Mechanisms underpinning semantic priming in spoken word retrieval

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Abstract

A number of studies have shown that speed and accuracy of word retrieval may be affected by the previous retrieval of a word with similar semantic meaning. This phenomenon is called semantic priming and includes both semantic interference or and facilitation. While there is a clear evidence for the presence of semantic priming, the mechanisms causing this effect are still under debate. Therefore, the goal of this PhD was to provide evidence regarding these mechanisms by systematically evaluating the effect of primes with different semantic relations on the speed and accuracy of spoken word retrieval in healthy subjects and people with aphasia.

Five experiments were implemented with healthy participants focusing on the effects in priming of semantic coordination, association and part-whole relations on spoken word retrieval with zero or four intervening items between prime and target (lags 0 and 4). Chapter Two reports two experiments using an alternating word reading and picture naming paradigm and Chapter Three, three experiments using a continuous picture naming paradigm. Chapter Four reports two experiments with people with aphasia examining the effects of identity, semantic coordination, association and their interaction on facilitation of picture naming. The results of these two experiments were analysed at both individual subject and group levels.

In Chapter Five, these experiments are placed in the context of the previous literature on semantic priming and theories of semantic representation. In this regard, the experimental results are taken to imply that semantic coordination, association, and part-whole relations can be attributed to different types of semantic relations that have different representation and organisation. Further implications of the experiments for our understanding of the mechanisms of lexical access and the nature of lexical representation are discussed.

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Table of Contents

List of Tables

List of Figures

Chapter 1. The nature of semantic and lexical representation and retrieval

1.1 Introduction

A number of studies have shown that the previous retrieval of one word can affect how easy it is to retrieve another word that is related in meaning and such an effect is known as *semantic priming* (e.g., Abdel Rahman & Melinger, 2007; Alario, Segui, & Ferrand, 2000; Costa, Alario, & Caramazza, 2005; Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Oppenheim, Dell, & Schwartz, 2010; Tree & Hirsh, 2003; Vitkovitch, Cooper-Pye, & Leadbetter, 2006). While the phenomenon of semantic priming is quite consistent among studies, the mechanisms underpinning this effect remain under debate. In turn, understanding these mechanisms is a key for better understanding of how the semantic system is organized and what mechanisms are involved in spoken word retrieval. This is important not only from a theoretical prospective but also for the development of more effective treatment for people with aphasia.

Aphasia is a language disorder that many people acquire after a stroke. Irrespective of the subtype of language impairment, one common issue in aphasia is difficulties in word finding. To date, a number of treatment techniques have been developed to cope with this issue (e.g., Beeson, Holland, & Murray, 1995; Best & Nickels, 1996; Butterworth, Howard, & Mcloughlin, 1984; Conley & Coelho, 2003; Marshall, Pound, White-thomson, & Pring, 1990) and some of these techniques (e.g., semantic feature analysis, word to picture matching, confrontation naming, semantic discrimination etc.) have been shown to be effective in improving word finding difficulties across case series of people with aphasia.

Many of these treatments focus on semantic relationships between words. Hence, in order to fully understand the mechanisms underpinning their treatment effects, it is important to understand the influence of the semantic relationships between words and other factors involved in lexical access in spoken word retrieval. To date, there is a wide agreement in the literature that words are semantically related if they share a certain portion of semantic information and that lexical access occurs by means of spreading activation. According to this assumption, the activation of semantic information of one word results in some portion of activation spreading to related words resulting in their partial activation. This leads to the hypothesis that successful retrieval of one word may affect subsequent retrieval of a word with which it shares a certain portion of semantic information (Boyle & Coelho, 1995; Goodglass & Baker, 1976). However, little has been done so far to test out how this mechanism works in practice, and to what extent manipulation of semantic relations affects the results of treatment for word finding difficulties in people with aphasia.

One phenomenon that can be used to test out the effect of different semantic relations on spoken word retrieval is semantic priming. As mentioned above, semantic priming is the effect of retrieval of one word on subsequent retrieval of a word with similar semantic meaning. However, to date semantic priming has been mainly examined with participants with unimpaired language (e.g., Abdel Rahman & Melinger, 2007; Alario et al., 2000; Costa et al., 2005; Howard, Nickels, et al., 2006; Lupker, 1979; Tree & Hirsh, 2003; Vitkovitch, Rutter, & Read, 2001; Wheeldon & Monsell, 1994) and little is known about how it works in people with aphasia. A number of studies that have tried to disambiguate the effect of different types of semantic relations have shown that different relations can produce different patterns of semantic priming (e.g., Alario et al., 2000; Crutch, 2005; Damian & Spalek, 2014; de Zubicaray, Hansen, & McMahon, 2013; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995; Tree & Hirsh, 2003). The most common finding in this regard is that semantic coordination produces interference while associated members of different semantic categories produce facilitation (e.g., Alario et al., 2000; Costa et al., 2005; Tree & Hirsh, 2003).

The limitation of these studies however is that they have examined the effect of different semantic relations only in conditions where primes were presented as written words (e.g., Alario et al., 2000; Costa et al., 2005; Mahon et al., 2007; Tree & Hirsh, 2003). This is important because other studies have shown that not only the type of semantic relations but also the modality of presentation and the task to be performed may affect the polarity of semantic priming. For instance, Abdel Rahman and Melinger (2007) compared the effect of associated members of different categories in the blocked-cyclic naming task and picture-word interference tasks. They found facilitation in word retrieval in picture-word interference and the first block of blocked cyclic naming; however, in later blocks this facilitation reversed to interference. A potential account for such a discrepancy is discussed later in this thesis, but it is worth noting that none of the studies, to our knowledge, that have been conducted so far, tried to provide a systematic evaluation of the effect of different semantic relations on spoken word retrieval in different modalities.

Therefore, the goal of this thesis was to conduct systematic evaluation of semantic priming produced by different types of semantic relations to provide better understanding of how the meaning of a word is represented and what factors are involved in lexical access for spoken word retrieval.

This chapter provides an introduction to some of the background literature relevant to this thesis. It starts with an outline of different types of semantic relations from a linguistic approach. This linguistic approach provides a clear logically-based account for different semantic relations, allowing for their accurate definition.

The second section reviews theories of the nature of representation of semantic meaning and semantic relatedness, focusing on the debates concerning the compositionality of semantic meaning and representation of different semantic relations as compared to their organization.

The third section of this chapter focuses on the debates concerning lexical access in spoken word retrieval. It discusses the stages of lexical access and different views concerning information flow from semantic to lemma (lexical) stage.

Finally, this chapter reviews the main accounts of mechanisms of semantic priming and provides a short outline of the following chapters.

1.2 The complexity of semantic relationships

The nature of the organization of semantic meaning of words is a central issue for further understanding of how the word meanings are represented and processed. Ferdinand de Saussure (1916) was the first to propose that the meaning of the word incorporates information from both *paradigmatic* and *syntagmatic* relations. Paradigmatic relations refer to semantic relations between words grouped together into semantic hierarchies. Cruse (2000) distinguished two types of such hierarchies: taxonomy and meronomy[1]. Taxonomy includes hierarchical relations between classes of words – semantic categories. Semantic categories incorporate relations between and within levels. Relations between levels join upper (hyperonyms) and lower (hyponyms) levels; for example, *'vehicle'* hyperonym for *'car'* and *'car'* is a

[1] In the experimental literature, Chaffin and Herrmann (1988) referred to meronymic relations as taxonomic. However, taxonomy by definition implies division into classes. As Cruse (2001) pointed out, the main difference between '*taxonomy'* and *'meronomy'* is that taxonomy implies division into classes while meronomy gradually distinguishes parts of wholes or bigger parts (e.g., *'arm'* is a body part, *'hand'* is a part of *'arm'* and *'fingers'* are parts of *'hand'*);

hyponym for *'vehicle'*. Relations within level join co-hyponyms (coordinates)[2] – items that belong to the same level within semantic taxonomy. *Meronomy* represents the hierarchy of part-whole relations. It includes relations between levels (e.g., *'tyre'* is part of *'car'*) and relations at the same level (e.g., *'tyre'* and *'seatbelt'* are parts of *'car'* (co-meronyms).

In each (paradigmatic) hierarchy, the relations between the levels are *inclusive* and relations within the levels are *exclusive*. Inclusion implies that the hypernym (item from the upper level) provides some information about the hyponym (item from lower level); for example, *'vehicle'* provides all the necessary semantic information to consider *'car'* as a *'vehicle'*. At the same time, the hyponym *'car'* provides some information to consider it a type of *'vehicle'.* In contrast to inclusion, exclusion implies that one item excludes the possibility that it can be another item; for example, defining *'car'* provides all necessary information that distinguishes it from *'bus'* and vice versa. However, while for coordinates exclusion is logical and well defined, for co-meronyms it depends on the degree to which the border between two items is established (e.g., there is no clear cut-off between *'upper'* and *'lower' 'torso';* therefore, exclusion criteria will not work for these types of relations*)*.

In contrast to paradigmatic relations, syntagmatic relations are context dependent and reflect semantic relations between words within the same context. For example, semantic relations between *'car'* and *'road'* are defined by their functioning within the same context (e.g., *'road'* is a location where *'car'* can be driven).

Two major types of paradigmatic relationship and one type of syntagmatic relationship have been the most studied experimentally. Paradigmatic relations that have been studied include semantic coordination (e.g., *'car'* – *'bus'*) and part-whole relations (e.g., *'tyre'* – *'car'*). *Semantic coordinates* represent words that share a certain number of semantic features and belong to the same level within a semantic category (e.g., *'mouse'* and *'rat'* are *'rodents'*) (e.g., Miller & Fellbaum, 1991; Rosch, 1975). *Part-whole relations* refer to the relations between the whole and its parts mediated via the link *'it has'* or *'a part of'*. As with other features, parts can be shared between wholes (e.g. *'tyre'* is a shared feature for *'car', 'bus'* and other vehicles) or distinctive within a category (e.g., *'goat'* has a *'beard'* but *'sheep'* does not*)* (e.g.,

[2] To maintain consistency within this research and consistency with experimental studies, 'coordinates' will be the preferred term for the rest of this thesis.

Vieth, McMahon, & de Zubicaray, 2014). Syntagmatic relations studied have focused on functional relations (e.g., *'road'* – *'car')* (Moss et al., 1995). These relations represent semantic relations between two words from different semantic categories (e.g., *'road'* is a place where *'car'* can drive).

Both paradigmatically and syntagmatically related items can also be associated; however, in contrast to these relations associative relations are asymmetric. This means that *'car'* can be associated to *'bike', 'road'* etc., but these words do not necessarily have to be associated to *'car'*.

The next subsections discuss functional approach to the representation and selection of these three types of relations: semantic coordination, part-whole relations, and functionally related items. Subsequently, the issue of the disambiguation of association and coordination is discussed.

1.2.1 *Semantic coordination*

Studies that aim to examine the nature of the organisation of the semantic and lexical system have most commonly focused on semantic coordination (e.g., Belke, Meyer, & Damian, 2005; Howard et al., 2006; Lupker, 1988; Rosch, 1975; Vitkovitch et al., 2006; Warrington & Shallice, 1984; Wheeldon & Monsell, 1994; Wilkins, 1971). When thinking about semantic representation, a central issue is whether semantic meaning is organized in categories and if so, whether this organization is strictly hierarchical or functional.

Collins and Quillian (1969) proposed a hierarchical, categorical model of semantic organization. In their model, every node inherits properties common to the category it belongs to and also has independent properties that make it different from other nodes within the category. For example, *'cat'* as a member of the category *'animal'* inherits typical properties common to animals and also has its independent properties such as: *'purrs'*. The strength and length of these shared properties is defined by the frequency of usage.

Collins and Loftus (1975) proposed a non-hierarchical model of semantic organization. According to this model, the meaning of every word is represented by a single node connected to a group of other nodes. Therefore, according to this account, there is no division of relations into taxonomic or meronymic (e.g., the relation of *'cat'* to *'animal'* is not treated as taxonomic and relation of *'cat'* to *'fur'* is not treated as meronymic). Instead, semantic relatedness between different words is represented by the different nature of connections; for example, *'cat'* is linked to *'animal'* with a, non-hierarchical, *'is an'* link and to *'fur'* with a, non-*meronymic, 'it has'* link. Likewise, the degree of semantic similarity between the target and prime words is defined by the number of shared connections and the strength of these connections (e.g., the difference between semantic relations of *'cat'* and *'animal'* or *'fur'*).

In contrast to Collins and Loftus (1975), Rosch (1975) and Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976) argued that the meaning of a word is organised in semantic categories. However, in contrast to Collins and Quillian (1969), they shifted the emphasis from structural to functional relations. According to this approach, semantic categories cannot be considered based on the language structure alone, but they must be driven by functional usage of the language. Rosch (1975) retained the idea that every category is established based on principles of similarity and distinctiveness. The principle of similarity implies that every category possesses features that are common to every member of the category. In contrast, the principle of distinctiveness implies that every member of the category possesses unique features that distinguish it from other members of the category.

The novelty of this approach was that shared features were not inherent properties of the category but were acquired with language usage. For example, *'cat'* did not belong to the category *'animal'* because it inherited its properties, but the properties that made one think of *'cat'* as an *'animal'* were acquired with language usage. Therefore, according to this approach, the relationships of shared properties to the category are defined based on the frequency of association of this feature with that category, and the importance of properties to a category are defined by the frequency with which this property is associated with that category. The same principle applied to distinctive features owned by the members of semantic category.

This functional approach to semantic organization proposed by Rosch (1975) and Rosch et al. (1976) became the groundwork for a number of subsequent studies focused on the nature of organization of semantic system. It has been widely assumed that belonging to a certain category implies greater featural overlap. Therefore, a number of experimental studies that focused on semantic priming in spoken word retrieval used material from semantic category norms (Alario et al., 2000; Costa et al., 2005; Mahon et al., 2007; Tree & Hirsh, 2003; Vitkovitch et al., 2001; Wheeldon & Monsell, 1994). However, McRae, de Sa, and Seidenberg (1997) asked people to list features of words from certain semantic categories, and then examined gradients of their semantic overlap. Their results showed that belonging to the same sematic category does not imply a high density of featural overlap. That is, not all members of the same semantic category are necessarily closer related than are some members of different semantic categories. Therefore, McRae et al. (1997) concluded that semantic relatedness should be defined by the degree of featural overlap and not by the association of a word with a certain semantic category.

This evidence challenges the traditional method of selection of experimental material using semantic category norms and interpretation of the mechanisms underpinning semantic priming via semantic features. For example, a number of accounts for mechanisms underpinning semantic priming are based on examining this effect between semantic coordinates. The coordinates are selected from category norms that are based on association of a certain item to a certain category (e.g., Rosch, 1975). At the same time, the mechanims of priming between such items have been accounted for via overlap of semantic features based on the assumption that the coordinates have dense feature overlap.

1.2.2 *Part-whole relations*

In a number of experimental studies, parts have been attributed to the relations with wholes via *'it has'* connections (e.g., Costa et al., 2005; Sailor & Brooks, 2014; Vieth et al., 2014). This principle has been also used for collecting feature norms (Ken McRae et al., 1997) and in Semantic Feature Analysis treatment for people with aphasia (e.g., Coelho, McHugh, & Boyle, 2000; Hashimoto & Frome, 2011; Wambaugh, Mauszycki, & Wright, 2014). However, Winston et al. (1987) suggested that *'it has'* relationships cover a range of different part-whole relations. Winston et al. (1987) distinguished 6 types of parts, two of which were relevant for objects: 1) components (e.g., *'handle-cup'*), 2) stuff (e.g., *'steel-bike'*)[3]. According to Cruse (2000), components can also be divided into: 1) attachments (e.g., *'handle'* for *'cup'*) and 2) integral features (e.g., *'handle'* for *'spoon'*). In this regard, McRae et al's., (1997) feature norms contained parts that were in different part-whole relations to their corresponding wholes.

Chaffin and Herrmann (1988) also examined the nature of part-whole relations. They showed that parts govern a family of relations – meronyms that can

[3] The others being: member-collection (e.g., *'ship'*-*'fleet'*), portion-mass (e.g. *'slice'*-*'pie'*), feature-activity (e.g., *'paying'*-*'shopping'*) and place-area (e.g., *'Everglades'*-*'Florida'*).

be organized into a hierarchy. However, this hierarchy, according to their account, has a different organization from the taxonomy for the representation of categorical relations. For example, in the categorical taxonomy, *'leg'* and *'arm'* need to have shared features to be attributed to the semantic category *'body parts'* and distinctive features to be separated into *'arm'* and *'leg'*. In contrast, in the meronymic hierarchy, the division is made based on part-whole relations, but not via shared or distinctive features. Therefore, *'arm'* as a part of a *'body'* does not have to contain distinctive features to be distinguished from *'leg'*.

In sum, the *'it has'* connection between part and whole governs a group of different part-whole relations; therefore, studies that using ambiguous *'it has'* classification may confound different part-whole relations with unknown consequences.

1.2.3 *Functional relations*

In the experimental literature, functional relations[4] between two words refer to their functioning in the same context (e.g., '*road' – 'car'*) (e.g., McRae et al., 1997; Moss et al., 1995). From the linguistic perspective, functional relations belong to syntagmatic relationships, which means that connected words form a syntagm (grammatical construction) (Cruse, 2000). However, not all items that appear in the same context form syntagmatic relations: some refer to paradigmatic relations while others are exclusively syntagmatic. For example, while *'fast'* and *'car'* can occur in the same phrase, they imply a paradigmatic relation where *'fast'* is an attributive feature of a *'car'*; in contrast, relations of *'road'* to *'car'* is purely syntagmatic and *'road'* refers to the location where *'car'* can be driven.

1.2.4 *Association*

Association is defined as when the retrieval of one word calls to mind another one (e.g., Alario et al., 2000; Chiarello, Burgess, Richards, & Pollock, 1990; Fischler, 1977); therefore, associative relationships are complex and comprise items with different types of relations to the prime. Association norms such as Edinburgh Associative Thesaurus (Wilson, n.d.) and Florida Associative norms (Nelson, McEvoy, & Schreiber, 2004) are generated by requiring participants to produce the

[4] Functional relations should not be confused with functional features (e.g., *'drive'* functional feature for *'car'* while *'road'* is a place where *'car'* can be driven).

first word that comes to mind. Such task results in a huge variety of possible relationships in responses. For example, associates can be semantic features of a noun (e.g. *‘red’*-*‘car’* where *‘red’* is an attributive feature of *‘car*’), they can be coordinates (e.g., *‘car’* – *‘bus’*) or function in the same context (e.g., *‘car’* – *‘road’*).

In early experimental studies, functionally related items were selected to be members of different semantic categories that did not share semantic features (e.g., Lupker, 1984; see Moss et al., 1995 for further revision). In other studies, non-categorically related items were selected from associative norms in order to manipulate association (e.g., Alario et al., 2000; Tree & Hirsh, 2003). However, non-categorical associates chosen in this way may confound non-categorical functional relations and part-whole relations or relations between other features and wholes (e.g., attributive feature *‘formal’* as an associate to *‘dress’* Tree & Hirsh, 2003). As noted above, in some studies, the range of possible associative relations has not been controlled.

Associative relations are not necessarily symmetrical. For example, while *'Christmas'* may have *'tree'* as an associate (it is associated to tree), the reverse is not the case (participants do not provide *'Christmas'* as a response given *'tree')*. Associative relations can be bidirectionally associated or unidirectionally associated. For example, *‘sheep’* - *‘animal’* and *‘goat’ - 'sheep'* associative relations are bidirectional; however, *’glass’ ‘cup’* association is unidirectional from *‘glass’* to *‘cup’*. Similarly, car is bidirectionally associated to a part - *‘tyre’,* and functional relations *‘drive’* and *‘road’* but while *‘seatbelt’* is associated to *‘car’*, *‘car’* is not associated to *‘seatbelt’*. Even bidirectional associative relations are often asymmetric. For example, while *‘tyre’* and *‘car’* are associated in both directions, there is a stronger associative connection from *‘tyre’* to *‘car’* than from *‘car’* to *‘tyre’* (e.g., Plaut, 1995; Seidenberg, Waters, Sanders, & Langer, 1984).

To date, the majority of experimental studies have not taken these complexities of association into account. Moreover, not all studies have clearly distinguished between semantic relations with and without association. Therefore, there is no unified terminology denoting different types of semantic and associative relations.

Table 1 summarises the terminology and the criteria used for the selection of semantic relations across the literature and illustrates the variety and inconsistency.

Table 1. Typical terminology, criteria for selection different semantic relations in studies examining semantic priming

	Coordination		
Authors	*Terms*	*Assoc. control*	*Semantic relatedness*
Lupker (1988)	categorical associates	-	rating at 7 cm line
Wheeldon and Monsell (1994)	structurally similar competitors functionally related non-competitors	-	rating >5 (1-7 scale)
Tree and Hirsh (2003)	competitors	weak associates	rating >4.2 (1-5 scale)
Alario et. al (2000)	co-ordinates	not associates	rating (1-5 scale)
Associative relationships			
Lupker (1988)	noncategorical associates	-	rating at 7 cm line
Tree and Hirsh (2003)	associates	prime-target	rating <1.8 (1-5 scale)
Alario et. al (2000)	associates	target-prime	-
Part-whole relationships			
Costa et al (2005)	'has a'	not controlled	
Vieth et.al. (2014)	parts		rating >5 (1-7 scale)
Sailor and Brooks (2014)	parts	target-prime/absent	

Note: 7 cm line implies that participants had to place the mark on the line and the more it was closer to the right side, the more items were considered related; and vice versa; 1-7 scale implies that participants had to judge semantic relatedness between the items by marking one of seven scales

As shown in Table 1, there is a lack of consistent definition of different types of semantic relations and, hence, no systematic evaluation of their effects. This results in difficulty in interpretations of the results in terms of the mechanisms underpinning semantic priming. Hence, the goal of this thesis is to fill this gap through a thorough examination of the effects of primes with different types of semantic[5] relationships to their targets on spoken word retrieval, in order to inform theories of lexical access.

[5] Here we use semantic in contrast to phonological or identity priming, as will become apparent we also examine priming from associates where the relationship may not necessarily be semantic.

The sections that follow outline theories of semantic and lexical representation and processing that are relevant to interpreting the effects found in the experimental chapters, but avoid duplication of literature where detail is provided in the introductions to each chapter.

1.3 Representation of semantic meaning

As described above, it is clear that some words are similar because they perform similar functions (e.g., both *'chair'* and *'sofa'* are used for *'sitting'*) or have similar structure (e.g., *'car'* and *'bus'* have shared features such us *'tyre'*, *'door'* etc.). Others are related by part-whole relations (e.g., a *'car'* has a *'tyre'*) or because they function in the same context (e.g. *'nail'* and *'hammer'* have different structures, perform different functions in isolation, but are associated with the same context). However, it remains debated how this similarity is represented. As illustrated in Figure 1, there are two main approaches to semantic representation: i) non-decomposed and ii) decomposed. In this section, the main ideas underpinning each theory are discussed.

1.3.1 *Non-decomposition*

In non-decompositional theories of semantics, the meaning of a word is represented as a holistic conceptual node with numerous interconnections (Collins & Loftus, 1975; Levelt, 1989; Levelt et al., 1999; Roelofs, 1997).

These connections are bidirectional and vary in strength depending on the frequency of usage. Collins and Loftus (1975) proposed that these links are based on the context and hence encompass both semantic and associative relationships. Some of the connections are direct (e.g., *'car'* is directly connected to *'tyre'*) and others are mediated via other nodes (e.g., *'car'* and *'bus'* are connected to *'vehicle'*; thus, *'vehicle'* is a mediator of the connection between *'car'* and *'bus')* (see Figure 1). Thus, semantic relatedness is based on the strength and the number of bidirectional interconnections between conceptual nodes. In addition, every conceptual node that can be verbalized is connected to one lemma node via a single bidirectional link (e.g., node *'car'* is connected to the lemma node *'car', 'tyre'* to *'tyre', 'bus'* to *'bus'* etc.). This model was further developed by, for example, Levelt (1989), Levelt, Roelofs, and Meyer (1999), and Roelofs (1992).

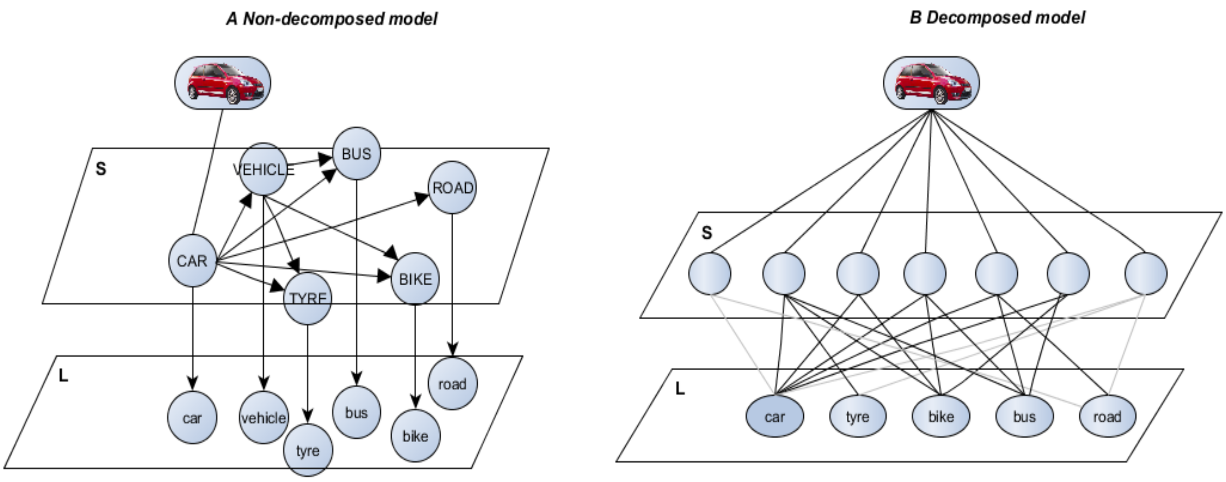


Figure 1. Illustration of models of semantic representation of a word.

Note: Panel A represents non-decomposed model (Collins and Loftus, 1975; Roelofs, 1996); Panel B represents decomposed (Smith 1974, Dell et al., 1997) semantic representations. S – semantic level; L – lemma level.

1.3.2 *Decomposition*

In theories incorporating decomposed semantic representations, the meaning of a word is represented by a set of semantic features (e.g., Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Oppenheim, Dell, & Schwartz, 2010; Smith, Shoben, & Rips, 1974). For example, the meaning of a word *'car'* is represented by semantic features. There are no connections between the features within the semantic level, but one-to-many bidirectional links from the semantic to lexical (lemma) level connect every semantic feature to a number of lemma nodes and vice versa. For instance, the semantic feature *'tyre'* is connected to lemma nodes for *'bus', 'car'* etc. (see Figure 1). Nevertheless, semantic relatedness between two words, in decomposed approaches, is defined by the number of shared semantic features.

1.4 Stages of lexical access

There is a wide agreement that lexical access in spoken word retrieval requires retrieval of both lexical-syntactic information and the phonological word form. However, the nature of the representation and order of activation of this information remains widely debated. There are two groups of models: 1) *two-stage models* (e.g., Dell & O'Seaghdha, 1992; Dell et al., 1997; Jescheniak & Levelt, 1994; Levelt, 1989; Levelt et al., 1999; Roelofs, 1992; Roelofs, Meyer, & Levelt, 1998;

Schriefers, 1992), and 2) *one-stage model* (e.g., Caramazza, 1997; Caramazza & Miozzo, 1997, 1998). The proponents of two-stage lexical access have argued that lexical-syntactic information is retrieved at the first stage – lemma (e.g., Kempen & Huijbers, 1983; Levelt, 1989; Roelofs, 1992; Roelofs, Meyer, & Levelt, 1998), and phonological information of the word in a second stage (also known as lexeme) (e.g., Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Levelt, Roelofs, & Meyer, 1999). The advocates of the one-stage model have argued that both lexical-syntactic and phonological information are retrieved in parallel and argued against distinguishing between lemma and word form (Caramazza & Miozzo, 1998). The further detail of these models are outlined below.

1.4.3 *Two-stage model of lexical retrieval*

The main idea of the two-stage model is that lexical retrieval occurs in two successive stages: 1) lemma stage, and 2) lexeme or phonological form stage (see Figure 3).

A study on sentence processing led Kempen and Huijbers (1983) to argue that the path from semantic processing to phonological processing was mediated with another level. This mediating *lemma* level enables retrieval of a syntactically specified pre-phonological lexical item. Later, Levelt (1989) adopted this idea to model single word processing. In this account, the lemma level aims to specify: 1) syntactic category; 2) grammatical functions (e.g., for a verb it specifies subject, object, etc.); 3) relations to complement (e.g., in a sentence *'he is tired',* linking verb *'is'* is the complement of *'tired'*), 4) lexical pointer that connects each lemma with its form, and 5) diacritic variables (tense, mood, aspect etc.). Altogether, according to Levelt (1989, 1992), the lemma is a node that contains both the semantic and syntactic information of a word.

Roelofs (1992) excluded semantic information from lemma and consequently this level retained only its syntactic properties. Dell and O'Seaghdha (1992) also showed that it is necessary for all the words to be syntactically specified prior to phonological word form retrieval. Based on these investigations, two-stage models of lexical retrieval were developed as depicted in Figure 2. Levelt et al. (1999) and Roelofs et al. (1998) further modified the lemma such that it became an *'empty'* lemma node. This node is activated by lexical-semantic information and then acts as a pointer to syntactic and word form information. Hence, while the lemma level still intervenes between semantics and phonological form, retrieval of syntactic information is not necessary prior to access to phonological form.

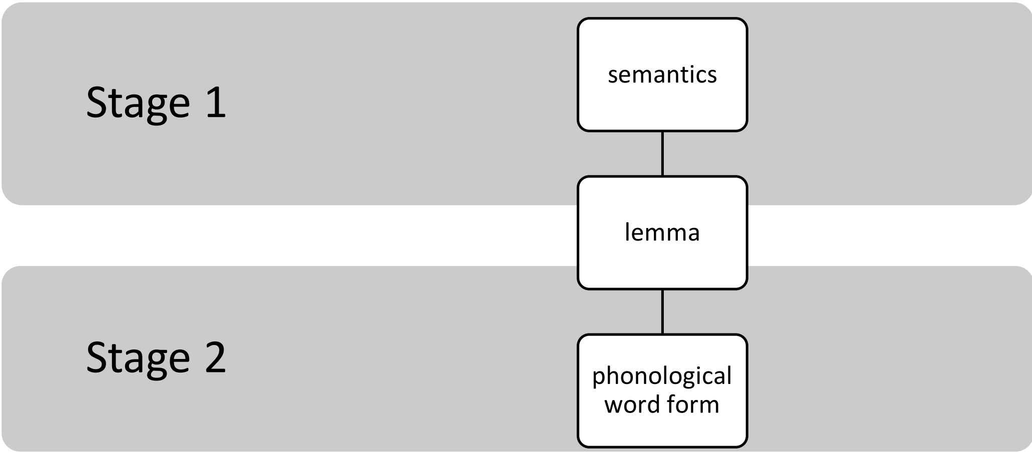


Figure 2. Two-stage lexical processing.

Note: Stage 1 illustrates transition from semantic level to lemma level; Stage 2 illustrates transition from lemma to phonological word form.

1.4.4 *One-stage model of lexical retrieval*

Caramazza and Miozzo (1998) argued against the necessity of proposing the lemma as a mediator between semantic and phonological stages. They argued that access to syntactic knowledge was independent of access to phonological information. They suggested that a separate stage for syntactic retrieval was not needed but rather that it can be retrieved in parallel with the phonological word form. This approach follows up on Caramazza (1997)'s Independent Network model (see Figure 3) where semantic, syntactic, and phonological information are represented as separate domains, with syntactic and phonological information being represented at the same stage.

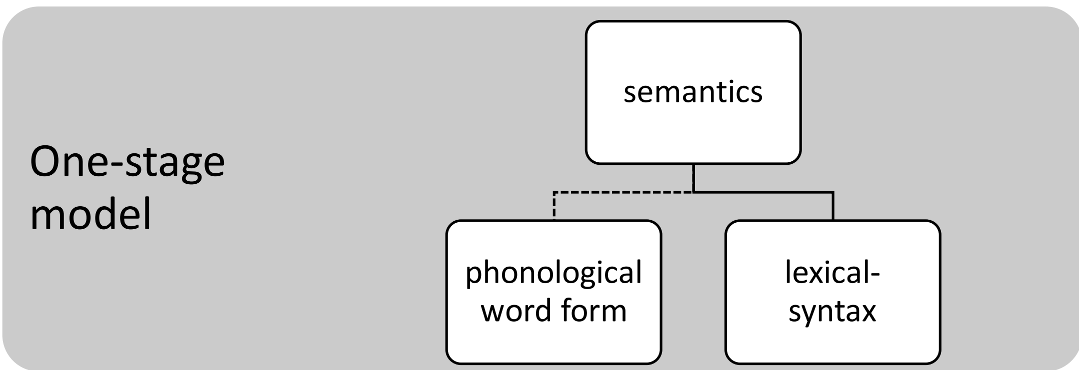


Figure 3. One-stage lexical processing.

Note: Phonological word form and syntactic information are retrieved independently and directly from the semantic level (Caramazza, 1997; Caramazza & Miozzo, 1998).

1.5 Information flow within the mental lexicon

To date, not only do theories of spoken word retrieval divide in terms of the nature of semantic representation, but they also assume different patterns of activation, either i) feedforward or ii) interactive models.

Levelt et al. (1999) proposed a *feedforward* model with non-decomposed semantic representation. According to this account, activation of every conceptual node spreads toward multiple conceptual nodes and the one lemma node it is connected to. Activation between conceptual nodes gradually decreases, the further it spreads. Hence, every conceptual node activated by means of activation spreading, receives a smaller proportion of activation than the conceptual node it was activated by. As result, the lemma node activated by the initial conceptual node is more highly activated than other co-activated lemma nodes and is the one that is selected for production.

In the other major theory of spoken word production, Dell et al. (1997) and later on Oppenheim et al. (2010) proposed *interactive activation* between levels. In this theory, activation of every lemma node starts with activation of a number of semantic features. Every semantic feature spreads its activation to all the lemma nodes it is connected to, and, critically, each activated lemma node also activates the semantic features that it is connected to. This results in activation of other semantic nodes which may not be directly connected to the target node. The activation of a lemma node depends on the number and weight of the multiple semantic-to-lexical connections. The lemma node that gathers the strongest activation is selected.

1.6 Mechanisms of semantic priming from different semantic relations

As noted above, most of the studies that compare the effect of primes with different semantic relationships to targets have found that different semantic relations can produce different effects on spoken word retrieval. For example, the majority of studies are consistent in finding interference from semantic coordinate primes and facilitation from associate primes that are members of a different semantic category from the target (e.g., Abdel Rahman & Melinger, 2007; Alario et al., 2000; Costa, Alario, & Caramazza, 2005; Tree & Hirsh, 2003). This led to two competing accounts of the mechanism of semantic priming in spoken word retrieval being developed: 1) lexical competition account, and 2) response exclusion account.

Both accounts agree that the lexical retrieval of a word involves spreading activation (Collins & Loftus, 1975); that is, one (target) node spreads its activation to other related nodes at the conceptual level. Therefore, both accounts agree that facilitation from association is a function of spreading activation at the conceptual level. However, there is no agreement on the mechanism underpinning semantic interference from coordination. The proponents of lexical selection by competition (e.g., Levelt, Roelofs, & Meyer, 1999; Roelofs, 1997) have stated that lexical access in spoken word retrieval occurs in two subsequent stages: *lemma stage* where the lexical-syntactic information of the concept is specified followed by a stage where the *phonological word form* information is specified. According to this account, interference results from competition at the lemma level between the target to be selected and other co-activated non-target lemmas. In contrast to this approach, proponents of the response exclusion account (e.g., Costa et al., 2005; Finkbeiner & Caramazza, 2006; Janssen et al., 2008) have argued that there is no lexical competition. Instead, interference occurs at post-lexical buffer when the prime is a potential candidate for the response.

One of the main differences between the two accounts is whether the polarity of the effect is driven by the degree of semantic relatedness between the prime and a target, or the type of semantic relatedness. In lexical competition (e.g., Levelt et al., 1999), the polarity of the effect has mainly been defined as a function of the spreading activation and competition without a particular restriction on the type of semantic relations (e.g., Abdel Rahman & Melinger, 2007; Damian & Spalek, 2014; Piai et al., 2011). For example, Abdel Rahman and Melinger (2007) proposed that if a prime is semantically related to the target, the polarity of semantic priming depends on the locus of activation but not on the type of semantic relations between them. That is, activation of the target spreads its activation to the prime. If the prime is activated only at the semantic level, facilitation occurs, but if the prime is strongly activated at the lemma level it becomes a strong competitor to the target and interference occurs. Once again, either of these effects can occurs regardless of the type of semantic relations, but is rather due to the strength and level of activation.

In the response exclusion account, the polarity of the effect is related to the types of semantic relations between the prime and a target (Costa et al., 2005; Finkbeiner & Caramazza, 2006; Janssen et al., 2008). The main argument in this account is that primes that are members of different semantic categories, while being semantically related to the target, are not potential candidates for the response; hence, the spread of their activation toward the target results in facilitation in target retrieval.

