting picture naming response times. Intrinsic properties of distractors other than lexical frequency, intrinsic properties of target words such as semantic neighbourhood density (e.g., Fieder, Wartenburger, & Abdel Rahman, 2019), a wider range of structural features shared between targets and distractors (e.g., size, shape and colour) that could possibly affect early stages of picture naming, visibility of distractor-denoted parts in target pictures, pure associative (probabilistic) target-distractor relations and the directionality of association in the context of the PWI task are among the avenues worth pursuing. Two, future PWI research should incorporate designs that minimise the risk of bias. Special care should be taken to prevent confounding influences of factors such as psycholinguistic properties of distractors, response congruency, visual similarity and association strength between targets and distractors, and relatedness proportion. Three, multiple hierarchical regression is a promising statistical tool with which to gauge independent contributions of different predictor variables to the PWI effect. Some promising results have already been obtained using this technique that have assessed the role of semantic distance above and beyond that of semantic relatedness and response relevance for picture naming latencies (see Aristei & Abdel Rahman, 2013). Other variables such as associative strength or visual similarity between targets and distractors could well lend themselves to this type of analysis.

Language production and inhibitory control are complex theoretical constructs, which cannot be directly measured. In an experimental context, a task is usually selected that is thought to best capture the processes of interest. Inferences about the role of inhibitory control in language production in this thesis have been made based on participants’ performance on individual tasks, which although standardised and widely used in experimental and clinical research present some reliability, validity and/or generalizability problems. For instance, the PWI effect is assumed to depend on spreading activation that is akin to the one underlying natural speech production, a process that is evident in slips of the tongue. In normal, everyday communication, speech errors often occur because activation spreads to non-target representations that inadvertently slip into one's verbal output (e.g., Dell, 1984). This situation is thought to be "simulated" in the PWI task, where conflict is amplified by the presentation of a distractor word. Indeed, some authors (Dhooge & Hartsuiker, 2011; Starreveld, & La Heij, 1999) have shown that in a speeded PWI task, speakers often erroneously produce the distractor name instead of the picture name. Nevertheless, the PWI task remains an experimental paradigm, in which competition is induced externally by context manipulation. Similar criticism can be levelled at the version of the number computation task (as adapted from Staub et al., 2009) in Study 3. Although the task is an improvement on the previously employed preamble paradigm (Bock & Miller, 1991), it places additional demand on comprehension, which is superfluous in normal production circumstances. With this in mind, the current findings can only inform language production research if we assume that the tasks discussed in this work are an accurate simulation of conflict arising during normal production processes. Future research would benefit from more naturalistic tasks that involve endogenous competition and impose minimal requirements on peripheral processes (e.g., the number agreement task adopted by Veenstra et al., 2018, is a promising change in this respect).

Although the object naming task with name agreement (NA) manipulation has been readily employed by authors to investigate the role of cognitive control in language production (e.g., Bose & Schafer, 2017; Kan & Thompson-Schill, 2004; Shao, Roelofs, & Meyer, 2014), the findings in Study 2 imply that the NA effect may not necessarily reflect competition between co-activated representations. As pointed out by Paivio, Clark, Digdon, & Bons (1989), the NA effect either stems from lateral inhibition (co-activated lexical entries send inhibitory links to one another delaying the selection of one candidate) or is an outcome of diffused activation – activation spreading over several pathways representing one-to-many concept-to-lemmas mappings. The idea that alternative names compete for selection in the NA task has recently been questioned by Oppenheim (2017). In their norming study, pictures with stronger secondary names were named faster than pictures with weaker secondary names, after accounting for dominant names, a pattern contrary to that expected by a competitive hypothesis. It is also speculated that production delays associated with low NA trials may be related to some pragmatic decision making. Given that perfect synonymy is exceedingly rare (see exposition by Taylor, 2003) and that some semantic or stylistic nuance will differentiate the words in an activated cohort, it is reasonable to assume that the speaker may assess the suitability of the activated candidates for the given communicative context before selecting the best fitting word, a process which takes time. For example, a Northerner in England may want to label a seating furniture “settee” in the first instance but after some consideration (taking into account that the experiment is being conducted in the south of the country) he or she may ultimately opt for “sofa”. Research has already distinguished between lexical and pre-lexical sources of interference in the NA task (e.g., Britt et al., 2016; Vitkovitch & Tyrrell, 1995), but more theoretical and empirical work is needed to pin down the specific processes that give rise to the NA effect.

