The Flexibility of Lexical-Semantic Representations: Studies of Word-Meaning Priming

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DECLARATION

I, César Antonio Gutiérrez Silva, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

ABSTRACT

Natural language exposure includes words with multiple meanings or senses (e.g. “crane”), a phenomenon called “lexical ambiguity”. This thesis explores the flexibility of lexical-semantic representations of English ambiguous words after recent encounters with them. Particularly, it tests the effects of mixed-exposures to the dominant and subordinate meanings, and possible differences in the effect of word-meaning priming and semantic priming.

In Experiments 1 (N= 60) and 2 (preregistered, N= 182) readers encountered both the subordinate and dominant meanings of ambiguous words once in training sentences. In Experiment 3 (preregistered, N= 340) each meaning was encountered three times and tested either immediately or the next day. Semantic relatedness judgements revealed a numerical facilitation effect for subordinate meanings and a null effect for dominant meanings (Experiment 1), a significant facilitation effect for subordinate meanings just on response times (Experiment 2), and a significant facilitation effect for subordinate meanings on accuracy and response times immediately and one day later (Experiment 3).

Experiment 4 (preregistered, N= 180), which is a replication of Rodd et al. (2013; Experiment 3) tested possible differences in the effects and time-course of word-meaning priming and semantic priming after 3 and 20 minutes. Participants heard sentences that disambiguated the ambiguous words (word-meaning priming) or an unambiguous synonym (semantic priming) toward their subordinate meaning. At both delays, the number of associates consistent with subordinate meanings was significantly greater in the word-meaning priming condition than in the semantic priming condition. Moreover, the semantic priming effect was absent at both delays.

Overall, our findings support the flexibility of lexical-semantic representations of English ambiguous words, which was found across all experiments. Specifically, our results

suggest that priming effects on subordinate meanings are stronger than the semantic competition between unrelated meanings of ambiguous words, and that word-meaning priming relies on the presence of the ambiguous word itself.

IMPACT STATEMENT

In English, most words have multiple interpretations. For example, the ambiguous word “crane” could either refer to a machine for lifting in suspension (dominant meaning), or to a type of bird (subordinate meaning). This challenges our capacity to select the intended meaning of a particular word, and consequently to understand what is being communicated in a specific situation. Aiming to better characterize how adults access and process the intended meaning of ambiguous words, this thesis provides evidence of how recent encounters with particular meanings of ambiguous words in context influence their subsequent processing. Specifically, it tests the effects of mixed-exposures to the dominant and subordinate meanings, and possible differences in the effect of word-meaning priming and semantic priming.

Our findings revealed a facilitation effect for subordinate meanings of ambiguous after mixed-exposures to the dominant and subordinate meanings, facilitation that was observed immediately after test and one day later. Moreover, after a recent exposure to the subordinate meaning of ambiguous words, a facilitation effect for subordinate meanings was observed after 3 and 20 minutes in the primed condition that included the ambiguous word, facilitation that was absent at both delays in the primed condition that included an unambiguous synonym as a replacement of the ambiguous word. Overall, these results have some implications inside and outside academia that are worth to analyse.

Theoretically, the facilitation effect found for subordinate meanings of ambiguous words supports the flexibility of lexical-semantic representations. Our results also suggest that current accounts of ambiguity resolution may provide a somewhat incomplete picture of the mechanism(s) behind this flexibility. Specifically, though our findings are compatible with important theories, such as the Immediate Alteration account and the Episodic Context

Account, they reveal the need to test this flexibility with tasks that better observe the mechanism(s) behind it.

In terms of methodological implications, the four experiments reported in this thesis collected data online. They therefore support the advantages of doing web-based research, which allowed the access to a larger (N= 760), and more diverse group of participants than in-person data collection. Moreover, three out of four experiments were well-powered, thus contributing to increasing the replication rate in the field of psycholinguistics. Furthermore, the preregistration of three experiments, and the data and analysis sharing of all of them on the Open Science Framework, promotes transparency in psychological research.

The findings presented here provide an important theoretical basic-science foundation for future more applied work. They may also have possible benefits for our society. First, since recent encounters with particular meanings of English ambiguous words have been shown to influence their processing, future research could test whether this generalises to children and real life settings. Furthermore, future studies could also test whether these types of interventions are beneficial for second language learners or people with language comprehension difficulties, aiming to improve their language communication skills.

STATEMENT OF CONTRIBUTIONS

The additional priming sentences included for Experiment 3 as well as the additional tests added for this experiment were selected by four UCL undergraduate psychology students, Chloe Taylor, Ophelia Lieng, Sylfiana Wong, and Selin Ozgen, work that was part of their third-year research project.

The probe words added for the training task in Experiment 3 were chosen with the contribution of one postdoctoral researcher, Lena Blott, and one research assistant, Anna Gowenlock. Furthermore, Lena Blott contributed significantly to the writing and checking of the analysis codes presented in Experiments 1, 2, and 3. Finally, a postdoctoral researcher, Rachael Hulme, contributed to the writing and checking of the analysis codes presented in Experiment 4.

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CHAPTER 1: GENERAL INTRODUCTION

1.1 Introduction

It is difficult to imagine our lives without being successful in understanding others. From our first years of life, we are exposed to many language environments, the speech of our parents, other family members, friends, etc. This language exposure makes it possible to acquire our native language and consequently to communicate with others. However, even once we have learned a language, its comprehension requires processing demands. For instance, as we are reading this sentence, we need to recognise the visual form of each printed word, access its meaning, combine it with the other word meanings in the sentence, and integrate this information into a representation of what is being communicated. In sum, even after we acquire our native language, the comprehension of what is being transmitted still requires a significant effort to understand the meaning of the intended message.

One key factor that is responsible for the complexity of language comprehension across different languages is the presence of multiple meanings for many words. This challenges our language skills as we need to be sure to access the right meaning of these words in each context. Recent research in the English language has revealed that adults make use of linguistic information learned through their lifetime when interpreting the meanings of ambiguous words (Rodd et al., 2016; Wiley et al., 2018), but that these interpretations are also influenced by very recent experiences (Rodd et al., 2016). These findings suggest that language comprehension is much more flexible than previously thought, but it is still unclear what are the limits of this flexibility and what are the mechanisms behind it.

To explore these issues, the present thesis investigates in the English language how recent encounters with particular meanings of ambiguous words in context influence the access of these meanings immediately or after short delays. To give the appropriate

information needed to understand the importance of this thesis, the next sections will provide a short and up-to-date presentation of the most relevant topics for our purposes. These topics include: (1) lexical ambiguity, (2) ambiguity as an advantage or disadvantage in language, (3) the representation of ambiguous words, (4) models of word-meaning access, (5) priming as a phenomenon to test the flexibility of lexical-semantic representations, (6) word-meaning priming, and (7) theoretical accounts of word-meaning priming.

1.2 Lexical Ambiguity

The presence of multiple meanings for many words challenges our language skills. This phenomenon is called "lexical ambiguity", and it is the rule rather than the exception in the English language. It is estimated that around 80% of words in English have more than one dictionary entry (Rodd et al., 2002) and some have many definitions. Remarkably, ambiguous words in English have on average 8.8 dictionary definitions per word (Parks et al., 1998), which challenges the reader/listener's capacity to select a single and contextually appropriate meaning. However, it is important to note that ambiguity is not restricted to the lexical level, it is a pervasive phenomenon in language that occurs at all levels of linguistic analysis including the morphological, phonological, syllabic, syntactic, semantic, and pragmatic levels (Piantadosi et al., 2012).

There are diverse types of lexical ambiguity identified by the literature (Cruse, 1986; Lyons, 1977, 1981). The most common type of ambiguity is called polysemy, which occurs when a word has multiple semantically related word senses. One clear example of polysemy is given by the word "run" which has many related dictionary senses (e.g., "the policeman runs after the thief", "the president runs for re-election"). Polysemy adds richness and flexibility to language comprehension because it allows the reuse of the same word with the same underlying meaning but in different contexts. Another type of lexical ambiguity in

language is called homonymy, these words share both orthographic and/or phonological form but have different meanings (e.g., “bark” as in dog or tree). Homonymy includes homographs, words that have different meanings that share their spelling but not their pronunciation (e.g. “sow” as in pig or to plant, and “lead” as in metal or to take charge), and homophones, words that have different meanings that either share their pronunciation and spelling (e.g. “bark”), or pronunciation but not their spellings (e.g. “meet/meat”, and “buy/by”) (Rodd, 2018). Even though homonyms reveal a clear example of lexical ambiguity, they are relatively rare, representing only about 7% of common English words (Rodd et al., 2002). Polysemy and homonymy are two well established classifications of ambiguity in the literature (e.g. Cruse, 1986) and, as will be analysed later, they have important implications for how words are represented and processed (Klein et al., 2001; Rodd et al., 2002; Rodd et al., 2004).

To better understand why lexical ambiguity adds complexity to language, it is necessary to consider that language comprehension relies on incremental processing, because we need to integrate the information that is available to us at any time, not waiting to access word meanings until the entire clause or sentence has been heard or read (e.g. Just et al., 1980; Tyler et al., 1977). In this context, ambiguous words require extra processing time and cognitive resources (e.g. memory retrieval, inhibition, etc.) compared to unambiguous words, as they have multiple possible interpretations/misinterpretations (Luke et al., 2016). For example, in the phrase “The boys watched the crane”, “crane” could either refer to a machine for lifting in suspension or to a type of bird. This phrase requires additional information to clarify the intended meaning of the word “crane”, which can be given by the phrase “The boys watched the crane by the river and saw that it was injured”, if the intended meaning refers to the type of bird (less frequent meaning), or by the phrase “The boys watched the crane that was holding an old car” if the intended meaning refers to the machine for lifting in

suspension (more frequent meaning). People hear ambiguous phrases every day and luckily they tend to cause little misunderstanding, but sometimes they do cause a detrimental effect on comprehension, as shown in a range of clinical and non-clinical populations (e.g. Gernsbacher et al., 2015; Norbury, 2005).

Overall, ambiguity is an important characteristic in language that adds complexity to its comprehension. Most English words have more than one sense, and some have multiple unrelated meanings. Considering this, we cannot understand the mechanisms that underpin successful language comprehension without considering ambiguity and its resolution. In the next sections, the scientific evidence that supports the view of ambiguity as an inherent characteristic of language will be presented. Then, a new perspective will be discussed that considers ambiguity to be beneficial, adding efficiency, effectiveness, and flexibility to language comprehension. This contrast will allow us to have a wider view of the main implications of ambiguity in language and a better understanding of how we process it.

1.3 Ambiguity as a Disadvantage in Language

1.3.1 Eye-Tracking Studies

Ambiguity can be seen as adding difficulty to language comprehension because extra effort is needed to disambiguate words that have more than one meaning or sense. The most compelling body of evidence that supports this idea comes from eye-tracking studies. When reading a text, we make a series of eye movements called saccades. Between these saccades, the eyes fixate for a brief period on a specific area of the text to gain information. When the text is more difficult, readers tend to (i) lengthen the duration of their fixations, (ii) reduce the distance that they jump forward on each saccade, and (iii) make more backward regressions to read earlier parts of the text (Rayner, 1998). Eye-tracking studies of lexical ambiguity have revealed that when highly dominant meanings of ambiguous words (e.g., “the machine for

lifting in suspension" meaning of "crane") are preceded by supportive sentence contexts, these meanings are easily accessed with no delay in processing compared to low-ambiguity control words. However, when the preceding context supports a highly subordinate meaning (e.g., the "type of bird" meaning of "crane") there is a delay in reading times that reveals the additional processing demands related to accessing the less frequent meaning (for a review, see Duffy et al., 2001).