However, some studies have shown that semantic interference between members of different semantic categories is possible (e.g., Sailor & Brooks, 2014; Vieth et al., 2014). For example, Sailor and Brooks (2014), in the picture-word interference task, examined the effect of parts that were associated to the target wholes and those that were not. They found that non-associated parts can produce interference when presented simultaneously with the target whereas parts that are associated to the target can produce facilitation only with early stimuli onset asynchrony. In another picture-word interference experiment, Vieth et al. (2014) examined the effect of parts that are shared (e.g., *'knee'* is a shared part of a *'camel'* and other members of the category of *'animals'*) and those that are distinctive for category members (e.g., *'beard'* for *'goat',* other animals do not have beards). They detected interference from parts that were shared features and no effect of distinctive features. Sailor and Brooks (2014) and Vieth et al. (2014) argued that semantic priming from parts occurs by means of competition at the lemma level.

The limitation of these studies however, is the absence of the evaluation of the effect of different types of semantic relations in different paradigms. This is important, because as has been shown above, not only the type of semantic relations but also the modality of presentation may affect the polarity of the effect. Therefore, we assume if semantic priming is underpinned by response exclusion mechanism, then semantic interference should be limited to the members of the same semantic category and facilitation should be observed from members of different semantic categories at lag 0. If semantic priming is driven by the competition at the lexical level, then interference should be observed from both members of the same as well as different semantic categories. Furthermore, if priming from semantic coordination and association is driven by the same mechanism as it is predicted by swinging lexical network, the same pattern of the effect should be observed in two modalities: 1) alternating word reading and picture naming and 2) continuous picture naming. Otherwise, if results of these experiments show that priming from association and coordination are provided by two different mechanisms, the existing hypothesis should be modified.

1.7 Key Issues

The focus of this thesis is on understanding the nature of semantic representation and information flow in the lexicon and how this affects spoken word retrieval using evidence from semantic priming. Despite the fact that a number of studies have provided evidence that different semantic relationships in different modalities can produce different effects on spoken word retrieval (e.g., Abdel Rahman & Melinger, 2007; Muehlhaus et al., 2012), these studies lack systematic evaluation of different semantic relations in different modalities.

Some studies examining the effect of different semantic relations lack clear criteria when dissociating between these relations. This concerns not only the dissociation between semantic relatedness and association, but also between different types of semantic relations. For example, Tree and Hirsh (2003) examined the effect of associated members of different semantic categories, but these primes were also in different semantic relations to the target and could be members of different syntactic classes. For example, prime *'skeleton'* was an associated member of a different semantic class' to the target *'cupboard,'* in contrast, *'peanut'* has a feature-whole relation to its target *'butter'.* There were also features that belonged to a different syntactic class to the target; for example, prime *'formal'* was not only attributive feature of the target *'dress'* but also belonged to a different syntactic class (adjective). Likewise, in the coordinate condition, they used items that were both strongly and weakly associated (e.g., *'leg'* is strongly associated coordinate to *'arm',* but '*lorry'* is weakly associated to *'car'*). However, as noted above, clear dissociation of different types of semantic relations is important to avoid confounding of different relations.

Another limitation of the majority of previous studies is that they have examined the effect of different relations using a single factor design (one experimental and one control condition per experiment) (e.g., Alario et al., 2000; Costa et al., 2005; Tree & Hirsh, 2003); while, modern research techniques allow several conditions to be built into cross-factorial design. By doing so, the effect of different semantic relations can be examined not only relatively to an unrelated condition but also taking into account performance in other experimental conditions and individual differences between participants and items. For example, while comparing the effect of semantic coordination and association, the previous priming studies examined the effect of coordination in one experiment and the effect of association in another experiment; however, using cross-factorial design allows one to examine the effect of both the effect of coordination and association in a single experiment. The engagement of such a technique is important for avoiding confounds and unwanted effects.

One more limitation of previous studies is the examination of the effect of different semantic relations has mainly occurred in the same paradigm; however, a number of studies have shown not only the type of semantic relations affects semantic priming, but also the modality of presentation (e.g., Abdel Rahman & Melinger, 2007; Piai et al., 2011; Vitkovitch et al., 2006). Therefore, the research presented here addressed this issue by providing a systematic evaluation of the effect of different semantic relations in different modalities and with different populations (Chapter 2 and 3 examine the effect of different semantic conditions with healthy adults (alternating word reading and picture naming paradigm in Chapter 2 and continuous picture naming in Chapter 3). Chapter 4 examines the effect of different semantic relations in people with aphasia.

1.8 Research aims

The research presented here aimed to overcome some of the limitations of earlier studies and provide systematic evaluation of the effect of different semantic relations by 1) tightly defining the criteria for each relation and ensuring that they were unconfounded; 2) applying a cross-factorial design to enable direct comparison of different relations; 3) use the same relations in different experimental paradigms to replicate and provide converging evidence; 4) use different populations (healthy participants and people with aphasia) to provide converging evidence.

1.9 Thesis outline

The structure of the thesis is as follows:

Chapter 2 examined the effect of semantic coordination, association and part whole relations on speed and accuracy of spoken word retrieval in an alternating word reading and picture naming paradigm in a group of healthy participants. The two experiments used a design where the participants were required to alternate between reading a written word aloud and naming a picture. In the first experiment, written word primes were presented at lags (the number of intervening items between the prime and a target) of zero or four before their corresponding targets were elicited in picture naming. In first experiment, prime-target relationships orthogonally varied semantic coordination and association to give four conditions (+associate +coordinate; +associate -coordinate; -associate +coordinate; -coordinate -associate). In the second experiment, the effects of associated coordinates were replicated and the effects of part-primes on whole-targets were examined, together with a manipulation of the direction of association.

Chapter 3 also examined the effect of semantic coordination, association and part-whole relations but in contrast to Chapter 2 this time the effect of different semantic relations was examined in a continuous picture naming paradigm.

Chapter 4 reported two experiments with a case series of people with aphasia using a facilitation paradigm to investigate the effects of association and coordination. The study involved three phases: 1) pre-facilitation: to record baseline response latency and accuracy in naming; 2) facilitation: where the stimuli were presented with an auditory prime word together with the target picture, and the participant was required to repeat the prime; 3) post-facilitation: all items (facilitated and unfacilitated) were once again presented for naming. In Experiment 1, we examined the effect of identity primes and primes that were both an associate and coordinate of the target. In Experiment 2, the effect of association and coordination were examined as separate factors.

Finally, *Chapter 5* provided a general discussion of results obtained in this research in line with existing hypotheses on the nature of semantic representation, factors involved in lexical access, and mechanisms underpinning semantic priming in spoken word retrieval.

Chapter 2. Is association always facilitatory? Direction matters!

2.1 Introduction

Studies with healthy participants have shown that the retrieval of one word may affect the speed and accuracy of the later retrieval of a related word – there is priming of word retrieval. The nature of this priming varies with the nature of the relationship between the prime and a target. For example, *'car'* and *'cart'* are similar phonologically: previous retrieval of *'cart'* affects the speed and accuracy of retrieval of '*car'* a word with similar phonological form (e.g., Collins & Ellis, 1992; Cronk, 2001; Schiller, 2004). On the other hand, *'car'* and *'bus'* are members of the same semantic category and retrieval of the word *'car'* is slower after the previous retrieval of *'bus'* compared to the unrelated word *'pan'* (e.g., Tree & Hirsh, 2003; Vitkovitch, Rutter, & Read, 2001; Wheeldon & Monsell, 1994). Such priming effects have been used as a tool to reveal the functional architecture of spoken word retrieval. The research reported here focuses on the priming between words that are related in meaning – *semantic priming*. Despite a relatively large number of studies examining semantic priming, there is a relative lack of systematic evaluation of the effects of different types of meaning relations on spoken word retrieval within the same paradigm.

2.1.1 *The most common paradigms for examining semantic priming from different semantic relations*

The most common method to examine semantic priming from different semantic relations has been to examine the effect of a previously presented written word on picture naming[6] (e.g., Alario, Segui, & Ferrand, 2000; Costa, Alario, & Caramazza, 2005; Lupker, 1979, 1988; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Sailor & Brooks, 2014; Tree & Hirsh, 2003; Vieth, McMahon, & de Zubicaray, 2014). Studies with word-primes and picture-targets have examined priming in four types of paradigm: i) picture-word interference, ii) masked priming, iii) unmasked priming, iv) alternating word reading and picture naming.

The *picture-word interference* paradigm involves experiments where the written word prime (distractor) is superimposed on the target picture and remains presented either for over 100 ms or for the whole duration of the target presentation.

[6] There is also an increasingly large body of literature on semantic interference using the continuous naming and blocked cyclic naming paradigms. However, in this chapter we focus on cross-modal experiments, but refer to the other literature as appropriate.

In this paradigm, stimulus onset asynchrony (SOA) can be manipulated (e.g., Costa et al., 2005; Damian & Spalek, 2014; Finkbeiner & Caramazza, 2006; Lupker, 1979; Mahon et al., 2007; Sailor & Brooks, 2014; Vieth et al., 2014). For example, if the target is *'car'* and the distractor *'bus'*, the written word *'bus'* may appear before, simultaneously, or after the target picture *'car'*, and can remain on the screen until the target is named, or is displayed for at least 100 ms. The participant's task is to name the picture while ignoring the written distractor. Naming can be *immediate* when both the target and the distractor are present, or *delayed* – naming the target after the prime has disappeared (e.g., Damian & Spalek, 2014; Finkbeiner & Caramazza, 2006; Janssen, Schirm, Mahon, & Caramazza, 2008; Piai, Roelofs, & Schriefers, 2011).

The *masked priming* paradigm involves a very brief presentation of the written prime (about 50ms) followed by a visual mask (e.g., a series of dollar signs) so that the subject is usually unaware that the prime has been presented (Damian & Spalek, 2014; Deacon, Hewitt, Yang, & Nagata, 2000; Finkbeiner & Caramazza, 2006). In contrast to masked priming, *unmasked priming* implies a longer duration of written prime presentation (about 100ms or longer), so that the participant can consciously recognize the prime (e.g., Alario et al., 2000; Lupker, 1988). Once again the prime is usually presented before the target and never overtly produced.

The *alternating* w*ord reading and picture naming* paradigm is the only paradigm that requires both the prime and the target to be produced. In this task, the participant is generally unaware that there are primes and targets as they are presented with a sequence of alternating written words (to read) and pictures (to name). This task has also been used to examine the duration of priming effects by manipulating the number of intervening items (lag) between the prime and a target (e.g., Tree & Hirsh, 2003).

2.1.2 *Semantic priming in alternating word reading and picture naming paradigm*

In the alternating word reading and picture naming paradigm, only Tree and Hirsh (2003), to our knowledge, have addressed the issue of the effect of different semantic relations on the speed and accuracy of spoken word retrieval. Given that Wheeldon and Monsell (1994) argued for an effect of the interval between the retrieval of a prime and target, Tree and Hirsh (2003) added lag as the factor to their study and examined the effect of semantic coordination and association at lags 0, 2, and 4. Their results showed facilitation from association and interference from coordination, and no effect of lag, nor an interaction. However, when they analysed the effect of association and coordination at each lag separately, they observed significant facilitation from association at lag 0 and interference from coordination at lag 2. Tree and Hirsh (2003) suggested that association at lag 0 produces facilitation by means of spreading activation at the conceptual level and coordinates produce interference at lag 2 as a function of lexical selection by competition. However, in their study, they used coordinates that were weakly associated and associates that were in several different types of semantic relations. Given this confound, it remains unclear whether facilitation in overt production tasks is really restricted to association between members of different semantic categories and interference to members of the same semantic category. Moreover, no studies, so far, have examined the effect of other non-categorical relations such as part-whole relations in alternating word reading and picture naming paradigm.

To address this issue, two experiments were conducted to examine the effect of semantic coordination, association, and part-whole relations on spoken word retrieval using an alternating word reading and picture naming design with written word primes and picture targets. Likewise, given the possibility of interaction of the type of semantic relations and the lag, we included lag as an additional factor.

2.2 Experiment 2.1: Semantic coordination and association

The aim of this experiment was to dissociate the effects of semantic coordination and association in spoken word retrieval. To dissociate the effects of these two factors, we examined differences between priming effects in prime-target pairs that belonged to the same semantic category and were associated *(+associate +coordinate)*, those that were associated but belonged to different semantic categories *(+associate –coordinate),* those that belonged to the same semantic category but were not associated *(–associate +coordinate)* and pairs that were unrelated. Previous studies have demonstrated that the nature of the priming effect depends not only on the type of semantic relationship between prime and target but also on the lag; consequently, we examined the effect of every condition at lag 0 and lag 4.

2.2.1 *Participants*

Forty-eight students of Newcastle University were tested in this experiment. This sample size was generated to have 0.8 power for one-tailed significance at 0.05. According to this estimation, the minimum sample size needed was 55 participants. However, because of 2x2x2 design of the experiment we had to select the number divisible by 8; hence, we recruited 48 participants (24 male), mean age 27.00 (± 3.00 SD) with English as their native language and normal or corrected to normal vision.

2.2.2 *Materials*

This experiment consisted of 4 semantic conditions: 1) *+associate +coordinate* (+A+C), 2*) +associate -coordinate (+A-C)*, 3) *-associate +coordinate (-A+C)*, and 4) *-associate -coordinate* (-A-C; unrelated - UNR) (see Appendix A). *Coordinates* were defined as members of the same semantic category in WordNet (Fellbaum, 1998a; Miller & Fellbaum, 1991) and the UCREL Semantic Analysis System (USAS)[7] (Rayson, 2008). For example, *'car'* and *'bus'* were both cohyponyms in WordNet (Miller & Fellbaum, 1991) and belonged to the same semantic field in USAS. In contrast, *'cup'* and *'bag'* were cohyponyms of *'container'* in WordNet but members of different semantic fields in USAS, so such pairs were not included in the experiment. WordNet enabled selection of items that share central semantic features (e.g., Hadjichristidis, Sloman, Stevenson, & Over, 2004; Sloman, Love, & Ahn, 1998) such as parts (e.g., *'car'* and *'bus'* both have a *'tyre'*) and functions (e.g., *'car'* and *'bus'* are both used for *'driving'*). On the other hand, usage of USAS ascertained that coordinates were conceptually coordinated. For instance, *'car'* and *'bus'* functioned within single semantic field (M3fn) 'means of transport (land)', while *'cup'* and *'bag'* belonged to different semantic fields (*'cup'* belongs to O2 (objects generally) and *'bag'* belongs to B5 (clothes and personal belongings). Noncoordinates (*-coordinate)* were not present at the same level of WordNet, nor at one level up or down, they belonged to different semantic fields within USAS, and were not in feature-whole relations (e.g., there were no *'tyre'* - *'car'* pairs, where *'tyre'* is a feature/part and *'car'* is a whole).

Associates were functionally related items (McRae et al., 2012; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995) retrieved from free association norms. All associates

[7] UCREL Semantic analysis system is a software framework for automatic semantic analysis of natural language data

were forward associated from the prime to the target (i.e., given the prime participants produced the target). As the experiment was run in the United Kingdom, the Edinburgh Associative Thesaurus (Wilson, n.d.) was used.

Hence, *+associate +coordinate* pairs met the criteria for both coordination and association*. +Associate -coordinate* pairs met the criteria for association, but were not related within WordNet and USAS. *-Associate +coordinates* met the criteria for coordination and association in prime-target direction in free association norms. -*Associate -coordinates* were selected such that they were neither coordinates nor associates.

All pairs were matched for association strength and semantic distance (see Table 1 and Appendix B). Semantic relatedness was matched using Latent Semantic Analysis (Landauer, Foltz, & Laham, 1998), so that the two *+coordinate* conditions were equally related to their targets and significantly more closely related than the two *-coordinate* conditions. For the two +associate conditions, association was matched for prime-target direction and checked for target-prime direction (see Table 2 and Appendix B). As is shown in Table 2, association in prime-target direction was significantly stronger than in target-prime association. The absence of association in prime-target direction was checked for the two *-associate* conditions. In addition, all four conditions were matched for (logarithm) spoken word frequency using the SUBTLEX-UK database (van Heuven, Mandera, Keuleers, & Brysbaert, 2014). To exclude the possibility of phonological priming between the prime and its target, we ensured that they did not share syllable onsets or rimes.

Table 2. Summary of properties of stimuli used in Experiment 2.1

Conditions	*Example*	*Frequency(log)*		*Association (number of responses)*				*Semantic distance*		*Length (number of phonemes)*	
				Target-Prime		*Prime-Target*					
		mean	*SD*	*mean*	*SD*	*Mean*	*SD*	*mean*	*SD*	*mean*	*SD*
Target (T)	*car*									5.42	1.46
+A+C	*bus*	4.14	0.72	0.07	0.10	0.12	0.13	0.41	0.18	5.50	1.37
+A-C	*road*	4.16	0.73	0.06	0.04	0.11	0.14	0.27	0.16	4.88	1.91
-A+C	*bike*	4.03	0.51	0.00	0.01	0.00	0.00	0.39	0.14	5.50	1.68
UNR(-A-C)	*mussel*	4.10	0.38	0.00	0.00	0.00	0.00	0.07	0.07	4.88	1.62

Note: +A+C: +associate +coordinate; +A-C: +associate -coordinate; -A+C: -associate +coordinate; -A-C/UNR: -associate-coordinate/unrelated; SD: Standard Deviation

As result, we obtained 24 experimental items with each item appearing in every semantic condition and at each lag. Primes were written words and targets were line-drawings selected from open sources from the Internet. Eighteen additional items were used as fillers and training items. These items had no semantic, associative and/or phonological relations with the experimental targets.

2.2.3 *Design*

This experiment used a 2x2x2 cross-factorial Latin-square design; thus, each subject saw every target once, with six prime-target pairs in each condition and three at each lag (zero or four). The lag between the prime and the target was either zero or four intervening items which were either other experimental items or fillers. All the pairs were uniquely randomized for each participant.

2.2.4 *Procedure*

The experiment was run in DMDX (Forster & Forster, 2003). No familiarisation was included to avoid repetition priming effects prior to the start of the experiment. Every experimental set started with 8 practice trials. Presentation of every item was preceded by an alerting cue (five asterisks in the centre of the screen) for 500 ms. The experimental item then appeared in the centre of a computer screen for 2000 ms and was followed by a blank screen for 250 ms. Response latencies to vocal onset were recorded by DMDX's voice key from the onset of the picture. Once collected, response times were manually checked using CheckVocal (Protopapas, 2007). Before the experiment started, every participant was instructed to read the words and name the pictures (with a single word) as rapidly and accurately as possible.

2.2.5 *Results*

Only responses named with the target word at the first attempt and within 2000 ms were considered correct. No alternative names were accepted as they could have different psycholinguistic properties and relationships with the primes. Three target items *'goose', 'mouse'* and *'pipe'* that had an extremely high error rate (> 25%) were excluded from further analysis. Removal of these items did not affect matching for frequency, semantic distance, or association strength between conditions (see Appendix B). In the remaining dataset, 7.24% of items were incorrect (1.28% incorrectly read primes, 5.65% incorrectly named targets, and 0.3% targets with no response) and were excluded from the analysis of reaction time but were included in the analysis of the accuracy of the response if their prime was read correctly (see Appendix B).

Analysis of reaction time

Prior to the analysis, RT was reciprocally transformed[8] (Box & Cox, 1964) using the MASS package (Venables & Ripley, 2002). Contrast coding was used to examine effects of semantic conditions, lag and the interaction between semantic condition and lag (for details of contrasts see Appendix C) in a linear mixed effect model in *lme4* package, version 1.1-7 (Bates et al., 2014) in GNU programming environment R version 3.1.1 (R Development Core Team, 2014). The dependent variable (1/RT) was examined for effects of semantic coordination, association, their interaction, lag and its two and three way interactions with the semantic conditions, as fixed effects and subjects and items as random intercepts. Based on the model outputs, responses were trimmed within 2.5 standard deviations (Baayen & Milin, 2010) and 24 (2.6%) data points were removed from the data. This improved the model in terms of R^2 from 0.44 to 0.52, and these data were used for both descriptive and linear mixed effect analysis. Table 3 summarizes the results (n=911) and Figure 4 summarizes mean latency of responses by condition (+*coordination* (+A+C and -A+C), -*coordination* (+A-C and -A-C), +*association* (+A+C and +A-C) and -*association* (-A+C and -A-C)) at lags zero and four.

[8] As reaction time is a continuous positively skewed dependent variable, it is important to screen its distribution for normality. Transformation of RT is usually applied when minimal λ in normality screening is below -1.

Table 3. Reaction time and accuracy of the response

Reaction time					*Errors (%):*		
Conditions:	*=n*	*Mean RT (in ms)*	*SD*	*Priming*	Primes	Targets	*Total*
+A +C	*228*	*781*	*175*	+48	.01	.06	.06
+*A -C*	*228*	*758*	*157*	+25	.02	.06	.08
-A +C	*230*	*760*	*175*	+27	.01	.07	.08
UNR	*225*	*733*	*153*		.01	.06	.07
		lag0					
+A +C	*117*	*792*	*181*	+53	.00	.05	.05
+*A -C*	*114*	*771*	*180*	+32	.02	.05	.08
-A +C	*118*	*756*	*171*	+17	.02	.05	.06
UNR	*110*	*739*	*150*		.02	.07	.09
		lag4					
+A +C	*111*	*770*	*168*	+43	.02	.05	.07
+*A -C*	*114*	*745*	*130*	+18	.02	.05	.08
-A +C	*112*	*765*	*180*	+38	.00	.09	.09
UNR	*115*	*727*	*156*		.01	.05	.05

Note: *+A+C*: +associate +coordinate; *+A-C*: +associate -coordinate; *-A+C*: -associate +coordinate; *-A-C/UNR*: unrelated; *N* = number of observations in every condition summed across 48 participants; *SD*: standard deviation of the mean reaction time (RT); *Priming*: difference in *RT* compared to unrelated - + slower responses in control condition as compared to unrelated; - faster responses; *Errors*: *Primes*: percentage of incorrect responses to primes; *Targets*: percentage of incorrect responses to targets for which primes were correct; *Total*: percentage of incorrect responses in every condition.

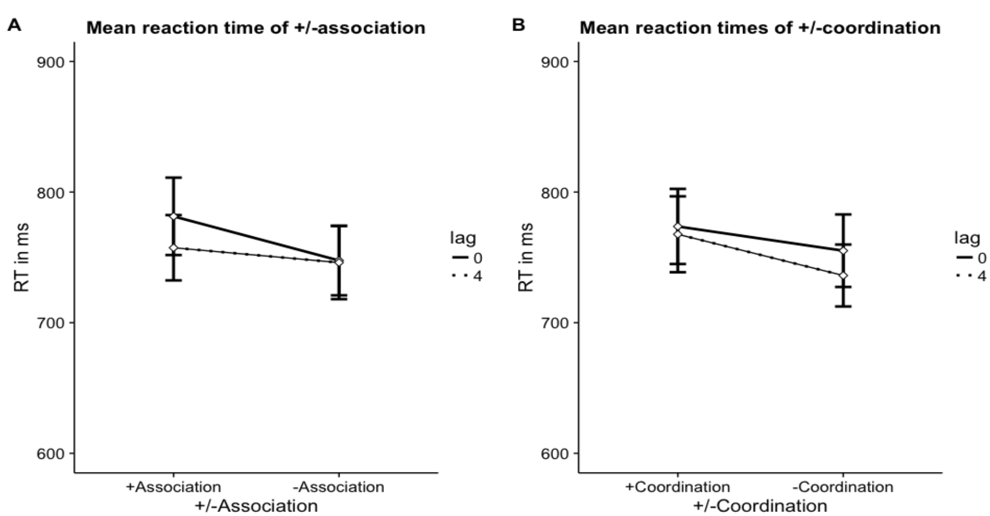


Figure 4. Mean reaction time for +/-coordination (Panel A) and +/-association (Panel B) and at lags 0 and 4.

Note: Error bars represent 2.5 standard error from the mean

Statistical analysis showed a main effect of association and coordination, no main effect of lag, no two-way interaction between association and coordination, and no three way interactions between lag and either association or coordination (see Table 4).

Table 4. Summary of the effect of +Coordination, +Association, lag and their interaction on mean RT of response

Condition	*Analysis of reaction time*				*CI*	
	coef	*SE*	*z*	*p*	2.50%	97.50%
Overall	*1/RT~Condition +(1|Subject)+(1|item)*					
Association	3.8E-05	1.3E-05	**2.908**	**0.004**	1.2E-05	6.3E-05
Coordination	3.5E-05	1.3E-05	**2.668**	**0.008**	8.9E-06	6.0E-05
lag	-1.9E-05	1.3E-05	-1.416	0.157	-7.7E-06	4.3E-05
*Assoc*Coord*	-7.4E-06	1.3E-05	-0.563	0.573	-3.3E-05	1.8E-05
lag0						
Association	4.9E-05	1.9E-05	**2.542**	**0.011**	1.1E-05	8.7E-05
Coordination	3.2E-05	1.9E-05	1.673	0.094	-5.5E-06	7.0E-05
*Assoc*Coord*	6.3E-06	1.9E-05	0.327	0.744	-3.1E-05	4.4E-05
lag4						
Association	2.2E-05	1.8E-05	1.203	0.229	1.1E-05	8.7E-05
Coordination	3.7E-05	1.8E-05	**2.028**	**0.043**	-5.5E-06	7.0E-05
*Assoc*Coord*	-2.0E-05	1.8E-05	-1.105	0.269	-3.1E-05	4.4E-05
Condition lag*	*1/RT~Condition*lag +(1|Subject)+(1|item)*					
*Association*lag*	-2.4E-05	2.6E-05	-0.905	0.365	-2.7E-05	7.5E-05
*Coordination*lag*	8.4E-06	2.6E-05	0.321	0.748	-5.9E-05	4.3E-05
*Assoc*Coord*lag*	-3.1E-05	2.6E-05	-1.191	0.234	-2.0E-05	8.2E-05

*Note: * interaction; 1/RT:* reciprocated reaction time*; se:* standard error; *CI:* confidence interval; ***BOLD*** font indicates a significant result *(Pr(>|z|) at p<.05); ITALIC* font indicates a trend *(Pr(>|z|) <.1);* N (observations) =911; n (participants) =48).

Analysis of the accuracy of the response

All the items were included in the accuracy analysis except pairs where primes were named incorrectly (1.28%). As is shown in Table 5, there were no significant effects of any condition nor any significant interactions between conditions.

Table 5. Summary of the effect of +Coordination, +Association, lag and their interaction on the accuracy of response

Condition	*Analysis of the accuracy of the response*			
	coef	*SE*	*z*	*p*
Overall	*Accuracy~Condition +(1|Subject)+(1|item)*			
Coordination	-0.516	0.402	-1.284	0.199
Association	0.516	0.402	1.284	0.199
lag	-0.285	0.402	-0.708	0.479
*Assoc*Coord*	-0.305	0.402	-0.759	0.448
lag0				
Coordination	-0.223	0.492	-0.453	0.651
Association	0.214	0.491	0.436	0.663
*Assoc*Coord*	0.211	0.491	0.430	0.667
lag4				
Coordination	-0.821	0.639	-1.285	0.199
Association	0.821	0.639	1.285	0.199
*Assoc*Coord*	-0.821	0.639	-1.285	0.199
*Condition*lag*	*Accuracy~Condition*lag +(1|Subject)+(1|item)*			
*Coordination*lag*	0.610	0.804	0.759	0.448
*Association*lag*	-0.610	0.804	-0.759	0.448
*Assoc*Coord*lag*	1.032	0.804	1.284	0.199

Note: Conditions are combined: *Association* (+associate +coordinate and associate -coordinate); *Coordination* (+associate +coordinate and -associate +coordinate); *Assoc*Coord* (+associate +coordinate and -unrelated); * interaction; *1/RT* - reciprocated reaction time; *se* - standard error; N (observations) = 1008; n (participants) =48.

2.2.6 *Discussion*

The goal of this experiment was to examine the effects of semantic coordination and association at lags zero and four in the alternating word reading and picture naming paradigm. We found significant interference from association and coordination, no effect of lag nor any interactions. Interference from coordination is consistent with previous studies (e.g., Abdel Rahman & Melinger, 2007; Alario et al., 2000; Costa et al., 2005; Damian & Spalek, 2014; Lupker, 1979; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Tree & Hirsh, 2003; Vitkovitch & Cooper, 2012; Wheeldon & Monsell, 1994). However, the interference from association conflicts with a range of studies with the prime presented as a written word (e.g., Alario et al., 2000; Mahon et al., 2007; Tree & Hirsh, 2003). The implications of these results in the context of existing accounts are discussed below.

To further understand the source of the discrepancy of our results, we compared the association from the *target* to the *prime* in the research presented here and the Tree and Hirsh (2003) study. It is apparent that in Tree and Hirsh (2003), around a third of the associative pairs were not associated from target to prime (11/32) – they were only unidirectionally associated from the prime to the target. In contrast, in our study eight pairs out of twenty-four had unidirectional association from prime to target and sixteen (16/24) were bidirectionally associated (but with stronger association from the prime to the target).

To examine whether the directionality of the association can affect priming, we conducted a post hoc analysis of the effects of directionality of associative strength using a linear mixed effect model. As shown in Table 6, association from the target to the prime (found in the bidirectional pairs) is critical for significant interference between associated members from different semantic categories. Interestingly however that Alario et al. (2000) in picture-word interference task used primes with target-prime direction of association and found facilitation from the association. Moreover, Abdel Rahman and Melinger (2007) who used the same stimuli as Alario et al. (2000) in blocked cyclic naming and picture-word interference tasks found both facilitation and interference from association. In particular, they found facilitation from association in picture-word interference task and the first block of naming, but in the later blocks this effect reversed to interference. Given that, it is possible that in some circumstances association may produce interference. However, as different tasks may produce different effects, more data are needed before conclusions are drawn.

Table 6. Summary of the effect of Bidirectional association, Unidirectional association, lag and their interaction on the reaction time of response

Condition	*Analysis of reaction time*				*CI*	
	coef	*SE*	*z*	*p*	2.50%	97.50%
Overall	*RecRT~Association +(1|Subject)+(1|item)*					
Bidirectional	3.79E-05	1.42E-05	**2.67**	**0.01**	0.01	0.07
Unidirectional	3.83E-05	2.33E-05	1.65	0.10	-0.01	0.08
-lag0 +lag4	-1.86E-05	1.32E-05	-1.42	0.16	-0.05	0.01
lag0						
Bidirectional	5.12E-05	2.09E-05	**2.45**	**0.01**	0.01	0.09
Unidirectional	4.07E-05	3.41E-05	1.20	0.23	-0.03	0.11
lag4						
Bidirectional	2.34E-05	2.01E-05	1.16	0.25	-0.02	0.06
Unidirectional	1.86E-05	3.28E-05	0.57	0.57	-0.05	0.08
*Condition*lag*	*RecRT~Association*lag +(1|Subject)+(1|item)*					
*Bidirectional*lag*	-2.40E-05	2.83E-05	-0.85	0.40	-0.08	0.03
*Unidirectional*lag*	-2.14E-05	4.35E-05	-0.49	0.62	-0.11	0.06

Note: Bidirectional: target-prime and prime-target association*; Unidirectional:* prime-target association only*; RT fitted within 2.5 sd; BOLD: significant results (p<.05); Italic: trend (p<.1);* N (observations) = 764; n (participants) =48.

From the results of this experiment in relation to the results of other studies examining the effect of association it can be concluded that both interference and facilitation from association have been observed in overt production tasks. In this regard, the polarity of this priming most likely depends not only on the task to be performed but also on the direction of association: 1) facilitation from prime-target direction of association (e.g., Tree and Hirsh, 2003), 2) interference in case of target-prime direction of association as found here. Given that it seems important to understand the effect of association in more detail; Experiment 2.2 addresses this issue.

2.3 Experiment 2.2: Semantic coordination and part-whole relations

Experiment 2.1 showed that both association and coordination can produce interference on spoken word retrieval. Likewise, it showed that the interference from association is driven by target-prime direction of association. Therefore, the goal of this experiment was to look closer at the effect of the direction of association in conditions when the prime shares some features within the target but also is a member of different semantic category. For this purposes, we selected primes that are in part-whole relations to the target. Like coordinates, parts share features with the target, but relatively fewer features. To examine the effect of the direction of association, we selected parts that were unidirectionally associated to the target in prime-target direction in one condition and parts that were associated in target-prime direction (mostly bidirectionally). Even though we did not observe an effect of lag nor any interaction in Experiment 2.1, separate analysis of the effect of coordination at lag 0 and 4 detected significant priming from semantic coordinates at lag 4. Therefore, in Experiment 2.2, we examined the effect of coordination and part-whole relations at lag 4.

2.3.1 *Participants*

Thirty-two students of Newcastle University with mean age 24.00 (SD=5.35) (14 male) with English as their native language took part in this experiment. All the participants had normal or corrected to normal vision and were native speakers of British English. Participants received a small gift for participating.

2.3.2 *Materials*

Only target pictures with name agreement greater than 70% (using a small sample of 10 subjects) were selected for the experiment, resulting in 16 target pictures matched with 4 types of primes: 1) *semantic coordinates* with bidirectional association (*‘car’* associated to *‘bus’*) and in three pairs unidirectional target-prime association, 2) *parts* with unidirectional (prime-target) association to their target wholes (e.g. given *'seatbelt'* subjects produce *‘car’*), but not vice versa, 3) *parts* with target-prime association (e.g., given *‘car’* participants produce *‘tyre’*), and 4) unrelated primes (*‘book’* – *‘car’*). Nevertheless, every target had primes in four matched conditions: 1) associate-coordinate; 2) part-whole associates; 3) whole-part associates; 4) unrelated (see Appendix D).

Semantic coordination and association were defined as in Experiment 2.1. Overall, parts were selected on the basis of picturability (for use in a parallel experiment using picture primes) and *'part of'* relations to the wholes (e.g., *'tyre'* is a part of *'car')* (see Table 7). The Experiment used an alternating word reading and picture naming paradigm; thus, all the primes were presented as written words and targets were coloured photos. The photos for the experiment were collected from open sources labelled for reuse and modification and adjusted in a way that parts were not visible on a whole.

Table 7. Summary of materials used in Experiment 2.2

Conditions		*Frequency (log)*		*Association*				*LSA*	
				Target-Prime		*Prime Target*			
		mean	*SD*	*mean*	*SD*	*mean*	*SD*	*mean*	*SD*
Target/Whole	*ship*	4.48	0.51	-		-		-	
Associate-coordinate	*boat*	4.36	0.43	0.05	0.12	0.09	0.05	0.47	0.17
Whole-Part association	*anchor*	4.00	0.51	0.04	0.04	0.08	0.17	0.33	0.25
Part-whole association	*deck*	3.71	0.38	0.00	0.00	0.06	0.11	0.33	0.16
Unrelated	*spoon*	4.03	0.46	0.00	0.00	0.00	0.00	0.08	0.10

Note: Frequency - zipfed logged frequency of spoken word; *Target-Prime* - association from the target to the prime*; Prime-Target* - association from the prime to the target; *LSA* - semantic distance according to latent semantic analysis system.

2.3.3 *Design and Procedure*

This experiment consisted of 16 experimental trials with 2x2 cross-factorial Latin-square design; the experimental sets were uniquely randomized for every subject. Every prime was separated from its target with four intervening items that were either stimuli from other trials or fillers and were presented either as written words or coloured photos. Every item appeared in the middle of a screen and had to be read/named aloud. The procedure was the same as in Experiment 2.1.

2.3.4 *Results*

One target *'tulip'* was deleted from the analysis because of an error rate exceeding 25%. The remaining data were subject to the analysis of reaction time and the accuracy of the response.

Analysis of reaction time

Analysis of reaction time of the response was conducted in GNU programming environment R version 3.1.1 (R Development Core Team, 2014) following the same procedure as the analyses in the first experiment. However, this time a simple contrast was applied; that is, +1 for the target condition -1 for the control condition and 0 for all other conditions (see Appendix E). Since, frequency was not matched across conditions, it was used as a random slope for participants to exclude unwanted confounds. As a result of data screening, four data points were excluded as outliers, and R^2 correlation improved from 0.55 to 0.6; thereafter, this dataset was used for further analysis. A summary of the remaining data (15 trials per subject x 32 subjects) is reported in Table 8.

Table 8. Mean reaction times (in ms) and standard deviations (shown in parentheses) by conditions for Experiment 2.2

Reaction time					Errors (%):		
Conditions:	*N*	*Mean RT (in ms)*	*SD*	*Priming*	Primes	Targets	*Total*
+A+C	*99*	*947*	*253*	41	.01	.15	*.16*
Whole-Part Ass	*103*	*894*	*280*	-12	.03	.11	*.14*
Part-Whole Ass	*102*	*915*	*267*	9	.03	.11	*.13*
Unrelated	*103*	*906*	*276*		.03	.10	*.13*

Note: +A +C: +associate +coordinate; *Whole-Part Ass:* whole-part associate; *Part-Whole Ass:* part-whole unidirectional associate; *N* = number of observations in every condition summed across 40 participants; *SD*: standard deviation of the mean reaction time (RT); *Priming:* difference in *RT* compared to unrelated: + slower responses in control condition as compared to unrelated; - faster responses; *Errors*: *Primes*: percentage of incorrect responses to primes; *Targets*: percentage of incorrect responses to targets for which primes were correct; *Total*: percentage of incorrect responses in every condition.

There was a significant main effect of coordination and no effect of parts associated in either direction. Further pair-wise comparison of conditions showed significant interference from semantic coordination relative to parts with whole-part direction of association. However, no effect of coordination was detected when compared to parts with unidirectional part-whole direction of association, nor was there a significant difference between the parts with whole-part predominant association and those with unidirectional part-whole association (see Table 9).