The conclusions of studies 2 and 3 presented in this thesis are based on the premise that the standard inhibitory control tasks measure what they purport to measures (i.e., non-verbal type of conflict that arises at different stages of information processing). However, the fact that they have traditionally been used as measures of inhibition does not preclude the possibility that they tap other salient processes that may ultimately obscure inhibitory effects (see the “task impurity” problem; Burgess, 1997). For example, while the flanker task involves stimuli from a non-linguistic domain and is generally considered to be a non-verbal task, it could conceivably engage a language component. The arrow stimuli are not completely arbitrary; the symbols could activate linguistic representations associated with the concept of direction (LEFT and RIGHT). Although it is generally maintained that active suppression of an incorrect response – a strong reflexive saccade towards a distractor - is critical to successful task performance on the anti-saccade task (e.g. Munoz & Everling, 2004), an alternative account, proposing that anti-saccade errors result from a failure to sufficiently activate a correct response in the opposite direction - a saccade towards the target – is also plausible (Nieuwenhuis, Broerse, Nielen, & Jong, 2004). Other standard inhibitory control tasks (e.g., Stroop, flanker, Simon) may engage processes that are primary to inhibition, such as conflict monitoring and working memory. As a result, performance on these tasks may be affected by variations in conflict detection or memory retrieval ability rather than inhibitory control *per se*.

The idea that monitoring processes may be intricately linked with inhibitory control has received some support from the results in Study 3. Here, occurrence of repairs was predicted by interference effects in the flanker and the anti-saccade tasks. While self-corrections may reflect poorer inhibition (both at intermediate and late stages of production), they can also suggest that a monitoring mechanism is in place that allows the speaker to detect an erroneously selected response and correct it on the fly. It comes as no surprise that the two (inhibition and monitoring) are increasingly talked about in tandem (e.g., Chevalier et al., 2014; Nozari & Novick, 2017). An important way forward therefore would be to disentangle the relative contributions of conflict detection (action monitoring) and inhibition, for example, by employing cross-factorial designs in which context and interference are jointly manipulated.

It could be argued that to eliminate, or at least, minimise process-specific impurities, it would be useful to use a large battery of inhibitory control tasks, as well as several language production tasks, and to subject them to statistical methods such as structural equation modelling to extract the common variance of these tasks into latent variables. This is a sound argument provided that the shared variance isolated from individual inhibitory control tasks represents the construct of interest and not other non-inhibitory processes that are common to the tasks under investigation (Snyder, Miyake, & Hankin, 2015). As it happens, tasks that have commonly been used as manifest variables of inhibition are also likely to involve monitoring (detection of an erroneously selected response or detection of a conflict between an activated but incorrect response and goal-relevant response) and working memory abilities (keeping the goals of the task in an active state). It is not clear therefore whether estimates provided by the latent variable analysis are superior to inferences based on less complex models such as analyses at the task level.

The findings of studies 2 and 3 are based on correlational evidence which needs to be bolstered by further work demonstrating a causal relationship between inhibitory control on non-verbal and language production tasks, while keeping in mind the distinction between various loci and types of interference. One way to do this is to investigate whether extensive practice on one type of non-verbal conflict resolution leads to improved performance on a language production task (both lexical and syntactic) where different types of interference are manipulated. Future research could investigate specific forms of interference at individual stages of the language production process, for example, by employing production tasks that require cancellation of articulatory programmes rather than the resolution of representational conflict.

Decades of research have been dedicated to identifying the inhibitory processes that underlie production failures and delays, while a bigger, more important question of how competition is implemented has barely been touched upon. Future efforts should therefore focus not only on the question of "whether" (is lexical and syntactic selection competitive), but also consider the question of "how" (how is selection of words and structures accomplished in the face of competing inputs). Two possible mechanisms have been suggested - the activation of target node exceeding the summed activation of non-target nodes according to the Luce's ratio (e.g., Levelt et al., 1999; Roelofs, 1992) as well as lateral inhibition (e.g., Cutting & Ferreira, 1999), but there is little empirical evidence to substantiate these claims. The negative priming paradigm could offer some hope in this respect but as discussed in Study 4 it will require more systematic work to demonstrate reliable negative priming effects as well as rule out potential non-inhibitory processes that may contribute to the overall effect in the first place. This may necessitate neurophysiological methods and computational models that can more precisely pin down the various processes involved in the task.

6.4 Concluding remarks

The present thesis sought to identify the types of interference and the processes that mediate their resolution in single and multi-word utterance production. Inspired by the ongoing debate on the competitive nature of language production and the substantial literature that has been generated in its course, it has made the first attempt at systematising empirical knowledge on the origins of picture-word interference effects, as well as assessing its relevance to competitive and non-competitive theories of word production. Motivated by recent empirical evidence for the separability of inhibitory control functions, it has applied the notion of distinct conflict resolution mechanisms to the study of lexical selection and further extended it to the study of grammatical encoding, a combination so far unexplored in psycholinguistic research.