Supporting the extra cost needed to access the less frequent meanings of ambiguous words, Duffy et al. (1988) monitored eye movements and specifically gaze durations (sum of durations of all consecutive fixations on first encounter of the word) for ambiguous relative to low-ambiguous control words, either when the disambiguating region preceded or followed the ambiguous word. Participants read sentences composed of two clauses, one that included a neutral context, and the other that contained the disambiguating region and the ambiguous word. There were four conditions, two of these were given by sentences that included balanced ambiguous words (equally frequent meanings), where the disambiguating region was either before the ambiguous word (e.g. "Because it was kept on the back of a high shelf, the pitcher (whiskey) was often forgotten") or after it (e.g. "Of course the pitcher (whiskey) was often forgotten because it was kept on the back of a high shelf"). The other two conditions were given by sentences that included biased ambiguous words (one more frequent meaning than the other), similarly in these sentences the disambiguating region was either before the ambiguous word (e.g. "Because it was always too hot to sleep in, the coach (cabin) needed air-conditioning") or after it (e.g. "Unfortunately the coach (cabin) needed air conditioning because it was always too hot to sleep in"). By modifying clause order, gaze durations were measured under conditions in which the disambiguating region either preceded or followed the reader's first encounter with the ambiguous word.

When the disambiguating region preceded ambiguous words, gaze durations did not differ for balanced ambiguous words compared to their low-ambiguity controls, however more time was spent on biased ambiguous words (which were always disambiguated towards the subordinate meaning) compared to the controls. These results were interpreted by the authors with the Reordered Access Model (Duffy et al., 1988) which promotes the idea that the speed with which meanings become available depends on both the meaning frequency and prior context. According to this model gaze durations for biased ambiguous words were lengthened because the processing of the subordinate meaning, which is the meaning consistent with the sentence context, received interference from the most frequent (dominant) meaning. Instead, gaze duration for balanced ambiguous words did not differ from low-ambiguous words, because the meaning that is consistent with the sentence context does not receive interference from the alternative meaning. Here, both meanings are equally frequent, which allows the meaning that is supported by the context to become available first. This allows the word to be processed as though it had only one meaning. In contrast, when the disambiguating region was presented after the ambiguous words, gaze durations were lengthened for balanced items compared to low-ambiguity controls, whereas time spent on the biased words did not differ from their controls. Gaze durations for balanced words were lengthened presumably because of the initial access and integration of two meanings, while for biased words only the most frequent meaning was accessed and integrated with the prior context.

Despite the prevalence of English studies on the ambiguity disadvantage reported by eye-tracking studies, the evidence is extended to other languages. For example, Shen et al. (2016) used eye-tracking to test whether the senses of polysemous words and meanings of homonyms are processed in similar or different ways in Chinese. To do so, readers read sentences that include polysemous words or homonyms. In these sentences, the context

preceding the target word was manipulated to bias the reader towards the dominant, subordinate, or neutral meaning of the target. Moreover, the disambiguating region that followed the target was also manipulated to favour the dominant or the subordinate meaning of ambiguous words. Interestingly, results showed similar eye movement patterns when readers read sentences containing polysemous words or homonyms. Specifically, when the prior context and the disambiguating region biases the interpretation toward the same meaning or sense, readers spent less total time on the target and the disambiguating region, also fewer regressions were made for the disambiguating region. In contrast, when the prior context and the disambiguating region biases the interpretation toward different meanings or senses, readers spent more total time on the target and the disambiguating region, also more regressions were observed in the disambiguating region. Overall, these results suggest that polysemous words and homonyms are represented in similar ways, both as separate entries in the lexicon.

In summary, over the past 40 years several eye-tracking studies have revealed that an additional effort is needed to solve ambiguity (for a review, see Duffy et al., 2001). Overall, these studies have revealed that when an ambiguous word is encountered in a neutral context, readers spend more time on balanced ambiguous words than biased words or low-ambiguous words, an effect that disappears when the context provides information consistent with the subordinate meaning. In contrast, for biased ambiguous words, readers spend more time on these words than balanced ambiguous words or low-ambiguous words, when the preceding context provides information consistent with the subordinate meaning, an effect that is absent when this context is neutral. The finding that readers spend more time on ambiguous words, which are disambiguated towards their subordinate meaning, than matched control words, is known as the subordinate bias effect, and provides one of the strongest pieces of evidence to consider ambiguity as a disadvantage in language.

1.3.2 Lexical Decision Studies

Studies that include lexical decision tasks have also revealed the additional processing cost for ambiguous words or words with multiple unrelated meanings (e.g. “crane” could either refer to a machine for lifting in suspension or to a type of bird) compared to low-ambiguous words or words with one meaning but that the context can emphasize a particular aspect of their meanings (e.g. “professor” could refer not just to the person who teaches but also to someone who works as a physician in hospitals). This distinction comes from dictionaries, where lexicographers add the results of their word studies, updating the knowledge that we have about words, for instance, the number of meanings that they can have. For example, in a series of three experiments, Rodd et al. (2002) found evidence of an ambiguity disadvantage. In Experiments 1 and 2 participants read the items and in Experiment 3 they heard them. These experiments showed three main findings. First, in all experiments participants showed a significant effect of ambiguity, ambiguous words were identified more slowly than low-ambiguous words. Second, Experiment 1 found an effect of meaning relatedness, ambiguous words were responded to faster when their meanings were semantically related, than when their meanings were unrelated. Taken together, these experiments revealed that words with multiple unrelated meanings were identified slower than low-ambiguous words, thus supporting the ambiguity disadvantage, and replicating the extensive body of research that has been developed during the last 20 years (Armstrong et al., 2016; Beretta et al., 2005; Hino et al., 2010; Klepousniotou et al., 2007; Mirman et al., 2009), that supports the view of the extra effort needed to solve lexical-semantic ambiguity. Remarkably, these experiments highlight that the ambiguity disadvantage was only seen for ambiguous words with unrelated meanings, ambiguous words with related meanings did not reveal this disadvantage.

Supporting the ambiguity disadvantage, Rodd et.al. (2010) found that participants were slower to decide if a letter was in upper or lower case when they simultaneously heard a sentence that contained a word with a different meaning (homophone), compared to those that didn't include homophones. The case judgement task was used as a secondary task to measure the processing load on the sentence comprehension task, thus its analysis revealed the additional cognitive and not linguistic effort needed to solve the semantic ambiguity.

1.3.3 Neuroimaging Studies

Neuroimaging studies also support the idea that ambiguous words require higher cognitive effort. One study found that the left inferior frontal gyrus (LIFG) and inferior temporal gyrus (LITG) were more active for sentences that include ambiguous rather than low-ambiguous words (Rodd et al., 2005). Subsequent studies have also found ambiguity-related activation in the LIFG in the presence of sentences that contain ambiguous words (Bekinschtein et al., 2011; Blott et al., 2023; Davis et al., 2007; MacGregor et al., 2020; Rodd et al., 2010; Rodd et al., 2012). Similarly, Vitello and colleagues explored the roles of the LIFG and left posterior temporal cortex (LPTC) during ambiguity resolution. When listening to sentences containing ambiguous relative to low-ambiguous words, activation was greater in both the LIFG and LPTC, and this increased activity was modulated by meaning dominance, where biased ambiguous words (words with one more frequent or dominant meaning) produced a higher activation than balanced ambiguous words (words with two equally frequent meanings), when the subordinate meaning was appropriate in the sentence context (Vitello et al., 2014). In sum, these findings provide convergent evidence of the additional effort needed to solve the ambiguity and identify the importance of frontal and temporal areas in the resolution of semantic ambiguity.

Supporting these findings Ihara et al. (2015) investigated the role of the left inferior frontal cortex (LIFC) in the processing of lexical ambiguities in Japanese. More specifically, it tested the influence of transcranial direct current stimulation (tDCS) in the processing of ambiguous and unambiguous words. After receiving the tDCS for 15 minutes (tDCS session), or 30 seconds (sham session), participants completed a semantic judgment task where they judged if a target word was semantically related or unrelated to the prime (items were visually presented). Controlling for the possible influence of facilitation or inhibition of attention and/or motor function in tDCS effects, participants completed a simple reaction task where they needed to gaze at a fixation point and press a key immediately when the cue was presented. Results showed that the anodal tDCS over the LIFC facilitates the processing of lexically ambiguous words, response times were shorter in the tDCS session than the sham session for ambiguous words, but not for unambiguous words. The simple reaction task revealed no difference in response times between the tDCS and sham sessions, making clear the absence of any influence of attention and/or motor function in tDCS effects. The results of this study are relevant because they support the involvement of specific brain regions in ambiguity processing, but also because they extend the evidence to other languages.

Taken together, reading, eye-tracking, and neuroimaging studies show increased cognitive effort and processing cost to resolve the ambiguity between unrelated meanings of ambiguous words. It is worth noting that these additional costs are observed when words are presented is isolation and in sentence contexts. Considering these pieces of evidence, an important question arises, why is ambiguity present in language if it slows down our language comprehension? To explore this question the next section will present a view that considers ambiguity as a beneficial characteristic of language that improves communication efficiency.

1.4 Ambiguity as Advantage in Language

The previous section provided evidence that supported the view of ambiguity as a disadvantage in language, identifying the increased cognitive effort and processing cost to resolve ambiguity (e.g. Duffy et al., 1988; Rodd et al., 2004, 2010; Vitello et al., 2014). But if this is the case, how would it be possible to consider ambiguity as an advantage in language? To discover this view it is necessary to analyse ambiguity from a different point of view.

Ambiguity is a phenomenon that is part of almost any language. When taken out of context words have multiple meanings and senses. The existence of ambiguity is a puzzle for functionalist theories which attempt to explain properties of linguistic systems in terms of communicative pressures (e.g. Hockett et al., 1960; Pinker et al., 1990). It will be possible to argue that in a perfect communication system, language would completely disambiguate meaning. In these "perfect communication systems" the difficulties in language communication and comprehension will be reduced because the access to a specific meaning will be given specifically for each word. Chomsky (2002) identified ambiguity as an undesirable property of language, stating that "If you want to make sure that we never misunderstand one another, for that purpose language is not well designed, because you have such properties as ambiguity. If we want to have the property that the things that we usually would like to say come out short and simple, well, it probably doesn't have that property" (Chomsky, 2002 p.107). However, if we consider ambiguity as an undesirable property of language we cannot answer the most obvious question, why is ambiguity so frequently present in language?

In an effort to identify ambiguity as an advantage in language, Piantadosi et al. (2012) argue that ambiguity is a functional property of language that improves communicative efficiency. They suggest that ambiguity can be understood as the trade-off between two communicative pressures which are inherent to any communication system: clarity and ease.

A clear communication system is one in which the intended meaning can be recovered from the signal with high probability. An easy communication system is one in which signals are efficiently produced, communicated, and processed. Piantadosi et al. illustrate this trade-off with the NATO phonetic system. This system used by the military and pilots gives names to letters – A is "Alpha", B is "Bravo", C is "Charlie", and it was created to avoid the confusion that might occur to communicate similar-sounding letter names across a noisy acoustic channel. By communicating letters with full words, a listener can easily recognize a letter in the presence of noise, the disadvantage is that full words take more time and effort to produce and comprehend, trading ease for clarity.

The benefits of ambiguity recognised by Piantadosi et al. (2012) are based on the argument that efficient communication systems will contain ambiguity. This argument is based on two perspectives: (i) the most efficient communication system will not convey information already provided by the context, which may mean that these systems appear ambiguous when examined out of context, and (ii) specifically for human language processing, ambiguity allows re-use of "easy" linguistic elements, words that are short, frequent, and phonotactically plausible (Piantadosi et al., 2012). Piantadosi et al. recognize that not all kinds of ambiguity make the language more efficient, for example, a linguistic system won't be efficient if it re-uses particularly difficult linguistic elements (e.g. words with a high number of syllables, such as, "experiment" or "construction"). Instead, they argue that any language system that aims to preserve communicative or cognitive efficiency will be ambiguous.