Table 9. Summary of the effect of Associated Coordination, Parts and Frequency on the reaction time of response

Condition	*Analysis of RT*				*CI*	
	coef	*SE*	*z value*	*Pr(>|z|)*	*2.50%*	*97.50%*
	1/RT~Condition +(1+LogFreq|Participant)+(1|item)					
vs. Unrelated						
+A+C	7.78E-05	3.12E-05	**2.47**	**0.01**	6.9E-05	7.0E-05
Whole-Part Ass	9.81E-05	3.13E-05	0.31	0.75	5.5E-06	7.0E-06
Part-Whole Ass	3.36E-05	3.14E-05	1.07	0.28	2.8E-05	2.9E-05
+A+C vs Whole-Part Ass	6.31E-05	3.06E-05	**2.06**	**0.04**	6.3E-05	6.6E-05
Part-Whole Ass vs Whole-Part Ass	2.22E-05	3.06E-05	0.73	0.47	2.2E-05	2.5E-05
+A+C vs Part-Whole Ass	4.09E-05	3.06E-05	1.34	0.18	-1.9E-05	1.0E-04
+A+C vs Whole-Part Ass	-2.22E-05	3.06E-05	-0.73	0.47	-8.2E-05	3.8E-05

Note: +A +C: +associate +coordinate; Whole-Part Ass: whole-part associate; Part-Whole Ass: part-whole unidirectional associate; 1/RT: reciprocated reaction time; se - standard error; CI - confidence interval; N (observations) = 411; n (participants) =32.

Analysis of the accuracy of the response

Analysis of the accuracy of the response was carried out with a generalized linear mixed effect model following a similar procedure to Experiment 2.1 and applying a simple contrast. No significant effects of coordination or parts associated to the whole in either direction were detected (see Table 10).

Table 10. Summary of the effect of Associated Coordination, Parts and Frequency on the accuracy of response

Condition	Analysis of the accuracy of the response			
	coef	*SE*	*z*	*p*
Accuracy~ Condition +(1|Subject)+(1|item)				
+A+C	-0.06	0.36	-0.16	0.87
Whole-Part Ass	0.31	0.37	0.82	0.41
Part-Whole Ass	-0.12	0.35	-0.35	0.72

Note: *+A +C: +associate +coordinate; Whole-Part Ass: whole-part associate; Part-Whole Ass:* part-whole unidirectional associate*; 1/RT:* reciprocated reaction time; *se:* standard error; N (observations) = 512; n (participants) =32.

2.3.5 *Discussion*

The results of Experiment 2.2 showed significant interference from +associate +coordinates, but no effect of parts with either target-prime or unidirectional prime-target direction of association.

Semantic interference from +associate +coordinates was consistent with the results found in Experiment 2.1 as well as with other studies examining this effect in the alternating word reading and picture naming paradigm (e.g., Tree & Hirsh, 2003) and other paradigms (e.g., Abdel Rahman & Melinger, 2007; Alario et al., 2000; Costa et al., 2005).

The absence of an effect of parts conflicts with previous studies that have shown either facilitation (e.g., Costa et al., 2005; Muehlhaus et al., 2012) or interference (e.g., Muehlhaus et al., 2012; Sailor & Brooks, 2014; Vieth et al., 2014). However, it is also possible that parts do produce interference but the effects are too small to be detected in this experiment (maybe because they are too small to be found beyond the 'noise'– variability in responses – that occurs in picture naming). As no previous studies have looked at the effect of parts in the alternating word reading and picture naming paradigm, more studies are needed to ensure that our finding is reliable. Similarly, as we examined the effect of parts at lag 4 only, further studies involving lag manipulations are needed to ensure that this (lack of) priming is not due to a fast decay of any effect (e.g., examining the effect of parts at lag 0). However, the absence of priming from parts associated to the target at lag 4 and its presence for associated coordinates implies that parts and semantic coordinates produce different patterns of priming despite sharing semantic features with the target. So the question arises what can this mechanism be?

Since both parts and coordinates share features and, in this experiment, both were associated to the target, there are two possible accounts. First, it is possible that parts do not share a sufficient number of semantic features to induce interference. Vigliocco, Vinson, Lewis, and Garrett (2004) suggested that semantic interference is a gradual effect that is not restricted to category relationships, but instead reflects the density of featural overlap. If this account is correct, then it is possible that parts do not show interference, because they do not share as many semantic features with the whole as coordinates do (e.g., *'tyre'* shares fewer features with *'car'* than *'bus'*). Similarly, Piai, Roelofs, and Schriefers (2011) and Damian and Spalek (2014) suggested that semantic interference occurs due to competition at the lemma level when a threshold of activation is met. That is, in their account, priming is not 'yes' or 'no' effect, but it is graded depending on the degree to which prime is a lexical competitor to the target. This degree of competition, in turn, reflects the degree of semantic similarity between the prime and a target. If the idea that degree of priming depends on the degree of semantic relatedness is correct, then it is possible that lemma nodes relating to parts do not reach the threshold of activation to be as efficient competitors as coordinates, and therefore do not produce a significant priming effect.

Second, if the priming from parts found previously was driven by association, it is possible that there is no effect at lag 4, because the effect of association is short-lasting and does not persist over lag 0, but as noted above further experiments need to be conducted to test this hypothesis. Further implications of the priming pattern detected in this experiment are discussed in the General Discussion.

2.4 General Discussion

This chapter has reported two experiments that used an alternating word reading and picture naming paradigm to examine the mechanisms underpinning priming of spoken word retrieval from semantic relationships while controlling for association. In Experiment 2.1, we found interference from both association and coordination, but no interaction. There was also no effect of lag, nor any significant interaction between the effects of coordination and association and lag. In a post hoc analysis, we determined that the interference from association was driven by the target-prime direction of association. In Experiment 2.2, which used a prime-target lag of four, we found semantic interference from coordination, but no effect of parts that were associated either to or from the target.

First, the finding of interference from association and no effect of parts challenges the response exclusion hypothesis, because according to this account only potential candidates for responses produce interference. Specifically, interference is argued to be restricted to coordinate primes and all non-categorical relations should produce facilitation. Our finding that functional associates can produce interference in spoken word retrieval directly conflicts with this account.

Second, our finding challenges the lexical competition account (Levelt et al., 1999) that suggests the same pattern of priming from different types of semantic relations; however, this account does not distinguish between semantic relationships and association. In the research presented here, we showed interference from both association and coordination and no interaction between the two, which means that the interference from association and coordination was additive. That is, following Sternberg's (1969) logic, these effects were produced by different mechanisms either at different levels, or by different mechanisms at the same level (Roberts & Sternberg, 1993). There was also no effect of parts. On the one hand, this finding may be compatible with the lexical competition account by showing that a certain degree of semantic similarity is needed for semantic interference to occur (as parts and associates have less semantic overlap with their targets compared to coordinates). However, it remains unclear how lexical competition could account for additive effects from association and coordination.

In addition, although no significant interaction with lag was observed in Experiment 2.1, a separate analysis of the effect of association and coordination at lags 0 and 4 showed significant priming from association at lag 0 and from coordination at lag 4. Since Experiment 2.2 examined lag 4 only, it is possible that parts may prime whole retrieval, but this effect dissipates quickly and is no longer significant at lag 4. Clearly, further research is required to investigate this tentative hypothesis, particularly given that we found no significant interaction with lag.

It also remains unclear whether the swinging lexical network (e.g., Abdel Rahman & Melinger, 2007) could provide an account for our results. According to this account, both semantic and lemma levels are involved in priming. Depending on the task and the degree to which a target competes for selection with the primed distractor this effect can be either facilitatory or inhibitory. Such flexibility of the lexicon allowed Abdel Rahman and Melinger (2007) to account for facilitation from association in picture-word interference and in the first block of the blocked cyclic naming task and interference in later blocks. However, here, we found interference from associates that were presented only once.

We now turn to discussing accounts for effects of each type of semantic relationship in turn.

2.4.1 *Priming from coordination*

In both the two experiments reported here, we observed interference from semantic coordination. This finding replicates previous studies that have examined the effect of semantic coordination in both picture-word interference and overt-production tasks (e.g., Abdel Rahman & Melinger, 2007; Alario et al., 2000; Damian & Spalek, 2014; Tree & Hirsh, 2003). Despite this consistency there is no unified view in the literature as to the mechanism underpinning this priming.

In studies based on picture-word interference tasks, Mahon et al. (2007) attributed semantic interference from coordination to a response exclusion mechanism. However, as discussed above, this position predicts interference for categorical relations and facilitation for non-categorical relations, consequently, this account cannot explain the findings of the research presented here.

The models that potentially could account for interference from coordination both relate to the effects of priming on lexical selection, but do so in different ways, either: 1) competition (Howard, Nickels, et al., 2006), and 2) non-competition (Oppenheim et al., 2010). According to the competition approach, interference from coordination occurs at a post-semantic level either via Luce choice ratio or lateral inhibition (e.g., Howard et al., 2006). Tree and Hirsh (2003), like us, used the alternating word reading and picture naming task, and accounted for interference from coordination via lexical competition. While they attributed this to the Luce choice ratio, their account is also compatible with lateral inhibition as the source of competition.

In the non-competition account, interference results from weakened semantic-to-lemma connections for words semantically related to the primes as well as strengthened connections for the primes (Oppenheim et al., 2010). However, our data cannot distinguish between these accounts.

2.4.2 *Priming from association*

Using the same set of stimuli in picture word interference and blocked cyclic naming tasks, Abdel Rahman and Melinger (2007) found facilitation from association in the picture-word interference paradigm but interference in the semantic blocking task. Given this finding, they suggested that, depending on the task, and the degree of semantic relatedness between the prime and a target, priming results either in facilitation or interference. Facilitation, according to this assumtion, occurs when a prime related to a target activates target but does not create a competitive environment; in contrast, interference occurse if a prime that is related to the target and creates a competing environment at the lemma level. This ‘swinging lexical network’ account may potentially explain both facilitation and interference from both association and coordination as a result of the same mechanism. However, they did not take into account the possibility of an effect of the direction of association. As mentioned in the discussion of Experiment 2.1, Tree and Hirsh (2003) found facilitation from association in an overt production paradigm and attributed this finding to the prime-target direction of association while we observed interference from association driven by target-prime direction of association.

As noted above, the swinging lexical network accounts for faciltation from association as a function of automatic spreading activation at the conceptual level and interference as a function of a lexical competition. Given this account, it should be assumed that facilitation, in Tree and Hirsh's (2003) study, results from automatic spreading activation and interference in the research presented here from lexical competition. However, such an account seems implausible, because both studies used the same paradigm (alternating word reading and picture naming) only differing in the direction of association. Therefore, the degree of lemma activation cannot account for the different polarity of the effect in these experiments. Given this, we suggest that not only the task but also the direction of association can result in a polarity reversal effects of priming.

As association by nature tends to be asymmetric (e.g., Moss et al., 1995; Plaut, 1995), it seems logical that any lateral associative connections are also asymmetric: for example, with prime-target association, activation of the prime will activate the target, but not vice versa. In addition, we also suggest that there are lateral associative connections between the nodes at the lemma level and that these lateral connections may result in interference or facilitation depending on the direction of association. Namely, for prime-target direction of association facilitation may occur, because:

1) when the prime is activated it does not only activate its lemma but also partially pre-activates the target and, therefore, both lemmas are primed,

2) when the target is activated it does not activate the prime (as these are not associated in target-prime direction),

3) consequently the prime is not an effective competitor with the target,

4) the priming (pre-activation) of the target by the prime results in facilitation in comparison to an unrelated prime.

For example, as is shown in Figure 4, if there is an association from a prime *'garage'* to a target *'car',* activation of the lemma of *'garage'* spreads toward, and primes, the lemma of *'car'*. However, if there is no association from *'car'* to *'garage',* they will not compete for selection and will facilitation occur. In comparison, if there is, target-prime direction of association (e.g., *'car'* – *'road'*), activation of a lexical concept *'car'* automatically spreads activation toward *'road'* and may produce facilitation at conceptual level as it was observed in picture-word interference tasks. However, in condition when the lemma of the prime *'road'* is selected prior to activation of lemma *'car'*, interference may occur. This is because activation of lemma *'road'* preactivates lemma *'car'*. Activation of lemma *'car'* also spreads its activation toward *'road'*, but since *'road'* is primed at the time, it becomes stronger competitor and laterally inhibits *'car'*.

In contrast, when there is association from the target to the prime, interference occurs, because:

1) previous retrieval of the prime results in pre-activation (priming),

2) target activation spreads to the already pre-activated prime,

3) the highly activated prime is a strong competitor to the target,

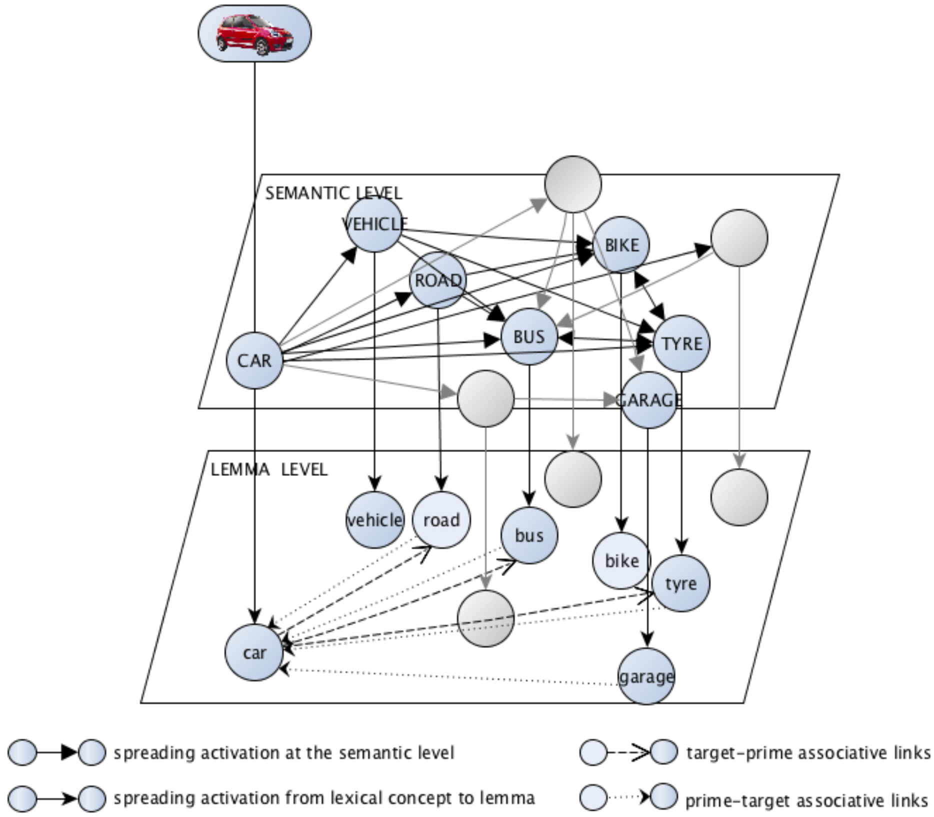


Figure 4. Model of semantic priming

For example, if there is an association from a target *'car'* to the prime *'road'*, activation of *'car'* will spread its activation to *'road'*. Since *'road'* is already primed it will compete more strongly with *'car'* for selection and slow retrieval latencies.

The question arises, however, of how to account for facilitation observed in picture-word interference tasks with target-distractor direction of association. While there is no pre-activation (priming) of the distractor word, under the account above one would predict interference as the target would increase activation of the distractor, indeed one might predict more interference than with a prime-target direction of association. Abdel Rahman and Melinger (2007) accounted for this effect via a swinging lexical network. According to this account, facilitation from target-distractor association in picture-word interference occurs due to spreading activation with no competition and interference in blocked cyclic naming in a strongly competitive environment results from lexical competition. However, no studies, to our knowledge, have examined the effect of direction of association in picture-word interference paradigm by manipulating different types of semantic relations. Therefore, further research is needed to examine whether the direction of association could polarize semantic priming in picture-word interference task.

Additionally, we should draw attention to the interaction of lag with the effects of priming from association. Interestingly, in the majority of studies, priming from association has been described as a short-lasting facilitatory effect. Indeed, in the post-hoc analysis of Experiment 2.1, when examining the effect of lag separately, we found significant interference from association at lag 0 and no effect at lag 4. Similarly, Tree and Hirsh (2003) showed priming (but facilitation) from association at lag 0 and not at lag 2 or lag 4. This might suggest that priming from association is short-lasting and does not persist over time; however, neither Tree and Hirsh (2003) nor our study showed significant interaction between lag and association. That is, neither of our studies could convincingly demonstrate that association produces priming which drastically dissipates at lags greater than zero.

2.4.3 *Priming from parts*

Prior to this study, priming from parts had been examined mainly in picture-word interference tasks, but even in those studies, there was no unified pattern of priming. Costa et al. (2005) found facilitation from parts and attributed this effect to priming at conceptual level. Sailor and Brooks (2014) found interference with the same set of stimuli and attributed it to lexical competition. Muehlhaus et al. (2012) found facilitation from parts in the picture-word interference task but interference in sentence production. However, Vieth et al. (2014) found interference from parts in picture-word interference but only when parts were features shared with other category members. In contrast to these findings, we found no effect of parts. Whether this is because of the different task we used, or because we controlled for association requires further examination. Nevertheless, all the evidence suggests that parts represent an independent type of semantic relation.

Since parts share some semantic features with the target, like coordinates, but do not show the same pattern of priming, we suggest that parts do not share a sufficient number of features to produce priming. This account is compatible with Damian and Spalek (2014) and Roelofs, Piai, and Schriefers (2013) who suggest that a distractor should reach a certain level of activation to produce interference in the picture-word interference task. Moreover, since, in our experiment, parts were associated to the whole, either in part-whole direction of association or vice-versa, but did not produce priming at lag 4, it is possible, that there could be an effect of parts at lag 0. However, the majority of studies interpret priming at lag 0 as one driven by association. Thus, further study is needed to test whether parts would produce priming effects at lag 0 and whether this effect would be significantly different from the (lack of) priming at lag 4.

2.5 Conclusions

Given the pattern of priming from association, coordination and part-whole relations demonstrated in this study, we suggest that association, coordination and part-whole relations differ in their representation and/or organisation.

We assume that interference from both association and coordination occurs by means of competition. Since associative relations refer to within-level asymmetric connections between nodes, interference from these relations occurs due to spreading activation at the lemma level increasing competition at this level. Interference from semantic coordination on the other hand is due to the spread of activation at the semantic level resulting in co-activation of lemmas, once again increasing competition at this level.

In contrast to coordinates, parts share significantly fewer semantic features with the whole and, therefore, their featural overlap with the target does not reach the threshold of activation to produce observable priming.

In summary, the research presented in this Chapter has added to the available knowledge on the range and scope of effects of semantic relations on word retrieval, in conditions when the prime is presented as a written word and a target is presented as a picture. However, as a number of studies have shown that even the same relations may produce different effects in different modalities, it is important to examine the effect of association, coordination and part-whole relations in one more modality to facilitate our understanding of the complex interplay between related words in the lexicon. For the purpose of the research presented here we selected continuous picture paradigm and Chapter 3 addresses this issue.

Chapter 3. Effects of Association, Coordination, and Part-whole primes in the continuous picture naming paradigm

3.1 Introduction

There is a consistent finding in studies of spoken word production that the retrieval of one word may affect the speed and accuracy of later retrieval of a semantically related word (e.g., Alario, Segui, & Ferrand, 2000; Costa, Alario, & Caramazza, 2005; Tree & Hirsh, 2003; Vitkovitch, Cooper-Pye, & Leadbetter, 2006; Wheeldon & Monsell, 1994). The previous chapter focused on the effect of coordinate, associate (functionally related associated members of different semantic categories), and part-whole relations in a paradigm where a prime was presented as a written word and the target was a picture. The purpose of this chapter is to further examine the effect of different semantic relations in a paradigm where both the prime and a target are presented as pictures.

Like the previous chapter, this chapter focuses on examining the effect of coordination, association and part-whole relations. In this regard, *coordination* represents taxonomic relationships between words that coexist at the same level within a semantic category (e.g., *'car*' and *'bus'* belong to the category *'vehicles'*). Associative relations between two words were identified via associative norms (e.g., Nelson et al., 2004; Wilson, n.d.). *Part-whole relationships* represented the subset of feature-whole relationships where the feature was a structural component of a whole (Tversky & Hemenway, 1984) connected via link *'a part of'* (e.g., *'tyre'* and *'seatbelt'* are parts of *'car'*). These relations were associative in target-prime direction of association (e.g., there is an association from a whole *'car'* to its part *'tyre'*) and unidirectional part-target direction of association (e.g., there is an association from part *'seatbelt'* to a whole *'car'* but no association is present from *'car'* to *'seatbelt'*).

In association norms, most (non-coordinate) associates are members of different semantic categories (e.g., *'road'* is associated with *'car'*); hence, in the literature, most of the studies which try to dissociate between semantic coordination and association, are, in fact, focusing more narrowly on the associates that are functionally related members of different semantic categories (e.g., Alario et al., 2000; Tree & Hirsh, 2003). Nevertheless, some studies also include associates that have different semantic relationships to the target; for example, parts, attributes (e.g., Tree & Hirsh, 2003). Some studies also examine the effect of parts that are associated and are not associated to the target. For example, Sailor and Brooks (2014) examined the effect of associated and non-associated parts in the picture-word interference paradigm and found that non-associated parts produced interference on spoken word retrieval. Unlike coordinates and associates, parts have been examined only in paradigms where the prime was a written word and no consistent pattern of priming effects have been found.

3.1.1 *Semantic priming from association and coordination*

To date, the examination of the effects of semantic relationships in picture naming paradigm has been primarily implemented in continuous and blocked cyclic naming tasks. The *continuous picture naming paradigm* involves prime and target pictures presented in a continuous set of pictures where both are named. In these tasks, the interval between the prime and a target can be manipulated; for example, primes can be presented immediately before the target or can be separated with several intervening items. Therefore, in continuous picture naming tasks, the participant is mostly unaware that there are primes and targets or that there is a manipulation of the relationships between pictures (e.g., Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Vitkovitch et al., 2006; Vitkovitch, Rutter, & Read, 2001). These characteristics of continuous picture naming paradigm make it an effective tool for the examination of the mechanisms underpinning semantic priming. However, to date no such studies have, to our knowledge, examined the effect of association and coordination as separate factors on spoken word retrieval.

In *blocked cyclic naming* (e.g., Abdel Rahman & Melinger, 2007; Belke, Meyer, & Damian, 2005; Lee, Schwartz, Schnur, & Dell, 2009), items are usually presented within homogeneous and heterogeneous blocks of pictures to name. *Homogeneous blocks* are blocks of pictures related with the same type of semantic relations (e.g., *'bus', 'car', 'truck', 'motorbike'* etc). *Heterogeneous blocks* are blocks where all the items are unrelated (e.g., *'bus' 'bee', 'knife', 'cup'* etc.).

Abdel Rahman and Melinger (2007) examined the effect of semantic coordination and association in blocked cyclic naming task: Homogeneous blocks contained items that were either associates or coordinates and heterogeneous blocks included unrelated items only. They found that, in the first presentation block, both association and coordination produced facilitation relative to the heterogeneous blocks. In subsequent blocks (2-4), the facilitation that was observed for the first presentation reversed to become interference.

3.1.2 *Lag*

Wheeldon and Monsell (1994) first detected an effect of lag on semantic priming between semantically related words in spoken word retrieval. In particular, they showed a significant effect of lag with responses at lag 2 being significantly slower than at lag 0. Since then, a number of studies focused on semantic priming in spoken word retrieval have included this factor to examine the effect of semantic relations (e.g., Tree & Hirsh, 2003; Vitkovitch, Rutter, & Read, 2001). However, to date, none of these studies observed significant effect of lag. For example, Vitkovitch et al. (2001) examined the effect of coordination at lags 0 and 2 but found no significant effect of lag.

As no studies have examined the effect of different semantic relations in the continuous picture naming paradigm, there are no studies examining the effect of lag between primes and targets related with different semantic relations. However, such studies have been implemented in the alternating word reading and picture naming paradigm. The majority of such studies have found no effect of lag on priming (e.g., Tree & Hirsh, 2003). Nevertheless, there is a consistent finding that associates produce significant priming at lag 0 and coordinates produce significant priming at lags greater than zero (e.g., Tree and Hirsh, 2003). For example, Tree and Hirsh (2003) found no effect of lag, but they found that associates produced stronger facilitatory priming at lag 0 and coordination produced priming at lag 2. In Chapter 2, we detected significant interference from association at lag 0 and interference from coordination at lag 4. However, neither of these studies showed an interaction between the priming effect and lag; therefore, it is not entirely clear how much weight can be put on these patterns.

In sum, the effect of different semantic relations on spoken word retrieval as well as the effect of lag remains under-researched in the continuous picture naming paradigm. Answering this question is important for understanding both the locus and mechanism of priming effects in spoken word retrieval. The research presented here addresses this issue by providing a systematic examination of the effect of different semantic relations on priming of spoken word retrieval.

3.1.3 *Word reading primes vs. picture naming primes*

To date, evidence from picture naming studies using both picture naming and word reading primes has been used to determine the mechanism of semantic priming. While it is assumed that semantic priming in both circumstances is driven by the same mechanism, it is also the case that word reading engages different processes from picture naming (e.g., Coltheart, Rastle, Perry, & Ziegler, 2001). For example, as shown in Figure 5, word reading involves both semantic (Orthographic input lexicon -> lemma -> phonological word form) and non-semantic (Orthographic input lexicon -> phonological word form) routes; in contrast, picture naming relies entirely on the semantic route. Importantly, when the prime is a picture it undergoes the same processing as the target while a written word prime engages only a subset of the same processes which may result in different priming effects.

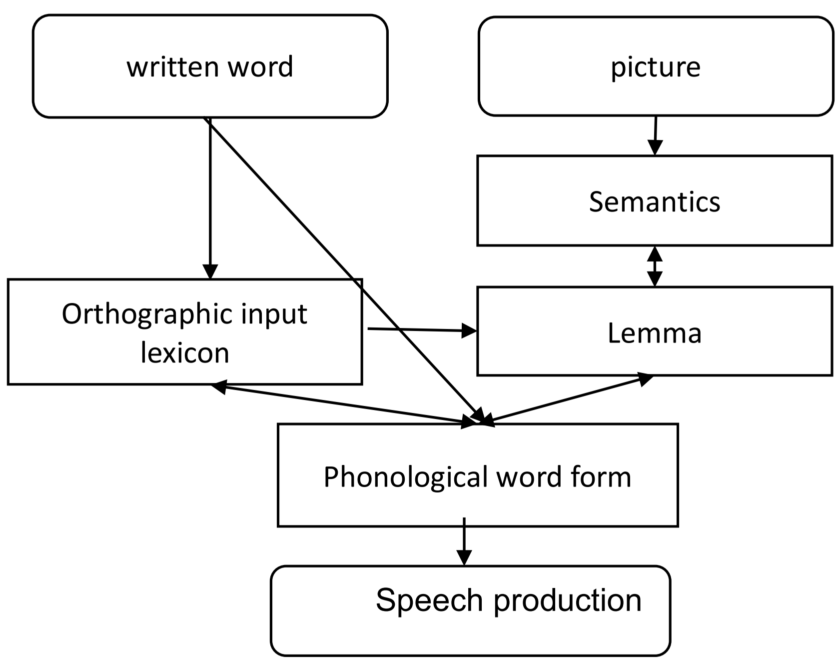


Figure 5. Architecture of spoken word retrieval from written word and a picture adapted from Coltheart et al. (2001) and Howard, Hickin, Redmond, Clark, and Best (2006)

Vitkovitch et al. (2006) explicitly compared priming across modalities using picture naming and word reading primes and targets (and coordinative relationships). They found semantic interference in picture naming from both picture and word primes. In contrast, when targets were words, they showed facilitation from picture primes and no effect when the prime was a written word. Consequently, they concluded that picture naming relies on the semantic route entirely, while word reading involves the semantic route in parallel with other routes (Vitkovitch et al., 2006). Although Vitkovitch et al. (2006) found the same effects on picture naming for picture and word primes, systematic evaluation of the effect of different modalities of primes with different relationships to the target may, nevertheless, be important to ensure full understanding of the locus of semantic priming.

3.1.4 *Locus and mechanism of semantic priming*

In the continuous picture naming paradigm, interference from semantically related primes has been accounted for either with lexical competition (Howard, Nickels, et al., 2006) or without competition (Oppenheim et al., 2010). Below, each account is discussed.

Semantic priming through competition

Howard et al. (2006) argued that competition was a prerequisite to account for semantic interference in word retrieval from semantic coordinates. In this account, priming occurs by strengthening connections between semantic and lemma levels when both are active (Howard et al., 2006). Semantic interference from the previous production of a semantically related item arises through competition for selection between the previously primed lemma node and the lemma node of the targets. Competition has been implemented using the Luce ratio (Levelt et al., 1999; Roelofs, 1992) and by lateral inhibition (Howard et al., 2006) (see Figure 6). According to the *Luce ratio,* the probability of selection of one node is influenced by the activation of that node and the number of other nodes that are active (and the extent of their activation): the stronger the coactivation of competitor lemma nodes the longer it will take to resolve the competition and the slower lexical retrieval will be. When implemented as lateral inhibition, competition occurs through inhibitory links between nodes at the lexical level (e.g., Howard et al., 2006). An activated node will suppress activation of other nodes, the more active a node, the more it will suppress the nodes it is connected to. Howard et al. (2006) simulated inhibitory priming from coordinates in models with both decomposed and non-decomposed semantic representations and showed that the Luce choice ratio as well as lateral inhibition succeed in simulating semantic interference. The critical point for that success was that presentation of the prime (e.g. *'bus'*) results in strengthening of the links between semantic and lemma nodes for this item (priming). For example, in Figure 6, when the target is presented (e.g. *'car'*) activation will also spread to the prime (*'bus'*) because of their shared semantics (Panel 2A: decomposed (featural) semantic representations; Panel 2B non-decomposed semantic representations). As a result of priming from its previous presentation, the prime (*'bike'*) will be more active than usual and thus a stronger competitor which will inhibit the target (*'car'*) resulting in slowed lexical retrieval compared to an unprimed condition.

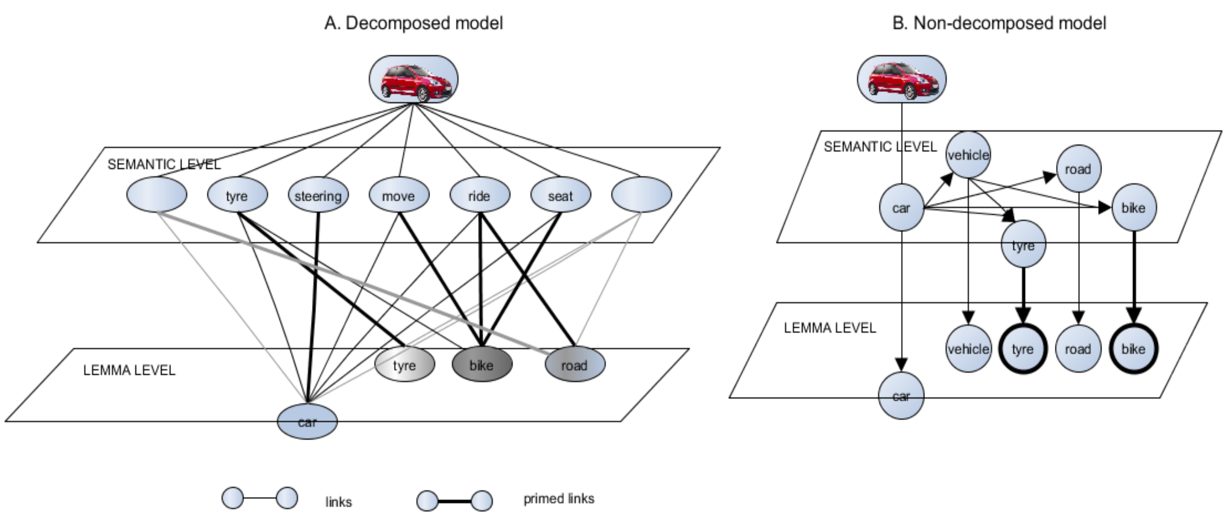


Figure 6. Semantic priming through competition.

Note: Panel A illustrates semantic priming with decomposed (featural) semantics and Panel B with non-decomposed semantics.

Semantic priming without competition

In contrast to Howard et al. (2006), Oppenheim et al. (2010) argued that competition was not necessary to simulate semantic inhibition. In order to achieve this, he implemented priming by not only strengthening the connections between semantic features and selected lemma node but also by weakening the connections between these features and other lemma nodes. For example as is shown in Figure 7, when the word *'bike'* is retrieved, the connections from its semantic features to its lemma are strengthened and connections from these features to other lemmas are weakened. Therefore, subsequent retrieval of a word *'car'* is slower, because its semantic-to-lemma connections are weakened and more time is needed until lemma *'car'* is sufficiently active to be selected.

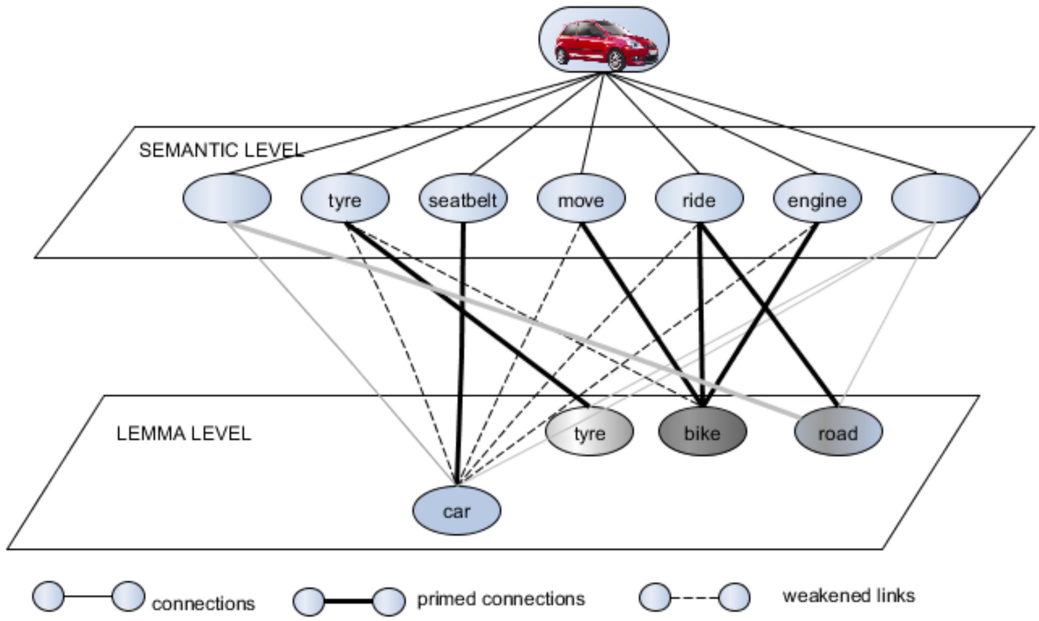


Figure 7. Semantic priming without interference (Oppenheim et al., 2010)

Abdel Rahman and Melinger (2007) detected interference from both associative and coordinate priming in blocked cyclic naming and proposed a 'swinging lexical network' to explain these results. Under this account, associates are organized into contextual networks in the same way as semantic coordinates are organized into semantic categories. In both cases, lexical access occurs by means of spreading activation. At first, the activation spreads at the semantic level and also to the lemma level. The priming that occurs at the semantic level is facilitatory and there is competition at the lemma level leading to inhibitory effects of priming. Therefore, both semantic coordinates and associates can induce both facilitation and interference as a function of the locus of prime activation. Namely, if the prime (an associate or coordinate) is active at the semantic level, then facilitation occurs as a function of automatic spreading activation. However, when the prime is an active competitor at the lemma level (as a result of the context of the task) then interference occurs as a function of lexical competition (see Abdel Rahman & Melinger (2009) for further details). However, under this account the precise effects of a prime depend on the exact context, therefore, it remains unclear whether, in the continuous picture naming paradigm, associates and coordinates will induce the same pattern of priming as is the case in blocked cyclic naming or different patterns of priming as is found in picture-word interference tasks.

More studies on the effect of association and coordination on spoken word retrieval have used picture targets with primes being presented as written words (which are not read aloud). As discussed in Chapter 2, these studies have shown different patterns of association and coordination. For example, Alario et al. (2000), in unmasked priming, found facilitation from associate primes at short stimulus onset asynchrony (SOA) and interference from coordinate primes at long SOAs. Damian and Spalek (2014) manipulated prime masking and found the same pattern in the unmasked condition. However, with masked primes, they found weak facilitation from coordination and no effect of association. Using an alternating word reading and picture naming paradigm (where the participants are not aware of prime/targets status), Tree and Hirsh (2003) showed facilitation from association and interference from coordination. However, Experiment 2.1 reported in Chapter 2 used the same paradigm, and showed interference from both association and coordination.

Priming from parts

Unlike the effect of semantic coordination and association, the effect of parts on spoken word retrieval has been examined, to date, only in paradigms where the prime was presented as a written word. These tasks involve picture-word interference and alternating word reading and picture naming (see Chapter 2 for review). However, no consistent pattern of priming from parts has been detected even within the same paradigm. Depending on the presence of association, the type of part (shared or distinctive feature) and the stimulus onset asynchrony between the presentation of part and whole, priming induced by parts has varied from facilitation to interference.

The studies that observed facilitation from parts have generally accounted for this by means of automatic spreading of activation at the semantic level (e.g. Costa et al, 2000). Costa et al. (2000) detected facilitation from parts that were associated to the target (target-prime direction of association). This, together with the facilitation from associates detected by Alario et al. (2000), led Costa et al. (2000) to argue that semantically related items from different semantic categories can induce only facilitation on spoken word retrieval as they are not potential responses in the task. Critically, however, not all studies have found facilitation from parts in picture-word interference tasks.