The findings of the systematic review do not give a definitive answer about whether or not the picture-word interference effect reflects lexical competition, but appear to constrain its locus to early rather than late processing stages. The review concludes that the post-lexical response relevance criterion checking mechanism is not the main driving force of semantic context effects, whereas the lexical competition remains a viable albeit a tentative hypothesis. Its tenability depends on the relative contribution of pre-lexical processes (object recognition and object identification/ concept selection), which remains to be confirmed by future research. This is not to deny the importance of post-lexical mechanisms in language production as such – it is simply to state that the response exclusion hypothesis and the self-monitoring accounts are not the dominant explanations for semantic context effects observed in the PWI task.

Indeed, the overall findings of the studies presented in this thesis suggest that at least two distinct types of interference and their resolution mechanisms may be involved in both single- and multi-word utterance production. One pertains to representational conflict, or interference arising at the intermediate stage of processing, with limited evidence on whether it is strictly lexical or conceptual in nature. The second concerns interference at the output level, where there is no competition in the strict sense, but at which point a delay is likely to ensue because of some criterion checking process (self-monitoring), recruitment of an inhibitory mechanism (response blocking) or both. It is important that future research teases these processes apart and assesses their relative contributions to the speed and ease with which utterances are produced. A potential way forward would also be to examine whether both prepotent and underdetermined competition are a source of variability in lexical and syntactic production skills, with an eye to establishing whether underdetermined competition truly reflects inhibitory processes.

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APPENDICES

Appendix A

Names of filler and target images with related and unrelated distractor words from the picture word interference task

Filler image	Target image	Related distractor word	Unrelated distractor word
ladder	broccoli	potato	anchor
egg	lion	zebra	nurse
battery	lemon	peach	brick
comb	bed	table	cloud
feather	guitar	cello	angel
wallet	cannon	rifle	penny
barrel	shirt	dress	chain
axe	scissors	tape	vase
sink	bike	plane	pillow
crown	trumpet	drum	soap
mic	cat	duck	rice
swing	hammer	pliers	school
glasses	giraffe	camel	brush
lips	ship	train	uncle
window	pear	cherry	button
bench	tree	flower	butter
chimney	chair	shelf	arrow
jug	sock	glove	radio
box	ear	foot	tent
drill	shovel	rake	book
bucket	horse	mouse	torch
razor	toaster	kettle	circle
fan	lamp	clock	apron
ashtray	hand	neck	rain
microwave	onion	carrot	hanger
lighter	fridge	dryer	wheel
nest	camera	phone	stone

Appendix B

Names of target images in the two conditions of the name agreement task

Low Name Agreement images	High Name Agreement images
mug	candle
bottle	broom
branch	cigarette
gift	dice
hat	CD
cup	envelope
bag	handcuffs
mixer	key
shoe	kite
pasta	lipstick
coins	mattress
wire	microscope
car	mushroom
container	wheelchair
tissue	umbrella
pin	toothbrush
couch	tomato
suitcase	belt
pushchair	football
monitor	snowman
trainer	screw
shell	ruler
gun	ring
cone	leaf

Appendix C

Animate object	Inanimate object	Past simple verb	Past participle verb	Filler object	Filler verb	Filler object	Filler verb
boy	ghost	saw	seen	queen	whispered	dog	ran
knight	horse	rode	ridden	fireman	fainted	monk	prayed
model	scarf	wore	worn	cow	mooed	hunter	whistled
cleaner	key	hid	hidden	truck	overturned	waiter	bowed
clown	bubble	blew	blown	sweater	shrunk	bird	tweeted
soldier	grenade	threw	thrown	prisoner	escaped	swimmer	snorkelled
gardener	grass	mowed	mown	angel	appeared	crown	sparkled
butcher	chicken	froze	frozen	fisherman	nodded	grapes	rotted
baby	rattle	shook	shaken	police	sneezed	trumpet	blared
cat	vase	broke	broken	engineer	arrived	flag	fluttered
girl	kite	flew	flown	scooter	zigzagged	ice-cream	melted
chauffeur	limousine	drove	driven	whistle	sounded	van	reversed
barman	coins	took	taken	farmer	agreed	referee	shouted
chef	eggs	beat	beaten	bee	buzzed	lion	roared
photographer	camera	chose	chosen	pilot	ejected	bell	chimed
priest	corn	grew	grown	fridge	defrosted	ship	departed
mouse	doll	bit	bitten	laptop	crashed	gymnast	somersaulted
pirate	cheese	ate	eaten	bridge	collapsed	plane	landed
artist	house	drew	drawn	bus	stopped	ball	bounced
burglar	bike	stole	stolen	suitcase	vanished	rooster	crowed
doctor	prescription	wrote	written	helicopter	exploded	hairdresser	coughed
courier	letter	forgot	forgotten	pillars	crumbled	diver	drowned
chief	basket	wove	woven	balloon	popped	log	floated
builder	phone	awoke	awoken	boat	capsized	rabbit	hopped