Ambiguity is an integral part of human communication systems, and homophony is a clear example. By re-using linguistic elements homophony contributes to the efficiency of human languages. Testing this claim Trott et al. (2020) constructed five series of artificial lexica, which were matched on phonotactics and distribution of word lengths of five real

languages (English, German, Dutch, French, and Japanese). These artificial lexica were compared in the quantity and concentration of homophony to real languages. Results indicated that the real lexica had either less or an equivalent number of homophones per wordform compared to the artificial lexica, and that the concentration of homophones tend to be higher among short and phonotactically plausible wordforms. These findings are consistent with the idea of efficient communication systems suggested by Piantadosi et al. (2012).

From a cognitive point of view, several explanations that support ambiguity as an advantage in language have been discussed by Wasow et al. (2005). The first is that ambiguity reduces the memory demands of storing a lexicon, though they conclude that human memory is not a bottleneck for vocabulary size. Second, they suggest that there may be some processing constraint against longer morphemes which leads to shorter morphemes being recycled for multiple meanings. Third, ambiguity might be useful in language contact situations where speakers of different languages should be able to handle the same word but with different meanings on each language, this happens for example with "false friends" or words that look and sound similar in two or more languages, but that have different meanings in each of them (e.g. the English word "gift" means poison in German and married in Norwegian). Lastly, they argue that ambiguity sometimes serves a communicative function when speakers want to be ambiguous intentionally, for example, when someone says "This English summer was great" they may intend to express how enjoyable the summer was in England or be ironic considering that it rained a lot.

To understand the benefits of ambiguity, we need to accept its cognitive costs, for instance, the use of context to select the intended meaning. This additional cognitive cost is made to preserve the transmission of the intended message and in the long term the reduction of the cognitive effort made to comprehend it. Supporting the idea that the cost of ambiguity

can be reduced, a growing body of evidence indicates that comprehenders are able to quickly use contextual information in the form of discourse context (Kaiser et al., 2004; Grodner et al., 2005), local linguistic context (Frisson et al., 2005; Levy, 2008), or more global world knowledge (Altmann et al., 1999; Kamide et al., 2003) in disambiguating language. In this scenario, ambiguity addresses in an effective way the dynamics of communication, because it allows the integration of linguistic and paralinguistic cues. For instance, comprehenders continually make inferences about what speakers are intending to convey (Sedivy et al., 1999; Levinson, 2000; Sedivy, 2002), what their utterances may mean on literal and pragmatic levels. In this sense Levinson (2000) argues that speaker articulation, not hearer inference, is the principal bottleneck in human language. Inference is "cognitively cheap", and comprehenders continually make use of it to understand the intention of a message.

In contrast to the previous section, this one describes ambiguity as an integral part of any communication system, which results from the pressure for efficient communication. However, this claim does not contradict the large body of evidence that promotes the idea that ambiguity is costly, instead it suggests that its cost is lower than its benefits. Overall, this view suggests that ambiguity is not detrimental per se, but rather an intrinsic characteristic of languages that allows efficient communication.

The next section will introduce how we represent ambiguous words to better understand why ambiguity challenges our language comprehension skills and the capacity of our cognitive system.

1.5 The Representations of Ambiguous Words

There are two main types of models that describe how ambiguous words are represented in the mental lexicon, Localist models and Distributed Connectionist models. It is relevant to clarify that the description of the types of models presented here explain the

representation of ambiguous words in the context of comprehension. From a theoretical perspective it does not make sense to apply comprehension models to word and sentence production, mainly because the process in which they deal with ambiguity is different. For comprehension, the reader/listener needs to select a particular meaning from various possible options in order to understand the intended meaning or sense of a particular fragment, dealing with the one-to-many mapping between form and meaning present in ambiguous words. Instead, for production the speaker needs to generate a single word from different alternatives, as a result the one-to-many mapping present in comprehension is reversed to a many-to-one mapping process that significantly reduces the impact of ambiguity. This aspect explains why models of production (e.g., Dell, 1986, 1988; Levelt, 1989, 1992; Roelofs, 1997; Shattuck-Hufnagel, 1979) have not considered the impact of lexical ambiguity in any detail.

Based on some earlier work, such as the Logogen model (Morton, 1969), the Localist model exemplified by McClelland & Rumelhart (1981) assumes that each word is represented by a single entry in our mental lexicon. These entries correspond to individual "nodes" or "units" and as soon as one of these units has been sufficiently activated in response to the incoming visual/auditory input, the reader/listener can then retrieve the necessary information about that word's meaning. In a Localist model each node may represent grammatical roles or relations, these are tied to other nodes that combined represent a word-token, which in turn is activated by the concurrent activation of these nodes (Montazeri et al., 2014). The main characteristic of Localist models is that each node represents one concept, and to integrate more concepts it is required to add new nodes, which gives the necessary flexibility to include additional information of a particular word at a later time point.

In contrast, Distributed Connectionist models (Montazeri et al., 2014) propose that each word is represented as a unique pattern of activation across sets of units that collectively represent its form (spelling/orthography or sound/phonology) and its meaning (Armstrong et al., 2008; Borowsky et al., 1996; Joordens et al., 1994; Kawamoto et al., 1994; Rodd et al., 2004). Individual units represent distinctive features of the words' form/meaning, for example, words with similar spelling (or sound) will activate similar sets of orthographic (or phonological) input units, while words with similar meanings will activate similar sets of semantic units. This approach can explain the ambiguity disadvantage (Rodd et al., 2004), because the model is slower to disambiguate words with distinct meanings as they compete for activation. To explain this process Rodd et al. (2004) suggest the idea of interactions within semantic representations through recurrent connections between semantic units. The idea is that the activation of the semantic network starts from a blend state, where all the meanings of an ambiguous word are viable options, and ends in an attractor state, which is the activation of a single meaning, hopefully the intended one. The need to move from a blend state to an attractor state is what slows processing of ambiguous words. Interestingly, Distributed Connectionist models can also explain the word-sense advantage also found by Rodd et al. (2004), since the model is faster to disambiguate words with related senses because the patterns of activation for each sense overlap with other similar senses. In other words, the activation of one sense can facilitate the activation of a second related sense through the partial activation of some units, which makes the second related sense more available. Distributed Connectionist models, and the claims made by Rodd et al. (2004) about them, seem to be the better theoretical explanation that allows us to understand ambiguity resolution.

In this context, theoretical models of semantic ambiguity have faced some inconsistent findings in the study of the effect of meaning relatedness in the processing

disadvantage for ambiguous words compared to low-ambiguous words, an inconsistency that can be explained by the type of task selected to measure this effect. Lexical decision tasks have found that ambiguous words with related senses are processed faster than low-ambiguous words, and that ambiguous words with unrelated meanings are processed slower than low-ambiguous words (e.g. Beretta et al., 2005 and Rodd et al., 2002). Semantic categorization tasks (e.g. Hino et al., 2006), have revealed that ambiguous words with unrelated meanings are associated with a processing disadvantage compared to low-ambiguous words, and that ambiguous words with related senses and low-ambiguous words do not show differences related to the speed of their processing. To explain the inconsistency in the relatedness effect between these tasks, Hino et al. (2006) argue that task differences cannot be accounted for by a general semantic encoding process, because this is shared across tasks, but to differences in the configuration of a decision making system. According to this account a similar semantic representation is activated across all tasks, but the difference relies on how the response system is configured to select a particular response. In contrast, Armstrong et al. (2008) suggest that these differences can be explained by taking into account the settling dynamics of semantic encoding within a distributed network. Essentially, the semantic settling dynamics account suggested by Armstrong et al. (2008) argues that task differences can arise due to different degrees of semantic precision required by each task. For instance, while general semantic information is enough for a lexical decision task, more detailed semantic information is needed in a semantic categorization task. The settling dynamics account seems to have an advantage over the one suggested by Hino et al. (2006), as it is based on the domain-general principles of the connectionist framework, and because it recognizes the importance of how cooperative and competitive dynamics unfold over time. These aspects seem to better describe how ambiguity resolution can be achieved, however more evidence is needed to clarify the mechanisms behind this process.

Localist and Distributed models are valid frameworks of how ambiguous words can be represented. However, the distributed framework seems to account in a better way the richness of the lexical-sematic representations and the disambiguation process needed to reach the intended meaning of ambiguous words. Despite the fact that Localist models suggest that it is possible to add new information about a word, thus providing a reasonable option, for example, to explain changes in meaning dominance and the integration of new meanings or senses for previous known words, Distributed models capture an important distinction that Localist models do not. Rodd (2020) suggests that this distinction refers to how we can have a more integrated view of homonymy and polysemy. Instead of building a lexical-semantic space by adding "nodes" or "units" that represent a meaning or sense as promoted by Localist models, Distributed models explain different meanings as distant points in the semantic space, while related word senses are characterised as representations that are closer to each other. This view implies that the difference between different meanings and senses can be understood as a continuum in the lexical-semantic space, different meanings are distant because they share less semantic features, related senses are closer because they share many of them. In this sense, Distributed models can account for the variability in relatedness between polysemous words, and importantly they provide the option to avoid the establishment of an arbitrary line between homonymy and polysemy.

The information presented previously described how ambiguous words are represented and how we can access their meaning when they are presented in isolation. Nevertheless, to understand how words are comprehended in natural language, necessarily we need to discuss how we can access word meanings in context. The next section will present the most influential models of access that have been developed with this purpose, providing a detailed description of their main claims, how they can be compared to each other, and how taken together they can contribute to this process.

1.6 Word-Meaning Access

Over the last 40 years the psycholinguistic literature has revealed a significant number of studies that have attempted to explain how we access the meanings of ambiguous words in context (Armstrong et al., 2016; Cai et al., 2017; Duffy et al., 1988; Onifer et al., 1981a; Rodd, 2020; Rodd et al., 2004; Rodd et al., 2012; Rodd et al., 2013, 2016; Schvaneveldt et al., 1976; Swinney, 1979; Twilley et al., 1994; Twilley et al., 2000; Vitello et al., 2014). This research has allowed the development of different views that aim to explain this process, such as the immediate activation of all word's meanings when a particular word is encountered in context, or the selective activation of the meaning of the word that is consistent with the context. Fortunately for all enthusiastic psycholinguists, a definitive answer to this issue is still far from being resolved. To enrich this dialogue this section will provide an overview of the main models, the main findings that support them, as well as a clear analysis of the development in the understanding of their implications aiming to provide an up-to-date view of how we can comprehend word-meaning access.

Addressing this debate, the Exhaustive Access model promotes a clear answer of how we can access word meanings in context. It argues that all the meanings of a word are activated from the perceptual input (Onifer et al., 1981). This argument was motivated by data from a cross-modal semantic priming paradigm used by Swinney (1979) and Onifer and Swinney (1981). In these studies English-speaking participants listened to sentences that contained an ambiguous word (e.g. "bug") and were presented with a visual target word that they had to name as quickly as possible or make a lexical decision about (Is this a real word?) immediately after the encounter with the critical ambiguous word. The context before the critical word in the prime sentences was neutral concerning the meaning of the ambiguous word (e.g. "Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several **bugs** in the corner of his room")

or disambiguated it towards one of its meanings (e.g. “Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several spiders, roaches, and other **bugs** in the corner of his room”). Target words were either semantically related to the meaning of the ambiguous word that was consistent with the sentence context (e.g. “ant”), related to the other, irrelevant meaning (e.g. “spy”), or unrelated to either meaning (“sew”). The results from these experiments were clear: lexical decisions related to each of the meanings were facilitated across all context conditions when these lexical decisions were immediately made after the occurrence of the ambiguity in the sentence (Experiment 1). When four syllables were presented following the ambiguity, only lexical decisions related to the contextually appropriate meaning of the ambiguity were facilitated (Experiment 2). The fact that the facilitation effect was absent for the contextually inappropriate meaning after the presentation of 4 syllables, shows that word meaning access is influenced by prior context at a later time point. These findings support the idea that all meanings of ambiguous words are activated to a certain degree, because the facilitation effect for a particular meaning was found across all context conditions when they were tested immediately after the exposure to the ambiguous word.