The studies that observed semantic interference from parts accounted for this effect as a function of lexical competition. For example, Sailor and Brooks (2014) compared the effect of parts that were or were not associated to the target (target-prime association) at different SOAs and found facilitation from associated parts presented at early SOAs; while, non-associated parts resulted in interference when presented simultaneously with the target. Vieth, McMahon, and de Zubicaray (2014) examined the effect of parts that were shared across a number of items in a category (e.g. *'stomach'* which is shared by *'pig'* with all other animals) or distinctive features of wholes (e.g. *'beard'* which, in the category of animals, is only true of *'goat'*) and found that only shared features produced interference.

However, In Chapter 2, we found semantic interference from association, but no effect of parts in an alternating word reading and picture naming paradigm. This finding showed that not only the type of semantic relatedness and the degree of prime activation are important for semantic priming (as stated by proponents of the swinging lexical network; Abdel Rahman and Melinger, 2007), but also the degree of similarity between the prime and a target. That is, the prime and target need to share a sufficient number of semantic features for semantic priming to occur. Like Muehlhaus et al. (2012), we suggested that associates and parts refer to different types of semantic relations. However, unlike Muehlhaus et al. (2012) we do not have evidence to suggest that priming from associates and parts are underpinned by the same mechanism.

In sum, given the evidence that not only types of relations but also the task may affect priming effects and their polarity (e.g., Abdel Rahman & Melinger, 2007; Damian & Spalek, 2014), it is important to examine the effect of different semantic relations in another paradigm before the firm conclusions can be drawn. Consequently, this study aimed to examine the effect of semantic coordination, association, and part-whole relations on spoken word retrieval when both primes and targets are presented as pictures using two continuous picture naming experiments. Experiment 3.1, focused on the examination of the effect of semantic coordination and association on spoken word retrieval at lags of zero and four intervening items. Experiment 3.2 examined the effect of part-whole relations as compared to associated coordinates with a time window for naming of 4000 ms in Experiment 3.2.1 and 2000 ms in Experiment 3.2.2.

3.2 Experiment 3.1

The goal of this experiment was to examine the effect of semantic coordination and association on priming of spoken word retrieval in a continuous picture naming paradigm. To do so we examined differences between items that belong to the same semantic category and are associated (+associate +coordinate), those that are associated but belong to different semantic categories (+associate -coordinate), items that belong to the same category but are not associated (-associate +coordinate), and unrelated items (-associate -coordinate). As previous studies have demonstrated that the priming effect depends not only on the type of semantic relationship between prime and target but also on the lag between them, we also manipulated lag.

3.2.1 *Participants*

Forty-eight adults (23 males) ranging in age from 18 to 50 years (M= 24.42; SD=6.84) with normal or corrected to normal vision and British English as their native language participated in this experiment.

3.2.2 *Materials*

The experiment used primes that fell into one of four semantic conditions: 1) *+associate +coordinate* (+A+C), 2*) +associate -coordinate (+A-C)*, 3) *-associate +coordinate (-A+C)*, and 4) *-associate -coordinate* (-A-C; unrelated - UNR) and which were presented in two lag conditions: lag 0 and lag 4 (zero or four items intervening between the prime and a target). Stimuli were selected from Chapter 2 (Experiment 2.1) such that a list of 24 targets was obtained with every item being paired with each of the four types of primes (see Appendix A). Coordination was established using a combination of WordNet (Fellbaum, 1998a) and UCREL Semantic Analysis System (USAS) (Rayson, 2008) that allowed selection of coordinate pairs that were both featurally and functionally at the same level within the semantic taxonomy. Association was established from Edinburgh Associative Thesaurus (Wilson, n.d.) as this was the association database that was culturally closest given that the experiment was conducted in northern part of the United Kingdom.

Hence, *+associate +coordinate* pairs were both associates and coordinates; *+associate -coordinate* were functionally related associates from different semantic categories; *-associate +coordinates* were not associated coordinates and *-associate –coordinates* were unrelated items. All the items were coloured photos selected from open sources on the Internet. Every experimental set consisted of 66 pictures with 48 experimental pictures (24 primes and 24 targets) and 16 filler pictures.

3.2.3 *Design*

This experiment followed a 2x2x2 cross-factorial Latin-square design and all the pairs were uniquely randomized per every participant. Hence, every prime-target pair appeared only once per participant and the list of six prime-target pairs appeared in every condition and 3 pairs at each lag (zero and four).

3.2.4 *Procedure*

The experiment was conducted in a quiet room at Newcastle University. Every participant was instructed to name every picture with a single word as rapidly and accurately as possible. There was no familiarisation phase prior to the experiment.

The experiment was programmed in DMDX (Forster & Forster, 2003) and presented on a laptop computer. Presentation of every item was preceded by an alerting cue (five asterisks in the centre of the screen) for 500 ms. The experimental item then appeared in the centre of a computer screen for 2000 ms and was followed by a blank screen for 250 ms before the next trial began automatically. Response latencies to vocal onset were recorded by DMDX’s voice key from the onset of the picture. Once collected, response times (RTs) for correctly named items were manually adjusted using CheckVocal (Protopapas, 2007).

3.2.5 *Results*

Only responses to targets which had correctly named primes were included in the analysis. In responses to targets, only responses named with the target word at the first attempt and within 2000 ms were considered correct. No alternatives were accepted as they could have different psycholinguistic properties and relationships with the primes. In addition, items were only considered correct and included in the analysis if the participant had correctly named its prime.

Prior to the analysis, RT was reciprocally transformed[9] (Box & Cox, 1964) using the MASS package (Venables & Ripley, 2003) in GNU programming environment R version 3.1.1 (R Development Core Team, 2014). Contrast coding was applied to factors (for details of contrast coding, see Appendix C) and statistical analysis was carried out with a linear mixed effect model in the *lme4* package, version 1.1-7 (Bates et al., 2014). 1/RT was the dependent variable with semantic coordination, association, lag, and their interactions as fixed effects and participants and items as random intercepts[10]. Based on the model outputs, responses were trimmed within 2.5 standard deviations (Baayen & Milin, 2010) and 11 (0.01%) data points were removed from the data. Model criticism showed that this fitting improved the model R^2 from 0.48 to 0.53 and these trimmed data were used for both descriptive and statistical analysis.

Table 11 summarizes the results of descriptive analysis which includes mean reaction time of correct responses per every condition and lag, priming and percentage of errors made in every condition.

[9] As reaction time is continuous positively skewed dependent variable, it is important to screen its distribution for normality. Transformation of RT is usually applied when minimal λ in normality screening is below -1.

[10] Random slopes for subjects were not be included in the model as it failed to converge under these conditions.

Table 11. Summary of mean reaction time and accuracy of the responses in Experiment 3.1

Reaction time					Errors (%):		
Conditions:	*N*	*Mean RT (in ms)*	*SD*	*Priming*	Primes	Targets	*Total*
+A+C	*192*	*970*	*247*	*+28*	*.20*	*.09*	*.29*
+A-C	*168*	*911*	*239*	*-32*	*.29*	*.08*	*.38*
-A+C	*180*	*913*	*232*	*-30*	*.24*	*.10*	*.33*
UNR(-A-C)	*223*	*943*	*269*		*.09*	*.09*	*.18*
lag 0							
+A+C	*101*	*946*	*237*	*+19*	*.22*	*.07*	*.28*
+A-C	*81*	*906*	*227*	*-21*	*.28*	*.09*	*.38*
-A+C	*88*	*884*	*220*	*-43*	*.24*	*.10*	*.34*
UNR(-A-C)	*108*	*927*	*259*		*.08*	*.11*	*.19*
lag 4							
+A+C	*91*	*998*	*256*	*+40*	*.18*	*.13*	*.31*
+A-C	*87*	*916*	*251*	*-41*	*.30*	*.10*	*.40*
-A+C	*92*	*939*	*240*	*-18*	*.23*	*.11*	*.34*
UNR(-A-C)	*115*	*957*	*278*		*.10*	*.08*	*.18*

Note: *+A+C*: +associate +coordinate; *+A-C*: +associate -coordinate; *-A+C*: -associate +coordinate; *-A-C/UNR*: unrelated; *N* = number of observations in every condition summed across 48 participants; *SD*: standard deviation of the mean reaction time (RT); *Priming*: difference in *RT* compared to unrelated - + slower responses in control condition as compared to unrelated; - faster responses; *Errors*: *Primes*: percentage of incorrect responses to primes; *Targets*: percentage of incorrect responses to targets for which primes were correct; *Total*: percentage of incorrect responses in every condition.

A summary of the effects in the combined +*association* (+A+C and +A-C) condition relative to the -*association* (-A+C and -A-C/UNR) condition across lags shown in Figure 8 A. Similarly, Figure 8 B illustrates the pattern for combined +coordination (+A+C and -A+C) and -coordination (+A-C and -A-C/UNR) conditions at lags of zero and four intervening items. As shown in Table 11, the mean reaction times of association with no coordination (+A-C) as well as coordination with no association (-A+C) were facilitatory, but when taken together (+A+C) the reaction time of response reversed to interference. However, when contrasted (see Appendix C), the mean reaction time from Association was inhibitory at lag 0 and no different from grand mean at lag 4 (see Figure 8); in contrast, mean reaction time from Coordination was inhibitory at lag 4 and no different from grand mean at lag 0 (see Figure 8). It should also be noticed also that, the error rate in all three related conditions was higher than the unrelated condition but only for the prime pictures.

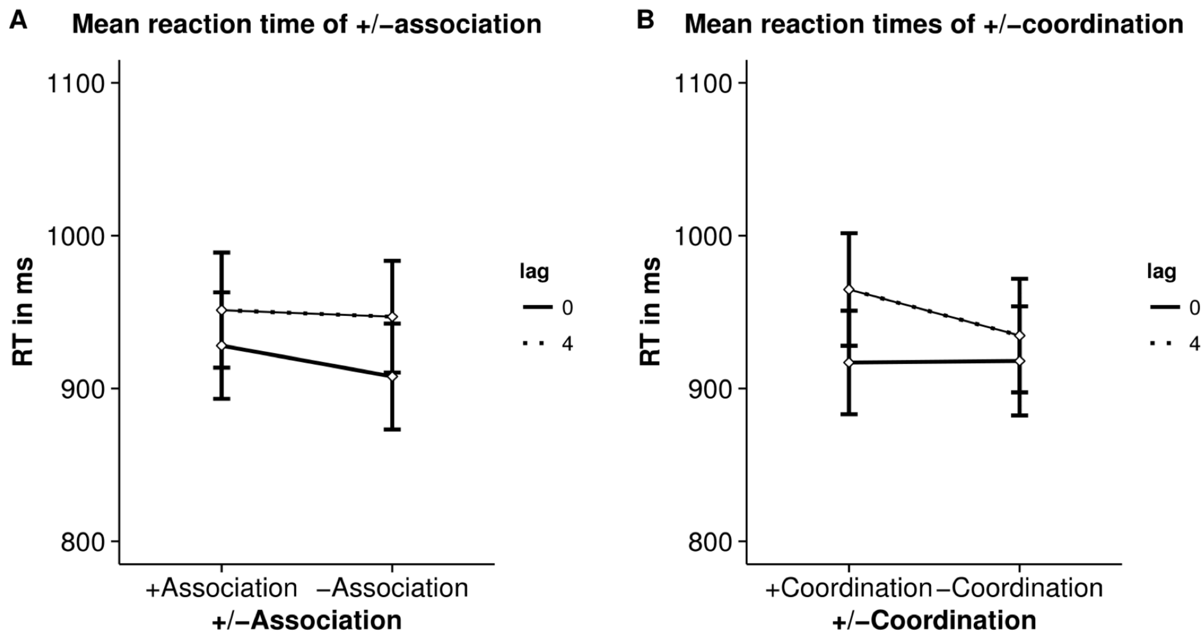


Figure 8. Mean reaction time for +/-association (Panel A) and +/-coordination (Panel B) and at lags 0 and 4.

Note: Error bars represent 2.5 standard error from the mean

Analysis of Reaction time

Statistical analysis of reaction time was carried out with linear mixed effect modelling following the procedure described above and a summary of the results is shown in Table 12. There was a significant effect of lag with responses being slower at lag 4 relatively to lag 0. There was significant interference from the interaction of association and coordination ($p < .01$) and close to significant an interaction between coordination and lag[11]. Given this, and the claims in the literature of different effects at

[11] It should be noted that while the interaction between coordination and lag was only marginally significant in this analysis, when fitted within 2.5 sd. When data were not fitted, or when fitted with 2sd there was a significant interaction between coordination and lag, and in the analyses at each lag there was a significant effect of coordination at lag 4 (See Appendix F for more details).

lag 0 and lag 4 (e.g., Wheeldon & Monsell, 1994), we also carried out separate analyses of the effects of association and coordination at lags 0 and lag 4 and detected significant interference from association at lag 0 (p=.04), and interference from coordination at lag 4 (p= .04). For coordination, this effect was driven by the interaction of association and coordination; that is both some portion of association and coordination were needed for semantic priming to occur. In case of association the interaction approached but did not reach significance (p= .05).

Table 12. Summary of the effect of +Coordination, +Association, lag and their interaction on mean RT of response

Condition	*Analysis of reaction time*				*CI*	
	coef	*se*	*z score*	*Pr(>|z|)*	2.50%	97.50%
Overall	*1/RT~Condition +(1|Participant)+(1|item)*					
Association	3.10E-05	1.45E-05	**2.14**	**0.03**	2.69E-06	5.93E-05
Coordination	2.18E-05	1.46E-05	1.49	0.14	-6.71E-06	5.03E-05
lag	4.50E-05	1.45E-05	**3.11**	**0.00**	1.67E-05	7.32E-05
*Assoc*Coord*	4.58E-05	1.46E-05	**3.14**	**0.00**	1.73E-05	7.43E-05
*Association*lag*	-1.84E-05	2.88E-05	-0.64	0.52	-7.47E-05	3.78E-05
*Coordination*lag*	5.25E-05	2.90E-05	*1.81*	*0.07*	-4.22E-06	1.09E-04
*Assoc*Coord* lag*	1.82E-06	2.90E-05	0.06	0.95	-5.49E-05	5.85E-05
lag 0						
Association	4.30E-05	2.12E-05	**2.03**	**0.04**	1.42E-06	8.46E-05
Coordination	-7.08E-06	2.12E-05	-0.33	0.74	-4.86E-05	3.45E-05
*Assoc*Coord*	4.18E-05	2.13E-05	*1.96*	*0.05*	1.04E-07	8.34E-05
lag 4						
Association	2.09E-05	2.04E-05	1.03	0.31	-1.91E-05	6.08E-05
Coordination	4.33E-05	2.09E-05	**2.07**	**0.04**	2.42E-06	8.43E-05
*Assoc*Coord*	5.09E-05	2.08E-05	**2.45**	**0.01**	1.02E-05	9.15E-05

*Note: * interaction; 1/RT - reciprocated reaction time; se - standard error; CI - confidence interval;* ***BOLD*** *font indicates a significant result (Pr(>|z|) at p<.05); ITALIC font indicates a trend (Pr(>|z|) <.1);* N (observations) =764; n (participants) =48.

Analysis of the accuracy of the response

This analysis included only those items where the prime was correctly named. The analysis was carried out with a generalised linear mixed effects model of family binomial in the *lme4* package, version 1.1-7 (Bates et al., 2014). Contrast coding was applied to every condition (details of contrasts are reported in Appendix C) and results of the analysis are reported in Table 13. As is seen from Table 13, there were no significant effects on the accuracy of the response.

Table 13. Summary of the effect of +Coordination, +Association, lag and their interaction on the accuracy of response

Condition	*Analysis of the accuracy of the response*			
	coef	*se*	*z score*	*Pr(>|z|)*
Overall	*Accuracy~Condition*lag +(1|Subject)*			
Association	-0.06	0.23	-0.24	0.81
Coordination	0.13	0.23	0.59	0.56
lag	-0.05	0.23	-0.21	0.83
*Assoc*Coord*	-0.15	0.23	-0.64	0.52
*Association*lag*	0.51	0.46	1.12	0.26
*Coordination*lag*	0.60	0.46	1.30	0.19
*Assoc*Coord*lag*	0.14	0.46	0.30	0.77
lag 0				
Association	-0.18	0.30	-0.62	0.53
Coordination	-0.16	0.30	-0.55	0.59
Assoc+Coord*	-0.23	0.30	-0.78	0.43
lag 4				
Association	0.22	0.33	0.68	0.50
Coordination	0.46	0.33	1.40	0.16
*Assoc*Coord*	-0.10	0.33	-0.30	0.77

Note: Conditions are combined: *Association* (+associate +coordinate and associate -coordinate); *Coordination* (+associate +coordinate and -associate +coordinate); *Assoc*Coord* (+associate +coordinate and -unrelated); * interaction; *1/RT* - reciprocated reaction time; *se* - standard error; N (observations) = 917; n (participants) =48.

3.2.6 *Discussion*

The goal of Experiment 3.1 was to examine the effect of association and coordination on spoken word retrieval in the continuous picture naming paradigm at lags of zero and four intervening items. The results showed significant interference from association, but this effect was driven by the interaction of association and coordination: targets that were both associates and coordinates (+A+C) showed slower naming than unrelated items; whereas targets that were either associates or coordinates, but not both (-A+C, +A-C), showed faster naming.

There was also a significant effect of lag with responses at lag 4 being significantly slower than at lag 0. A separate analysis of the effect of association and coordination at each lag showed significant interference from association at lag 0. At lag 4, there was significant interference from coordination, driven by its interaction with association.

The pattern of priming in this naming task was slightly different from the alternating word reading and picture naming paradigm used in Chapter 2 that showed significant interference from both association and coordination, no effect of lag and no interaction. In contrast, here, in continuous picture naming, an effect of lag was observed with responses at lag four being significantly slower than at lag zero. Likewise, significant interference was observed from coordination and association driven by the interaction of association and coordination. However, when separated, neither association nor coordination produced significant interference; moreover, as noticed above, the mean reaction time in each of those conditions was facilitatory as compared to the unrelated condition. But once again, neither of these differences were significant so any speculations concerning the mechanisms that could potentially underpin such a facilitation should be treated with caution.

In Chapter 2, we found significant interference from primes with bidirectional association to targets, but no effect from primes with unidirectional prime-target direction of association. Consequently, we also examined the effect of direction of association here, in the continuous picture paradigm. To do so, as in Chapter 2, we examined the effect of association from two associate conditions (+A+C and +A-C) by dividing them into: 1) bidirectional association, 2) unidirectional association as compared to the non-associated condition that comprised of two non-associated conditions (-A+C, -A-C). This analysis was carried out with a minimal linear mixed effect model, reaction time was reciprocated, and simple contrast coding was applied to a three-level factor[12] (+1 for condition of interest, -

[12] To examine the effect of direction of association, a three-level factor was coded: 1) *bidirectional* factor included all the items that were associated to the target in target-prime and prime-target direction of association; 2) *unidirectional* factor – that included all the items that were unidirectionaly associated to the target with prime-target direction of association; 3) *none* (control) – factor that involved all the items that were not associated to the target.

1 for control condition, and 0 for the other condition). Results of this analysis are reported in Table 14 and as is seen from the table neither direction reached significance. However, an inhibitory trend was shown for the bidirectionally associated primes and this trend was stronger at lag 0.

Table 14. Summary of the effect of Bidirectional association, Unidirectional association, lag and their interaction on the reaction time of response

Condition	*Analysis of reaction time*				*CI*	
	coef	*SE*	*z*	*p*	2.50%	97.50%
Overall	*RecRT~Association +(1|Subject)+(1|item)*					
Bidirectional	3.42E-05	1.80E-05	*1.89*	*0.06*	-1.12E-06	6.94E-05
Unidirectional	-1.54E-05	2.80E-05	-0.55	0.58	-7.02E-05	3.93E-05
lag	5.48E-05	1.89E-05	**2.90**	**0.00**	1.78E-05	9.17E-05
*Bidirectional*lag*	-2.43E-05	3.56E-05	-0.68	0.50	-9.38E-05	4.52E-05
*Unidirectional*lag*	9.50E-05	5.19E-05	*1.83*	*0.07*	-6.58E-06	1.96E-04
lag 0						
Bidirectional	4.75E-05	2.61E-05	*1.82*	*0.07*	-3.85E-06	9.87E-05
Unidirectional	-5.14E-05	4.00E-05	-1.29	0.20	-1.30E-04	2.67E-05
lag 4						
Bidirectional	2.16E-05	2.59E-05	0.83	0.41	-2.92E-05	7.22E-05
Unidirectional	-1.47E-06	4.08E-05	-0.04	0.97	-8.13E-05	7.84E-05

Note: Bidirectional : target-prime and prime-target association ; Unidirectional: prime-target association only; RT fitted within 2.5 sd; BOLD: significant results (p<.05); Italic: trend (p<.1); N (observations) = 764; n (participants) =48.

In sum, there were different patterns of priming in continuous picture naming as compared to the alternating word reading and picture naming paradigm. This difference in results shows that the nature of priming from association and coordination does not only depend on the type of semantic relations, but also on the task to be performed. If we consider the processing requirements of the tasks, picture naming relies only on the semantic lexical route in comparison to word reading that engages both semantic and non-semantic lexical routes. Given this, the finding of different patterns from word and picture primes enables us to better localise the sources of priming effects. For example, stronger involvement of semantic-lexical route may decrease the impact of lateral activation at the lemma level and this may be the reason why no significant effect of bidirectional association was found in the continuous picture naming paradigm. The further implication of these results are discussed in the General Discussion.

In order to extend our understanding of the role of different types of semantic relation on priming, Experiment 3.2 examined the effect of part-whole relations and direction of association as compared to associated coordinates.

3.3 Experiment 3.2

The goal of this experiment was to examine the effect of picture naming of coordinate or part primes on spoken word retrieval, while controlling for association and its direction, and when the prime is separated from its target by four intervening items.

3.3.1 *Experiment 3.2.1*

Participants

Forty participants (14 male), mean age 24.00 years (sd=5.35), with normal or corrected to normal vision and British English as their native language took part in this experiment.

Materials

This experiment included 16 experimental targets used in Experiment 2.2 in Chapter 2 with every target being paired with four types of primes: 1) *+associate +coordinate*, 2) *whole-part associate,* 3) *part-whole associate,* 4) *unrelated (-associate -part -coordinate)*. *+Associate +coordinate* primes were coordinated and had bidirectional association between target and prime. *Whole-part associate* primes were parts with association from the target (whole) to the prime (part) (6 pairs also were prime-target associated). *Part-whole associate* primes were parts with unidirectional association from prime to the target. Semantic coordination was established using a combination of cohyponyms in WordNet (Fellbaum, 1998a) and UCREL Semantic Analysis System (Rayson, 2008) that allowed selection of coordinates that were featurally and structurally similar. Association was defined using the Edinburgh Association Thesaurus (Wilson, n.d.). Parts were selected on the basis of picturability and ‘part of’ relations.

All the items were coloured photos selected from open Internet sources. The photos were adjusted in a way that wholes were not visible on parts and parts were not visible on wholes (see Figure 9).

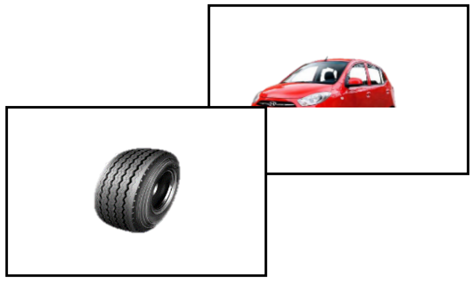


Figure 9. Stimulus picture example showing adjustment such that parts used as primes are not visible on wholes.

Design

The experiment included 16 pairs with 2x2 cross factorial Latin-square design with every prime-target pair being separated by 4 intervening items and uniquely randomized per participant. Thus, every target appeared only once per participant.

Procedure

This experiment was programmed and run in DMDX (Forster & Forster, 2003) in a quiet room at Newcastle University. Since this experiment included adjusted pictures (cropped parts or wholes with excluded parts), the pilot experiment was run with 6 participants using the same 2000ms timeout and automatic progression as in Experiment 3.1 (2000 ms). Given the high error rate in naming and recommendations from participants to increase the time window available for the response, the time frame was increased to 3000ms and tested with other 6 volunteers. These participants also recommended an increased time window, thus a 4000 ms timeout was selected for the experiment.

In the final version, therefore, presentation of every item was preceded by fixation time of 500 ms presented with asterisks in the centre of the screen, followed by a blank screen for 250 ms and item remaining on a screen for 4000 ms. RTs were recorded by DMDX voice key from the onset of the picture. Responses were checked with CheckVocal application to DMDX (Protopapas, 2007).

Results

Only responses correctly retrieved from the first attempt and no-alternatives were accepted, as the alternatives used did not fit the matching criteria for association (e.g., production of *'coach'* for the target *'bus'* would be coded as an error). Prior to analysis, RT was reciprocally transformed following the same procedure as in Experiment 2.1. Data were trimmed within 2.5 standard deviations, as a result, three data points were excluded as outliers and R^2 improved from 0.46 to 0.53. The results are summarised in Table 15.

Table 15. Mean reaction times (in ms) and standard deviations (shown in parentheses) by conditions of Experiment 3.2.1

Reaction time					*Errors (%):*		
Conditions:	*N*	*Mean RT (in ms)*	*sd*	*Priming*	Primes	Targets	*Total*
+A+C	*133*	*1074*	*376*	+48	.01	.15	*.16*
Whole-Part Ass	*92*	*1049*	*383*	+23	.03	.20	*.23*
Part-Whole Ass	*117*	*1079*	*357*	+53	.03	.11	*.13*
Unrelated	*144*	*1026*	*329*		.03	.10	*.13*

Note: +A +C: +associate +coordinate; *Whole-Part Ass:* whole-part associate; *Part-Whole Ass:* part-whole unidirectional associate; *N* = number of observations in every condition summed across 40 participants; *SD:* standard deviation of the mean reaction time (RT); *Priming:* difference in *RT* compared to unrelated: +slower responses in control condition as compared to unrelated; faster responses; *Errors*: *Primes:* percentage of incorrect responses to primes; *Targets:* percentage of incorrect responses to targets; *Total:* percentage of incorrect responses in every condition.

Statistical analysis of reaction time was carried out using a linear mixed effect model applying simple contrast to conditions (see Table 16) and scaling frequency[13]. Since the distractors in each condition were not matched for frequency, log frequency of spoken word selected from SUBTLEX was added as a random slope for participants. There were no significant effects of any condition (see Table 16).

[13] Since Frequency is a continuous variable, scaling was applied to centre the intercept around zero.

Table 16. Summary of the effects of Associate Coordinates and Parts on reaction time

Condition	*Analysis of RT (4 sec)*				*CI*	
	coef	*SE*	*z value*	*Pr(>|z|)*	*2.50%*	*97.50%*
			1/RT~Condition +(1+LogFreq|Participant)+(1|item)			
vs. Unrelated						
+A+C	2.82E-05	2.45E-05	1.152	0.249	-3.86E-05	6.43E-05
Whole-Part Ass	-8.91E-06	2.74E-05	-0.326	0.745	-6.48E-05	3.41E-05
Part-Whole Ass	1.53E-05	2.52E-05	0.605	0.545	-8.06E-05	3.23E-05
+A+C vs Whole-Part Ass	1.29E-05	2.63E-05	0.493	0.622	-3.86E-05	6.43E-05
Part-Whole Ass vs Whole-Part Ass	-2.42E-05	2.88E-05	-0.839	0.401	-8.06E-05	3.23E-05
+A+C vs Part-Whole Ass	3.72E-05	2.80E-05	1.328	0.184	-1.78E-05	9.18E-05

Note: +A +C: +associate +coordinate; Whole-Part Ass: whole-part associate; Part-Whole Ass: part-whole unidirectional associate; 1/RT - reciprocated reaction time; se - standard error; CI - confidence interval; N (observations) = 463; n (participants) =40.

Statistical analysis of accuracy was carried out with generalised linear mixed effect model of family binomial applying simple contrast as in the analysis of reaction time. In result, no significant effect of associated coordinates and parts associated to the whole in either direction were observed (see Table 17).

Table 17. Summary of the effect of Associate Coordinates and Parts on the accuracy of response

Condition	*Analysis of Accuracy (4 sec)*			
	coef	*SE*	*z value*	*Pr(>|z|)*
Accuracy~Condition +(1+LogFreq|Participant)+(1|item)				
vs. UNR				
+A+C	0.220	0.465	0.473	0.636
Whole-Part Ass	-0.027	0.419	-0.065	0.948
Part-Whole Ass	0.007	0.441	0.015	0.988
+A+C vs Whole-Part Ass	-0.034	0.449	-0.076	0.939
Part-Whole Ass vs Whole-Part Ass	0.213	0.488	0.437	0.662
+A+C vs Part-Whole Ass	-0.247	0.470	-0.525	0.599

Note: *+A +C:* +associate +coordinate; *Whole-Part Ass:* whole-part associate; *Part-Whole Ass:* part-whole unidirectional associate; *1/RT:* reciprocated reaction time; *SE:* standard error; N (observations) = 541; n (participants) =40.

Discussion

We found no effects of any of the prime conditions on either speed or accuracy of response in this experiment. A possible reason for this null result could be the time window used for this experiment. In contrast to two seconds allotted for the response in Experiment 3.1, a four second time out was used in this experiment. Therefore, it is possible that participants could have developed a slow response pace and consequently sensitivity to semantic priming may have been lost. Indeed, the responses were around 101 ms slower on average for the +A+C condition in Experiment 3.2.1 compared to Experiment 3.1.

To exclude the possibility that the long-time window affected the pattern of results, we repeated the experiment with a reduced time window. In addition, a thorough examination of the responses showed a tendency among participants to name parts with their wholes. Consequently, we also added a practice phase where feedback was provided.

3.3.1 *Experiment 3.2.2*

The goal of this experiment was to examine whether unexpected results obtained in Experiment 3.2.1 resulted from methodological constraints or was a replicable pattern.

Participants

Thirty-two native speakers of British English mean age 24.1 years (sd = 5.3) with normal or corrected to normal vision took part in this experiment.

Material

The same material was used as in Experiment 3.2.1 with the addition of 2 practice pairs with one item being a part and the other one being a whole (e.g., picture of *'comb'* and *'chicken'*) and 8 other items as fillers.

Design and Procedure

This experiment followed 2x2 cross factorial Latin Square design in the same way as Experiment 3.2.1: all the pairs were randomized for every participant and every prime was separated from its target with four intervening items. However, there were changes to the procedure: practice, timing, and progression. Given the high error rate observed in Experiment 3.2.1, Experiment 3.2.2 started with a short practice phase before the main experiment. As previously, participants were instructed to name the picture as quickly and accurately as possible with a single word. During the practice phase, practice items (parts, e.g. '*comb*' and wholes, e.g. *'chicken'*) were given consecutively in pairs. If the response to both pictures was the same (e.g. *'chicken'),* participants were stopped and asked whether these two pictures were identical and reminded to name exactly what was shown on the computer screen. This was followed by one more practice pair (e.g., *'handle'* and *'saucepan'*) and a set of 8 more fillers with randomly assigned part or coordinate primes were presented for naming before the main experiment started. Neither of the training pairs presented during the practice phase was presented during the main experiment.

Another modification in this experiment was a shortening of time window allotted for the response from four seconds to two seconds and substituted automatic progression with manual progression. Thus, every item remained on the screen for 2 seconds, once time allotted for the response expired the picture disappeared from the screen and the blank screen remained until the participant pressed the space bar to move on to the next item. Given these modifications, the responses to primes were considered correct if they were retrieved correctly before or after 2 seconds (as we were not interested in latencies of primes), but responses to targets were considered correct only if they were retrieved before 2 seconds (as latencies could not be recorded over 2 seconds).

Hence, presentation of every item was preceded by fixation of asterisks in the centre of the screen for 500 ms, followed by a blank screen for 250 ms, then the stimulus picture for 2000 ms followed by a blank screen. The space bar was used to move on to the next item. RTs were recorded by DMDX's voice key from the onset of the picture. Response times for correctly retrieved items were manually checked using CheckVocal (Protopapas, 2007).

Results

Prior to the analysis, RT was checked for the normality of the distribution using the Box and Cox (1964) function. Since λ was around 0 no inversion was applied, instead, RT was logged for further analysis. Data were trimmed with 2.5 sd following the same procedure as in Experiment 3.2.1 and 4 data points were excluded. This trimming improved R^2 from 0.45 to 0.51, so these data were used for both descriptive and statistical analysis. A summary of data is reported in Table 18.

Table 18. Mean reaction times (in ms) and standard deviations (shown in parentheses) by conditions for Experiment 3.2.2

Reaction time					*Errors (%):*		
Conditions:	*n*	*Mean RT (in ms)*	*SD*	*Priming*	*Primes*	*Targets*	*Total*
+A+C	*69*	*1279*	*344*	+127	.05	.20	*.23*
Whole-Part Ass	*72*	*1209*	*362*	+57	.02	.15	*.19*
Part-Whole Ass	*64*	*1161*	*296*	+9	.07	.18	*.07*
Unrelated	*83*	*1152*	*283*		.00	.18	*.00*

Note: +A +C: +associate +coordinate; *Whole-Part Ass:* whole-part associate; *Part-Whole Ass:* part-whole unidirectional associate; *N* = number of observations in every condition summed across 40 participants; *SD*: standard deviation of the mean reaction time (RT); *Priming:* difference in *RT* compared to unrelated - + slower responses in control condition as compared to unrelated; - faster responses; *Errors*: *Primes*: percentage of incorrect responses to primes; *Targets*: percentage of incorrect responses to targets; *Total*: percentage of incorrect responses in every condition.

Statistical analysis of reaction time and accuracy of the response were implemented following the same procedure as in Experiment 3.2.1 and using the same predictors, random intercepts, and slopes.

The analysis of reaction time showed significant interference from +associate +coordinate as compared to unrelated primes and compared to both parts primes conditions (see Table 19). No significant effects of parts primes associated in either direction were detected.

Table 19. Summary of the effect of Associate Coordinates and Parts on reaction time

Condition	*Analysis of RT*				*CI*	
	coef	*SE*	*z value*	*Pr(>|z|)*	*2.50%*	*97.50%*
	1/RT~Condition +(1+LogFreq|Participant)+(1|item)					
vs. UNR						
+A+C	0.093	0.034	**2.726**	**0.006**	0.026	0.161
Whole-Part Ass	0.024	0.034	0.706	0.480	-0.043	0.091
Part-Whole Ass	-0.015	0.035	-0.430	0.667	-0.084	0.054
+A+C vs Whole-Part Ass	0.070	0.035	**1.971**	**0.049**	-0.001	0.140
Part-Whole Ass						
vs Whole-Part Ass	-0.039	0.037	-1.052	0.293	-0.112	0.035
+A+C vs Part-Whole Ass	0.108	0.037	**2.914**	**0.004**	0.035	0.182

Note: +A +C: +associate +coordinate; Whole-Part Ass: whole-part associate; Part-Whole Ass: part-whole unidirectional associate; 1/RT - reciprocated reaction time; se - standard error; CI - confidence interval; N (observations) = 288; n (participants) =32.

Analysis of the accuracy of the response showed no significant effects of any prime condition (see Table 20).

Table 20. Summary of the effect of Associate Coordinates and Parts on the accuracy of response

Condition	*Analysis of Accuracy (2 sec)*			
	coef	*SE*	*z value*	*Pr(>|z|)*
1/RT~Condition +(1+LogFreq|Participant)+(1|item)				
vs. UNR				
+A+C	-0.537	0.357	-1.506	0.132
Whole-Part Ass	0.114	0.375	0.304	0.761
Part-Whole Ass	-0.436	0.359	-1.214	0.225
Part-Whole Ass				
vs Whole-Part Ass	-0.651	0.359	-1.812	0.070
+A+C vs Part-Whole				
Ass	-0.550	0.360	-1.530	0.126
Whole-Part Ass	-0.247	0.470	-0.525	0.599

Note: *+A+C:* associate-coordinate; *WPA:* parts with target-prime association; *PWA:* parts with prime-target association; N (observations) = 433; n (participants) =32.

Discussion

The goal of Experiment 3.2.2 was to examine whether the time window allotted for the response affected the pattern of semantic priming found in spoken word retrieval. The results showed interference in picture naming for target picture naming following naming of +associate +coordinate primes and no effect from part primes associated with the target in either direction. Although no significant effect of +associate +coordinate primes was found in Experiment 3.2.1, the direction of the effect was the same as in this experiment. This effect is also consistent with other studies showing semantic priming from +associate +coordinates in picture naming subsequent either to picture or word primes (e.g., Vitkovitch et al., 2006).

As we found a significant effect in this experiment, it is clear that our adjusted pictures were not the source of the failure to find a significant effect in Experiment 3.2.1. However, it seems that perhaps the shorter time window and practice phase in Experiment 3.2.2 may have had an influence as the effect of associate coordinate primes was only significant in this experiment. However, further investigation is needed to examine in greater detail the influence of pacing on priming.

The finding of no effect of part primes associated to the target in either direction shown in this experiment is consistent with Experiment 3.2.1 and with Chapter 2 where parts were presented as written words. Given the priming from associate coordinates but no such effect from parts associated to targets in either direction, we suggest that coordination and part-whole relations are most likely represented differently. The mechanisms for and implications of these results are further discussed in the General Discussion.

3.4 General Discussion

This chapter reported two experiments that were conducted to examine the effects of primes with association, coordination, and part-whole relations on spoken word retrieval in the continuous picture naming paradigm. Experiment 3.1 examined the effect of association and coordination at lags 0 and 4 and revealed significant interference from association driven by the interaction of association and coordination. A significant effect of lag was found with responses at lag 4 being slower than at lag 0.