Appendix D

Experimental trials			Filler trials		
Low interference singular					
The colour of the shirt	F. WERE pale	K. WAS pale	The cake that the chef	F. WERE baking	K. WAS baking
The road to the cottage	F. WERE bumpy	K. WAS bumpy	The sentence that the criminal	F. WERE serving	K. WAS serving
The tour of the museum	F. WERE interesting	K. WAS interesting	The claim that the judge	F. HAS dismissed	K. HAVE dismissed
The apartment with the leak	F. IS spacious	K. ARE spacious	The message that the student	F. HAS emailed	K. HAVE emailed
The path around the lake	F. IS steep	K. ARE steep	The villa that the son	F. HAVE inherited	K. HAS inherited
The view on the postcard	F. ARE stunning	K. IS stunning	The meeting that the judge	F. HAVE cancelled	K. HAS cancelled
The prescription from the doctor	F. WERE free	K. WAS free	The meal that the guest	F. WERE served	K. WAS served
The confession of the preacher	F. WAS false	K. WERE false	The lake that the path	F. WAS surrounding	K. WERE surrounding
The defect in the car	F. WAS corrected	K. WERE corrected	The tour that the museum	F. HAS organised	K. HAVE organised
The letter from the friend	F. WAS emotional	K. WERE emotional	The program that the presenter	F. HAVE mentioned	K. HAS mentioned
The threat to the president	F. ARE serious	K. IS serious	The bottle that the waiter	F. HAS broken	K. HAVE broken
The meal for the guest	F. WAS served	K. WERE served	The class that the pupil	F. HAS attended	K. HAVE attended
Low interference plural					
The stains on the walls	F. WERE removed	K. WAS removed	The crates that the ships	F. WERE carrying	K. WAS carrying
The streets with the cars	F. WAS congested	K. WERE congested	The prizes that the contestants	F. HAVE won	K. HAS won
The beliefs about the planets	F. WERE genuine	K. WAS genuine	The letters that the lawyers	F. HAS sent	K. HAVE sent
The problems in the schools	F. ARE complex	K. IS complex	The stories that the kids	F. HAS heard	K. HAVE heard
The slogans on the billboards	F. ARE offensive	K. IS offensive	The rooms that the lights	F. HAS lit	K. HAVE lit
The rewards for the employees	F. WAS generous	K. WERE generous	The gifts that the boys	F. HAS received	K. HAVE received
The maps with the creeks	F. ARE illegible	K. IS illegible	The flags that the fans	F. WAS waving	K. WERE waving
The classrooms with the computers	F. IS free	K. ARE free	The tickets that the drivers	F. WERE given	K. WAS given
The styles of the suits	F. IS classic	K. ARE classic	The talks that the leaders	F. WERE holding	K. WAS holding
The lights in the rooms	F. WAS bright	K. WERE bright	The streets that the protesters	F. WAS occupying	K. WERE occupying
The contracts for the actors	F. WAS cancelled	K. WERE cancelled	The paintings that the museums	F. HAVE displayed	K. HAS displayed
The conclusions of the analysts	F. WERE premature	K. WAS premature	The battles that the soldiers	F. WERE fighting	K. WAS fighting