Providing additional support for the Exhaustive Access model, Swaab et al. (2003) measured the N400 (event related potential that is sensitive to lexical integration processes) in English-speaking participants who were exposed to sentences that were either related or unrelated to target ambiguous words. Results showed that for both dominant and subordinate meanings, the N400 amplitude was reduced to the targets in the related compared to the unrelated sentence context conditions, thus confirming a process of lexical integration. It is worth noting that the N400 revealed that dominant meanings were always partly activated regardless of the context, and that dominant and subordinate meanings were activated at least initially. This pattern of activation supports a model of sentential processing, in which lexical

access is an autonomous process where all the meanings of a word are momentarily accessed during sentence comprehension, no matter if they are contextually appropriate or inappropriate. However, the specific context tends to have a stronger influence for subordinate than dominant meanings.

The opposite idea is given by the Selective Access model which proposes that activation of the meanings of ambiguous words is influenced immediately by prior context (Schvaneveldt et al., 1976). This approach is based on the idea of spreading activation across a semantic network. In this sense, if the context includes words like “lake” and “nature”, words related in meaning are activated, so when the processing system encounters “crane”, its “bird” meaning is activated. Supporting this model, priming studies indicated that prior context can have early effects on meaning activation. Schvaneveldt and colleagues (1976) asked English-speaking participants to make lexical decisions about sequences of words, e.g. RIVER – BANK – WATER, or RIVER – BANK – MONEY. Results revealed faster responses to “water” compared to “money”, suggesting that the context “river” primed only the contextually appropriate interpretation of “bank”. It is important to note that this study tells us about the final state of the response, not making a distinction if meaning access is selective or exhaustive at the earliest stages of this process. To clarify the time course of meaning activation, Simpson et al. (1991; Experiment 1) ran an experiment where English-speaking participants read sentences aloud that at the end contained as a target word a homograph, then they needed to name the target. Results revealed that when the sentences included a context that did not prime either meaning of the homograph, there was a facilitation effect for the dominant meaning, this meaning was accessed more quickly and retained for a longer period when compared to the subordinate meaning. For those sentences that included a context that biased the interpretation of one meaning, only the target related to that meaning was facilitated. Taken together these findings provide evidence that the

information provided by the context influences both earlier and later stages of meaning access, thus providing support to the Selective Access model.

Even though the Exhaustive and the Selective Access models are two valid options to explain word-meaning access, they have been criticised, leading to the development of hybrid models. One example of these hybrid models is the Reordered Access model (Duffy et al., 1988), which argues that when a word form is encountered its different meanings are activated simultaneously. Then, the timing of which specific meaning is available relies on two key factors: (a) the word meaning's relative frequency in the language, also called dominance, and (b) the preceding sentential context. These factors secure rapid access and integration of word meanings that are common in everyday language (high frequency) and those that are rare (low frequency). This model has proven useful in describing word-meaning access and is supported by a wide range of evidence in written and spoken English as well as other languages (for review, see Vitello & Rodd, 2015), such as Chinese (Li et al., 2002).

Another example of a hybrid model is Twilley and Dixon's (2000) Independent Activation model of lexical access. This model suggests that that all meanings of ambiguous words receive activation from the input, but at the same time, each meaning has a certain resting-state level of activation that is given by experience with it (frequency). To test the validity of this model, the authors reported a series of simulations where the strength of context and the resting activation level were manipulated, finding that when the context was weak, the model produced priming effects that can be explained by the "Exhaustive Access" model, while stronger context leads to priming effects that can be explained by the "Selective Access" model. Interestingly, the variation of the resting activation level revealed that subordinate meanings were only activated when the context supported this meaning, while dominant meanings were always active due to their higher levels of resting activation.

Importantly, this model assumes that the perceptual input decays over time and that the input from the context that biases the interpretation of one meaning can act to suppress the contextually inappropriate meaning. This assumption is perhaps the most differential characteristic of this model because it supports the claim of an activation of all the meanings of words, not just initially as the Reordered Access model argues.

Given the overreliance of linguistic studies on English, as identified by Blasi et al. (2022), it is worth to clarify that the previous models of ambiguity are not just based on English, in fact some of the most important studies comes from other languages. Mehler et al. (1978) investigated the influence of ambiguous words on phoneme detection in French speakers. Participants read sentences containing ambiguous words that were disambiguated toward one of their meanings (e.g., for the ambiguous word "glace" the sentence was: "La dame a acheté une **glace** pour offrir á sa fille", French sentence that translated to English means: "The lady bought an **ice cream/a mirror** to offer to her daughter"), or unambiguous control words (e.g., for the unambiguous word "dinde" the sentence was: "La dame a acheté une **dinde** pour offrir á sa fille", French sentence that translated to English means: "The lady bought a **turkey** to offer to her daughter") (examples taken from Mehler et al. (1978)). Measures of length and frequency of ambiguous and unambiguous words were controlled. Immediately after the presentation of the target, participants responded as quickly and accurately as possible if the following word contained one of the target phonemes /p, b, t, d/. Results revealed that the ambiguity of the word did not increase the time needed to detect the phoneme; sentences with long ambiguous words before the phoneme had faster responses compared to short unambiguous words. These earlier findings in the French language are consistent with the Selective Access model because the speed with which the phoneme was detected does not depend on the ambiguity or non-ambiguity of the test word. This suggests that both types of words, when encountered in sentence contexts, are processed as if they

have a single contextually appropriate meaning, making clear the immediate influence of the sentence context in meaning selection.

Another example is the study led by Hagoort et al. (1989; Experiment 1), who investigated the processing of lexical ambiguities in Dutch. In this study Dutch participants completed a lexical decision task, deciding whether the third word of an auditory presented triplet was real. In the concordant condition, the first prime and the target were associated with the same meaning of the second ambiguous word (e.g., bier-kater-DRANK; German words that translated to English refer to the meanings of "beer-tomcat/hangover-drink", respectively). In the discordant condition, the first prime and the target were associated with different meanings of the second prime (e.g., poes-kater-DRANK; "puss-tomcat/hangover-drink"). In the neutral condition the first word was unrelated to the second and the third word was related to one of the meanings of the second word (e.g., piano-kater-DRANK; "piano-tomcat/hangover-drink"). Lastly, the unrelated condition included three words that were unrelated and unambiguous (e.g., poes-piano-DRANK; "puss-piano-drink") (examples taken from Hagoort et al. (1989; Experiment 1)). Results revealed that: (i) the concordant condition showed faster response times compared to all other conditions; (ii) the neutral condition showed faster response times compared to the discordant and unrelated conditions; and (iii) no difference between the discordant condition and the unrelated baseline. Overall, these results support the Selective Access model because the significant difference between the concordant and the neutral condition suggest that the context immediately influences the activation of the meanings of ambiguous words.

Moreover, early findings from Zwitserlood (1989), who using cross-modal priming investigated the role of word information and context in the access to word meanings in Dutch. Results revealed that the information provided by the context does not influence the selection of contextually appropriate words before the presentation of the word of interest, in

fact contextual effects were found after the word is encountered, when the contextual information is required to select the intended meaning. This result is of fundamental relevance because it is taken as foundational data for the models of ambiguity described previously, and in particular for the Reordered Access model.

At this point it is worth noting that Dutch is structurally similar to English, which limits the applicability of the models of ambiguity to other languages that are structurally quite different, such as Chinese and Arabic. However, this situation is changing thanks to the emergence of more recent evidence that suggest that these models can explain ambiguity resolution in structurally different languages. For instance, Li et al. (2002), using cross-modal priming, investigated the processing of monosyllabic homophones in Cantonese and disyllabic homophones in Mandarin Chinese. This was done through the manipulation of factors, such as, context type, dominance, interstimulus intervals, meaning relatedness, and homophone density (number of alternative meanings). The results of these experiments revealed that in both Cantonese and Mandarin Chinese, listeners use prior context to solve ambiguity, and also that sentence context and meaning dominance influences ambiguity resolution. The evidence found by this study, as well as others carried out in Chinese (e.g. Li et al. (1996); see also Ahrens (2002)) provides support to the idea that the Reordered Access model can be applied to the Chinese language.

Aljadaan et al. (2024) investigated the presence of semantic priming in Arabic, evaluating if it is possible to boost all related material to the context. To investigate this, the experiment used two varieties of Arabic, the Najdi and the MSA, aiming to find if the priming in one variant could cause that all the homographs tested could retrieve the meaning of that variant (for example, the Arabic homograph “ نجيب” in the MSA variant refers to the adjective “good”, while in the Najdi variant refers to the verb “bring”; example taken from Aljadaan et al. (2024)). To do so, on day one participants completed a reading task, where

they read a Najdi text which included seven homographs, a filler ask, where they answer a question, and a word recognition task, where they were asked to provide the meanings of the homographs. On day two participants completed the same tasks but read an MSA text (the other Arabic variant). Findings from the word recognition task revealed that participants did not give the Nadji meaning to all the homographs after they were primed in that variant, or the MSA meaning to all the homographs primed in this variant. This finding is quite interesting because it reveals the need to investigate in more detail the influence of the context and its interaction with word frequency in ambiguity resolution in Arabic. Although, findings from Aljadaan et al. (2024) does not provide clear support for a particular model of ambiguity, they do not eliminate the possibility that ambiguity resolution in Arabic could be explained by the models described previously.

Despite the relevance of the studies carried out in Chinese, Cantonese, and Arabic, future work is needed to better understand how the specific characteristics of individual languages modulate how ambiguous words are represented and processed. In this context, to evaluate the models of ambiguity across languages it is necessary to characterize the mapping between form and meaning more broadly, rather than identifying the specific differences in the degree of ambiguity present on each particular language. With this purpose, Dautriche et al. (2017) suggested a global pattern of systematicity in form to meaning mappings. This idea emerges from the fact that she and her colleagues found a correlation between semantic similarity and phonological similarity across the whole vocabulary of the100 languages analyzed. This result challenges the view of arbitrariness in the mapping between form and meaning. This finding led to the possibility of a functional pressure that applies across languages, however, the authors warn that a causal link between functional pressure and the pattern of systematicity cannot be established. In this sense, Dautriche et al. (2017) findings inspire future research on language evolution that could address with more precision how the

form-to-meaning mapping emerges across languages, which in turn could provide a more complete picture or maybe the general rules of how ambiguity is present across the wide variety of languages that exist.

Furthermore, it is relevant to mention that the models mentioned before are within-language ambiguity models, however, it is worth considering if they can be applied to multilinguals or people who speak more than one language. Context-independent models, such as the Exhaustive Access model (Onifer et al., 1981), could be applied in a context of cross-linguistic ambiguity. For instance, multilinguals could activate the target-language of words with different meanings in different languages, and the meaning that corresponds to the non-target-languages(e.g. the word “pie” means dessert in English and foot in Spanish) . Moreover, context-dependent models like the Selective Access model (Schvaneveldt et al., 1976) could also be applied cross-linguistically, suggesting that multilinguals activate just the target-language meaning of interlingual homographs. Despite the plausibility of both selective and nonselective-access accounts that explain cross-linguistic ambiguity, most of the current evidence reveals greater support for nonselective-access accounts (for a review see Degani et al. (2010)).

However, as is the case for monolingual ambiguity, cross-linguistic ambiguity seems to be better explained by models that combine more than one factor. In this scenario, Degani et al. (2010) propose a three-factor framework to account for cross-language ambiguity. This model suggests that in addition to the factors of frequency and semantic/syntactic context identified by the monolingual hybrid models mentioned before, language context or the knowledge accumulated for a particular meaning within a specific language plays a key role in the resolution of ambiguity across languages. Specifically, this model is an extension of the Reordered Access model (Duffy et al., 1988) that allows the study of the interactions between frequency, semantic/syntactic context, and language context, explicitly stating that

these three factors can activate the different meanings of interlingual homographs, and consequently resolve cross-linguistic ambiguity. It is worth noting that this model leaves open the possibility that the three factors could have their influence at different time points, thus revealing a more complex pattern of interactions. This picture along with the lack of studies that have explored cross-linguistic ambiguity resolution, reveals the need to further explore these processes, which can contribute to a better understanding of ambiguity resolution within and across languages.