Separate analysis of responses at lag 0 and 4 revealed significant interference from association at lag 0 and interference from coordination at lag 4, but the latter was driven by the interaction of association and coordination.

Experiment 3.2 examined the effect of associated coordinates and part primes. Part primes were associated to the target in target-prime direction in one condition and had unidirectional prime-target association in the second condition. This experiment encompassed two sub-experiments: Experiment 3.2.1 and Experiment 3.2.2. The main difference between these experiments was the time window allotted for the responses and the method of progression between items. In Experiment 3.2.1, four seconds were allowed for the response and automatic progression was applied. In Experiment 3.2.2, two seconds were allowed for the response and manual progression was applied. In Experiment 3.2.1, no significant effects were detected, but, in Experiment 3.2.2, there was significant interference from associated coordinates. No effect of parts associated to the target in target-part or part-target direction of association was detected in either of these experiments.

The finding of semantic interference from association and coordination driven by their interaction conflicts with previous accounts arguing that these two effects are a function of the same mechanism. This is because, if both effects were driven by the same mechanism, the same pattern would be expected in the different modalities. Instead, the pattern of priming observed in the continuous picture naming paradigm differed from that shown in Chapter 2 where primes were presented as written words, where we found main effects of both association and coordination but no interaction. Moreover, this pattern of priming excludes the possibility that semantic interference from associates and coordinates is due to a quantitative difference in the degree of similarity between the items (e.g., McRae, Khakhali, & Hare, 2012; Vigliocco, Vinson, Lewis, & Garrett, 2004). Instead, it supports the idea that associates and coordinates not only represent different types of relations but also have a qualitatively different nature of organization. In Chapter 2, we suggested that similarity between coordinates is defined by the number of shared features at the semantic level activating the lemma level, while associative connections represent lateral connections at the lemma level.

The overall inhibitory pattern of priming driven by the interaction of association and coordination observed in the continuous picture naming paradigm is consistent with the interference detected in a number of studies that did not distinguish between these two types of semantic relations (e.g., Howard et al., 2006; Vitkovitch et al., 2001; Wheeldon & Monsell, 1994). Likewise, similar to Wheeldon and Monsell (1994), we observed a significant effect of lag with responses at lag 4 being significantly slower than at lag 0. However, the results are only partially consistent with studies that have focused on distinguishing between association and coordination. For example, in the blocked-cyclic naming task interference from both association and coordination was observed independently (Abdel Rahman & Melinger, 2007). However, this effect emerged only for the presentation of a target within later blocks and not for the first presentation, where blocking produced facilitation. Moreover, this task also involved a familiarisation stage; so that, while participants produced facilitation for association and coordination when presented in the first block, this was not the first time they had seen these items. In contrast, in the research presented here, no familiarisation stage was involved and interference was observed for the first presentation of the target. Since Abdel Rahman and Melinger (2007) examined the effects of association and coordination as separate factors without including a condition with both association and coordination, it remains unclear whether the priming from association and coordination may also have interacted.

The second question that arises is what mechanism underpins the difference of semantic priming effects in the continuous picture naming and alternating word reading and picture naming paradigms. In the introduction to this chapter, we noted that word reading and picture naming require slightly different processing. In particular, word reading engages both lexical semantic and non-semantic routes, while picture naming entirely relies on the lexical semantic route. Therefore, it is likely that such a difference in results is caused by the difference of the tasks. However, the question is how to explain these differences.

The first discrepancy between the findings of the first experiments of Chapter 2 and 3 is the effect of lag. While in both cases, we observed significant interference from association at lag 0 and interference from coordination at lag 4, there were some discrepancies between the two experiments. In both cases there was strong interference from association at lag 0, in Chapter 2 we also showed that this effect was driven by the target-prime direction of association. In contrast, in Chapter 3, there was no significant effect of direction of association, although there was an inhibitory trend for the target-prime direction of association. It is possible that such attenuation of the effect of direction of association in the continuous picture naming paradigm is caused by the stronger involvement of semantic processing. In both paradigms there was interference from coordination at lag 4; however, in Chapter 3, this effect was driven by the interaction of association and coordination. This is discussed below.

3.4.2 *Priming from association and coordination*

The second discrepancy between the two experiments refers to the different effects of the interaction of association and coordination. In Chapter 2, we found interference from both association and coordination and no effect of the interaction between the two. Given this, we assumed that these two effects are independent and are produced by different mechanisms. In particular, while we assumed that both effects result from increased competition from the prime, we suggested that in the case of coordination this resulted from activation of the prime due to its overlap in semantic features with the target; in contrast, interference from associates with target-prime direction of association was hypothesised to result from increased competition due to lateral activation at the lemma level.

In contrast, in this chapter, we observed that the effect of association was driven by the interaction of association and coordination. There are two accounts suggested for interactions in general: 1) they reflect an effect that is driven by the same mechanism (Sternberg, 1969), 2) they reflect the overlap of two additive effects in cascaded processing (e.g., McClelland, 1979). When an interaction is driven by the same mechanism, this effect should be observed across different paradigms. Alternatively, if an interaction is driven by different mechanisms, then the interaction could be observed in some paradigms but not in others. Applying McClelland's (1979) approach to the interaction observed in Experiment 3.1 of this chapter, it is possible that the picture prime, by relying entirely on the lexical-semantic route, engages stronger activation of semantic information as compared to the word prime. Therefore, the interaction of association and coordination could refer to the overlap of two additive effects outlined in Chapter 2: 1) interference from coordination, and 2) interference from association.

3.4.3 *Priming from coordination*

In Chapter 2, we suggested that semantic priming from coordination results from lexical selection by competition that can be implemented either by the Luce Choice ratio or lateral inhibition. That is, semantic features spread activation to all of the lemmas to which the features apply. The strength of co-activation of non-target lemmas depends on the number of shared features and the strength of the connections between the semantic features and the lemma. As noted above, previous naming of a target has been hypothesised to increase the strength of the semantic-lemma connections for that target (Howard et al., 2006). Hence, primed lemmas will be more active and stronger competitors than unprimed lemmas.

3.4.4 *Priming from association*

In Chapter 2, we assumed that semantic interference from association results from reactivation of the prime via lateral connections at the lemma level. This effect is only significant when there is association from the target to the prime. Specifically, once activated, every lemma laterally spreads activation toward other lemmas to which it is associated and co-activates them. The strength and degree of this co-activation, and the degree of interference depends on the degree to which the prime lemma is activated by the target.

3.4.5 *Interaction of association and coordination*

Given that, in Chapter 2, we attributed interference from association and coordination to be the result of two independent mechanisms (albeit underpinned by a single priming locus), the question arises of how to account for the fact that there was an interaction between these two factors with picture naming primes in Experiment 3.1. In this regard, we suggest that this overlap is a function of a cascaded processing of lemma retrieval. That is, semantic features spread activation to all of the lemmas to which the features apply. The strength of co-activation of non-target lemmas depends on the number of shared features and the strength with which these features are activated. Activated lemmas will also activate any lemmas with which they are associated through the within-lemma-level connections. This will occur prior to lemma selection. In other words, the co-activation of lemmas occurs by cascading; hence, following McClelland (1979) the interaction of the effect of coordination and association can result from their overlap. That is, stronger involvement of semantic processing and hence stronger activation of semantic features and semantic to lemma connections in the continuous picture naming paradigm may result in stronger priming for the primes in this paradigm compared to word primes which are purely read aloud. Consequently, activation of a coordinate prime is stronger and increases the cascading activation; that is, it increases the time for lemma selection. This, in turn, increases the difference in time when every activated lemma laterally spreads activation toward other lemmas. So, the overlap of priming from coordination and association that occurs results in their interaction.

3.4.6 *Priming from parts*

In this chapter, Experiment 3.2 showed no effect of parts consistent with the pattern found in Chapter 2. Just as for Chapter 2, it seems most likely that this finding can be accounted for by an insufficient number of features shared between prime and target (e.g., Vigliocco et al., 2004).

3.5 Conclusion

The evidence of priming revealed in this chapter, combined with that observed in Chapter 2 enhances our suggestion that association, coordination and part-whole relations refer to different types of semantic relations that have different organization and means of co-activation. We propose that the interaction observed from association and coordination in this chapter can be attributed to the overlap of priming from association and coordination that results from cascaded processing of lemma retrieval. The absence of the effect of parts further justifies that critical number of shared semantic features is needed for semantic interference to occur. However, little remains known about whether such a pattern of semantic priming would be observed in case series of people with aphasia. Chapter 4 addresses this issue.

Chapter 4. Does producing semantically related words aid word retrieval in people with aphasia?

4.1 Introduction

Difficulties in word retrieval are one of the most prevalent language impairments in aphasia. Poor word retrieval can be caused by a semantic impairment or an impairment in activation of the phonological form (e.g., Binder et al., 2016; Butterworth, Howard, & Mcloughlin, 1984; Cutting & Ferreira, 1999; Howard & Gatehouse, 2006; Howard, Hickin, Redmond, Clark, & Best, 2006; Nickels, 1997, 2002; Nozari, Kittredge, Dell, & Schwartz, 2010). Understanding the nature of this breakdown can both assist in developing more effective treatment for word finding difficulties and understanding the mechanism of lexical access in spoken word retrieval in healthy participants.

To date, a number of studies with both healthy participants and people with aphasia have demonstrated that *previous retrieval of a target* improves subsequent retrieval of the same word and this effect is called *repetition priming*. The effect of previous retrieval has been studied both within tightly controlled repetition priming experiments, where time is manipulated (lags between items and between testing sessions) and within therapeutic interventions. In healthy participants, repetition priming has been reported as a long-lasting effect (e.g., Wheeldon & Monsell, 1992) and, in people with aphasia, it has been shown to improve accuracy of response (e.g., Best, Herbert, Hickin, Osborne, & Howard, 2002; Nickels & Best, 1996).

4.2 Semantic priming

The effects of different semantic relationships on spoken word retrieval, in healthy participants, have been mainly examined using *semantic priming tasks* (Alario et al., 2000; Howard, Nickels, et al., 2006; Lupker, 1988; Tree & Hirsh, 2003; Wheeldon & Monsell, 1994). Semantic priming occurs when the prime is semantically related to the target and, depending on the relations and the task to be performed, can produce either *interference* (slowing of response) or *facilitation* (speeding of response). Interference of response latency has been mainly detected when a previously retrieved prime was a semantic coordinate to the target; for example, *'car'* and *'bus'* are semantic coordinates within the semantic category *'vehicle'* (e.g., Alario et al., 2000; Tree & Hirsh, 2003; Wheeldon & Monsell1994). Facilitation has been observed mainly when the distractor was a functionally related and associated member of a different semantic category that does not share structural semantic features with the target (e.g. *'road' -> 'car'*; Alario et al., 2000; Tree & Hirsh, 2003), and some studies have reported such an effect from associated parts (e.g., Costa, Alario, & Caramazza, 2005). While interference from semantic coordination has been shown to be consistent, the effect from association differs among studies. For example, in alternating word reading and picture naming, Tree and Hirsh, (2003) used written word primes with predominantly prime-target direction of association and found facilitation. In Chapter 2, in the same task, we found interference from association and to understand the nature of this discrepancy, we compared the effect of primes with prime-target direction of association to those with target-prime direction and found that interference from associative primes was driven by target-prime direction of association. However, in Chapter 3, where both primes and targets required picture naming (but using the same materials as in Chapter 2), significant interference was found from association driven by the interaction of association and coordination at lag 4. Given this, we suggested that priming from association and coordination are driven by different mechanisms. In particular, interference from association results from lateral spreading activation at the lemma level and interference from coordination results from spreading activation via shared semantic features.

4.3 Facilitation tasks

In studies with case series of people with aphasia, facilitation tasks have been more commonly used than semantic priming tasks (e.g., Best et al., 2002; Heath et al., 2013; Howard, Hickin, et al., 2006; Howard, Patterson, Franklin, Orchard-Lisle, & Morton, 1985). A *facilitation task,* in this context, refers to a technique where one task is performed and its effect on the speed and/or accuracy of performance of another task is examined a short time later. This can be thought of as analogous to a long-lag priming technique.

To date, the majority of facilitation studies have focused on examining the effect of prime processing on subsequent target retrieval when the prime was identical to the target (although items in the priming/facilitation task may be different to the target (picture naming) task). These facilitation tasks have included repeating the prime (e.g., Patterson, Purell, & Morton, 1983; Podraza & Darley, 1977), naming a picture of the prime following a phonological cue (e.g., Patterson et al., 1983; Podraza & Darley, 1977), or pointing to the prime from a selection of pictures (e.g., unrelated pictures, semantic coordinates, associates) given its auditory counterpart (e.g., Howard et al, 1985; Howard, Hickin, et al., 2006). The main finding in all these studies was improvement (in terms of accuracy) in the ability to retrieve the target word in response to a picture subsequent to facilitation with the identical prime; that is, repetition priming. Howard, Hickin, et al. (2006) also found that the type of distractor pictures used in a facilitation word-picture matching task (unrelated, semantic coordinates, semantic associates) had no impact on the amount of benefit from facilitation. Howard, Hickin, et al. (2006) attributed the positive effect of facilitation to strengthening connections between amodal lexical-syntactic representations (lemmas) and phonological word form representations.

Podraza and Darley (1977) examined the effect of semantic relationships on spoken word retrieval by asking people with aphasia to name a picture that was associated (in free association norms) with 3 auditory stimuli presented by the examiner (e.g., name the picture of *'bee'* preceded by auditory primes: *'sting', 'hive', 'honey'*). Three out of their five participants performed worse (in terms of accuracy) in this condition as compared to an unfacilitated control condition and 2 participants performed no differently[14]. Thus, for at least some of their participants, Podraza and Darley (1977) showed a pattern of inhibition from primes which were associated to the targets. This pattern contradicts some studies with healthy participants mentioned above; for example, Alario et al. (2000) and Tree and Hirsh (2003) found facilitation from prior naming of associate primes (that were not also coordinates). However, it is similar to the pattern we found in healthy participants using an alternating word reading and picture naming task in Chapter 2. Earlier in this thesis, the importance of clearly defining and controlling for the relationships between items was highlighted and we argued that differences in, for example, the direction of association, or the degree of semantic relatedness could affect the patterns of results. If we consider the previous research on aphasia, Podraza and Darley (1977) did not provide a clear delineation between the

[14] Podraza and Darley do not provide statistics at the single subject level, however, we have used the rule of thumb that in a McNemar's test at least 6 items difference between conditions is required for a significant result.

different types of semantic relationships, so it remains unclear whether in their study they included semantic coordinates that were associated as well as associates from a different semantic category.

In spoken word-to-picture matching, Howard et al. (1985) examined the effect of semantic relatedness using a word-picture matching facilitation task with semantically related primes[15]. For example, during the facilitation task, people with aphasia were asked to point to the picture of *'lion'* (from four unrelated pictures) and in a subsequent naming task they were asked to name a picture of *'tiger'*. There were no significant effects from this task; picture naming of targets following facilitation by a semantically related prime was almost the same as in an unfacilitated group of items, and significantly less accurate than targets facilitated with identical primes. This contrasts with the results from much of the literature with healthy participants, where *naming* a semantically related prime produces inhibitory effects compared to a control condition (Howard, Nickels, et al., 2006). However, as in other studies, the majority of Howard et al.'s (1985) coordinates were likely to also be associated to the target.

To our knowledge no evidence has been reported to date regarding how previous repetition of words with different semantic relationships affects spoken word retrieval in people with aphasia; this is the goal of the experiments reported here. This is important because data from people with aphasia can be used to further test theories of word retrieval, which need to be able to account for priming effects in people with aphasia as well as those found in healthy participants (Howard, Hickin, et al., 2006).

Given the limited amount of research on the effects of semantically related stimuli on word retrieval in aphasia, and the inconsistent effects in the research with healthy speakers, we report here two facilitation experiments that were conducted to address this issue. In both of these experiments, the facilitation task required repetition of a prime word in the presence of a picture of the target, followed, later, by attempted naming of the target picture.

In the first experiment, the to-be-repeated prime had one of three possible relationships to the target:

i) **identity** (e.g., repetition of *'car'* in the presence of the picture *'car'*)

[15] Note that Howard et al. (1985) called this condition "associate" but clearly state that these items were "the most closely related member of the [target's] category of which we had a picture" (p61).

ii) **associated coordinates** (+Associate +Coordinate) (e.g., repetition of *'bus',* which is both associated and shares the same semantic category as the target *'car'*)

iii) **unrelated** (-Associate -Coordinate) (e.g., repetition of *'pen'* in presence of picture of *'car'*).

In the second experiment, we aimed to further tease apart the effects of the nature of any semantic relationship, by manipulating whether items were linked by coordination and/or association using following prime conditions:

i) Identity

ii) **coordination** (-Associate +Coordinate) (e.g., repetition of *'bike'* in presence of a picture *'car'*)

iii) **association** (+Associate -Coordinate) (e.g., repetition of *'road'* in presence of a picture of *'car'*)

iv) **unrelated** (-Associate -Coordinate).

4.4 Experiment 4.1

This experiment examined whether previous retrieval of associated coordinates affected subsequent spoken word retrieval in people with aphasia. As a facilitating task we chose to use repetition in the presence of a picture. This task has been shown to be effective in improving word retrieval using identity primes in both facilitation (e.g., Best & Nickels, 1996; Howard et al., 1985; Patterson et al., 1983; Podraza & Darley, 1977) and in treatment studies (e.g. Lambon Ralph, & Fillingham, Sage, 2006; Fillingham, Sage, & Ralph, 2005), and is similar to priming tasks used in healthy participants in that it requires overt production of the stimulus.

The second type of primes chosen were associated coordinates of the target since studies with healthy participants have uniformly reported significant semantic interference using primes with these characteristics (e.g., Howard, Nickels, et al., 2006; Vitkovitch, Cooper-Pye, & Leadbetter, 2006; Wheeldon & Monsell, 1994). Howard, Nickels, et al. (2006) assumed that such an effect requires four aspects: 1) shared semantic space between the distractor and a prime (i.e., sharing semantic features), 2) spreading activation, 3) priming and 4) competition. Selection of the distractor results in strengthening its semantic-to-lemma connections; that is, priming. Then, if the prime and a target share the same semantic space, activation of the target node spreads toward the prime. Therefore, this (primed) node is a stronger competitor to the target (than unprimed or semantically unrelated stimuli) and affects reaction time and/or accuracy of target retrieval.

However, Howard et al. (1985) in their facilitation study with people with aphasia found no effect from word-picture matching with coordinates (that were probably often also associated) on later target naming. Hence, this experiment will investigate whether the same is true when the associated coordinate is also produced. It is possible that, when there is a word retrieval impairment, the prior successful retrieval of the prime word (e.g., *'car')* may also prime the semantic-lemma links for the target (by activating semantic information necessary for the retrieval of the target (e.g., *'bus')*), thereby facilitating its later retrieval. This, in turn, could result in improvement of the accuracy of the response in people with aphasia. Experiment 4.1 investigates which of these possible outcomes (improvement, no change, or interference) is the case.

4.4.1 *Participants*

Twelve people with aphasia were recruited for this experiment. Since the goal of the research presented here was to examine the effect of semantic priming on word retrieval in a case series of people with aphasia, the initial inclusion criteria for participants was self-reported aphasia and word finding difficulties. Participants had sufficient visual acuity and hearing to perform the task, no severe apraxia of speech or dysarthria, and they were able to repeat at least some words. To be included in the results reported here participants had to exhibit word finding difficulties indicated by 10 – 75% accuracy in picture naming on the experimental set as assessed during the first session of the first experiment. This criterion was chosen to include a wide range of people with aphasia at the same time ensuring that people were able correctly respond to at least some items. Seven participants were recruited via an aphasia support centre (in the United Kingdom) and 5 participants via the Aphasia Participant Database of the Department of Cognitive Science, Macquarie University (Sydney, Australia).

According to local policies, participants in the UK participated on a voluntary basis and subjects in Sydney were paid based at the standard university participation rate. General biographical details and profile are provided in Table 21.

Table 21. Participants' profile

Participants	**CSH**	**IRM**	**NGH**	**DHE**	**SRT**	**CBH**	**SSJ**	**DTF**	**HBC**	**HOE**	**LBL**	**ICM**
Age	67	55	62	70	52	72	52	73	62	63	52	65
Gender	M	M	F	M	M	F	M	M	F	M	F	M
Time Post Onset (years)	>6 months	1	8	4	15	2	15	2*	6	3	5	2
Fluency	NF	NF	NF	NF	F	F	NF	F	F	F	F	F
Pattern of breakdown												
Semantic							Y					
Phonological		Y	Y			Y	Y					
Sem-phon	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Proportion of naming responses by type												
Correct	0.14	0.23	0.42	0.25	0.44	0.38	0.41	0.56	0.47	0.74	0.63	0.75
Phonological errors	0.23	0.08	0.07	0.08	0.13	0.05	0.38	0.05	0.19	0.06	0.04	0.24
Semantic errors	0.12	0.13	0.08	0.08	0.27	0.13	0.03	0.13	0.02	0.08	0.06	0.01
Unrelated errors	0.00	0.02	0.00	0.00	0.01	0.00	0.05	0.00	0.00	0.00	0.00	0.00
No response	0.51	0.55	0.43	0.59	0.15	0.44	0.13	0.26	0.32	0.12	0.27	0.00

*Note: * 2 years after 3rd stroke; NK: not known: see text for explanation; NF: non fluent defined based on performance tasks that refer to fluency of speech at single word level and connected speech (see Appendix A for details); Y – sign of breakdown; It should be noted also that to maintain anonymity, participants have been assigned pseudo initials.*

4.4.2 *Background assessment*

To identify the pattern of language impairment at the single word level, and particularly the pattern of impairment in spoken word production, where possible participants were examined using subtests from the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA) (Kay, Coltheart, & Lesser, 1992) and the Comprehensive Aphasia Test (CAT) (Swinburn, Howard, & Porter, 2004). Due to ill health, two participants, CSH and LBL, were not able to complete the background assessments. Instead, their language impairments were evaluated based on their responses during the first naming session and repetition task during the facilitation session in Experiment 4.1.

Given the performance on PALPA and CAT, three patterns of breakdowns were identified: i) semantic, ii) phonological, and iii) semantic-phonological. Semantic breakdown was attributed to poor performance on spoken and written synonym judgement tasks and word-to-picture matching. Phonological breakdown was associated with poor performance on repetition including phonological errors as well as length effect. Semantic-to-phonological impairment was attributed to poor performance in picture naming. Given these criteria (see Table 21), SSJ showed signs of impairment at both semantic and phonological levels as well as the transition between the two. Three participants (IRM, NGH, CBH) showed signs of breakdown at phonological level and the transition from semantic to phonological levels. Seven participants (CSH, DHE, SRT, DTF, HBC, HOE, LBL) showed pattern of breakdown at the transition from semantic to phonological levels, and ICM showed no pattern of breakdown at single word level processing.

Fluency of speech was judged based on performance single word and connected speech tasks taken from CAT (see Appendices G and H). At single word level, every participant was asked to: 1) retrieve words that start with letter ‘s’, and 2) retrieve words associated to a category ‘animal’ within a minute. At connected speech level, every participant was asked to describe a picture. As provided in Table 21, five participants (CSH, IRM, NGH, DHE, SSJ) were non-fluent and other 7 participants (SRT, CBH, DTF, HBC, HOE, LBL, ICM) were fluent.

Overall, every participant selected for the experiment showed signs of aphasia with significant difficulties in word finding as can be seen in Appendix G. ICM did not show patterns of impairment at the single word level, but he showed sign of aphasia in tasks requiring connected speech processing and made over 25% of errors in the naming session within the experiment. The detailed results performance of every participant is reported in Appendices G and H.

4.4.3 *Method*

The aim of this experiment was to examine the effect of priming by repetition of an auditory presented word on subsequent spoken word retrieval. The word to repeat was either: (i) identical (identity), (ii) both associate and a category coordinate (+associate + coordinate), or (iii) unrelated (neither associated nor a category coordinate) to the picture presented. The identity and unrelated conditions were primarily used as control conditions. The *identity* condition was included in order to ascertain that each participant replicated the previously observed effects of a benefit for subsequent naming from repetition of the target word in the presence of the target picture. The *unrelated* condition was used to ascertain that any interference from the +associate +coordinate condition could be specifically attributed to the semantic relationship rather than a general inhibition from repetition of a non-target word.

In addition, there was a set of not facilitated targets, which allowed determination of the direction of any performance differences relative to this baseline.

4.4.4 *Materials and Design*

One hundred and twenty colour photographs were selected from open Internet sources to be targets and every target was allocated to two conditions: 1) associated coordinate primes, 2) unrelated primes (see Appendix I).

Associated coordinate primes were selected using WordNet (Fellbaum, 1998b) and the Edinburgh Associative Thesaurus (Kiss, Armstrong, Milroy, & Piper, 1973; Wilson, n.d.). Only items that were co-hyponyms (e.g., *'cat'* – *'dog'*) in WordNet were considered semantic coordinates. An association between semantic coordinates was defined as items produced by participants when provided with the target. For example, when given the target *‘cat’* 52% of participants produced the word *‘dog’*. Thus, items that were both semantic coordinates in WordNet and associates of the target in Edinburgh Associative Thesaurus were accepted as +associate +coordinate primes.

Unrelated primes were items that were not co-hyponyms (WordNet) nor associated in either direction (prime-target, or target-prime; Edinburgh Associative Thesaurus).

4.4.5 *Procedure*

All targets were presented as coloured photographs, and primes were auditory words. The auditory stimuli were recorded via the Audacity application (‘Audacity download | SourceForge.net’, n.d.) by a male native speaker of British English. The experiment was programed in DMDX (Forster & Forster, 2003) and run on a PC computer, with the audio stimuli presented via headphones. This experiment contained three phases:

1. pre-facilitation picture naming phase where all pictures were presented;
2. facilitation (repetition in the presence of the target picture) where 3 out of 4 conditions were presented;
3. post-facilitation naming where all facilitated and unfacilitated pictures were presented.

These three phases were conducted in two sessions: 1) pre-facilitation during the first session, and 2) facilitation and post-facilitation interleaved in the second session (see Figure 10).

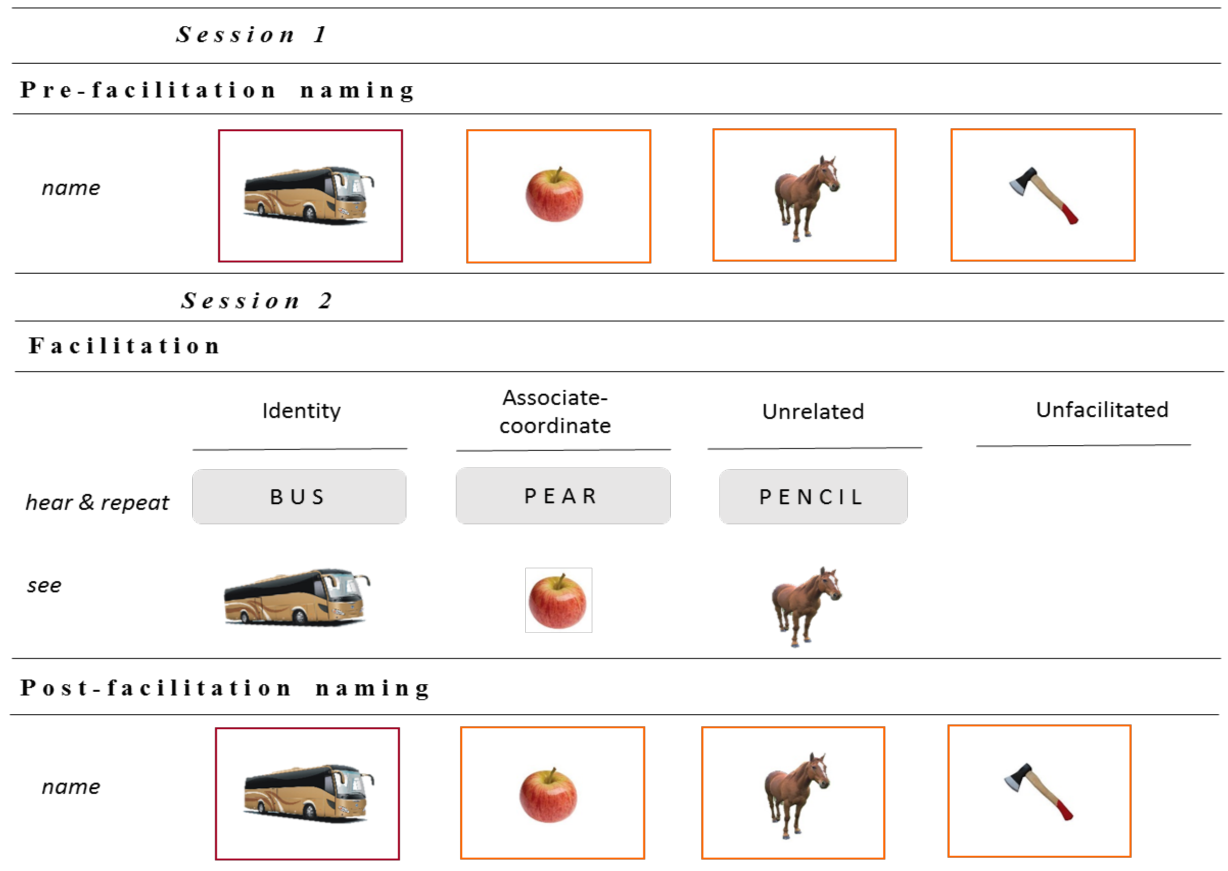


Figure 10. Phases of the experiment.

Note: This figure illustrates the tasks participants performed during pre-facilitation naming (Session 1), facilitation and post-facilitation (Session 2).

Phase 1. Pre-facilitation naming

During this phase, every participant was instructed to name each picture that appeared on a computer screen as clearly and accurately as possible with a single word. All 120 target pictures were presented for naming, preceded by 6 practice items to familiarise people with the procedure. Presentation of each picture was preceded by a string of asterisks in the centre of the screen for 500ms. The picture remained on the screen for 5000ms (5 sec) and was followed by a blank screen. Once the participant responded or indicated that he/she could not respond to an item, the experimenter pressed the space bar to move on to the next item. Voice onsets were recorded on the microphone and checked for accuracy and reaction time using CheckVocal (Protopapas, 2007).

Following pre-facilitation naming, the stimulus pictures were randomly assigned for each participant to 4 sets of 30 items which were matched by a computer programme for pre-facilitation naming accuracy and correct reaction time, frequency of the spoken word from SUBTLEX-UK (van Heuven et al., 2014), number of phonemes and number of syllables. The four sets were then randomly allocated to the four experimental conditions (identity, +associate +coordinate, unrelated, unfacilitated). As a result, the composition of sets was different for each participant.

Phase 2. Facilitation: Repetition in the presence of the picture

During the facilitation phase, participants were simultaneously presented with a picture and an auditory stimulus via DMDX and asked to look at the picture and repeat the auditory stimulus. The auditory stimulus represented one of the three facilitation conditions (identity, + associate +coordinate, or unrelated). Facilitation occurred in blocks of six items with two items from each of the three facilitation conditions being presented in each block in a random order.

Presentation of each experimental trial was preceded by a string of asterisks in the centre of the screen for 500ms. The picture and auditory stimuli were presented simultaneously, the picture remained on the screen for 5000ms (5 sec) and was followed by a blank screen. Every participant was told to look at the picture and repeat the word s/he heard. They also were warned that the auditory word may or may not be the name of the picture. Responses were collected following the same procedure as for Phase 1.

Phase 3. Post-facilitation naming

Post-facilitation naming blocks were interleaved with facilitation blocks. During this phase, participants were presented with a block of 9 pictures and were asked to name every picture with a single word as in the pre-facilitation phase. To avoid switch cost effects from the change of tasks, every block started with 1 filler item for naming, followed by 8 target pictures, 6 of which had been presented during the previous facilitation task and 2 were from the unfacilitated condition. As a result, each item that had been facilitated by a repetition trial was presented with, on average, a lag of 7 intervening trials (range 1-13). Presentation of items and collection of responses followed the same procedure as during Phase 1.

4.4.6 *Data coding*

Picture naming responses were checked for accuracy. Responses were considered accurate if they were correctly started or corrected within 5000ms. No alternatives were accepted and the response was considered correct only if it matched the target word form. Non-target responses including phonological errors, no responses, and correct responses retrieved after 5000ms were considered incorrect.

4.4.7 *Results*

To examine the effect of facilitation on subsequent spoken word retrieval, both accuracy and reaction time were analysed. Both analyses examined 1) effect of facilitation – the change in performance from pre- to post-test for each condition, and 2) effect of semantic relations – difference in post-test performance across conditions. Given the heterogeneity of language breakdown in aphasia, both analyses were implemented at both individual participant and group levels.

Analysis of accuracy

Effect of facilitation

The proportion of correct responses at individual participant and group levels before and after facilitation are summarised in Table 22. Statistical analysis of pre- to post-test differences at an individual participant level was implemented with McNemar's test (McNemar, 1947). According to these analyses, 9 participants (CSH, NGH, DHE, CBH, SSJ, HBC, HOE, LBL, ICM) showed significant improvement from pre- to post-facilitation in the identity condition, CBH also showed significant improvement in the unfacilitated condition.

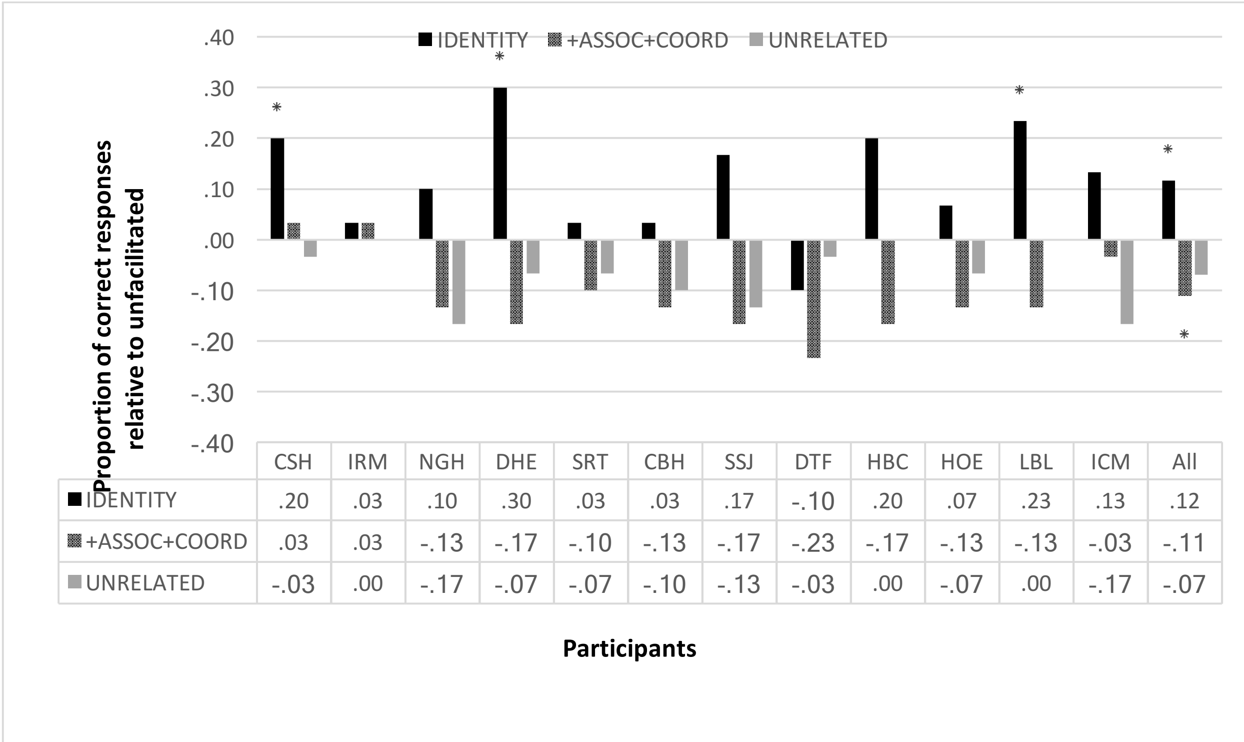
At the group level, statistical analysis was carried out giving equal weight to each participant's results using procedures based on Leach (1979). Leach's procedures allowed statistical combination of the results of the individual analysis of participant's results. A homogeneity test was then used to assess whether or not there were significant differences among participants in their effect sizes. Results of this analysis showed significant improvement in three conditions: 1) *identity* ($z = -6.87$, $p < .0001$ (1-tailed)), 2) *unrelated* ($z = -2.25$, $p = 0.012$. (1-tailed)) and, 3) *unfacilitated* ($z = -3.62$, $p = 0.0001$ (1-tailed)). These effects were homogeneous across participants in identity ($H (11) = 12.03$, $p = 0.36$) indicating that we have no evidence that the effects of identity priming differed between participants, despite some participants showing significant effects and others not in the individual analyses. The effects of the unfacilitated ($H (11) = 2.73$, $p = 0.99$) and unrelated conditions ($H (11) = 4.25$, $p = 0.99$) were homogeneous as well. No significant changes were detected in the *+associate +coordinate* condition ($z = -1.599$, $p = 0.05$ (1-tailed)), and this pattern was homogeneous ($H (11) = 1.09$, $p = 0.99$). Hence, despite different participants showed different patterns of response from pre- to post-test, the effects in every condition were homogeneous.