Experimental trials			**Filler trials**		
High interference singular					
The regulation about the lorries	F. IS tough	K. ARE tough	The lights that the room	F. WAS fitted	K. WERE fitted
The result of the talks	F. ARE shocking	K. IS shocking	The prescriptions that the doctor	F. HAS written	K. HAVE written
The advisor for the students	F. WERE unhappy	K. WAS unhappy	The rumours that the worker	F. WERE spreading	K. WAS spreading
The purpose of the tools	F. ARE unknown	K. IS unknown	The cities that the ruler	F. HAVE founded	K. HAS founded
The photo of the baby	F. WAS pretty	K. WERE pretty	The earrings that the girl	F. WAS wearing	K. WERE wearing
The warning from the experts	F. IS useful	K. ARE useful	The prices that the shop	F. HAVE increased	K. HAS increased
The criminal behind the attacks	F. WAS violent	K. WERE violent	The roofs that the builder	F. WERE repairing	K. WAS repairing
The window with the ornaments	F. ARE huge	K. IS huge	The results that the scientist	F. HAVE published	K. HAS published
The switch for the lights	F. WAS fixed	K. WERE fixed	The films that the director	F. HAS produced	K. HAVE produced
The crown with the diamonds	F. WAS shiny	K. WERE shiny	The warnings that the expert	F. HAVE issued	K. HAS issued
The vase with the flowers	F. WERE colourful	K. WAS colourful	The pictures that the postcard	F. HAS depicted	K. HAVE depicted
The table with the figurines	F. WERE moved	K. WAS moved	The schools that the problem	F. HAS concerned	K. HAVE concerned
High interference plural					
The hopes of the fugitive	F. WAS frail	K. WERE frail	The threat that the terrorists	F. WERE making	F. WAS making
The manuals for the machine	F. ARE outdated	K. IS outdated	The match that the spectators	F. WERE watching	K. WAS watching
The doors to the office	F. ARE closed	K. IS closed	The book that the authors	F. HAS translated	K. HAVE translated
The labels on the bottle	F. IS transparent	K. ARE transparent	The fee that the councils	F. HAVE imposed	K. HAS imposed
The keys to the cabinet	F. WERE rusty	K. WAS rusty	The song that the musicians	F. WERE playing	K. WAS playing
The memos from the accountant	F. WAS confidential	K. WERE confidential	The basket that the baguettes	F. HAVE fit	K. HAS fit
The discussions about the topic	F. WAS boring	K. WERE boring	The street that the cars	F. WAS blocking	K. WERE blocking
The teachers with the certificate	F. ARE proud	K. IS proud	The meeting that the politicians	F. HAS missed	K. HAVE missed
The holes in the stocking	F. ARE tiny	K. IS tiny	The reward that the employees	F. WAS promised	K. WERE promised
The claims about the worker	F. WERE dropped	K. WAS dropped	The attack that the criminals	F. HAS committed	K. HAVE committed
The politicians at the meeting	F. WAS ruthless	K. WERE ruthless	The cabinet that the keys	F. HAVE matched	K. HAS matched
The statues in the garden	F. WAS destroyed	K. WERE destroyed	The rate that the hotels	F. WAS charging	K. WERE charging

Appendix E

	PALT (participants study 27 word-picture pairs)		**NP Task** (participants name the target picture while ignoring the distractor word when one is present)			
	word	**picture**	**Prime target picture**	**Prime distractor word**	**Probe target picture (intact condition)**	**Probe target picture (recombined condition)**
Block 1						
1	cat	FLAG	DOG	cat	FLAG	GHOST
2	apple	TENT	PEAR	apple	TENT	BELL
3	knife	CLOCK	FORK	knife	CLOCK	MIRROR
4	glove	BELL	HAT	glove	BELL	EGG
5	hand	GHSOT	FOOT	hand	GHOST	TENT
6	guitar	MIRROR	TRUMPET	guitar	MIRROR	FLAG
7	stool	KEY	CHAIR	stool	KEY	BOMB
8	grass	BOMB	TREE	grass	BOMB	KEY
9	pencil	EGG	BOOK	pencil	EGG	CLOCK
Block 2						
10	cherry	ENVELOPE	BANANA	cherry	ENVELOPE	WATCH
11	rake	FISH	SAW	rake	FISH	CANDLE
12	shirt	BARREL	DRESS	shirt	BARREL	FISH
13	stone	CANDLE	LEAF	stone	CANDLE	GLASSES
14	moon	BOTTLE	SUN	moon	BOTTLE	ENVELOPE
15	potato	WATCH	CARROT	potato	WATCH	BOTTLE
16	boat	CROWN	PLANE	boat	CROWN	TABLE
17	pan	GLASSES	KETTLE	pan	GLASSES	BARREL
18	boot	TABLE	SOCK	boot	TABLE	CROWN
Block 3						
19	spade	GLASS	AXE	spade	GLASS	WHISTLE
20	oven	ARROW	TOASTER	oven	ARROW	SCARF
21	bear	SUITCASE	PIG	bear	SUITCASE	GLASS
22	stairs	UMBRELLA	LADDER	stairs	UMBRELLA	BOX
23	plate	SCISSORS	CUP	plate	SCISSORS	UMBRELLA
24	bread	SCARF	CAKE	bread	SCARF	PIPE
25	sofa	WHISTLE	BED	sofa	WHISTLE	ARROW
26	cow	PIPE	HORSE	cow	PIPE	SUITCASE
27	river	BOX	MOUNTAIN	river	BOX	SCISSORS