The models of word-meaning access presented previously have attempted to explain how listeners and readers can access the intended meaning of a particular word in context. Taking the basis of the Exhaustive Access model and the Selective Access model, hybrid models, such as, the Reordered Access model and the Independent Activation model seem to describe in a better way how word-meaning access happens, because they suggest an interaction between word frequency and the context where this word is encountered. Even though these models are useful, they do not seem to explain one key characteristic of our lexical semantic knowledge, its flexibility. Although the importance of meaning frequency is undisputed, little is known how meaning preferences emerge, and how they are maintained over time. One option is that meaning preferences reveal a stable property of long-term lexical-semantic representations, which cannot be modified by recent experiences. The second option is that preferences for word meanings reveal a fluid and flexible aspect of our lexical-semantic representations that can be significantly modified by our most recent experiences.

To provide a theoretical account that recognises the flexibility of word meanings, Rodd (2020) presented a new account of English word-meaning access that puts semantic disambiguation as a key characteristic. There are three major features that describe this new account. First, words have distributed representations of their meanings, these representations

can be understood as stable states within a complex, structured, and high dimensional space (Armstrong et al., 2016; Rodd et al., 2004), Second, ambiguity resolution is facilitated by the use of several linguistic and paralinguistic cues that are present in the context. The primary source of disambiguation is provided by the context, but the integration of non-linguistic cues complete this process, for instance, the accent of the speaker (Cai et al., 2017). Lastly, learning mechanisms shape and maintain lexical-semantic knowledge. This characteristic is particularly important because it recognises that our linguistic knowledge is shaped across the life span, where different meanings and senses for known words are updated, and new words with their new meanings are integrated into our pre-existing lexical-semantic knowledge (e.g., Rodd, et al., 2012) after a recent linguistic experience (Rodd et al., 2013; 2016). This is the key difference of this model compared to hybrid models mentioned previously, and without doubt makes a key contribution to the understanding of how our linguistic knowledge works.

This section has focused on how ambiguous words are represented and how it is possible to access the different meanings of these words. To investigate how recent encounters with particular meanings of ambiguous words in context influence the access of these meanings, the next section will describe how priming allows us to test the flexibility of lexical-semantic representations of these words.

1.7 Priming as a Phenomenon to Test the Flexibility of Representations

Evidence suggests that the language system retains significant plasticity during adulthood. This plasticity allows us to, for example, adapt our perception of phonemes when exposed to unfamiliar accents (Norris et al., 2003), solve phonetic ambiguities (Davis et al., 2002; McQueen et al., 2006), tailor our production system to reflect the statistical structure of our environment (Dell et al., 2000), acquire and retain new forms (Gaskell et al., 2003),

meanings (Fang et al., 2017; Rodd et al., 2012), and syntactic constructions (Branigan, 2007; Branigan et al., 1995; Kaschak et al., 2004; Ryskin et al., 2017; Tooley et al., 2010), and update our lexical-semantic representations for ambiguous words after a recent experience with a particular meaning (Curtis et al., 2022; Gaskell et al., 2019; Gilbert et al., 2018; Rodd et al., 2013, 2016).

In this context, priming has become one of the most popular phenomena to measure the plasticity of the adult language system, although the technique extends beyond psycholinguistic research. Priming is fundamental in psychology because it shows how our past experiences can influence our present and future behaviour. It is a general phenomenon that can take many forms, from efficient processing the second time we encounter a stimulus (repetition priming), to activation of other related concepts (semantic priming), to triggering an associated goal (goal priming) (Doyen et al., 2014). In this sense, priming influences much of human behaviour, including perception, memory, decision-making, and action. Although priming takes many forms, we focus on the approach that has been used in cognitive psychology and in particular psycholinguistics. In this type of study the assumptions are as follows: (1) a prime stimulus is presented and activates an internal representation, (2) the activated representation influences other representations, and (3) those other activated representations lead to behavioural changes (Doyen et al., 2014).

Having introduced priming as a valid phenomenon to induce changes in the lexical-semantic representations of words, the next section will introduce a type of priming called word-meaning priming, how it works, what are the mechanisms behind it, why it can be considered as a useful method to test the flexibility of lexical-semantic representations, and how it helps us to understand the organization of the lexical semantic system.

1.8 Word-Meaning Priming

Supporting the idea that lexical-semantic representations are flexible after recent encounters, word-meaning priming has proven to be an effective type of priming to increase the likelihood of retrieval of the recently encountered meaning. Word-meaning priming happens when the presentation of an ambiguous word in a sentence context influences the preferred meaning for that word in a subsequent encounter.

Rodd et al. (2013) used word-meaning priming to explore how English-speaking people's preferences for the different meanings of ambiguous words are modified by prior exposure to the ambiguous words during sentence comprehension. Exemplifying how word-meaning priming works, in a series of three experiments Rodd et al. (2013) included prime sentences that contained target ambiguous words, which were disambiguated towards their subordinate meanings. For instance, to disambiguate the word 'ruler' towards its less frequent (subordinate) meaning that refers to the person that leads a group of people, participants heard the sentence "The **ruler** of the country was very popular indeed". At test, meaning preferences were measured with a word association task where participants needed to type the first word that came to mind that was related in meaning to the word just heard. The results of this task indicated that, even after a delay of up to 20 minutes, the proportion of responses related to the primed meaning increased by 30% (Experiments 1 and 2) or 40% (Experiment 3) when compared to the unprimed baseline condition. These results reveal how a recent experience with a particular meaning of an ambiguous word influences its subsequent interpretation. Experiment 1 also showed that the magnitude of word-meaning priming is modulated by the baseline dominance of the ambiguous word's meanings since priming effects are largest for words with low baseline (unprimed) dominance scores. Overall, Rodd et al.'s findings have two main implications: (1) they validate word-meaning priming to alter meaning preferences of ambiguous words, and (2) they support the view that

the use of recent experiences to guide disambiguation is likely to be an important factor in making listeners so efficient at dealing with ambiguities in natural conversations (Rodd et al., 2013).

One key characteristic of word-meaning priming that has been revealed is that it is lexically specific, which means that it relies on the presence of the ambiguous word within the prime sentences, and not by a more general semantic priming that relies on the information provided by the context. This characteristic was identified by Rodd et al. (2013) Experiment 3, which compared the effectiveness of prime sentences that contained the target ambiguous word (e.g. "The footballers were greeted warmly by the adoring **fans**") to matched sentences with highly similar meanings that did not contain the ambiguous word (e.g. "The footballers were greeted warmly by the adoring **supporters**"). After a short delay of 3 minutes, results from the word association task revealed no significant differences between word-meaning priming and semantic priming. However, after 20 minutes results from the same task showed that the number of associates was significantly greater in the word-meaning priming condition than the semantic priming condition. Moreover, after 20 minutes no significant differences were observed in the number of associates generated between the semantic priming condition and the unprimed condition.

These findings must be taken with caution because Curtis et al. (2022) used the same word-meaning effect and similar spoken sentences in English to prime a particular aspect of the meaning of low-ambiguous words (e.g. "luggage-heavy vs. luggage-suitcase") and found evidence of semantic priming after a somewhat longer delay. Specifically, Curtis et al. (2022) revealed semantic priming after a delay of up to 25 minutes, when meaning preferences were measured through relatedness judgement and word association tasks. This inconsistency will be addressed specifically in Chapter 4 by replicating Rodd et al. (2013; Experiment 3), for now it will be better just to consider semantic priming as a short-lived phenomenon that can

be observed across a time-scale of only a few minutes (McNamara, 2005), and that doesn't rely on the presentation of the particular ambiguous word as word-meaning priming does.

Another characteristic of word-meaning priming is that this effect is relatively abstract, in the sense that it seems to be independent of the perceptual information received during the exposure phase. For example, Rodd et al. (2013; Experiment 2) tested if the word-meaning priming effect reflects a modulation of abstract lexical-semantic representations by changing the identity of the English speaker. This was done by re-recording the sentences used in Experiment 1 by a female and a male speaker. During priming, participants heard sentences spoken by one female and one male speaker. At test, they just heard the ambiguous word read by the same female speaker that they heard during the priming phase. The associates generated in the word association task indicated that similar associates were generated between priming and test in the same-voice and the different-voice condition. Providing further support to the consideration of word-meaning priming as an abstract phenomenon, Gilbert et al. (2018) tested if word-meaning priming allows the transfer of information in English that is gained within one modality (e.g. "speech") to the other (e.g. "reading"). This was done through two web-based experiments where ambiguous target words were primed with either written or spoken sentences that were disambiguated towards their subordinate meanings. 20 minutes after this exposure, target words were tested in either written or spoken form. Experiment 1 tested meaning preferences using a word association task and Experiment 2 a semantic relatedness task. These experiments revealed significant unimodal and cross-modal priming compared to the unprimed condition, and they showed no significant differences in priming levels between unimodal and cross-modal prime-test conditions. Taken together, Rodd et al. (2013) and Gilbert et al. (2018) by using different approaches have found that word-meaning priming is abstract, it doesn't rely on the perceptual information provided during the priming phase, the first suggesting that word-

meaning priming doesn't rely on the identity of the speaker, and the second that word-meaning priming works in a modality-general way. As will be considered in the next section, these findings will have important consequences for the theories that aim to explain the mechanisms behind word-meaning priming.

Rodd et al. (2013) (Experiment 3) explored the duration of word-meaning priming. They found that after priming the subordinate meanings of English ambiguous words with spoken sentences, the associates generated in the word association task after delays of 3 and 20 minutes didn't differ significantly, although a numerical decrease was observed after the longer delay. In order to further explore the time course of word-meaning priming, Rodd et al. (2016) created a modified version of the previous experiment where participants heard in one block all the prime sentences, then they completed a word association task in different blocks to measure their responses after 1, 20 or 40 minutes respectively. The strongest effect of word-meaning priming was observed for those responses generated after a delay of 1 minute, responses collected after a delay of 20 or 40 minutes revealed a lower rate of primed responses, however, this was higher than the unprimed condition. Providing additional evidence for the duration of word-meaning priming effects in a series of three experiments, Betts et al. (2018) primed the subordinate meanings of English ambiguous words through spoken sentences. The associates generated in subsequent word association tasks replicated the finding that one encounter with a particular meaning of ambiguous words favours the interpretation towards the primed subordinate meaning after a 20 to 30 minute delay. To sum up, these studies demonstrate that word-meaning priming effects are long lasting, being observed up to 40 minutes after priming, but they also suggest that during this time there is a not significant decay at longer delays. These observations must be considered in future studies that can attempt to explore the duration of word-meaning priming effects at longer time-scales to complete the characterization of its time course.

Providing further support for word-meaning priming, Rodd et al. (2016) carried out a series of experiments that aimed to replicate word-meaning priming effects in more naturalistic environments. In the first experiment, 1800 English-speaking participants listened to a radio programme that included short descriptions that included various fully disambiguated ambiguous words. Immediately after or up to a week after this exposure they were invited to complete an online experiment which collected word association responses related to the ambiguous words previously heard. Results showed that more associates related to the primed meaning were generated in the primed condition vs the unprimed (baseline) condition, but just when these associates were generated on the same day of exposure, no differences between priming conditions were revealed when these associates were tested after two days, or after three to eight days. This pattern of results by revealing word-meaning priming effects after a naturalistic exposure to the primed meaning of ambiguous words, and a decay of this effect over time, provides additional support for the idea that lexical-semantic representations are highly flexible.