Table 22. Proportion of correct picture naming responses before and after facilitation

Subject	***Condition***							
	IDENTITY		*+ASS+COORD*		*UNRELATED*		*UNFACILITATED*	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
CSH	.13	***.40****	.17	.23	.13	.17	.13	.20
IRM	.23	.20	.23	.20	.23	.17	.23	.17
NGH	.43	***.67****	.43	.60	.40	.40	.40	.50
DHE	.27	***.60****	.23	.13	.23	.23	.27	.30
SRT	.47	.53	.43	.40	.43	.43	.43	.50
CBH	.33	***.70****	.43	.53	.33	*.57*	.43	***.67****
SSJ	.40	***.67****	.40	.33	.43	*.37*	.43	.50
DTF	.57	.60	.53	.47	.57	.67	.57	.70
HBC	.47	***.77****	.47	.40	.47	.57	.47	.57
HOE	.73	***.93****	.73	.73	.73	.80	.77	.87
LBL	.60	***.97****	.63	.60	.63	.73	.63	.73
ICM	.77	***.97****	.77	.80	.73	.67	.77	.83
All	.45	***.67****	.46	.45	.44	***.48****	.46	***.54****
sd	*.19*	*.23*	*.19*	*.21*	*.20*	*.22*	*.20*	*0.23*

Note: BOLD ITALIC ASTERISK refers to changes that are significant (p<.05 (1-tailed) according to McNemar's test for the individual subjects and Combined z-score for the case series; N (observations) =30 in every condition; n (participants) = 12.

To examine whether these differences resulted from the opportunity to name the items again or from the facilitation task, the accuracy of post-facilitation responses in facilitated conditions was contrasted to the accuracy of the unfacilitated conditions. Figure 11 summarises the differences of post-facilitation responses in facilitated and unfacilitated conditions. To examine whether any differences seen were statistically significant, we used 2-sample t-tests (e.g., Snecdecor & Cochran, 1989) and according to the results 3 participants (CSH, DHE, LBL) showed a significantly larger proportion of accurate responses in the identity condition, with no significant differences observed in associated coordinate condition.

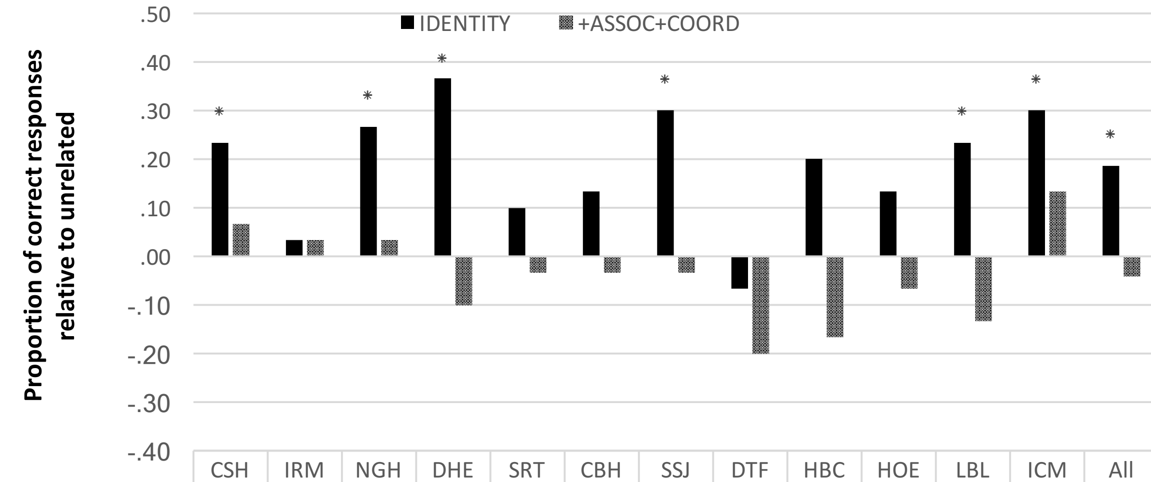


	CSH	IRM	NGH	DHE	SRT	CBH	SSJ	DTF	HBC	HOE	LBL	ICM	All
IDENTITY	.20	.03	.10	.30	.03	.03	.17	-.10	.20	.07	.23	.13	.12
+ASSOC+COORD	.03	.03	-.13	-.17	-.10	-.13	-.17	-.23	-.17	-.13	-.13	-.03	-.11
UNRELATED	-.03	.00	-.17	-.07	-.07	-.10	-.13	-.03	.00	-.07	.00	-.17	-.07

Figure 11. Proportion of correct responses in Identity and +Assoc +Coord conditions as compared to unfacilitated condition.

Note: Asterisks indicate significant difference of the accuracy of responses compared to unrelated. At the individual subject level (2 sample t-tests, 1-tailed) analysis was applied. At group level, generalized linear mixed effect modelling was applied.

In order to examine the effects of facilitation across conditions, the difference in the proportion of correct responses in the identity and associated coordinate conditions relatively to the unrelated condition was analysed (see Figure 12). Statistical analysis of these differences at an individual participant level was carried with 2-sample t-tests. According to the results, 6 participants (CSH, NGH, DHE, SSJ, LBL, ICM) produced a significantly larger proportion of accurate responses in the identity condition than in the unrelated condition, but no individual showed a significant difference in the associated coordinate condition (relative to unrelated).



	CSH	IRM	NGH	DHE	SRT	CBH	SSJ	DTF	HBC	HOE	LBL	ICM	All
IDENTITY	.23	.03	.27	.37	.10	.13	.30	-.07	.20	.13	.23	.30	.19
+ASSOC+COORD	.07	.03	.03	-.10	-.03	-.03	-.03	-.20	-.17	-.07	-.13	.13	-.04

Figure 12. Proportion of correct responses in Identity and +Assoc +Coord conditions as compared to unrelated condition.

Note: ASTERISKS indicate significant difference of the accuracy of responses compared to unrelated. At the individual subject level (2 sample t-tests, 1-tailed) analysis was applied. At group level, generalized linear mixed effect modelling was applied.

Group analyses

At the group level, statistical analysis of accuracy in post-test naming (given that performance was matched at pre-test) was carried out with binomial generalized linear mixed effect model (*glmer*) in *lme4* package, version 1.1-7 (Bates et al., 2014) in GNU programming environment R version 3.1.1 (R Core Team, 2014). Participants and items were assigned as random intercepts and logged frequency, number of syllables and phonemes as random slopes for participants. Simple contrast was applied to conditions (1 – for condition of interest vs. -1 for control condition (unrelated or unfacilitated) and 0 for other conditions. For example, in the contrast of the identity condition to unrelated, the identity condition would be assigned with +1, unrelated -1, associated coordinate and unfacilitated with 0 (e.g., Sundström, 2010). When comparing post-test performance in every condition to the unfacilitated condition there was a significant improvement in accuracy of response in the identity condition and significant worsening in associated coordinate condition. The unrelated condition was close to being significantly worse than the unfacilitated condition (see Table 23). When comparing the post-test performance with the unrelated condition there was significantly higher level of accuracy in the identity condition, and no significant difference for the associated coordinate condition. However, in the comparison of the post-test performance in the identity and associated coordinate condition, the level of accuracy in the associated coordinate condition was significantly worse than in the identity condition.

Table 23. Effect of facilitation on accuracy in post-test naming (generalized linear mixed effect modelling)

Accuracy3 ~ Condition + (1 + logFreq + sylls + phons |Participant) + (1| item)					
Condition	*est*	*se*	*z score*	*Pr(>|z|)*	
vs. Unfacilitated					
Intercept	*1.04*	*0.48*	*2.18*	*0.029*	*
IDENTITY	0.57	0.19	**3.05**	**0.002**	**
+ASSOC +COORD	-0.47	0.18	**-2.64**	**0.008**	**
UNRELATED	*-0.32*	*0.18*	*-1.76*	*0.079*	
vs. Unrelated					
Intercept	*1.04*	*0.48*	*2.18*	*0.029*	*
IDENTITY	0.88	0.19	**4.74**	**2.19E-06**	***
+ASSOC +COORD	-0.16	0.18	-0.88	0.381	
vs. Identity					
+ASSOC +COORD	-1.05	0.1852	**-5.663**	**1.49e-08**	***

*Note: Accuracy3: accuracy of responses during post-test naming; ~ Condition indicates the effect of condition on the accuracy of the response (at first all the conditions were contrasted to Unrelated condition and then to Unfacilitated condition); Participant, item (targets): random intercepts; logFrequency (logged frequency of items based on SUBTLEX-UK), sylls (syllables), and phons (phonemes): random slopes for participants; BOLD ASTERISKS indicate significance: *p < .05. **p < .01. ***p < .001); N (observations) =1440; n (participants) =12*

Analysis of Response Latency

Effect of facilitation

In addition to examining response accuracy, we also considered response latency for items that were correct on both occasions. Table 24 summarizes the proportion correct and mean reaction time of responses retrieved correctly before and after facilitation and shows the difference of mean response latency between the two. Statistical analysis of these differences at individual participant level was implemented with paired t-test and at group level with combined z-score test.

Table 24. Mean reaction time (in seconds) for items correct at both pre-test and post-test

	Condition											
	IDENTITY			*+ASSOC +COORD*			*UNRELATED*			*UNFACILITATED*		
Participants	*proportion correct*	Pre-test	Post-test	*proportion correct*	Pre-test	Post-test	*proportion correct*	Pre-test	Post-test	*proportion correct*	Pre-test	Post-test
CSH	*.13*	3.36	***3.04****	*.07*	3.13	3.06	*.10*	3.45	3.29	*.13*	3.34	***3.39****
IRM	*.10*	3.28	3.19	*.10*	3.18	3.08	*.10*	3.23	3.37	*.10*	3.10	3.24
NGH	*.33*	3.30	***3.16****	*.27*	3.31	3.33	*.27*	3.21	3.27	*.33*	3.29	3.18
DHE	*.17*	3.32	3.31	*.07*	3.44	***3.18****	*.10*	3.30	3.20	*.17*	3.33	3.38
SRT	*.37*	3.25	***3.05****	*.20*	3.29	3.25	*.20*	3.28	***3.14****	*.37*	3.28	3.27
CBH	*.23*	3.32	***3.04****	*.30*	3.25	3.15	*.30*	3.24	3.15	*.40*	3.34	***3.09****
SSJ	*.37*	3.11	3.07	*.30*	3.04	3.14	*.37*	3.04	3.07	*.37*	3.08	3.06
DTF	*.40*	3.31	***3.16****	*.33*	3.26	3.18	*.47*	3.29	3.19	*.53*	3.31	***3.15****
HBC	*.40*	3.35	3.23	*.23*	3.25	3.42	*.33*	3.29	3.16	*.30*	3.41	3.34
HOE	*.73*	3.37	***3.12****	*.57*	3.33	3.29	*.60*	3.32	***3.19****	*.73*	3.37	3.29
LBL	*.60*	3.30	***3.14****	*.40*	3.32	3.37	*.53*	3.27	3.30	*.57*	3.31	***3.15****
ICM	*.77*	3.27	***3.12****	*.70*	3.30	3.27	*.60*	3.30	***3.20****	*.70*	3.26	***3.10****
All	*.38*	3.29	***3.14****	*.29*	3.26	3.23	*.33*	3.27	***3.21****	*.39*	3.29	***3.22****
sd	*.22*	*.07*	*.08*	*.19*	*.10*	*.11*	*.19*	*.09*	*.08*	*.21*	*.10*	*.11*

Note: +ASSOC+COORD: associated coordinate; *proportion correct*: proportion of responses that are correct both at pre-test and at post-test and therefore included in the analysis; *BOLD ITALIC ASTERISK* refers to changes that are significant (t>2.00) according to paired t-test and Combined z score for the case series; maximum n =30 in each condition.

At the individual participant level, paired t-tests of responses that were correct before and after facilitation showed significant facilitation (reduction in response latency in post-test naming relatively to pre-test) in the identity condition for 8 participants (CSH, NGH, SRT, CBH, DTF, HOE, LBL, ICM). Four of these participants (CBH, DTF, LBL, ICM) also showed significant facilitation in the unfacilitated condition, and three (SRT, HOE, ICM) showed facilitation in the unrelated condition. Participant CSH also showed significant interference in the unfacilitated condition. DHE showed significant facilitation in only the associated coordinate condition.

At the group level, combined z-score with equal weighting by participants showed that there was significant speeding of reaction time from pre- to post- naming subsequent to identity ($z = -6.98$, $p <.0001$, one tailed), unrelated ($z = -2.499$, $p =0.006$, one tailed), and unfacilitated ($z = -3.504$, $p =0.0002$, one tailed) facilitation conditions, and a trend from associate-coordinate primes ($z = -1.572$, $p =0.058$, one tailed). These changes were homogeneous in all the conditions (Identity: $H(11) =14.90$, $p = 0.19$; +Assoc. +Coord.: $H(11) = 11.07$, $p=0.44$; Unrelated: $H(11) =14.01$, $p=0.33$; Unfacilitated: $H(11) =29.35$, $p= 0.002$).

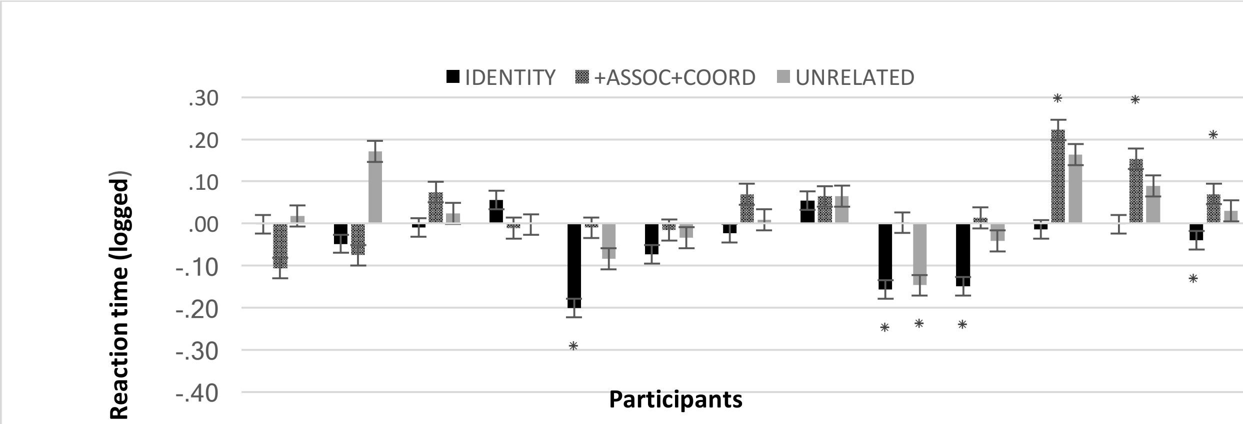
Statistical analysis of the effect of facilitation on post-test performance in facilitated conditions relatively to unfacilitated condition at individual participant level was carried out with 2-sample t-tests. Table 25 summarises the reaction times for those items correct at post-test and Figure 13 summarizes the difference of mean reaction time compared to the unfacilitated condition. Two participants (SRT, HOE) showed significant facilitation in identity condition, HBC showed significant facilitation in identity and unrelated conditions, 2 participants (LBL, ICM) showed significant interference in associated coordinate and unrelated conditions, and 7 participants (CSH, IRM, NGH, DHE, CBH, SSJ, DTF) showed no significant differences (but given the small numbers of items in the analyses for some participants the power to detect effects is not great).

When compared to the unrelated condition, 4 participants (SRT, HOE, LBL, HBC) showed significantly faster reaction times in the identity condition compared to the unfacilitated condition and HBC also showed significantly slower reaction times in the associated coordinate condition (see Table 25 and Figure 13). Seven participants (CSH, IRM, NGH, DHE, CBH, SSJ, DTF) showed no significant differences across conditions in post-test naming.

Table 25. Mean Reaction time in post-test naming

Participant	Proportion of correct responses	*IDENTITY*	Proportion of correct responses	*+ASS+COORD*	Proportion of correct responses	*UNRELATED*	Proportion of correct responses	*UNFACILITATED*
CSH	.40	3.34	.23	3.23	.17	3.36	.20	3.34
IRM	.20	3.14	.20	3.11	.17	3.36	.17	3.18
NGH	.63	3.25	.40	3.33	.37	3.28	.53	3.25
DHE	.60	3.36	.13	3.29	.23	3.30	.30	3.30
SRT	.53	3.07	.40	3.26	.43	3.19	.50	3.27
CBH	.70	3.15	.53	3.21	.57	3.19	.67	3.22
SSJ	.67	3.04	.33	3.13	.37	3.07	.50	3.06
DTF	.60	3.20	.47	3.21	.67	3.21	.70	3.14
HBC	.77	3.24	.40	3.40	.57	3.25	.57	3.40
HOE	.93	3.14	.73	3.30	.80	3.24	.87	3.29
LBL	.97	3.15	.60	3.38	.73	3.33	.73	3.16
ICM	.97	3.13	.80	3.28	.67	3.22	.83	3.13
All	.66	3.17	.44	3.28	.48	3.24	.55	3.21
(sd)	.	.10		.09		.08		.10

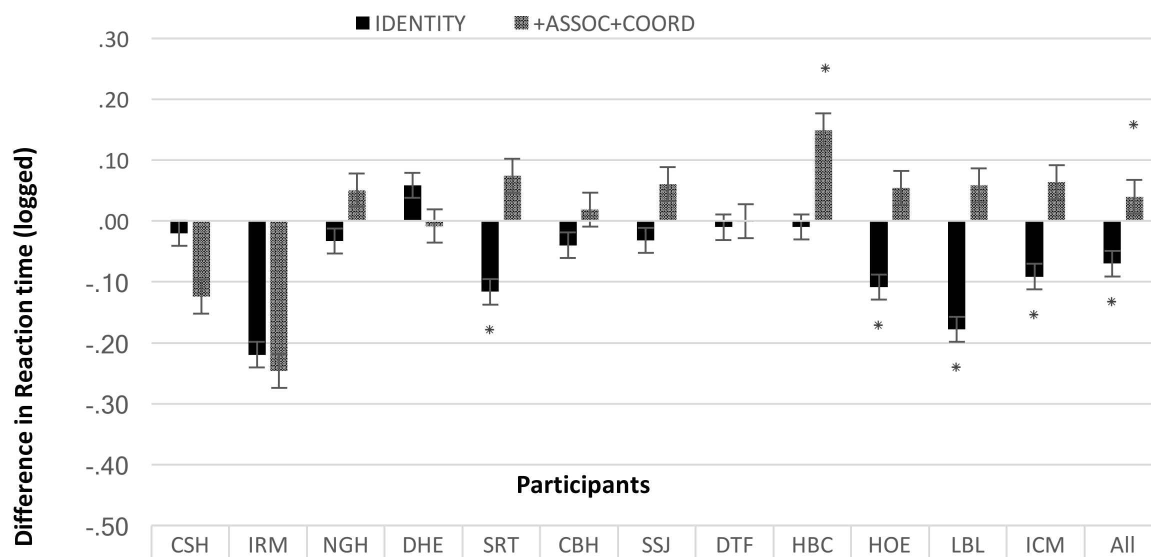
Note: Proportion of correct responses refers to all responses retrieved correctly during post-test naming.



	CSH	IRM	NGH	DHE	SRT	CBH	SSJ	DTF	HBC	HOE	LBL	ICM	All
IDENTITY	.00	-.05	-.01	.06	-.20	-.07	-.02	.05	-.16	-.15	-.01	.00	-.04
+ASSOC+COORD	-.11	-.08	.07	-.01	-.01	-.02	.07	.06	.00	.01	.22	.15	.07
UNRELATED	.02	.17	.02	.00	-.08	-.03	.01	.06	-.15	-.04	.16	.09	.03

Figure 13. Mean reaction time of responses at post test compared to the unfacilitated condition.

Note: Asterisks indicate significant difference compared to unfacilitated condition (2 sample t-test).



	CSH	IRM	NGH	DHE	SRT	CBH	SSJ	DTF	HBC	HOE	LBL	ICM	All
IDENTITY	-.02	-.22	-.03	.06	-.12	-.04	-.03	-.01	-.01	-.11	-.18	-.09	-.07
+ASSOC+COORD	-.12	-.25	.05	-.01	.07	.02	.06	.00	.15	.05	.06	.06	.04

Figure 14. Mean reaction time of responses at post test as compared to the Unrelated condition.

Note: ASTERISKS indicate significant difference compared to unrelated condition (2 sample t-test).

Group level

At the group level, statistical analysis of reaction time in post-test naming was implemented with linear mixed effect model (LMEM) in *lme4* package, version 1.1-7 (Bates et al., 2014) with participants and items as random intercepts and logged frequency, number of syllables and phonemes as random slopes for participants (see Table 26). To implement this analysis, reaction time was reciprocated using the function of Box and Cox (1964) to preserve normality of distribution. To improve R^2, data were trimmed within 2.5 standard deviations and this fitting improved R^2 from 0.24 to 0.30. As result, 6 extreme values were excluded from the analysis and 817 observations remained. As for accuracy, simple contrasts (Sundström, 2010) were applied to conditions (1 for condition of interest, -1 control condition and 0 for other conditions).

As shown in Table 6, the comparison of facilitated conditions (identity, +associate + coordinate, unrelated) to the unfacilitated condition revealed significant facilitation from identity and inhibition from associated coordinates. The comparison of performance in unrelated and unfacilitated conditions showed no significant difference.

The comparison of the effect of identity and associated coordinate conditions to the unrelated condition showed significant facilitation of reaction time in the identity condition ($p < 0.0001$) and interference for associated coordinates ($p < 0.05$). When reaction time in responses in associate coordinate condition compared to identity condition, significant interference was detected from associated coordinates.

Table 26. Effect of facilitation on reaction time in post-facilitation naming

RecRT3 ~ Condition + (1 + logFreq + sylls + phons |Participant) + (1| item)					
Condition	est	se	z score	Pr(>|z|)	
vs. Unfacilitated					
Intercept	-6.47E-04	2.53E-05	-25.553	< 2e-16	
IDENTITY	-8.41E-05	2.24E-05	-3.755	**<0.001**	***
+ASSOC +COORD	7.99E-05	2.43E-05	3.285	**<0.001**	***
UNRELATED	3.07E-05	2.39E-05	1.288	<0.198	
vs. Unrelated					
Intercept	-6.47E-04	2.53E-05	-25.554	< 2e-16	*
IDENTITY	-1.15E-04	2.32E-05	-4.952	**<.001**	***
+ASSOC +COORD	4.92E-05	2.49E-05	1.971	**0.049**	*
vs. Identity					
+ASSOC +COORD	1.640E-04	2.35E-05	6.975	**<0.001**	***

Note: RecRT 3: mean reaction time of responses during post-test naming; Participant and item random intercepts; logFreq ((logged frequency of items based on SUBTLEX-UK), *sylls* (syllables), *phons* (phonemes): random slopes for participant); *est:* estimate; *se*: standard error; *Pr(>|z|)*:p value estimated based on z-score; ASTERISKS indicate significance: **p < .05. **p < .01. ***p < .001. .p>.05 and <.08 indicates trend;* N (observations) =817; n (participants) =12.

4.4.8 *Discussion*

In this experiment, we examined the effect of a facilitation task using word repetition in the presence of the picture on subsequent spoken word retrieval in a group of people with aphasia. We used primes that were both associates and coordinates of the targets, and compared facilitation effects to the effects from identity and unrelated primes and unfacilitated targets. Given the heterogeneity of language impairments in aphasia, we analysed the effect of facilitation at individual participant and group levels.

In the analysis of the effect of identity, we observed a consistent pattern of improved performance (higher proportion of accuracy and faster reaction time) in post-facilitation naming at both group and individual participant levels. At individual participant level, all participants except (IRM) showed benefit from facilitation with identity primes in at least one circumstance (i.e., in comparison of performance before and after facilitation, and/or in comparison post-facilitation performance in different conditions). It should be noted that IRM also showed no benefit in any other condition. Given that IRM responded correctly to only 20% of items in this condition which equates to 6 items out of 30, it is possible that the severity of his language impairment played a role in the lack of significance. However, CSH, who showed a more severe naming impairment than IRM, did benefit from the identity condition; this might be because of less impaired semantic processing. As shown in Participant's profile table, while CSH and IRM had approximately the same proportion of errors in prefacilitation naming, CSH made more phonological errors and fewer semantic errors, while IRM showed an opposite effect (fewer phonological errors and more semantic errors). Otherwise, the benefit from identity repetition observed in the research presented here converges with the evidence shown in previous aphasia studies (e.g., Patterson et al., 1983; Podraza & Darley, 1977) as well as with repetition priming studies implemented with healthy participants (e.g., Wheeldon & Monsell, 1992). Although, not every participant showed this effect, there was no evidence for non-homogeneity, so it is possible that with larger sets and greater power more participants would show significant effects. However, until this can be confirmed, the benefit from repetition priming cannot be guaranteed for every individual with aphasia.

In the analysis of the effect of associated coordinate primes at group level, we observed poorer performance (lower accuracy and slower responses) in post-facilitation naming subsequent to facilitation with associated coordinate primes relative to unfacilitated responses. This pattern of priming is consistent with interference from associated coordinates shown in a number of naming studies with healthy participants (e.g., Howard, Nickels, et al., 2006; Vitkovitch, Rutter, & Read, 2001; Wheeldon & Monsell, 1994).

However, despite an overall finding of interference at the group level, at the individual subject level, only four participants (DHE, HBC, LBL, ICM) showed a significant effect of associated coordinates on reaction time in post-facilitation naming. DHE showed facilitation of reaction time in post-test naming as compared to pre-test naming; however, this effect should be treated with caution, because it is based on only 7% of correct responses (2 items out of 30), and also was not significantly greater than the unfacilitated condition. Likewise, during an assessment, DHE did not exhibit a different pattern of performance to HBC at least. Three other participants (HBC, LBL, ICM) showed significant interference from facilitation with associated coordinate primes. HBC showed interference from associated coordinates relative to both unfacilitated and unrelated conditions, while LBL and ICM showed this effect only relative to the unfacilitated condition. Since LBL and ICM did not show significant differences in naming latencies for associated coordinates compared to the unrelated primes, it seems that any non-target prime interferes with naming latency for these participants. A possible explanation for such discrepancies in performance could relate to different patterns of language impairments these participants showed. Unfortunately, assessment data was not available for LBL and ICM did not exhibit worse performance at either semantic or phonological levels as well as at the transition from semantic to phonological level; however, as can be seen from prefacilitation performance (see Table 21), ICM made more semantic errors than LBL. Likewise, the comparison of patterns of performance observed in HBC, LBL and ICM indicated that while HBC had less semantic errors than ICM but more missed responses (see Table 21). However, during an assessment, HCB showed worse performance in naming than ICM. In addition, HBC showed worse performance in post-facilitation naming than LBL and ICM. Therefore, it is possible that HBC's performance could be affected by semantic relationships more than LBL and ICM. This may be due to his impairment between semantic and phonological levels, which perhaps increases the susceptibility to interference from associated coordinates subsequent to priming at this level. However, due to the confound of both association and coordination as prime characteristics used in this experiment, it remains unclear whether this effect was driven by association or coordination and therefore it is hard to clearly interpret the potential locus of interference. A similar issue applies to overall interference of reaction time detected at a group level as a function of associated coordinate primes.

To provide a better understanding of the nature of priming detected from associated coordinates in this Experiment, we conducted Experiment 4.2 where association and coordination were examined as separate factors.

4.5 Experiment 4.2

In Experiment 4.1, some participants showed significant interference in reaction time of the response from associated coordinates and this effect was significant at the group level when compared to the unfacilitated condition; however, this effect was heterogeneous across participants. Since, in Experiment 4.1, association and coordination were confounded, we conducted Experiment 4.2 to examine the effect of association and coordination as independent factors. Therefore, the goal of Experiment 4.2 was to further examine the effect of repetition primes that are associates (+associate -coordinates) and coordinates (-associate +coordinates) on subsequent accuracy and reaction time of response in people with aphasia. In this experiment we used an unrelated condition as a control.

4.5.1 *Participants*

Nine people with aphasia took part in this experiment. These participants had all participated in Experiment 4.1, and three participants (CSH, LBL and HOE) who participated in Experiment 4.1 did not complete Experiment 4.2.

4.5.2 *Materials and design*

One hundred and twenty photographs were selected for this experiment (some of these photos coincided with those used in Experiment 4.1 due to conditions matching and other photos were new) (see Appendix J). Every target was paired with four different types of prime: *Associate* (+associate -coordinate), *Coordinate* (-associate +coordinate), *Unrelated* (-associate -coordinate), and *Identity* primes following the same principles as in Experiment 4.1. Associates were primes that were associated to the target in the Edinburgh Associative Thesaurus (Wilson, n.d.) selected for target-prime direction of association, but were neither coordinates (members of the same category) nor were semantic features of the target (e.g., *'road'* is associated to *'car'* but is neither its semantic coordinate nor a semantic feature). Coordinate primes were semantic coordinates that were not associated to the target (e.g., *'motorbike'* is not associated to *'car'*, but they are semantic coordinates in the category of *'vehicles'*).

4.5.3 *Procedure*

This experiment followed a similar procedure (including matching) as Experiment 4.1; however, this time all conditions were subject to facilitation (see Figure 15). This experiment was carried out at least 1 week after Experiment 4.1.

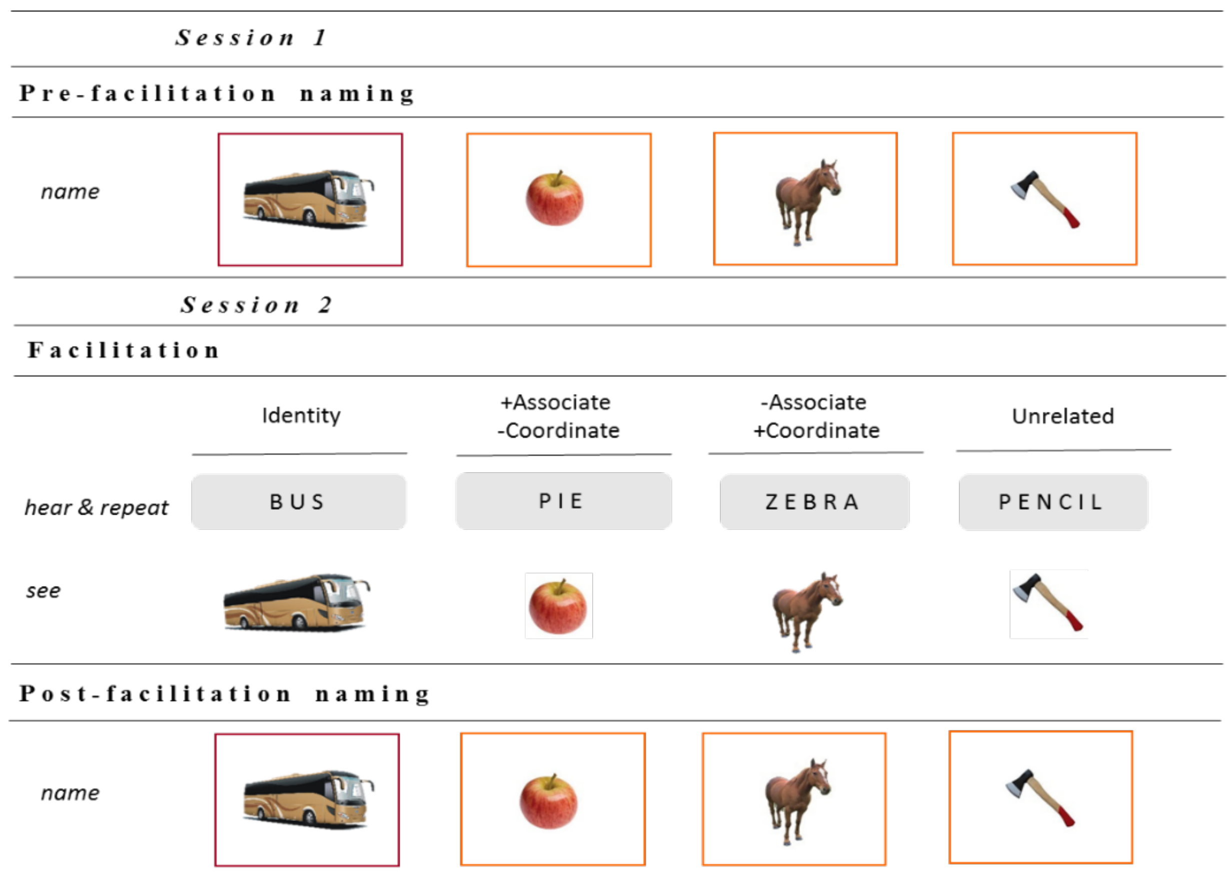


Figure 15. Phases of the Experiment 4.2.

Note: This figure illustrates naming and repetition tasks, participants performed during pre-facilitation phase (Session 1), facilitation and post-facilitation (Session 2).

4.5.4 *Results*

Analysis for Experiment 4.2 was implemented at both individual participant and group levels following the same rationale as in Experiment 4.1. First, we examined the effect of facilitation on post-facilitation naming by comparing the difference in performance before and after facilitation within each condition. Then, we examined the effect of semantic relations by comparing performance in these conditions to performance in the unrelated condition (identity, +associate –coordinate, and –associate +coordinate relative to the unrelated condition). Both analyses included the analysis of the accuracy of the response and reaction time of the response and both were performed at group and individual subject level.

Analysis of accuracy

Effect of facilitation

Table 27 summarises the proportion of correct pre- and post-test responses in identity, associate, coordinate, and unrelated conditions. Statistical analysis of responses at the individual subject level before and after facilitation was carried out with McNemar's test (McNemar, 1947). SSJ showed significantly higher proportion of correct responses during post-test in identity condition, DHE showed significant worsening in the associate condition, and NGH showed significant worsening in the coordinate condition. The other 6 participants (IRM, SRT, CBH, DTF, HBC, ICM) showed no significant changes in the accuracy of response between post-test naming relative to pre-test.

Table 27. Proportion of correct responses before and after facilitation

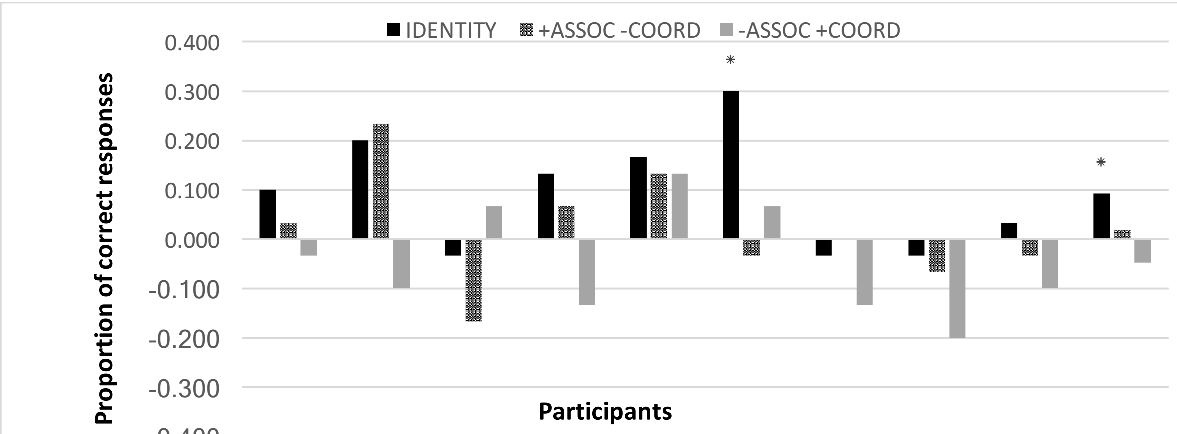
Participant	*Condition*							
	IDENTITY		*+ASSOC - COORD*		*-ASSOC +COORD*		*UNRELATED*	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
IRM	.20	.27	.23	.20	.20	.13	.23	.17
NGH	.40	.50	.40	.53	.43	**.20***	.40	.30
DHE	.27	.27	.33	**.13***	.40	.37	.30	.30
SRT	.47	.60	.33	.53	.40	.33	.37	.47
CBH	.57	.70	.60	.67	.60	.67	.60	.53
SSJ	.40	**.73***	.40	.40	.37	.50	.40	.43
DTF	.53	.67	.67	.70	.47	.57	.63	.70
HBC	.43	.50	.40	.47	.43	.33	.43	.53
ICM	.77	.93	.80	.87	.80	.80	.77	.90
All	.45	***.57****	.46	***.50****	.46	***.43****	.46	***.48****
sd	.17	.22	.18	.23	.17	.22	.17	.22

Note: *+ASSOC-COORD* - +associate-coordinate; *-ASSOC +COORD* - -associate +coordinate; *BOLD ITALIC ASTERISK* refers to changes that are significant (p < .05) based on paired McNemar's test for the individual subjects and Combined z-score for case series; N (observations in every condition) = 30.

At the group level, statistical analysis was implemented with combined z-score giving equal weight to each participant's results. The results of the analysis showed significant improvement in naming from pre- to post-facilitation in 3 conditions (identity, associate, unrelated) and significant worsening in the coordinate condition. This pattern of priming was homogeneous across participants (*Identity:* z = -3.03, p = 0.003, one tailed; H (7) = 3.89; p = 0.21; *+Associate: Coordinate condition*: z = -2.74, p = 0.003, one tailed; H (7) = 3.13; p = 0.13, *-Associate +Coordinate condition*: z = 2.47, p = 0.01, one tailed; H (7) = 3.59; p = 0.17; *Unrelated:* z = -2.05, p = 0.02, one-tailed; H (7) = 1.22; p = 0.01).

Effect of semantic relations

The proportion of correct responses in identity, associate, and coordinate conditions compared to unrelated condition are summarized in Figure 16. Statistical analysis of these differences was carried out with 2-sample t-tests at individual subject level and generalized linear model at group level.



	IRM	NGH	DHE	SRT	CBH	SSJ	DTF	HBC	ICM	All
IDENTITY	0.100	0.200	-0.033	0.133	0.167	0.300	-0.033	-0.033	0.033	0.093
+ASSOC -COORD	0.033	0.233	-0.167	0.067	0.133	-0.033	0.000	-0.067	-0.033	0.019
-ASSOC +COORD	-0.033	-0.100	0.067	-0.133	0.133	0.067	-0.133	-0.200	-0.100	-0.048

Figure 16. Proportion of correct responses in Identity, +Assoc -Coord, and -Assoc +Coord conditions as compared to Unrelated condition.

Note: ASTERISKS indicate significant difference of the accuracy of response.

At the individual subject level (see Figure 16), SSJ showed significantly greater improvement in accuracy in the identity condition compared to the unrelated condition. The other eight participants (IRM, NGH, DHE, SRT, CBH, DTF, HBC, ICM) showed no significant differences. At the group level, statistical analysis was implemented with generalised linear mixed effect model of family binomial with participants and items as random intercepts and logged frequency as random slope for participants[16]. In summary, significant facilitation was observed in the identity condition and no other effects were found (see Table 28).

[16] In contrast to analysis in Experiment 1, syllables and phonemes were not used as random slopes, because model failed to converge.

Table 28. Accuracy of responses in Identity, +ASSOC -COORD, -ASSOC +COORD conditions contrasted to Unrelated condition

Accuracy3 ~ Condition + (1 + logFreq | Participant) + (1 | item)					
	est	*se*	*z score*	*Pr(>|z|)*	
Intercept	0.48233	0.51344	0.939	0.348	
IDENTITY	0.47839	0.20872	**2.292**	**0.022**	*
+ASSOC -COORD	0.06721	0.20712	0.324	0.746	
- ASSOC +COORD	-0.26038	0.20741	-1.255	0.209	

*Note: Accuracy3: accuracy of responses during post-test naming; ~ Condition indicates the effect of Condition on the Accuracy of the response; Participant, items (targets): random intercepts; logFrequency (logged frequency of items based on SUBTLEX-UK): random slope for participants; BOLD ASTERISKS indicate significance: *p < .05. **p < .01. ***p < .001. N (observations) = 600; n (participants) = 9.*

Analysis of Response latency

Effect of facilitation

The summary of reaction time of responses before and after facilitation is reported in Table 29. Statistical analysis of the effect of facilitation on reaction time in post-facilitation performance, at the individual subject level, was carried out with paired t-tests. In summary, five participants showed significant priming from associates, with SRT showing significant interference and four other participants (CBH, SSJ, HBC, ICM) significant facilitation. Three of these participants (CBH, DFT, ICM) also showed facilitation from the identity condition, and two participants (HBC, ICM) showed facilitation from the unrelated condition.

Table 29. Proportion and Mean reaction time for items correct at both pre- and post-test

Participant	*Condition*											
	IDENTITY			*+ASSOC -COORD*			*-ASSOC +COORD*			*UNRELATED*		
	proportion correct	**Pre-test**	**Post-test**	*proportion correct*	**Pre-test**	**Post-test**	*proportion correct*	**Pre-test**	**Post-test**	*proportion correct*	**Pre-test**	**Post-test**
IRM	.10	3.22	3.14	.13	3.32	3.19	.10	3.20	3.24	.10	3.28	3.25
NGH	.33	3.32	3.21	.30	3.28	3.38	.17	3.35	3.39	.20	3.29	3.17
DHE	.13	3.28	3.18	.10	3.37	3.38	.23	3.30	3.23	.17	3.30	3.46
SRT	.33	3.22	3.16	.23	3.08	***3.27****	.10	3.19	3.32	.23	3.14	3.23
CBH	.33	3.30	***2.99****	.23	3.35	***3.23****	.10	3.29	3.23	.23	3.33	3.24
SSJ	.43	3.18	3.05	.53	3.15	***3.04****	.47	3.17	3.06	.43	3.16	3.25
DTF	.30	3.21	***3.07****	.30	3.16	3.19	.30	3.14	3.02	.23	3.21	3.06
HBC	.40	3.38	3.22	.57	3.39	***3.23****	.33	3.42	3.20	.53	3.36	***3.28****
ICM	.27	3.28	***3.08****	.33	3.28	***3.14****	.27	3.28	3.17	.33	3.25	***3.14****
All	.29	3.26	***3.12****	.30	3.27	3.23	.23	3.26	3.21	.27	3.26	3.23
(sd)	.11	.06	.08	.16	.11	.11	.13	.09	.12	.14	.07	.11

Note: IDENT: identity; *+A-C:* +associate-coordinate*; +A-C:* +associate- coordinate; *UNR:* unrelated; *BOLD I ASTERISKS* refers to changes that are significant (t >2.00) based on paired t-test and Combined z-score for case series; *proportion correct:* the proportion of items that were correct at both pre- and post-test.

Across the group, there was significant facilitation in identity, associate and coordinate conditions which was homogeneous across participants (1) Identity (z=-5.12, p <0. 0001; H (7) =13.99, p= 0.95), 2) +Associate – Coordinate (z=-2.38, p =0. 009, one tailed; H (7) =18.41, p= 0.99), 3) –Associate + Coordinate (z =-2.29, p =0. 01, one tailed; H (7) =9.54, p= 0.78)) and no significant effect was observed in the unrelated condition (z =-1.16, p = 0.12; H (7) =16.94, p= 0.98).

Effect of semantic relations

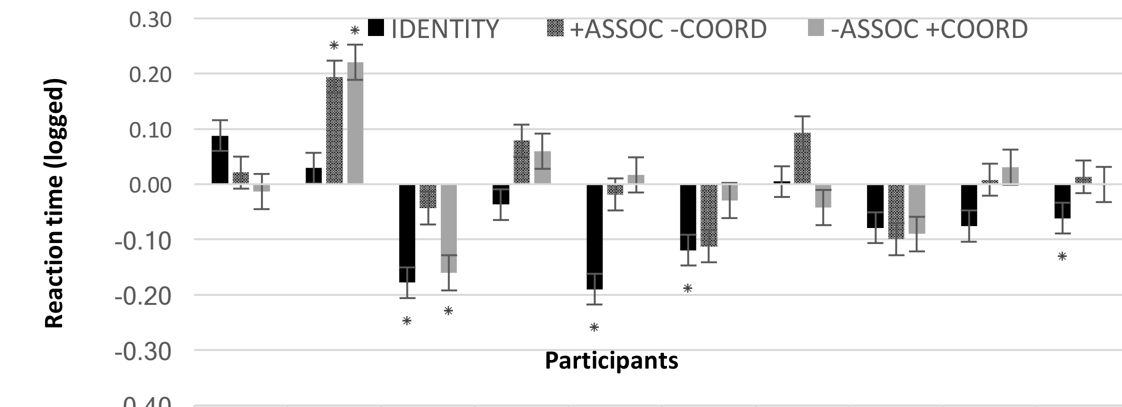
Summary of proportion of mean reaction time of correctly retrieved items in post-test naming are summarized in Table 30.

Table 30. Mean reaction time for items correct in post-test naming

	Proportion correct (post-test)	***IDENTITY***	*Proportion correct (post-test)*	**+ASSOC -COORD**	*Proportion correct (post-test)*	**-ASSOC +COORD**	*Proportion correct (post-test)*	***UNRELATED***
IRM	.27	3.30	.20	3.24	.13	3.20	.17	3.21
NGH	.50	3.24	.53	***3.40****	.20	***3.43****	.30	3.21
DHE	.27	***3.25****	.13	3.38	.37	***3.27****	.30	3.43
SRT	.60	3.18	.53	3.30	.33	3.28	.47	3.22
CBH	.70	***3.06****	.67	3.23	.67	3.26	.53	3.25
SSJ	.73	***3.07****	.40	3.08	.50	3.16	.43	3.19
DTF	.67	3.12	.70	3.20	.33	3.07	.53	3.11
HBC	.50	3.25	.47	3.23	.33	3.24	.53	3.33
ICM	.93	3.07	.87	3.15	.80	3.18	.90	3.15
All	.57	3.17	.50	3.25	.41	3.23	.46	3.23
(sd)		0.093		0.103		0.099		0.095

Note: Proportion of correct responses refers to all responses retrieved correctly during post-test naming; BOLD italic: refers to changes that are significant (t >2.00) based on paired t-test comparing each condition with the Unrelated condition and Combined z-score for case series.

The difference of mean reaction time in the identity, associate, coordinate conditions compared to unrelated condition are shown in Figure 17. At the individual subject level, 2 participants (CBH, SSJ) showed significantly faster naming in the identity condition compared to the unrelated, DHE showed significantly faster naming in both the identity and coordinate conditions, and NGH showed significant interference in both the associate and coordinate conditions relative to the unrelated item.



	IRM	NGH	DHE	SRT	CBH	SSJ	DTF	HBC	ICM	All
IDENTITY	0.088	0.029	-0.178	-0.036	-0.190	-0.119	0.005	-0.079	-0.076	-0.062
+ASSOC -COORD	0.021	0.194	-0.043	0.079	-0.019	-0.113	0.093	-0.099	0.008	0.013
-ASSOC +COORD	-0.013	0.221	-0.160	0.059	0.017	-0.029	-0.042	-0.090	0.031	-0.001

Figure 17. The difference of mean reaction time in Identity, +ASSOC -COORD, -ASSOC +COORD conditions and Unrelated condition.

Note: ASTERISKS indicate significant difference of the mean reaction time of response.

At the group level, statistical analysis of reaction time was carried out with a linear mixed effect model (Bates et al., 2014) following the same procedure as in Experiment 4.1. A simple contrast was applied to conditions (+1 – for condition of interest, -1 for control condition, and 0 for other conditions), and RT was reciprocated to normalise the distribution. The model was fitted within 2.5 standard deviations as it slightly improved the R^2 correlation from 0.26 to 0.29 and 1 data point was removed. There was significant facilitation of naming latencies in the identity condition relative to the unrelated condition but no significant effects in either of the related conditions (see Table 31).

Table 31. Effect of facilitation on reaction time in post-facilitation naming

RecRT3~ Condition + (1 logFreq + sylls + phons | Participant) + (1 | Item)					
	est	*se*	*z score*	*Pr(>|z|)*	
(Intercept)	-6.86E-04	4.07E-05	-16.862	<2e-16	***
Identity	-1.00E-04	3.10E-05	**-3.238**	**0.001**	**
+Associate -Coordinate	3.33E-05	3.18E-05	1.048	0.295	
-Associate +Coordinate	-6.95E-06	3.31E-05	-0.21	0.834	

*Note: Participants and items random intercepts; logFreq (frequency), sylls (syllables), phons (phonemes): random slopes for participant); ASTERISKS indicate significance: *p < .05. **p < .01. ***p < .001. N= number of data points included in the analysis; N (observations) = 305; n(participants) =9.*

4.5.5 *Discussion*

In this experiment, we examined the effect of repetition of primes that were identical, associates (+associate -coordinate), or semantic coordinates (- associate +coordinate) to the target on subsequent picture naming.

In the analysis of the effect of repetition of identical primes, we found overall improvement in post-test naming. At the group level, repetition of identical primes resulted in a general improvement of accuracy and speeding of reaction time in post-test naming, both compared to pre-test and relative to an unrelated prime. At the individual subject level, four participants (DHE, CBH, SSJ, ICM) showed benefit from this facilitation in at least one circumstance (relative to performance before facilitation and/or in comparison to facilitation with unrelated prime). It should be noted that despite the fact that significant priming in identity condition was detected in Experiment 4.2, fewer participants showed this effect compared with Experiment 4.1. Interestingly, however, the participants that showed significant effect of repetition priming in Experiment 4.2 always showed significant priming in Experiment 4.1, suggesting an overall weakening of the effect of identity priming but not a qualitatively different pattern.

The analysis of the effect of facilitation with primes that were either associates (+associate –coordinate) or coordinates (- associate +coordinate) to the target showed no consistent pattern of priming on subsequent accuracy or reaction time in spoken word retrieval. At the group level, improvement from association and worsening from coordination were observed in post-facilitation naming accuracy compared to before facilitation. However, when compared to the effect of unrelated primes, neither association nor coordination showed significant priming.

At the individual subject level, no homogeneous pattern of priming was observed across participants. Comparing pre- to post-facilitation performance, two participants (DHE, SRT) showed worsening and four participants (CBH, SSJ, HBC, ICM) showed a benefit from association; likewise, two participants (LBL, ICM) showed benefit from coordination. However, comparing performance to the unrelated condition, NGH showed worsening from both association and coordination and DHE showed benefit from coordination.

Overall, the heterogeneity of the effects produced by primes that were either associates or coordinates challenges the finding from Experiment 4.1 where we showed significant interference in reaction time at group level from +Associate +Coordinates. Since Experiment 4.2 included only 9 out of 12 participants that took part in Experiment 4.1, one of potential reasons could be the number of participants. To test this out, we reran the analysis of reaction time (at group level) for Experiment 4.1 with only those participants that took part in Experiment 4.2.

Comparison of accuracy of the response before and after facilitation showed the same pattern of changes: significant improvement in the identity condition ($z = -2.96$, $p < 0.002$; $H(7) = 23.75$, $p = 0.99$) and no effects in associated coordinate and unrelated conditions. Comparison of accuracy in post-facilitation naming in identity and associated coordinate conditions with unrelated condition (see Table 32) showed significant improvement in identity condition and no effect of associated coordinate primes.

The analysis of reaction time before and after facilitation, showed significant facilitation in the identity condition ($p < 0.001$) in both accuracy and reaction time of response. Associated coordinates produced no significant effect on the accuracy of the response, and only a trend was detected in the analysis of the reaction time of response ($p=0.07$). The comparison of the latency of response in identity and associated coordinate conditions with the unrelated condition showed significant facilitation from the identity condition and interference from the associated coordinate (see Table 32) condition.

Table 32. Effect of facilitation on accuracy and reaction time of response

ACCURACY: Accuracy3 ~ Condition + (1 |Participant) + (1| item)					
Condition	est	se	z score	Pr(>|z|)	
Intercept	0.6506	0.5616	1.158	0.247	***
Identity	0.7133	0.2075	**3.437**	**0.001**	**
+ASSOC +COORD	-0.1258	0.2018	-0.623	0.533	
vs. Identity					
+ASSOC +COORD	-0.8392	0.2061	**-4.071**	**0.001**	
***REACTION TIME:** RT3 ~ Condition + (1 + logFreq + sylls + phons |Participant) + (1| item)*					
Intercept	-6.72E-04	2.97E-05	-22.634	< 2e-16	***
Identity	-8.98E-05	2.67E-05	**-3.371**	**0.001**	**
+ASSOC+COORD	5.13E-05	2.84E-05	*1.810*	*0.070*	.
vs. Identity					
+ASSOC +COORD	1.42E-04	2.71E-05	**5.248**	**<0.001**	***

Note: RecRT 3: mean reaction time of responses during post-test naming; Participant and item random intercepts; logFreq (logged frequency of items based on SUBTLEX-UK), *sylls* (syllables), *phons* (phonemes): random slopes for participant); *est:* estimate; *se*: standard error; *Pr(>|z|)*: p value estimated based on z-score; ASTERISKS indicate significance: *p < .05. **p < .01. ***p < .001. .p>.05 and <.08 indicates trend; BOLD refers to significance and Italic to trend; N (observations) =1008 in the analysis of Acurracy; N (observations) = 598 in the analysis of Reaction time; n (participants) = 12.

Thus, the analysis of accuracy for the group of 9 participants showed the same pattern of priming in the identity condition as the analysis with 12 participants. However, in the analysis of reaction time, the same pattern was detected in identity condition only; while in the associated coordinate condition the significant interference attenuated to an inhibitory trend when compared to unrelated condition, but the reaction time of responses in the associated coordinate condition remained significantly slower than in identity condition.

Given these results, it follows that the overall interaction of both association and coordination can produce semantic interference with response latency in spoken word retrieval; however, the robustness of this effect varies depending on the participants. In this particular case, one participant excluded from this analysis had the most severe impairment of abilities to retrieve the word; in contrast, two other participants were fluent and had relatively preserved ability to retrieve words while having all characteristics of aphasia. Further implications of these results are discussed within the Chapter 5.

4.6 Conclusion

The goal of the research presented here was to examine the effect of semantic relationships on spoken word retrieval in a case series of people with aphasia, to provide better understanding of the mechanisms involved in lexical access in spoken word retrieval. To do this, two experiments were conducted: in both experiments we examined the effect of identity on subsequent spoken word retrieval in order to relate this research to previous priming studies with people with aphasia. In Experiment 4.1, we also examined the effect of associated coordinate primes on spoken word retrieval and, in Experiment 4.2, we further tested the effect of association and coordination as separate factors. In Experiment 4.1 we contrasted performance with both unrelated and unfacilitated conditions and in Experiment 4.2 only with an unrelated condition.

The results of both experiments showed convergent evidence of improved word retrieval subsequent to facilitation with identical primes. Statistically, this effect was homogeneous across participants although not every participant showed a significant effect in every condition. Taken together, the pattern of priming from the identity condition is consistent with a number of other studies conducted with people with aphasia (e.g., Best, Herbert, Hickin, Osborne, & Howard, 2002; Nickels & Best, 1996) as well as with studies implemented on healthy participants (e.g., Wheeldon & Monsell, 1992). Nevertheless, having previously produced a word facilitates retrieval of that word even with several intervening items (an average of seven in this study).

Analysis of the effect of semantic relationships revealed no consistent pattern of priming. Associated coordinates showed significant interference in post-facilitation naming at group level; and at the individual subject level the only significant effects also showed interference (compared to unrelated). However, when implemented with 9 participants, no significant interference from associated coordinates was detected but only an inhibitory trend. The analysis of association and coordination as separate factors (Experiment 4.2) detected no main effects at group level. At the individual subject level, the effects of association on post-facilitation naming varied from interference to facilitation. Similarly, at the individual subject level the effect of coordinates was heterogeneous and not directly related to the pattern of performance during an assessment.

Given these results, the question arises how do they relate to theories of spoken word retrieval? There is a wide agreement in the literature that lexical access in spoken word retrieval involves spreading activation (e.g., Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Howard, Nickels, et al., 2006; Levelt, 1999; Roelofs, 1992). According to this theory, selection of a lemma node results in strengthening of its semantic-to-lemma connections. Since semantically related words share semantic information, it was suggested that retrieval of one node may result in co-activation of the semantic information relevant to other nodes. For example, retrieval of semantic information relevant to the node ‘CAR’ would co-activate semantic information relevant to nodes such as: ‘VEHICLE’, ‘BUS’, ‘TYRE’ etc, perhaps strengthening the semantic-lemma connections for the target as well as the prime. Therefore, it is possible that retrieval of a semantically-related item might result in improved accuracy of the response for the main target. However, as results of two experiments conducted, neither of the semantic relations examined in the current experiment resulted in improved accuracy of the response in post-test naming at group level.

On the other hand, we did detect interference in reaction time from primes that were associated coordinates to the target. This finding is consistent with the finding of semantic priming from associated coordinates detected in a number of studies with healthy participants (e.g., Howard, Nickels, et al., 2006; Vitkovitch et al., 2006; Wheeldon & Monsell, 1994) and also in Chapters 2 and 3 of this Thesis. Semantic interference from associated coordinates reinforces the idea that semantic relationships do matter in lexical access of spoken word retrieval. Moreover, it supports our suggestion that a certain degree of overlap of semantic features is needed for the semantic priming to occur. However, as at the individual subject level no consistent priming was detected it remains unknown what mechanism underpins these variations. Therefore, more thorough examination of the effect of different types of semantic relationships on spoken word retrieval is needed before applying it as a treatment of semantic relationships. Further implications of these results are returned to in the final chapter of this thesis.

Chapter 5. General discussion

5.1 Summary of Results

The goal of this thesis was to examine the mechanisms underpinning semantic priming in spoken word retrieval in order to inform our understanding of theory regarding the nature of the organisation of word meaning and the mechanisms involved in lexical access for speech production. To do so, we conducted a systematic evaluation of the effects of different semantic relations on speed and accuracy in spoken word retrieval in several experiments with healthy participants (Chapters 2 and 3) and people with aphasia (Chapter 4).

In Chapter 2, two experiments were conducted to examine the effect on picture naming of association, coordination, part-whole relations, and lag with written word primes in an alternating word reading and picture naming paradigm. In Experiment 2.1, we examined the effects of association and coordination in priming at lags zero and four and found significant interference from association, and coordination, but no effect of lag nor any type of interaction. In Experiment 2.2, we examined, at lag 4, the effect of primes which were associated coordinates, and also primes that were parts associated to the target in either target-prime direction of association or unidirectional prime-target direction. Significant interference from associated coordinates was observed, but no effect of parts associated to the target in either direction.

These results led us to conclude that association, coordination, and part-whole relations differ in the nature of their organisation which leads to the different patterns of semantic priming. First, significant interference was observed from both association and coordination, but there was no interaction. These effects were therefore additive and hence independent (Sternberg, 1969). Second, in Experiment 2.2, interference from associated coordinates was observed at lag 4, but there was no effect of parts associated to the target in either target-prime or prime-target direction of association. We suggested that the nature of these relations is different; in particular, assuming that both associated coordinates and parts share semantic features with the target, it is probable that parts share substantially fewer semantic features than associated coordinates. This reduced overlap for parts would result in less reactivation of the prime than occurs for associated coordinates. We hypothesise that the reactivated prime consequently does not compete with the target sufficiently to impact on the latency of target retrieval.

Following up on Chapter 2, Chapter 3 examined the effect of association, coordination and part-whole relations but using picture rather than word primes. In the continuous picture naming paradigm, we observed significant interference from prime association driven by the interaction of association and coordination, and an effect of lag. There was also an interaction between coordination and lag[17], with significant interference at lag 4 but not at lag 0. In the second experiment in Chapter 3, there was significant interference from associated coordinate primes, but once again no effect from part-primes associated to the target in either direction. Following McClelland (1979), we accounted for the interaction of association and coordination observed in the continuous picture naming paradigm as due to an overlap of two additive effects as a function of cascaded lemma retrieval.

Chapter 4 used a different source of evidence from the previous two chapters. It examined the effect of priming of picture naming by repeating words aloud while looking at a target picture (facilitation) in a case series of people with aphasia. Two experiments were conducted with the first being focused on the examination of the effect of primes that were either identical or associated coordinates of the target and a second experiment where primes were: 1) identical, 2) associates, or 3) coordinates.

Given the heterogeneity of language impairment in people with aphasia, all the results were analysed at individual subject and group levels. At the group level, there was a significant facilitation in the identity condition in both Experiments 1 and 2. For individual subjects, all participants showed a tendency for improvement in postfacilitation naming subsequent to facilitation with the identity prime; however, the effect was only significant for 9 participants in Experiment 4.1 and four participants in Experiment 4.2. In Experiment 4.1, for the group, there was interference from associated coordinates, but no significant effects of association and coordination independently were observed in Experiment 4.2. At an individual level, the effects of semantically related primes was heterogeneous across participants and varied from facilitation to interference.

[17] This was marginally significant when the data were fitted to 2.5 SD but significant for the unfitted data and when fitted to 2 SD.

Given the benefit from repeating the prime identical to the target, it was assumed that this effect resulted from the same mechanism of priming as occurs in unimpaired subjects; that is, strengthening of semantic-lemma connections. While a number of authors agree that the mechanisms underpinning improvement with facilitation are the same as priming in healthy participants (e.g. Nickels, 2002), the literature does not always agree on the level at which this occurs. Indeed, while Howard, Nickels et al. (2006) suggested priming in unimpaired subjects is most likely in semantic-lemma connections, Howard, Hickin, et al. (2006) argue for lemma-phonological priming underpinning facilitation in people with aphasia. The effect of interference we found from associated coordinates is compatible with the pattern in healthy participants observed in Chapters 2 and 3 where the effect of semantic interference was observed in associated coordinate condition. Consequently, it seems probable that the same mechanism underpins the effects in both people with aphasia and healthy participants.

Further implications of the results of the experiments conducted in this thesis on the theory of semantic representation and lexical access are discussed below.

5.2 Compatibility of these results with previous studies

In finding semantic interference from coordination, the results of our research are consistent with previous studies. However, depending on the task this effect was either independent (Chapter 2) or driven by the interaction with association (Chapter 3 and Chapter 4).

In the majority of previous studies of the effects of associate or coordinate primes/distractors on picture naming, there has been a consistent finding of facilitation from association and interference from coordination (e.g., Alario, Segui, & Ferrand, 2000; Costa, Alario, & Caramazza, 2005; Tree & Hirsh, 2003) and, therefore, it was assumed that association and coordination refer to different types of semantic relations with different mechanisms underlying their effects. However, some studies have detected semantic interference from both relations (e.g., Rahman & Melinger, 2007) and, based on this, Rahman and Melinger (2007) have assumed that semantic interference from association can be driven by the same mechanism as interference from coordination. In the research presented here, we also observed semantic interference from both association and coordination. However, while with word reading primes there was no interaction between these two factors, with picture naming primes there was significant interference from association driven by the interaction of association and coordination, and an interaction with lag with significantly slower responses subsequent to coordinate primes at lag 4. So the question arises how to account for such differences.

There are several factors that could, at least partially, account for the discrepancy in the results observed in the experiments carried out in this thesis relative to previous studies. First of all, the design of the study may have contributed to this discrepancy. In the majority of previous studies, the effect of different types of semantic relations has been examined in different experiments. That is, one experiment would focus on the examination of the effect of association and another on the effect of coordination (e.g., Alario et al., 2000; Costa et al., 2005; Tree & Hirsh, 2003). In contrast, the current study employed cross-factorial design; that is, every participant was shown all the conditions in the same experimental trial. This design provides a far stronger control as the same participants were tested on every condition and every item was also tested in every condition. The disadvantage of such a design, however, is the relatively small data set that results from the necessity of finding target stimuli that can be paired with primes in all four conditions while matching for relevant factors. For example, in order to achieve matching across all the conditions for Experiment 2.1 and 3.1, only 24 items could be retained from around 200 potential targets that were initially selected. In Experiment 2.2 and 3.2 (Chapters 2 & 3), stimulus constraints resulted in only 16 experimental targets remaining. Therefore, a relatively high number of participants is needed to reach sufficient power to detect priming effects. In addition, with small sets, there is greater concern regarding the possibility that the characteristics of these particular stimuli could have influenced the results.

Another distinction of the research presented here is the statistical analysis used. In the majority of previous studies every condition was examined in a separate experiment and Analysis of Variance (ANOVA) was mainly used to analyse the results (e.g., Alario et al., 2000; Costa et al., 2005; Rahman & Melinger, 2011; Tree & Hirsh, 2003). However, the cross-factorial design applied to this research allowed the use of multilevel statistical analysis. The advantage of such analysis is that it allows the examination of the effect of a particular factor relative to a grand mean of responses averaged from all the conditions engaged in the particular experiment. That is, unlike conventional ANOVA statistical analysis, multilevel analysis allows for contrast coding of conditions to be used. No less important is that it also allows an examination of these contrasts by taking into account participants and items as random intercepts (rather than averaging data across participants or items).

Such discrepancies in the design of the experiment along with different method of statistical analysis could have resulted in the slightly different outcomes observed in the research presented here. However, as mentioned above, in finding significant interference from coordination, the results of the experiments presented here are, nevertheless, consistent with previous studies; therefore, it is unlikely that any influence of the design was great.

In addition to such methodological differences, no less important are the differences in the materials selected. To date, the majority of studies that have examined the effect of association and coordination by examining the effect of associated members of different semantic categories and not associated members of the same semantic category. However, as mentioned in the Introduction (Chapter 1), semantic relations differ not only in whether they are categorical or not, but there is also further subdivision within every class of relations. For example, items that belong to different categories can be functionally related (e.g., *'road'* – *'car'*) or refer to feature-part relations (e.g., part-whole relations: *'tyre'* is a part of *'car'*). Moreover, even within the same type of relations further division is possible; for example, within part-whole relations several types of relations have been identified so far. To date, not all studies have been careful to select items with only one type of semantic relations and this according to McClelland (1979) could result in a confound of the effect of different semantic relations. To avoid such an issue, in the research presented here, we selected items taking into account the possibility of further subdivision. Moreover, the majority of studies while selecting coordinates from the same semantic category did not control for the degree of functional semantic relatedness. In contrast, we controlled for semantic distance by using latent semantic analysis data (Landauer et al., 1998).

Another issue related to the material selected refers to the nature of associative relations. Associative relations differ from semantic relations in the sense that all semantic relations are symmetrical while associative relations may be asymmetric (e.g., Plaut, 1995). This asymmetry implies that, for example, *'car'* may be associated to '*garage'*, but *'garage'* is not necessarily associated to *'car'*. In this regard, not all previous studies controlled for the direction of association. For example, the majority of studies with unmasked priming or picture-word interference tasks used target-prime direction of association (Alario et al., 2000; Costa et al., 2005; Damian & Spalek, 2014; Rahman & Melinger, 2011) while Tree and Hirsh (2003) in alternating word reading and picture naming used prime-target direction of association. However, these studies did not specify whether the stimuli were also associated in the other direction (i.e., bidirectionally associated). Plaut (1995) distinguished between association with forward (prime-target) and backward (target-prime) associative relations in simulation study whith both primes and targets being presented as written words. In result, Plaut (1995) found significant facilitation from forward association and no effect from backward association. In the research presented here, we controlled for both directions of association and found that the effect of association was clearly influenced by the direction in which target and prime were associated.

In sum, the differences in the material selected along with different method used, could have resulted in the discrepancy between our study and others regarding the pattern of priming observed. Thus, we will now address what the implications of our results might be.

5.3 Implications for the mechanisms underpinning semantic priming in spoken word retrieval

To date, semantic priming from different semantic relationships in spoken word retrieval has been accounted for either as a function of different mechanisms or as a function of the same mechanism. Alario et al. (2000) observed facilitation from association and interference from coordination and suggested that the difference between these types of relations resulted in the different patterns of priming. In particular, association has been argued to produce facilitation at the conceptual level and coordination to produce interference as a function of lexical competition at the lemma level (Alario et al., 2000). Later, Costa et al. (2005) observed the same pattern of priming when comparing the effect of associated parts and associated coordinates and accounted for the different polarity of the effects as a function of the same mechanism: response exclusion. According to this account, semantic interference is restricted to the members of the same semantic category and occurs at the post-lexical buffer; in contrast, facilitation from associated members of different semantic categories is argued to occur from spreading activation at the conceptual level. These activated items do not compete for selection in the buffer as they are not candidates for production. However, in the research presented here, we observed interference from both association and coordination which means that semantic interference is not restricted to members of the same semantic category but can be driven also by other factors such as association.

Abdel Rahman and Melinger (2007) also found interference from both association and coordination and suggested that priming from different semantic relations is a function of the same mechanism. According to their view, depending on the locus of priming and the degree to which the prime is a competitor of the target, either facilitation or interference can occur. That is, according to this account, both association and coordination can produce both facilitation and interference depending on the degree of their activation. While in our experiments we also observed semantic interference from both association and coordination, we showed that these effects were additive; that is, driven by different mechanisms. Likewise, it is hard to account for why, using alternating word reading and picture naming task, we found interference from association while Tree and Hirsh (2003) found facilitation. In the Discussion to Chapter 2, we suggested that the polarity of such effect may be driven by the direction of association. So, in contrast to Abdel Rahman and Melinger's (2007) model according to which the polarity of priming from association depends on the locus and degree of prime activation, results of our experiments revealed that the polarity of priming from association can be driven by direction of association, that is with a target-prime direction of association, interference can be observed and prime-target direction of association as in Tree and Hirsh's (2003) study may result in facilitation.

Taken together, we suggested that priming from both coordination and association results from lexical competition at the lemma level; however, for coordination this is a competition due to shared semantic features, while for association this competition as a function of lateral activation at the lemma level. However, in Chapter 3, we observed an effect of association driven by the interaction of association and coordination and also interference from coordination at lag 4. As discussed in Chapter 3, we suggested that since with word primes there was no interaction between the two types of relations such an interaction was a function of cascaded lemma retrieval. That is, activation of one lexical concept spreads activation toward others and so on, and at the same time every concept activates its corresponding lemma node. Depending on the strength to which the concept is activated, it activates the corresponding lemma to a greater or lesser extent. In turn, every lemma, once activated, spreads activation to the other lemmas to which it is associated. Therefore, if a lemma has been previously selected and is primed it becomes a stronger competitor to the target and inhibits its selection. This effect can be explained from the view of both decomposed and non-decomposed models.

5.3.1 *Non-decomposed model of priming*

Panel A in Figure 18 illustrates the selection of the lemma *'car'* from the non-decomposed model point of view. According to this approach, at first, the lexical concept *'car'* spreads activation toward all the lexical concepts it is connected to, with stronger connections for more closely semantically related items. Then, every conceptual node further activates its corresponding lemma; this process is independent for every concept-lemma mapping and depends on the strength of activation of the lexical concept. Therefore, some lemmas can accumulate activation faster (e.g., *'bus'*) if they share more semantic information with the target and others slower (e.g., *'tyre'*) if they share less semantic information (e.g., Collins & Loftus, 1975; Roelofs, 1992). The lemmas that receive greater activation become stronger competitors with the target (e.g., 'bus') for selection than the lemmas that received less activation (e.g., 'tyre'). Therefore, stronger interference can be observed from *'bus'* to *'car'* than from *'tyre'* to *'car'*.

For association, since *'car'* is associated to *'bus'* and *'road'* it spreads activation via lateral links at the lemma level towards their lemmas. If one of these lemmas represents a prime, it will be more active than normal and, hence, it becomes stronger competitor to *'car'* slowing its selection and thereby producing interference.

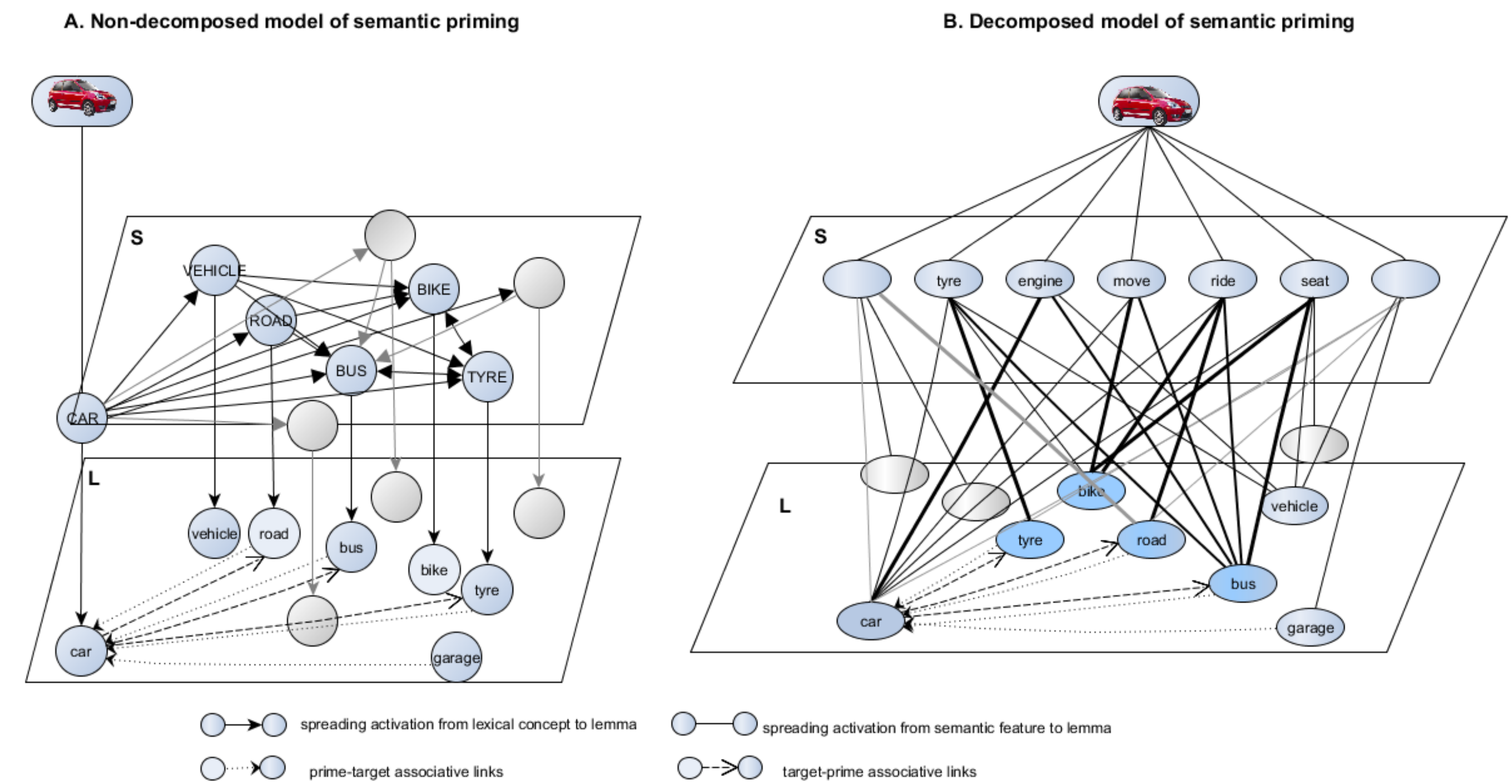


Figure 18. Models of semantic priming.

Note that in both models competition is assumed at the lemma level; this could be implemented using Luce Choice Ratio or by within level inhibitory links which are not depicted.