To further investigate word-meaning priming effects in naturalistic settings, Rodd et al. (2016; Experiments 3 and 4) aimed to study the change of meaning preferences in English-speaking participants that have atypical linguistic experiences, and whose meaning preferences will be different when compared to the rest of the population. For this purpose Rodd et al. (2016; Experiments 3 and 4) studied recreational rowers. In Experiment 3, 87 rowers and 27 control participants with no rowing experience made word associations to 101 words, 21 of them were homographs with a rowing related meaning and 80 fillers. These words were presented visually, and participants needed to type the first word that came to their mind that was related in meaning to the target word. Lastly, participants were asked to provide information about their main sport, their frequency of practice (years, last practice, times of practice per week), and what was the purpose of the study. The results indicated that

the mean proportion of rowing responses was higher in rowers compared with controls. Furthermore, a multiple regression analysis tested the effect of participants' age and their rowing experience on word association performance. This model indicated that age was a significant negative predictor, meaning that older participants retrieved a lower proportion of rowing responses, whereas the length of rowing experience showed that rowers with more rowing experience provided more rowing related responses. These results suggest that it is possible to reshape lexical-semantic representations of ambiguous words based on long-term experience, but also that the degree of flexibility of them relies on age, where younger adults are more susceptible to reshaping their lexical-semantic representations than older adults. Interestingly, recent rowing experience (during the last few days) did not have a significant effect on rowing related responses.

The absence of a significant effect of recent rowing experience on rowing related responses was followed up in Experiment 4. The design of this experiment was the same but this time English-speaking participants provided information about every occasion on which they had rowed over the last week. Results showed that the mean proportion of rowing related responses was significantly higher for rowers that rowed on the same day, compared to those that rowed on the previous day, despite a median delay of 8 hours. Moreover, a multiple regression analysis showed that age had a non-significant negative effect, which means that older participants did not retrieve a significantly lower proportion of rowing responses compared to younger participants, whereas long-term experience predicted a higher proportion of rowing responses. Taken together, the results from Rodd et al. (2016; Experiments 3 and 4) extends to a naturalistic scenario the possibility to reshape lexical-semantic representations on the basis of recent and long-term experiences. However, it is worth noting that these experiments, when compared to previous word-meaning priming studies, lose control of the type of exposure that participants had, and the frequency of these

encounters (since we don't know the frequency with which the rowing meanings were actually encountered during training), thus revealing the need to develop future studies that better address these issues.

Overall, the findings revealed by Rodd et al. (2016) Experiments 1, 3, and 4 show us that the facilitation effect of recent experiences with the less frequent meanings of ambiguous words can be extended to naturalistic environments. This was found for participants whose meaning preferences represent the population (Experiment 1) and for those that have a particular linguistic experience, such as rowers (Experiments 3 and 4). Overall, this evidence supports the notion that meaning preferences for a particular meaning of ambiguous words are influenced by recent experiences, but also that these experiences can have cumulative effects over time.

More recently, eye-tracking studies in English have replicated the ambiguity disadvantage, but now testing how a recent exposure to the less frequent meaning of ambiguous words can reduce the subordinate bias effect. Leinenger et al. (2013) tested whether an encounter with a homograph could reduce the subordinate bias effect in a subsequent encounter. To do so, participants read sentences that included either a homograph or a low-ambiguous control word. Overall, early and late eye-movement measures indicated that a previous encounter with the homograph reduced the subordinate bias effect on a subsequent encounter. Furthermore, Parker et al. (2023) also found greater reductions in go-past times and total reading times for subordinate meanings of ambiguous words, after reading sentences that included the less frequent meanings of these words. Such effect was not found for low-ambiguous control words, thus indicating that the reduction of the subordinate bias effect cannot be explained by simple repetition effects. In sum, by providing evidence of a possible reduction of the subordinate-bias effect, these studies made a step further in the comprehension of lexical ambiguity, not just saying that the ambiguity

disadvantage is present in language, but also suggesting that it is possible to reduce its effect by having a recent exposure to the less frequent meanings of ambiguous words.

To conclude, this section has introduced word-meaning priming as an effect that modifies word meaning preferences. By presenting an ambiguous word in a sentence context that biases its interpretation towards the less frequent meaning, it is possible to facilitate the access to this meaning in future when the word is encountered in isolation. The studies presented here have revealed some important characteristics of this type of priming including: (1) it is lexically specific, relying on the presentation of the target word, (2) it is relatively abstract, generalizing across speakers and modalities, (3) it decays over time, this has been found across timescales of minutes (up to 40 minutes) and days (up to 1 week), and (4) it has been replicated in naturalistic settings, with participants whose meaning preferences represent the population as a whole and for those who have a specific linguistic experiences (e.g. rowers). The next section will describe the main theoretical accounts that have been developed to explain the possible mechanisms behind word-meaning priming.

1.9 Theoretical Accounts of Word-Meaning Priming

1.9.1 Immediate Alteration Account

One of the preferred accounts to explain word-meaning priming effects is the Immediate Alteration Account. The original version of this account suggested by Rodd et al. (2013) and named by Gaskell et al. (2019) argues that word-meaning priming effects can be explained as an immediate updating of long-term connections between a word's written or spoken form and its lexical/semantic representation. For instance, an encounter with a spoken word immediately strengths the connection between its phonological and semantic representation, in contrast an encounter with the written form of a word immediately strengths the connection between its orthographic and semantic representation. Although the

original version of the Immediate Alteration Account offers a viable option to explain word-meaning priming effects revealed by previous English studies (e.g. Rodd et al., 2013, 2016), its main weakness is that only can account for these effects in a modality-specific way, making it inconsistent with the presence of cross-modal priming revealed by recent evidence. In particular, results from Gilbert et al. (2018) revealed no significant differences between unimodal and cross-modal prime-test conditions.

Gilbert et al.'s (2018) findings led to an alternative version of the Immediate Alteration Account. This version suggests that word-meaning priming results from a strengthening of the connections among semantic units. This explanation of long-term priming based on semantic information was originally proposed by Becker and colleagues (1997) who argue that experience with prime words deepens the attractor basins for those words in the semantic layer. Consequently, semantically related words are affected by this change because of their overlap in semantic space. Similarly, Rodd et al. (2016) argue that equivalent changes to the connections within the semantic layer could potentially make the attractor basin for that meaning more stable, relative to the alternative unprimed meaning. These changes in the semantic layer can explain why during the next encounter with an ambiguous word, even in the absence of any biasing context, the final settled state of the network is more likely to be consistent with the primed meaning. This version of the Immediate Alteration Account is the preferred one now because it can explain the results of Gilbert et al. (2018) but also those found by Rodd et. al. (2013, 2016).

Even though the Immediate Alteration Account provides a clear explanation of word-meaning priming effects, an alternative account has been developed to integrate some recent findings related to the duration of this effect, and the possible influence of a sleep associated consolidation in the subsequent retrieval of a particular meaning of ambiguous words. The next section will describe this alternative account as well as the main studies that support it.

1.9.2 Episodic Context Account

A growing body of evidence has revealed the involvement of consolidation processes in the learning and retention of language. Several studies of infants (Friedrich et al., 2017; Gómez et al., 2006; Horváth et al., 2015), children (Friedrich et al., 2017; Henderson et al., 2012; James et al., 2017; Sandoval et al., 2017), and adults (Bakker et al., 2014; Bakker-Marshall et al., 2018; Dumay & Gaskell, 2007; Kurdziel et al., 2017) have revealed that a consolidation period and specifically a period of sleep can be beneficial for the retention and integration of novel linguistic knowledge (Tamminen et al., 2010). Given this evidence Gaskell et al. (2019) proposed a new account to explain how these consolidation processes can be integrated in the learning of new linguistic knowledge, as well as in the updating of established linguistic knowledge.

This new account, called the Episodic Context Account proposes that when a novel word is encountered in a disambiguating context, a new and temporary memory trace for the comprehension episode is created by the hippocampus. This temporary representation acts as an additional source of information alongside permanent lexical knowledge and influences a word's subsequent interpretation (Gaskell et al., 2019). Instead of immediate changes in connections weights between semantic units, as is suggested by the latest version of the Immediate Alteration Account, the Episodic Context Account argues that when a word is encountered in a sentence context the hippocampus creates a new memory for that episode, combining in a particular way all the elements of the sentence, or a new association between words (Eichenbaum et al., 1995).

The Episodic Context Account is based on the Complementary Learning Systems Account (CLS) (McClelland & O'Reilly, 1995.; Norman & O'Reilly, 2003; O'Reilly & Rudy, 2000), which identifies one memory system for unique context-specific representations (episodes), and another for knowledge that must be generalized beyond this context (semantic

representations). The first memory system guides the processing of context-specific representations, is located principally in the hippocampus, and provides plasticity in the acquisition of new episodes without the interference of previous linguistic knowledge. The second one is located in the neocortex and oversees the creation and the maintenance of the distributed representations of words, which maintain memories for longer periods of time, contributing to the permanent storage of the lexical-semantic knowledge.

The CLS account suggests that consolidation happens when there is a transfer of hippocampal memories to the neocortex, thus securing the integration of the new episode in the long-term storage of linguistic knowledge, and avoiding the loss of hippocampal memories which are assumed to decay either passively, or through interference from newly instantiated hippocampal memories (McClelland, et al., 1995). The benefit of sleep in this transfer process was first identified by Wilson et al. (1994) who through the study of hippocampal cells in rats found that slow-wave sleep involves replay of the firing patterns observed during food-reinforced spatial behavioural tasks, thus giving the chance to promote the integration of new episodic memories in the neocortex. Furthermore, within the CLS account Norman et al. (2006) suggested that sleep supports hippocampal replay and the restructuring/strengthening of memories enabling learning. In this context, offline learning processes present during sleep are considered to play a crucial role in training neocortical networks and secure the consolidation of temporal and newly instated hippocampal memories.

The evidence that supports the Episodic Context Account comes from two sources, sleep studies, and those studies that investigate priming effects on other word types, such as low-ambiguous words, and the influence of word-class in this effect. Starting with sleep studies, Gaskell et al. (2019; Experiment 1), using the word-meaning priming, tested if consolidation effects can be extended to the processing of highly familiar English words.

Participants heard sentences that biased the interpretation of ambiguous words towards their subordinate meanings. After a delay of 2 and 12 hours the retrieval of these meanings was measured through a word association task, where participants typed the first word that comes to their minds after the presentation of the target ambiguous word. Results showed that word-meaning priming effects were stronger after a delay of 12 hours that included a period of sleep, than after a 12 hour delay without sleep. This finding supports the Episodic Context Account because it is consistent with the idea that an unprimed word uses the cortical long-term storage of a word, whereas a recently encountered word could use both the cortical storage, and also the temporary representation of that word that is located in the hippocampus. Critically in the 12 hour condition this recent experience is more likely to be transferred to the cortex following a period of sleep. The Immediate Alteration Account cannot account for this effect of sleep because it predicts an immediate update of the long-term lexical-semantic knowledge and is unable to explain the consolidation effect on the retention of this temporary representation.

Aiming to further characterise sleep benefits, Gaskell et al. (2019; Experiment 2) using the same paradigm of Experiment 1, aimed to explore if sleep benefits could be explained by active consolidation or due to passive protection from linguistic interference. According to Gaskell et al. (2019) the benefit of sleep seen in Experiment 1 could have been due to passive protection if the interference before sleep has the same detrimental effect than the interference after it. To test this idea, one group of English-speaking participants was primed in the morning, they were tested immediately, and after a delay of 24 hours, thus allowing the influence of subsequent linguistic exposure prior to sleep. In contrast, the second group of English-speaking participants was primed in the evening, they were tested immediately, and after a delay of 24 hours allowing the immediate influence of sleep consolidation effects. Word association responses showed stronger priming effects after 24

hours for those participants primed in the evening than those primed in the morning. This result suggest that the passive protection account is not the best to explain the word-meaning priming effects seen in Experiment 1. Instead, they suggest that sleep maintains the subsequent processing benefit of a particular meaning of an ambiguous word due to a process of active consolidation.