5.3.2 *Decomposed model of semantic priming*

Panel B in Figure 18 illustrates a model of lexical retrieval with decomposed semantic representations. According to this approach, different types of semantic relations share semantic features, but the more semantic features items share, the closer they are related. Lemma retrieval, according to this decomposed model, starts with activation of a concept's semantic features which, in turn, activate the corresponding lemma. Once the prime lemma is selected its semantic-to-lemma connections are strengthened and primed. When the target is presented, the shared features between prime and target cause the prime lemma to be reactivated. Due to the strengthening of the semantic-lemma connections, this primed lemma receives more activation and becomes a stronger competitor to other lemmas with which it shares semantic features. Thus, the more semantic features two lemmas share, the stronger the competition between them and the greater the impact of priming; moreover, if two items do not share sufficient number of semantic features interference may not reach significance. For example, lemmas *'car'* and *'bus'* share more semantic features than *'car'* and *'tyre';* therefore, it is possible that only in the former case significant interference can occur.

For association, the same mechanism is involved as in the non-decomposed model. The retrieved lemma laterally spreads activation to all the lemmas with which it is associated. If there is a target-prime direction of association, the previously retrieved prime is activated at the time of target selection and, hence, is a stronger competitor than non-associated (and/or non-primed) lemmas.

Given that in the alternating word reading and picture naming paradigm the effects of coordination and association were independent and that in continuous picture naming there was priming driven by interaction, we assume that both coordination and association have a different nature of representation and the interaction refers to the overlap between these effects. We assume that this can be due to a larger involvement of semantic processing in continuous picture naming as compared to alternating word reading and picture naming.

5.4 Effect of lag

Another discrepancy between the priming effects with word primes and picture primes was the effect of lag observed in the latter task; in particular, significant interference from coordination at lag 4. The question arises, what mechanism underpins effect of lag and why there is a difference between two tasks that use the same types of relations? Wheeldon and Monsell (1994) proposed that priming at lag 0 is transient; that is, facilitatory and occurs when there is dense semantic overlap between the prime and a target. In contrast, they argued that interference at lag 2 or greater occurs due to competition between the prime and a target, However, several further studies in alternating word reading and picture naming (Tree & Hirsh, 2003) and continuous picture naming (Vitkovitch et al., 2001) while showing significant interference from coordination at lags greater than zero found no effect of lag. Therefore, the question arises, why in some conditions there is an effect of lag and in others not.

In the research presented here, the major difference between the two experiments examining the effect of lag was that in the first experiment primes were written words and, in the other, primes were pictures. Hence, it is possible that the effect of lag is strongest in conditions where stronger semantic processing is involved. This is because, as mentioned in Chapter 3, picture naming in comparison to word reading entirely relies on the lexical-semantic route and involves stronger competition. However, at the same time, the priming in both conditions is underpinned by the same mechanism, because in both conditions significant interference from coordination was observed at lag 4, but only in continuous picture naming the interference at lag 4 was significantly slower than at lag 0.

5.5 The implications for the nature of organisation of semantic relations

Given the different pattern of priming from association and coordination, the question arises whether the organisation of these relations also differs. Vigliocco, et al. (2004) suggested that the meaning of a word is represented by a set of semantic features and that the difference in semantic relatedness between words is defined by the number and weight of shared features, but not by the difference in their organisation. However, they did not dissociate between association and semantic relationships. McRae et al. (2012) conducted such a comparison and suggested that almost all associative-relations are also meaningful, that is association and semantic relationships are inseparable. However, they did not reject the possibility that association and coordination may have different organisation. Since in the experiments presented here we manipulated association in the presence of semantic relations (i.e. associates were also functionally related to these targets), we have no evidence to reject the hypothesis that association and semantic relatedness are two sides of the same coin; however, we have suggested that these two types of relations have different organisation. Importantly, while the associates we used here were functionally related, we do not mean to suggest that functionally related items have a different nature of organisation to coordinates at the conceptual level. That is, ‘car’ may share semantic features with both ‘road’ and ‘bus’, but to a different extent. However, in addition to the semantic relationship, items (whatever their semantic relationship) that are associated will also have links between lemmas.

Nevertheless, it is possible that the principles underlying the organisation of functional relations of ‘car’ and ‘road’ differ from that of coordinates ‘car’ and ‘bus’, as it was discussed in the context of paradigmatic and syntagmatic relations. However, this requires another study where functional counterparts are contrasted with and without association similarly as we did for semantic coordination. Only then we can determine whether these relations have the same or different principle of organisation. The study presented here did not address the issue of the effect of functional relations themselves without association; therefore, we do not have evidence on the representation of functional relations.

Altogether, given the pattern of priming in the experiments conducted, we suggested that semantic relatedness can be represented either via semantic networks or via shared semantic features. In both cases, semantic relations are usually symmetric and; for example, *‘car’* is related to *‘bus’* as *'bus'* is related to *‘car’*. In comparison, associative relations are asymmetric and are attributed to lateral connections within the same level. For example, in bidirectional associative relations like ‘car’ and ‘road’, the association from ‘road’ to ‘car’ can be stronger than from ‘car’ to ‘road’. In unidirectional asymmetry, for example, *‘garage’* is not associated to *‘car’*, but *‘car’* is associated to *‘garage’*.

The question however, remains how the semantic meaning of the word is represented: as decomposed semantic representations or non-decomposed semantic representation? While this is important, the current study cannot provide an answer to this issue, and primarily because of the nature of the logic of these claims. Howard, Nickels, et al. (2006) in their study successfully simulated semantic priming using both decomposed and non-decomposed semantic representation. However, while both computational models were implemented successfully, they governed only a limited part of semantic meaning, and this is an issue for the majority of computational models developed so far. Therefore, before providing an answer to such a question it is important to outline all, or at least the characteristic, constituents of semantic meaning and only then can a full model of semantics be simulated – this requires further research.

5.6 Implications for treatment language impairments

Given the results of Chapter 4, it is clear that most people with aphasia benefit from the repetition of a prime that is identical to the target presented. However, this effect, while being generally homogeneous, may not be applicable to all people with aphasia, as not all participants showed significant benefit from this task. Moreover, we also showed that not all participants who showed benefit from identity primes show this effect consistently or to the same degree. For example, some participants who showed repetition priming in Experiment 4.1 did not show this effect in Experiment 4.2. Further research needs to be done to understand in greater detail under which circumstances identical primes do not produce significant facilitation on spoken word retrieval and the factors influencing consistency of these effects.

Given the results of the effects of semantic relations on spoken word retrieval in people with aphasia and healthy participants, it is apparent that semantically related primes produce interference on both reaction time and accuracy of the response in spoken word retrieval. The results of our experiments showed that this needs further examination in people with aphasia. First of all, only a few participants showed significant priming from semantic relations. These effects were heterogeneous and while mostly were interference, under some conditions for some individuals we did find facilitation. Moreover, at the group level only associated coordinates produced significant interference and the primes that were either associates or coordinates showed no significant effect. Therefore, a more thorough examination of the effect of different semantic relations on spoken word retrieval has to be conducted before they are applied as a treatment technique for people with aphasia. Nevertheless, it seems that there is sufficient evidence to suggest that caution is required before using associated coordinates as a treatment tool, as there is more evidence for them interfering than facilitating word retrieval.

5.7 Conclusion

The goal of this thesis was to examine the mechanisms underpinning semantic priming in spoken word retrieval. Three studies were conducted to examine these mechanisms by providing a systematic evaluation of different semantic relationships in different modalities in healthy participants and case series of people with aphasia. The modalities of the research involved priming from both reading aloud (Chapter 2) and picture naming (Chapter 3) with healthy participants and facilitation using word repetition in a case series of people with aphasia (Chapter 4). In the experiments with healthy participants, we examined the effect of association and coordination at lags 0 and 4, and the effect of part-whole relations at lag 4. In the experiments with people with aphasia, we examined the effect of repetition of an identical prime, associated coordinate, not associated coordinate and associated non-coordinate.

Altogether, the novelty of our findings is that not only coordination but also association can produce interference on spoken word retrieval and this effect is driven by the target-prime direction of association. Secondly, we showed that both association and coordination are independent and have different nature of organization. Thirdly, we showed that the interaction that can be observed between these factors can result from their overlap, which results from cascaded process of lemma retrieval.

We also argued that interference from semantic relationships only occurs when a sufficient number of semantic features are shared, because of the lack of priming from parts to their wholes in either paradigm.

In the case series of people with aphasia, the results showed that both identical primes and semantic relations could affect speed and accuracy in people with aphasia, but that these effects may be different in degree for different participants. Therefore, further more detailed examination of the effects of different relations is needed before applying them as treatment tools for people with aphasia.

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Appendices

Appendix A. Stimuli used in Experiment 2.1 and 3.1

+A+C	+A-C	-A+C	-A-C	Target
spear	target	bullet	lamp	arrow
sack	carpet	package	fire	bag
magazine	reader	manuscript	tunnel	book
car	conductor	ferry	volcano	bus
zip	hole	lace	frog	button
biscuit	tea	bread	mussel	cake
radish	donkey	potato	bomb	carrot
watch	hour	dial	eagle	clock
mug	championship	glass	battery	cup
nurse	illness	pharmacist	panel	doctor
skirt	fashion	shorts	root	dress
door	lodge	window	blanket	gate
duck	mother	chicken	sponge	goose
cap	wig	scarf	elevator	hat
bottle	pickle	barrel	drill	jar
tongue	whistle	throat	soil	lips
hill	climber	canyon	gift	mountain
rat	trap	squirrel	tyre	mouse
toadstool	cloud	yeast	lightning	mushroom
accordion	tuner	drum	balloon	piano
hose	clay	straw	shark	pipe
tulip	garden	lavender	glove	rose
goat	clippers	llama	olive	sheep
radio	producer	newspaper	spoon	T.V.

Note: +A+C: +associate + coordinate; +A –C: +associate –coordinate; –A+C: associate + coordinate; 'goose', *'mouse'* and *'pipe'* were excluded from Experiment 2.1

Appendix B. Association and frequency matching (Experiment 1, Chapter 2)

This table contains one-way ANOVA examination of conditions matching for semantic distance, association, and frequency.

Conditions	*Before deletions*	*After deletion 3 items*
LSA		
+coordinate+associate vs. +coordinate-associate		F(1,40)=0.01, p = 0.94
+coordination vs. -coordination	F(1,94)=47.72, **p<0.01**	F(1,82)=5.43, p = **0.02**
Association		
Prime target association	F(1,46)=0.05, p =0.83	F(1,40) = 0.13, p = 0.72
Target prime association	F(1,46)=0.15, p=6.96	F(1,40) = 0.51, p = 0.48
Dominance of association	F(1,94)=4.36, **p=0.04**	F(1,82)= 2.68, p = 0.11
Frequency		
All conditions	F(1,92)=0.12, p=0.73	F(1,80)=0.12, p=0.73

Note: Conditions were matched in one way ANOVA; BOLD refers to significant difference in association between conditions (p < 05); Dominance of association compares prime-target vs. target-prime direction of association in bidirectionally associated prime-target pairs.

Appendix C. Contrast Coding of +/-Association and +/-Coordination, and lag

This table contains contrast coding of association, coordination and their interaction as well as the contrast of lag applied to the (generalised) linear mixed effect modelling in the first experiment of Chapter 2 and Chapter 3.

Experiment 2.1, 3.1

	Interaction	Association	Coordination
+A+C	0.5	0.5	0.5
+A-C	-0.5	0.5	-0.5
-A+C	-0.5	-0.5	0.5
-A-C	0.5	-0.5	-0.5

lag 0 vs. lag 4

	lag
lag 0	-1
lag 4	1

Note: +A+C: +associate +coordinate; +A-C: +associate -coordinate; -A+C: -associate +coordinate; -A-C/UNR: unrelated;

Appendix D. Stimuli for the Experiment 2.2 of Chapter 2 and 3.2 of Chapter 3

+A+C	*Whole-Part Ass*	*Part-Whole Ass*	*Unrelated*	*Target*
temple	spire	altar	headphones	church
rose	petal	bulb	lid	tulip
radio	aerial	remote	volcano	television
stool	cushion	caster	speaker	chair
sheep	beard	horn	battery	goat
bracelet	beads	clasp	mountain	necklace
arm	hair	ankle	lamp	leg
fence	lock	hinge	pen	gate
bus	tire	seatbelt	microscope	car
accordion	keyboard	pedal	hat	piano
boat	anchor	deck	spoon	ship
fridge	door	timer	blanket	oven
trousers	pocket	sleeve	mop	jacket
bath	plug	drain	tent	sink
shoes	laces	zip	stethoscope	boots
biscuits	cream	layer	pipe	cake

Note: *+A +C: +associate +coordinate; Whole-Part Ass: whole-part associate; Part-Whole Ass: part-whole unidirectional associate.*

Appendix E. Contrast coding of associated coordinates and parts

Contrast coding for Experiments 2 of Chapter 2 and 3

Conditions	*+A+C*	*Whole-Part Ass*	*Part-Whole Ass*
+A+C	1	0	0
Whole-Part Ass	0	1	0
Part-Whole Ass	0	0	1
UNR	-1	-1	-1

Note: +A +C: +associate +coordinate; Whole-Part Ass: whole-part associate; Part-Whole Ass: part-whole unidirectional associate.

Appendix F. Summary of the effect of +Coordination, +Association, lag and their interaction on mean RT of response

Results of not fitted modeling to Experiment 3.1:

Condition	*Analysis of reaction time*				*CI*	
	coef	*se*	*z score*	*Pr(>|z|)*	2.50%	97.50%
Overall	*1/RT~Condition +(1|Participant)+(1|item)*					
Association	2.49E-05	1.54E-05	1.62	0.11	-5.11E-06	5.49E-05
Coordination	2.17E-05	1.54E-05	1.40	0.16	-8.47E-06	5.18E-05
lag	4.13E-05	1.53E-05	**2.70**	**0.01**	7.82E-06	6.82E-05
*Assoc*Coord*	3.80E-05	1.55E-05	**2.46**	**0.01**	1.14E-05	7.12E-05
*Association*lag*	-1.55E-05	3.05E-05	-0.51	0.61	-7.51E-05	4.41E-05
*Coordination*lag*	6.64E-05	3.07E-05	**2.16**	**0.03**	6.44E-06	1.26E-04
*Assoc*Coord*lag*	-6.60E-06	3.07E-05	-0.22	0.83	-6.66E-05	5.34E-05

*Note: * interaction; 1/RT - reciprocated reaction time; se - standard error; CI - confidence interval;* ***BOLD*** *font indicates a significant result (Pr(>|z|) at p<.05); ITALIC font indicates a trend (Pr(>|z|) <.1);* N (observations) =774; n (participants) =48; R^2= .48.

Results of modelling fitted within 2 SD to Experiment 3.1:

Condition	*Analysis of reaction time*				*CI*	
	coef	*se*	*z score*	*Pr(>|z|)*	2.50%	97.50%
Overall	*1/RT~Condition +(1|Participant)+(1|item)*					
Association	2.86E-05	1.37E-05	**2.09**	**0.04**	1.88E-06	5.54E-05
Coordination	1.97E-05	1.38E-05	1.43	0.15	-7.17E-06	4.66E-05
lag	4.56E-05	1.36E-05	**3.35**	**0.00**	1.90E-05	7.22E-05
*Assoc*Coord*	4.16E-05	1.37E-05	**3.03**	**0.00**	1.48E-05	6.84E-05
*Association*lag*	-1.07E-05	2.71E-05	-0.39	0.69	-6.37E-05	4.23E-05
*Coordination*lag*	5.37E-05	2.74E-05	**1.96**	**0.05**	2.07E-07	1.07E-04
*Assoc*Coord*lag*	1.94E-05	2.74E-05	0.71	0.48	-3.41E-05	7.29E-05

*Note: * interaction; 1/RT - reciprocated reaction time; se - standard error; CI - confidence interval;* ***BOLD*** *font indicates a significant result (Pr(>|z|) at p<.05); ITALIC font indicates a trend (Pr(>|z|) <.1);* N (observations) =740; n (participants) =48; R^2= .56

Appendix G. People with aphasia: Performance on assessment: Proportion of correct responses

Appendix H summarises the results of assessment on single word processing (comprehension, repetition and production) and fluency of speech. The proportion of errors is shown for each participant, and the cut off (error rate) for control participants. Where the error rate exceeds the control cut off, this is bolded.

		Maximum raw score	***Control cut off***	***CSH***	***IRM***	***NGH***	***DHE***	***SRT***	***CBH***	***SSJ***	***DTF***	***HBC***	***HOE***	***LBL***	***ICM***
							Comprehension								
							PALPA synonym judgement[18]								
auditory (synonym judgement)	*high imageability*	30	*.09*	**NK**	**.20**	**.13**	**.17**	**.23**	**.13**	**.30**	**.27**	.00	**.27**	***NK***	**.10**
	low imageability	30	*.04*	**NK**	**.43**	**.40**	**.40**	**.20**	**.60**	**.33**	**.20**	.00	**.30**	***NK***	.03
written (synonym judgement)	*high imageability*	30	*.18*	**NK**	**.23**	**.27**	.03	.07	.00	**.33**	.00	.00	.00	***NK***	.00
	low imageability	30	*.06*	**NK**	**.30**	**.40**	**.37**	.00	.00	**.50**	.03	**.17**	.07	***NK***	.00
							CAT								
Word-to-picture matching															
spoken word-to-picture matching	***Total errors***	30	*.17*	**NK**	.07	.07	.07	**.23**	.13	**.30**	**.17**	.13	.13	***NK***	.00
	phonological	15	*.00*	**NK**	.00	.00	.00	.13	.00	.07	.07	.07	.00	NK	.00
	semantic	15	*.00*	**NK**	.00	.00	.00	.00	.00	.20	.00	.00	.00	NK	.00
	unrelated	15	*.00*	**NK**	.00	.00	.00	.00	.00	.00	.00	.00	.00	NK	.00
	missed	15	*.00*	**NK**	.00	.00	.07	.00	.00	.00	.00	.00	.00	NK	.00

[18] *Note*: The cut-off on performance in PALPA task is taken from Croft and Nickels (2004)

		Maximum row score	Control cut off	CSH	IRM	NGH	DHE	SRT	CBH	SSJ	DTF	HBC	HOE	LBL	ICM
							Comprehension								
written word-to-picture matching	***Total errors***	30	*.10*	**NK**	**.30**	.00	**.10**	.00	.03	**.37**	.07	.07	**.10**	NK	.03
	phonological	15	*.00*	**NK**	.00	.00	.00	.00	.00	.00	.00	.00	.00	NK	.00
	semantic	15	*.00*	**NK**	.20	.00	.07	.00	.00	.33	.07	.00	.07	NK	.00
	unrelated	15	*.00*	**NK**	.07	.00	.00	.00	.00	.00	.00	.00	.00	NK	.00
							Production								
Repetition															
Total errors		32	*.09*	**NK**	**.34**	**.63**	**.13**	**.31**	**.63**	**.38**	**.31**	**.13**	**.16**	***31.16***	.03
Error types	*phonological*	8		**NK**	.00	.00	.00	.00	.00	.00	.25	.00	.00	NK	.00
	semantic erros	8		**NK**	.25	.56	.13	.25	.25	.38	.06	.06	.19	NK	.00
	unrelated	8		**NK**	.06	.00	.00	.00	.00	.00	.00	.00	.00	NK	.00
	missed	8		**NK**	.06	.19	.00	.00	.00	.00	.00	.00	.00	NK	.00
Frequency	*high*	8		**NK**	.38	.38	.25	.25	.50	.38	.38	.13	.00	NK	.00
	low	8		**NK**	.25	.88	.00	.25	.63	.38	.25	.00	.25	NK	.00
Imageability	*high*	16		**NK**	.38	.50	.13	.25	.50	.38	.25	.13	.13	NK	.00
	low	16		**NK**	.25	.75	.13	.25	.63	.38	.38	.00	.13	NK	.00
Length	*1*	16		**NK**	.25	.38	.13	.25	.50	.13	.50	.13	.13	NK	.00
	3	16		**NK**	.38	.88	.13	.25	.63	.50	.13	.00	.13	NK	.00
	complex words	6	*.17*	**NK**	**.67**	**1.00**	**.33**	**.67**	**1.00**	**1.00**	**.33**	.17	**.67**	NK	.17
	nonwords	10	*.50*	**NK**	**.80**	**.80**	**.60**	**.60**	**.80**	**.60**	**.80**	**.80**	**.60**	NK	.40

		Maximum row score	Control cut off	CSH	IRM	NGH	DHE	SRT	CBH	SSJ	DTF	HBC	HOE	LBL	ICM
							Naming								
Naming objects															
	Total errors	48	*.10*	**NK**	**.85**	**.67**	**.50**	**.46**	**.42**	**.40**	**.35**	**.29**	**.25**	***47.38***	.00
Error types	*phonological*	8		**NK**	.13	.13	.17	.13	.04	.83	.08	.25	.08	NK	.00
	semantic	16		**NK**	.17	.33	.04	.21	.25	.54	.17	.04	.13	NK	.00
	unrelated	12		**NK**	.13	.04	.00	.04	.00	.71	.00	.00	.00	NK	.00
	missed	12		**NK**	.21	.25	.17	.04	.00	.00	.00	.00	.33	NK	.00
Frequency	*high*	12		**NK**	.63	.50	.25	.25	.00	.38	.00	.00	.00	NK	.00
	low	12		**NK**	.94	.69	.13	.44	.25	.25	.44	.31	.13	NK	.00
Imageability	*high*	24		**NK**	.83	.50	.25	.17	.17	.25	.33	.17	.08	NK	.00
	low	24		**NK**	.83	.75	.08	.58	.17	.25	.33	.25	.08	NK	.00
Length	*1*	24		**NK**	.75	.50	.25	.25	.08	.17	.33	.17	.00	NK	.00
	3	24		**NK**	.92	.75	.08	.42	.25	.42	.33	.25	.17	NK	.00

		Maximum row score	Control cut off	CSH	IRM	NGH	DHE	SRT	CBH	SSJ	DTF	HBC	HOE	LBL	iCM
Writing objects															
	Total errors	48	*.10*	**NK**	**1.00**	**1.00**	.08	**.29**	.08	**.96**	**.33**	**.50**	**.25**	***NK***	.04
Error types	*phonological*			**NK**	.00	.00	.00	.08	.04	.21	.75	.04	.08	NK	.00
	semantic	24		**NK**	.33	.67	.08	.21	.00	.46	.92	.38	.17	NK	.04
	unrelated	24		**NK**	.33	.00	.00	.00	.00	.29	.00	.00	.00	NK	.00
	missed	24		**NK**	.33	.29	.00	.00	.04	.00	.00	.04	.00	NK	.00
Frequency	*high*	8		**NK**	1.00	1.00	.13	.13	.13	.88	.38	.25	.25	NK	.00
	low	16		**NK**	1.00	1.00	.19	.31	.06	1.00	.31	.56	.25	NK	.06
Imageability	*high*	12		**NK**	1.00	1.00	.00	.33	.00	.92	.25	.42	.25	NK	.08
	low	12		**NK**	1.00	1.00	.17	.17	.17	1.00	.33	.58	.25	NK	.00
Length	*1*	12		**NK**	1.00	1.00	.00	.00	.00	.92	.00	.25	.08	NK	.00
	3	12		**NK**	1.00	1.00	.17	.50	.17	1.00	.58	.75	.42	NK	.08
Fluency of speech															
Single word level	*animals*		*13*	**NK**	9.00	4.00	10.00	0.00	10.00	10.00	0.00	1.00	8.00	NK	0.00
	s		*13*	**NK**	5.00	1.00	10.00	0.00	5.00	2.00	0.00	0.00	9.00	NK	0.00
Connected speech	*picture description*		*33*	**NK**	28.00	4.00	16.00	0.00	10.00	13.00	0.00	6.00	10.00	NK	0.00

Note: In writing object tasks, the same items as the CAT spoken naming subtest were used and therefore the same criteria of assessment were used to semantic errors and phonological errors were evaluated, but not compared to cut off; NK applies to two participants who were not assessed due to healthy issues, but these participants took part in Experiment 4.1 and their naming abilities were drawn out from their performance on the prefacilitation naming task.

Appendix H. T-test in task performance

		Maximal performance	***Control cut off***	***CSH***	***IRM***	***NGH***	***DHE***	***SRT***	***CBH***	***SSJ***	***DTF***	***HBC***	***HOE***	***LBL***	***ICM***
CAT															
Word-to-picture matching															
spoken word-to-picture matching	***Total correct***	65	51	0	58	58	58	47	23	45	51	53	53	0	65
written word-to-picture matching	***Total correct***	65	55	0	45	65	55	65	60	44	58	58	55	0	60
Production															
Repetition															
Total correct (n=16)		65	56	0.58	48	45	55	49	45	48	49	55	53	0.84	60
	complex words	62	55	0	47	38	52	47	38	38	52	55	47	0	55
	nonwords	67	51	0	46	46	49	49	46	49	46	46	49	0	53
Naming objects															
	Total correct	***74***	***61***	0.14	**45**	**47**	**50**	**51**	**51**	**52**	53	**54**	**56**	0.62	74
Writing objects															
	Total correct	***69***	***58***	0	**38**	**38**	60	**52**	60	**40**	53	**48**	**53**	0	62

Fluency of speech															
Single word level	*animals*	***37+***	***57***	0	**43**	**48**	**43**	**52**	**10**	**51**	51	**53**	**10**	0	**54**
	s	***37+***	***57***	0	**37**	**43**	**37**	**53**	**49**	**43**	48	**49**	**45**	0	**54**
Connected speech	*picture description*	***65+***	***60***	0	**47**	**47**	**47**	**49**	**49**	**46**	70	70	**58**	0	**60**

Note: *T test is used to identify strength and weakness in performance on certain language tasks by normalizing non-linearly distributed row scores. The score with mean: 50 = 50th percentile of the standardization score, 60 = 60th percentile; 70 = 96th percentile (Swinburn et al., 2004).*

Appendix I. Stimuli for the Experiments 1 of Chapter 4

Stimuli for Experiments 4.1

Target	*+A+C*	*Unrelated*
APPLE	PEAR	ORCHESTRA
COMPASS	MAP	STETHOSCOPE
LION	TIGER	ANCHOR
SCARF	GLOVES	ANGEL
BUTTERFLY	MOTH	FUEL
WITCH	DEVIL	ARENA
TELEVISION	RADIO	MEAT
CASTLE	TOWER	CARTOON
HORSE	DONKEY	ASPARAGUS
PARROT	CANARY	BALLET
MOTORCYCLE	BIKE	BALLOON
PIN	NEEDLE	BARBECUE
SPEAR	ARROW	BARN
DOCTOR	NURSE	BEAK
PEN	PENCIL	BEAR
LIZARD	SNAKE	BEARD
NECKLACE	BRACELET	BLANKET
BUS	CAR	SEA
BAT	MOUSE	BOMB
HONEY	SUGAR	BOOMERANG
ORANGE	LEMON	BRAIN
HOSE	PIPE	BRIDE
RAIN	SNOW	BROCCOLI
BOOK	MAGAZINE	BUBBLES
SKATES	ROLLERS	CACTUS
BLUEBERRY	STRAWBERRY	ROD
VASE	JUG	CALENDAR
BAG	SACK	CAVE
SOLDIER	SAILOR	CLOUD
LIPS	TONGUE	CLOWN
HAMMOCK	SWING	COMPUTER
COW	BULL	SHAMPOO
PLANE	HELICOPTER	CROCODILE
TENT	PAVILION	CELL
CHEESE	MILK	DRUG
CHURCH	MUSEUM	DRUM
HAT	CAP	DUVET
ISLAND	PENINSULA	LABORATORY
BADMINTON	TENNIS	ENVELOPE

+A+C	***Unrelated***	***Target***
MONKEY	APE	FILTER
TIE	CRAVAT	FOX
PILLOW	CUSHION	POTATO
PLATE	SAUCER	GIRAFFE
FIREPLACE	CHIMNEY	GLASSES
TWEEZERS	PLIERS	GRAPES
CAKE	BISCUIT	FISH
RADISH	CARROT	GUTTER
LOCK	PADLOCK	SALAD
LIGHTNING	THUNDER	SONG
CARPET	MAT	HAY
THERMOMETER	BAROMETER	HEDGE
TORCH	LAMP	ICEBERG
MICROSCOPE	TELESCOPE	ROCK
BEE	WASP	WRENCH
MOUNTAIN	HILL	KENNEL
UMBRELLA	PARASOL	KITE
BEER	WINE	ELEPHANT
BEAN	PEA	LADLE
FAN	HEATER	LAWN
SCULPTURE	PICTURE	MASK
BRICK	CEMENT	MAZE
CAT	DOG	MEDAL
SPEAKER	MEGAPHONE	MELON
GATE	DOOR	MIRROR
RAIL	TRAIL	MIXER
DRAWER	CUPBOARD	NEST
DRESS	SKIRT	OIL
LADDER	STAIRS	OLIVE
JAR	BOTTLE	PADDLE
PRAM	COT	PALM
KING	QUEEN	PARACHUTE
TRIANGLE	SQUARE	PEACOCK
SWITCH	SOCKET	PEANUT
SLEDGE	SKI	PEG
COAT	JACKET	PICKLE
VICAR	BISHOP	PICNIC
BANDAGE	PLASTER	POND
TIGHTS	STOCKINGS	POTTERY
CUP	MUG	PUMPKIN
COFFEE	TEA	RIVER

+A+C	*Unrelated*	*Target*
CAULIFLOWER	LETTUCE	ROBOT
SINK	BATH	SAFE
EAGLE	OWL	SANDWICH
CLOCK	WATCH	SCOOP
PORK	SAUSAGE	SHOVEL
SEAL	WALRUS	SKELETON
BUSH	TREE	GIFT
KNIFE	SCALPEL	SNOWMAN
TICKET	FARE	SOCK
SPOON	FORK	SOIL
AXE	HAMMER	SPIDER
RAKE	SPADE	SPONGE
SUBMARINE	SHIP	SPRAY
ARM	LEG	SQUIRREL
TULIP	ROSE	STADIUM
PLANET	STAR	STAGE
PIANO	ACCORDION	STAMP
SHOES	BOOTS	STATUE
LIPSTICK	MASCARA	BUCKET
CHICKEN	TURKEY	STICKER
SUN	MOON	COWBOY
KIDNEY	HEART	SWAN
OVEN	FRIDGE	TANK
CRAB	LOBSTER	FLAG
MOP	BROOM	TEARS
COFFIN	GRAVE	TOASTER
BEETLE	ANT	TOWEL
BIN	BASKET	TOY
SHEEP	GOAT	TROPHY
TABLE	CHAIR	TRUCK
COMB	BRUSH	VEST
FLUTE	HARP	RICE
KETTLE	TEAPOT	WAGON
SAXOPHONE	CLARINET	WAITER
FROG	TOAD	WALLET
ELEVATOR	ESCALATOR	WHALE
KEYBOARD	TYPEWRITER	WHISTLE
ONION	GARLIC	DUST
BLOUSE	SHIRT	WOLF
ZIP	BUTTON	MONEY

Appendix J. Stimuli for the Experiment 4.2 of Chapter 4

+A-C	*-A+C*	*UNR*	*Target*
BLOSSOM	WALNUT	SACK	ALMOND
BANDAGE	NECK	SAUSAGE	ARM
TREE	KNIFE	JACKET	AXE
NAILS	SUITCASE	FOX	BAG
BAT	KITE	DIAL	BALL
REEF	DOOR	COTTON	BARRIER
RADIO	CHARGER	SCULPTURE	BATTERY
BACON	RICE	STADIUM	BEAN
HIVE	ANT	PALM	BEE
PUB	BRANDY	NURSE	BEER
TOWER	WHISTLE	PEG	BELL
PARK	SOFA	CHIMNEY	BENCH
BOY	SCOOTER	SWING	BIKE
CHALK	PANEL	MILK	BLACKBOARD
BUGS	DUVET	ICE	BLANKET
BEARS	CHERRY	SADDLE	BLUEBERRY
TRIP	SUBMARINE	CAT	BOAT
WAR	MINE	SPONGE	BOMB
OFFICE	CAN	CLOUD	BOX
WRIST	EARRINGS	CROCODILE	BRACELET
BUTTER	CAKE	SCISSORS	BREAD
RIVER	BALCONY	HAMMER	BRIDGE
CONDUCTOR	FERRY	KING	BUS
TIGER	KENNEL	ZIP	CAGE
SAND	GIRAFFE	PLANET	CAMEL
PHOTOGRAPH	RECORDER	SALAD	CAMERA
RABBIT	BEETROOT	SANDWICH	CARROT
SAUCE	BROCCOLI	MAGNET	CAULIFLOWER
PRISON	WIRE	COMPASS	CHAIN
MOUSE	CREAM	CELL	CHEESE
SOUP	GOOSE	VEST	CHICKEN
GOD	MOSQUE	MAT	CHURCH
WALL	TIMER	MAZE	CLOCK
CIRCUS	COMEDIAN	ROBOT	CLOWN
BODY	CRATE	SCALES	COFFIN
BEACH	MUSSEL	PILLOW	CRAB
COW	POPPY	PIZZA	DAISY
FOREST	MOOSE	KNOT	DEER
COWBOY	FIELD	TROPHY	DESERT
RAG	TEDDY	HOOK	DOLL
CLOTHES	WARDROBE	CIGARETTE	DRAWER

+A-C	*-A+C*	*UNR*	*Target*
HOLE	HACK	CARTOON	DRILL
STAMP	PARCEL	MOTH	ENVELOPE
BELT	BLOWER	WAGON	FAN
ENGINE	FLASH	GLOVE	FIRE
SPRAY	MOSQUITO	MARKER	FLY
PANE	CUP	TELESCOPE	GLASS
CUTTER	REED	PERFUME	GRASS
DOG	CANNON	PLASTER	GUN
WATER	BOILER	PANDA	HEATER
RIDER	ZEBRA	PADDLE	HORSE
BOARD	VACUUM	ORCHESTRA	IRON
HONEY	BARREL	PLANE	JAR
MOULD	SWEETS	SIGNATURE	JELLY
TEA	URN	HELICOPTER	KETTLE
WEDDING	BUTTON	CORAL	LACE
LOFT	CRANE	MONEY	LIFT
TAMER	LEOPARD	LABORATORY	LION
LIPSTICK	NOSE	LOCK	LIPS
BLOOD	LUNG	LIBRARY	LIVER
ROCK	FROG	LADDER	LIZARD
DINNER	PUMPKIN	AERIAL	MELON
SINGER	HEADPHONES	COMPUTER	MICROPHONE
BANANA	RHINO	SWITCH	MONKEY
CLIMBER	VOLCANO	LAMP	MOUNTAIN
CROSSWORD	BOOK	LOBSTER	NEWSPAPER
TEARS	FENNEL	POT	ONION
SUN	LIME	CHIPS	ORANGE
RECITAL	ACCORDION	GIFT	ORGAN
BUN	MICROWAVE	EAGLE	OVEN
FLIGHT	BALLOON	DRUG	PARACHUTE
SOAP	LEMON	SOIL	PEAR
PAPER	CRAYON	OWL	PEN
BIRTH	DROPS	DRYER	PILL
CUSHION	CLIP	ELEPHANT	PIN
JUICE	COCONUT	CASTLE	PINEAPPLE
CLAY	STRAW	MUSHROOM	PIPE
MEAL	BOWL	DRUM	PLATE
FISH	LAKE	FLOOR	POOL
PEELER	TURNIP	TURTLE	POTATO
CHILD	CART	TUNNEL	PRAM
RAIN	WAVE	PYRAMID	RAINBOW

+A-C	*-A+C*	*UNR*	*Target*
GARDEN	SHOVEL	GATE	RAKE
MENU	CLUB	SALMON	RESTAURANT
FINGER	PENDANT	ROD	RING
CROWN	TULIP	SUNGLASSES	ROSE
ROCKET	EARTH	NEST	SATURN
COLLEGE	HAT	DUST	SCARF
ISLAND	PENGUIN	FILTER	SEAL
SHEPHERD	LAMA	SKELETON	SHEEP
BUCKET	TOILET	GLASSES	SINK
SNOW	SKATES	POTTERY	SKI
VENOM	EEL	SHOES	SNAKE
ARMY	POLICE	PEANUT	SOLDIER
WEB	SCORPION	HAWK	SPIDER
CUSTARD	SCOOP	STATUE	SPOON
COURT	BADMINTON	JET	SQUASH
NUTS	RAT	PIG	SQUIRREL
ACTOR	ARENA	SHARK	STAGE
SKY	SATELLITE	MIRROR	STAR
DOCTOR	SYRINGE	COMB	STETHOSCOPE
TANK	MUSEUM	TRIANGLE	STORAGE
HUNTER	TURKEY	UMBRELLA	SWAN
CLOTH	COUNTER	TIE	TABLE
DRIVER	TRUCK	STAIRS	TAXI
KIOSK	TELEVISION	NECKLACE	TELEPHONE
SCOUT	HUT	WHALE	TENT
HOSPITAL	METER	TOWEL	THERMOMETER
COLLECTOR	VOUCHER	PICNIC	TICKET
BALLET	SOCKS	HEDGE	TIGHTS
BEARER	CANDLE	HEDGEHOG	TORCH
TRAIN	AIRLINE	CARPET	TRACK
HAIR	WRENCH	HURRICANE	TWEEZERS
BAKERY	CARAVAN	PEACOCK	VAN
FLOWERS	BOTTLE	MEDAL	VASE
CAFE	CAPTAIN	OIL	WAITER
AXLE	HOOP	PENCIL	WHEEL
EGG	BLENDER	OCTOPUS	WHISK
BROOM	MAGICIAN	SEA	WITCH
HUNGER	HYENA	LAWN	WOLF