The Episodic Context Account suggests a vital role for declarative memory systems to aid comprehension. Considering this, all linguistic input comprehended by the reader or listener will need to promote the generation of a contextual representation in memory to secure comprehension. Making this assumption, word-meaning priming could be found for any word where the sentence context modifies its meaning to a certain degree. To probe this, Curtis et al. (2022) tested if word-meaning priming can be found for English non-homonyms or low-ambiguous English words, in a series of three experiments. During priming participants read sentences that highlighted particular aspects of the meanings of low-ambiguous words (e.g. “professor-doctor vs professor-teacher”). At test, meaning preferences were measured through semantic relatedness judgements and a word association task after a 10 to 30 minute delay. Results showed that an encounter with a low-ambiguous word in a sentence context that biased its interpretation towards a specific meaning or sense, facilitated the selection of a similar interpretation after a delay of up to 30 minutes. These findings were replicated by Mak et al. (2023; Experiment 1) using the same paradigm. Overall, the results of this experiment support the Episodic Context Account because they reveal the use of a context specific representation of the particular aspect of meaning to facilitate the subsequent processing of it. In contrast, the Immediate Alteration Account struggles to deal with these findings, because for this account it is the same meaning that is being primed, regardless of the specific information provided by a particular context, thus predicting no differences between meaning preferences for a particular aspect of that meaning at later time points.

Providing additional, but not exclusive, support to the Episodic Context Account, Mak et al. (2023; Experiment 2) manipulated the word-class of English words through sentences that included the less common word-class (e.g. loan as verb: "He will **loan** me money"), rather than the more common word-class (e.g. loan as noun: "He will take out a **loan** for £5,000"). Results indicated a bigger impact on the usage of word-class ambiguous words after a night of sleep than after a day without it. The existence of word-class priming suggests that priming can be extended to a morphosyntactic level, capturing a significant amount of context-specific information. Although the use of specific morphosyntactic information provided by the context adds additional support to the Episodic Context Account, it is worth noting that the Immediate Alteration Account can also explain word-class priming. As pointed out by MacDonald et al. (1994) the lexicon is the repository for all types of knowledge associated with words, including syntactic functions, grammatical and probabilistic relations between them, so it may be possible that a recent exposure to a particular word-class can immediately update all the knowledge about that word, thus explaining the subsequent preference for the word-class encountered previously. It is worth noting that the theory suggested by MacDonald et al. (1994) does not take into account any sleep effect, so it may be recommended to test the influence of this effect on it.

In summary, the Immediate Alteration Account and the Episodic Context Account are two potential accounts to explain the mechanisms behind word-meaning priming effects. Although the active consolidation suggested by sleep studies, and the word-meaning priming effects found for low-ambiguous words seem to be more compatible with the Episodic Context Account, more evidence is needed to judge between them. Nowadays, there is no direct evidence from neuroimaging or sleep recording techniques that provide stronger support to specific claims about brain regions (e.g. hippocampus) and the active role of sleep. Although the experiments presented in this thesis were not designed to decide between these

two competing accounts, their results will be interpreted within them, aiming to explore the flexibility of lexical-semantic representations within word-meaning priming effects. The purpose is to integrate the findings of this thesis into the word-meaning priming literature and expand the comprehension of how word-meaning priming operates. This analysis will shed more light on the organization of the lexical-semantic system, and how recent experiences with particular meanings of ambiguous words can update our permanent linguistic knowledge.

1.10 The Present Thesis

This thesis investigates the flexibility of lexical semantic representations of ambiguous words using a word-meaning priming. The general objective is to investigate how recent encounters with particular meanings of ambiguous words in context influence their subsequent disambiguation. A total of four experiments were run and 760 participants were tested.

Chapter 2 investigates how a single exposure to both the dominant and subordinate meanings of ambiguous words influence the subsequent processing of these two meanings immediately after test. The purpose is to explore how the language system handles this natural and inconsistent exposure to both meanings of ambiguous words. Results show a weak but significant facilitation effect on response times for subordinate meanings, facilitation that was absent on accuracy.

Chapter 3 explores immediate and longer-term effects (24 hours) of inconsistent exposures to the dominant and subordinate meanings of ambiguous words. The aim is to find if the processing benefit for subordinate meanings can be extended for 24 hours. Evidence reveals a significant facilitation effect for subordinate meanings immediately after test and one day later.

Chapter 4 characterizes the time course of word-meaning priming and semantic priming at short (3 minutes) and prolonged delays (20 minutes). The goal is to clarify if word-meaning priming is based on a temporary change in the representation of a particular ambiguous word, or on a general form of semantic priming. Findings show that word-meaning priming effects are significantly larger than semantic priming effects at both delays.

Lastly, Chapter 5 summarizes and analyses the main findings from this series of experiments, discusses the methodological approaches used, and makes suggestions for future research.

CHAPTER 2: THE IMPACT OF A MIXED-EXPOSURE TO THE MEANINGS OF AMBIGUOUS WORDS ON THEIR SUBSEQUENT PROCESSING

2.1 General Introduction

In exploring the flexibility of lexical-semantic representations, word-meaning priming has revealed that it is possible to improve the access and processing of the different meanings of ambiguous words (e.g. “crane”, which can refer to the machine for lifting in suspension, or to the type of bird). In particular, the word-meaning priming literature has focused on showing how the selection of subordinate meanings of English ambiguous words can be boosted by experience just with that meaning (Betts et al., 2018; Gaskell et al., 2019; Gilbert et al., 2018 & Gilbert et al., 2021; Rodd et al., 2013 & Rodd et al., 2016). However, to better understand the mechanisms underlying our disambiguation skills we also need to consider the consequences of inconsistent exposures to different meanings of ambiguous words.

These inconsistent exposures are relevant because everyday language includes exposure to multiple meanings of ambiguous words. For example, if you are in a construction site and you hear the phrase “be careful with the crane” you will retrieve the meaning referring to the machine for lifting in suspension (dominant meaning), but if you are in a picnic at the park with your friends and you hear the phrase “look that crane wants to eat our food” you will process the meaning related to the type of bird (subordinate meaning). In this context, the key question to answer is: how does the language system handle this inconsistent exposure to both the dominant and subordinate meanings of ambiguous words? The experiments presented in this chapter therefore use mixed-exposure to explore how a recent exposure to both dominant and subordinate meanings of ambiguous words influence the subsequent processing of dominant (Experiment 1) and subordinate meanings (Experiments 1

and 2). The purpose of this is to test whether the previously observed facilitation effect for subordinate meanings persists when the reader is primed with both meanings.

Testing both dominant and subordinate meanings after a mixed-exposure adds additional complexity because researchers need to understand how different meanings of ambiguous words interact with each other after these recent exposures. Providing a useful framework for considering the interaction between meanings, Distributed Connectionist models of word meaning access (Gaskell & Marslen-Wilson, 1997; Joordens & Besner, 1994; McLeod et al., 2001; Norris, 2013; Plaut, 1997) characterize this interaction as a semantic competition, where each meaning competes to be selected. The next section explains how these models of word recognition describe meaning access for ambiguous words, along with the evidence provided by single word studies and learning studies that support their claims.

2.1.1 Semantic Competition

To comprehend the possible outcomes of exposure to both the dominant and subordinate meanings of ambiguous words, it is necessary to talk about how we access the different meanings of these type of words. Different models of spoken and visual word recognition (Gaskell & Marslen-Wilson, 1997; Joordens & Besner, 1994; McLeod et al., 2001; Norris, 2013; Plaut, 1997) suggest that ambiguous words compete to activate a semantic representation. These Distributed Connectionist models conceive meaning selection as an association or mapping between form (orthographic or phonologic representation) and meaning (semantic representation), where each word is represented as a unique pattern of activation across a set of orthographic/phonological and semantic units (Rodd et al., 2002). For an ambiguous word like “crane”, the orthographic/phonological pattern of this word is associated with the semantic pattern that correspond to the meaning that refers to the machine

for lifting in suspension (dominant meaning), and the one that corresponds to the type of bird (subordinate meaning). When we hear the word “crane”, the phonological pattern is presented to the network, which tries to simultaneously instantiate the dominant and subordinate meanings across the same set of semantic units in what is known as semantic competition.

The resolution of the semantic competition described is well addressed by Rodd et al. (2004), who suggest the idea of interactions within semantic representations through recurrent connections between semantic units. The need to select just one meaning of ambiguous words, involves activation settling across the network on the basis of the current weights of semantic units. The activation of the semantic network begins in a *blend state*, where all the meanings of an ambiguous word are viable options to select because the blend state contains elements of meaning that correspond to multiple inconsistent meanings, and ends in an *attractor state*, which is the activation of a single meaning, hopefully the intended one. The need to move from a blend state to an attractor state is what explains the additional time and effort needed to select a particular meaning of ambiguous as compared to unambiguous words. Furthermore, it is possible that a recent experience with an ambiguous word causes a change in the weights of semantic units, thus suggesting that these encounters can promote learning, and consequently changes to our language comprehension.

Distributed Connectionist models integrate the influence of semantic representations and their interactions to explain the processing disadvantage for ambiguous words. Instead of using localist and abstract lexical representations as is the case in Localist models, these connectionist models use distributed lexical representations, where a specific pattern of activation across orthographic, phonological, and semantic units of a particular word allows the access to its intended information. The interactions between semantic units are what describe with precision how semantic competition between meanings arises, thus making

Distributed Connectionist models an important theoretical framework to explore the access to the different meanings of ambiguous words, and specifically for the purpose of this chapter, the role that semantic competition can have in the context of a mixed-exposure.

One example of evidence that supports the semantic competition described by Distributed Connectionist models comes from studies that test words in isolation. These single word studies, where participants make lexical decisions (e.g. Gottlob et al., 1999; Piercey et al., 2000; Rodd et al., 2002), have shown that words with multiple meanings are identified with lower accuracy and more slowly than unambiguous control words, which is known as the ambiguity disadvantage. In particular, Rodd et al. (2002) found that while English words with multiple related senses are recognized faster, it takes more time to recognize words with multiple unrelated meanings. This relatedness effect is explained by Rodd (2020), who under a distributed framework, argues that related word senses share many aspects of meaning, which makes them closer in semantic space facilitating their subsequent activation; instead unrelated word meanings do not share these semantic features, consequently they are located on distant locations which slow down their activation. The relatedness effect is important because it suggests that the ambiguity disadvantage can be reduced if meanings are semantically related. As a result, the modulation of the ambiguity disadvantage by meaning relatedness supports the view of the active involvement of semantic representations on lexical competition. Taken together, the ambiguity disadvantage and the relatedness effect revealed by single word studies support the semantic competition between meanings of ambiguous words described by Distributed Connectionist models.

Learning studies provide additional evidence of semantic competition. These studies involve learning a new meaning for a previously unambiguous word, allowing us to observe in an induced ambiguity situation, the processing of the original meaning in the presence of a new one. The within-item design of these studies allows the control between conditions of

psycholinguistics features (e.g. word frequency) that naturally correlate with ambiguity, which adds validity to their results. An example comes from Rodd et al. (2012), which showed that English-speaking participants' responses in cued-recall and lexical decision tasks were faster and less errorful when the new meaning was semantically related to the original meaning. Overall, these results: (i) replicate the modulatory effect of semantic relatedness on the ambiguity disadvantage, (ii) reveal the strong influence of a recent exposure to a new meaning, and (iii) indicate the pervasive influence of meaning relatedness during meaning acquisition and consolidation. Moreover, Fang et al. (2019) found that at immediate test the original meaning of high frequency English words, which were trained with a new meaning, showed longer decision times than unambiguous control words in semantic relatedness judgements, which they explained in terms of a perturbation of the existing connections between form and meaning. However, as this perturbation was found on high but not low frequency words, these results must be taken with caution, because Distributed Connectionist models predict more competition for low frequency words, as the newly acquired meaning would be more able to compete with the weaker connection between form and meaning. In summary, learning studies using a within-item design replicate the ambiguity disadvantage and the semantic relatedness effect observed by single word studies. Findings are broadly consistent with Distributed Connectionist models where the processing disadvantage for ambiguous words is a consequence of semantic competition between word meanings. This idea of semantic competition is critical to understanding mixed-exposure priming because it suggests that the positive boost provided by encountering any particular meaning might, to some extent, be cancelled out by the additional semantic competition that arises when its alternative meaning has also been boosted.

2.1.2 Evidence of Mixed-Exposure

The description of how single word studies and learning studies support semantic competition is relevant to understand what can happen after a mixed-exposure. However, to complete the evidence needed to predict the effects of a mixed-exposure, it is essential to describe the one study that has attempted to test this effect in English. This study was conducted by Betts et al. (2018; Experiment 1) and had two aims. First, it explored how multiple encounters with the same subordinate meaning boost priming effects compared to just one exposure. Second, it tested the effects of encounters with the different meanings of ambiguous words. For the purpose of the experiments presented in this chapter, just the results that test the processing after a single exposure to each meaning independently, and those that test a single exposure to the subordinate meaning followed by an exposure to dominant one will be described. Betts et al.'s experiment used a 3 x 2 within-subjects design with the independent factors of subordinate meaning repetitions (Unprimed/One repetition/Three repetitions) and dominant meaning repetition (Unprimed/One repetition). This design allowed to test priming effects for subordinate meanings after a single or three exposures to this meaning, and priming effects for dominants meanings after a single exposure to this meaning. Moreover, it allowed to test priming effects for subordinate and dominants meanings after a single mixed-exposure to the subordinate meaning followed by an exposure to the dominant meaning. Lastly, it permitted to test priming effects for subordinate meanings after three exposures to this meaning followed by an exposure to the dominant one.

Participants completed the procedure, which included a subordinate prime phase, a filler task, a dominant prime phase, and finally a word association test phase. To prime subordinate meanings participants listened to short paragraphs that included one or three exposures to the ambiguous word that was disambiguated towards the subordinate meaning.

To prime dominant meanings participants listened to sentences that disambiguated the ambiguous word towards the dominant meaning. At test after hearing the ambiguous word participants needed to type the first word that came to their minds and analyses examined whether this was related to the dominant meaning, the subordinate meaning, or another meaning. It is worth noting that the dominant prime phase was presented quite recently before the test phase (approximately 9 minutes), compared to the subordinate prime phase (approximately 32.5 minutes), which could make the generation of associates more likely to be related to the dominant meanings of ambiguous words.

Results revealed two important outcomes. First, a positive priming effect was observed for each meaning after a single exposure to each meaning independently, suggesting that even for the more frequent dominant meanings it is possible to improve its subsequent processing. Positive priming effects are well supported for subordinate meanings (e.g. Betts et al., 2018; Gaskell et al., 2019; Gilbert et al., 2018 & Gilbert et al., 2021; Rodd et al., 2013 & Rodd et al., 2016), but not for dominant meanings since Betts et al. (2018; Experiment 1) is the only study that tested their subsequent processing. Second, it was found that one subordinate meaning encounter followed by one dominant meaning encounter did not significantly change the number of associates related to subordinate meanings generated by participants, relatively to the unprimed condition (absence of mixed-exposure). This finding is particularly relevant because it suggests that a single exposure to the subordinate meaning, and then a single exposure to the dominant meaning, cancels the facilitation effect observed in studies that just prime subordinate meanings. One interpretation of this null effect for subordinate meanings is that the boost expected for this meaning is cancelled due to the interference that comes from the subsequent boost of the dominant meaning. This interpretation suggests that positive priming effects for both meanings can maintain (or increase) the semantic competition that already exists between them, which gives as a result a

null effect for subordinate meanings. However, this interpretation must be taken with caution, because as mentioned previously, the dominant primed phase was presented recently before the test phase compared to the subordinate prime phase, which could make the associates more susceptible to be related to dominant meanings.

This section has described the theoretical implications of Distributed Connectionist models for word meaning access and, more specifically, the competition between semantic representations of ambiguous words. Furthermore, the different types of studies that support this semantic competition were described. Next, the aim of the current study will be described, in particular why it is important to consider semantic competition in the context of mixed-exposure, and the possible outcomes of this mixed-exposure.

2.1.3 The Current Study

This study explores the impact of a mixed-exposure to the dominant and subordinate meanings of English ambiguous words, testing whether the previously observed facilitation effect for subordinate meanings, when primed in isolation, persists when the reader is primed with both meanings. This study is an improvement on Betts et al. (2018; Experiment 1) for two reasons. First, the order of priming for dominant and subordinate meanings will be randomized, thus providing the opportunity to test if the order of presentation of each meaning influences their subsequent processing. Second, the delay between the prime and test phase will be the same for dominant and subordinate meanings, thus eliminating the possibility to favour the prime of the dominant meanings over the subordinate ones.

The concept of semantic competition described above is important when considering the possible outcomes from mixed-exposure priming because it predicts that we cannot boost the different meanings of an ambiguous word independently, but rather that boosting the availability of one meaning will necessarily come at expense of the other meaning. In this

context, the present study will explore whether mixed exposures can lead to facilitation, interference, or null effects for one or both meanings of ambiguous words. Integrating the theory and the evidence that supports semantic competition, the following outcomes are possible after a mixed-exposure:

1. A significant facilitation effect on the processing of both dominant and subordinate meanings: This will imply that both meanings can be boosted relatively independently, such that any interference caused by semantic competition is minimal compared with the positive effect of priming.
2. A significant interference on the processing of both meanings: This will suggest that priming each meaning makes the processing of the alternative meaning worse, and that this interference overrides positive priming effects. However, this outcome is unlikely because it will suggest that semantic competition is stronger than priming effects, which will contradict previous findings of positive priming effects.
3. A null effect on both meanings: This would suggest that the positive boost from exposure to one meaning is entirely cancelled out by the additional interference caused by exposure to the alternative meaning. This outcome would be consistent with the presence of strong semantic competition between meanings.

In addition to testing the hypotheses about the main effect of priming described above, the design used in this experiment also enables comparisons between dominant and subordinate meanings. This allows us to explore whether priming and semantic competition effects might vary as function of dominance. Lastly, aiming to provide a baseline condition to compare the outcomes of a mixed-exposure for ambiguous words, Experiment 1 also includes the test of priming effects for unambiguous words, this is based on the idea that current models predict no priming effect for these words.

To explore these outcomes, the next section presents Experiment 1, which analysing word-meaning priming effects, explores semantic competition between meanings of ambiguous words in the context of a mixed-exposure to these meanings.

2.2 Experiment 1

2.2.1 Introduction

Aiming to test the impact of a mixed-exposure on the subsequent processing of both dominant and subordinate meanings of ambiguous words, the present study uses a similar word-meaning priming procedure to that used by Rodd et al. (2013). This experiment includes three parts: (i) a sentence comprehension task, where participants are exposed to both meanings of ambiguous words, (i) a vocabulary test, to secure a short delay between priming and test, and (ii) a semantic relatedness task, where participants decide if ambiguous words are semantically related to a probe word. It is worth noting that in all priming conditions participants are exposed to both the dominant and the subordinate meaning of ambiguous words, but they are only tested on one of these meanings on the semantic relatedness task. For unambiguous words participants are exposed to the single meaning of these words twice, to secure their match with ambiguous words in relation to the total number of exposures to the word form.

Semantic relatedness judgements for ambiguous and unambiguous control words are analyzed using linear mixed effect models on accuracy and response time data. These models follow a 2 x 3 within-subjects experimental design that includes the two level factor of Priming (deviation coded as Primed 1/2 and Unprimed -1/2), and the three level factor of Word Type, which is coded in two variables, Ambiguity (deviation coded as Subordinate -1/3, Dominant -1/3, and Unambiguous 2/3), and Ambiguous Word Dominance (deviation coded as Dominant 1/2 and Subordinate -1/2). This approach for the three-level variable

allows to directly look at main effects of (i) Ambiguity (across levels of dominance), (ii) Ambiguous Word Dominance (within ambiguous words only), and (iii) the interactions with Priming of these two variables.

Given the exploratory nature of this study, the only specific hypothesis made is a main effect of ambiguity, more accurate and faster responses for unambiguous words compared to the ambiguous ones, collapsed across priming conditions. As set out above there are multiple possible outcomes as to the main effect of priming, and the way in which priming might be modulated by ambiguity, so no predictions are made for priming effects or the mentioned interactions.

2.2.2 Method

Participants

60 participants aged between 18 and 40 were recruited online through Prolific (Palan et al, 2018, www.prolific.co), all of whom were native speakers of British English, currently reside in the U.K. (verified with IP address geolocation), without any language impairment, and with normal vision. Those participants that did not meet these requirements were not allowed to take part in the study. Participants received £6 for taking part in the experiment. No participants were excluded after data collection. The UCL Department of Experimental Psychology Ethics Committee approved the study.

Design

This experiment used a 2 x 3 within-subjects design with the independent factors of Priming (Primed/Unprimed) and Word Type (Dominant/Subordinate/Unambiguous). Each participant was trained on half of the ambiguous (n = 14) and half of the unambiguous (n = 14) words. For ambiguous words participants were primed on both the dominant and subordinate meanings. Participants were tested on the dominant and subordinate meanings of

ambiguous words, as well as on the meanings of unambiguous words. To avoid order effects during testing, each participant was tested on one meaning of each ambiguous word.

Stimuli

Ambiguous Words. Twenty-eight English ambiguous nouns (e.g. "crane") were selected from the "New UK-Based Word Association Norms for Spoken Ambiguous Words" (Gilbert et al., 2022). For each ambiguous word, the dominant meaning and the most frequent subordinate meaning were selected for this experiment. Although these words can have more than two meanings, the rest of their meanings have an extremely low dominance and are rarely used in natural language contexts (see the File S1 for the list of ambiguous words and their dominance scores: https://osf.io/4kgwt). Table 2.1 shows the mean dominance, standard deviation of dominance, and range of dominance for the ambiguous words used in this experiment. Statistics of frequency of ambiguous words were taken from the "SUBTLEX-UK: A new and improved word frequency database for British English" (Van Heuven et al., 2014) (see the File S2 for the list of ambiguous words, and their frequency and length scores: https://osf.io/9jbvk).

Table 2.1

Experiments 1 and 2. Statistics of Dominance for Dominant and Subordinate Meanings of Ambiguous Words.

Type of meaning	Mean of dominance	Standard deviation of dominance	Range of dominance
Dominant meanings	0.6598	0.0894	0.5120-0.8026
Subordinate meanings	0.3319	0.0897	0.1764-0.4880

Note. Mean, standard deviation and range of dominance for the dominant and subordinate meanings of the 28 ambiguous words. These measures were taken from the "New UK-Based Word Association Norm for Spoken Ambiguous Words" (Gilbert et al., 2022).

Unambiguous Words. Twenty-eight English unambiguous nouns (e.g., "cactus") were selected as control words to ensure that any training effects on ambiguous words reflect exposure to their meanings rather than their word forms. These words were selected from the Wordsmyth dictionary (Parks et al., 1998), and set-wise matched across conditions on length and frequency scores with ambiguous words. Statistics of frequency of unambiguous words were taken from the "SUBTLEX-UK: A new and improved word frequency database for British English" (Van Heuven et al., 2014) (see the File S2 for the list of unambiguous words and their frequency and length scores: https://osf.io/9jbvk).

Priming Sentences. 112 priming sentences were chosen from the British National Corpus (Leech & Rayson, 2014) to provide a natural semantic context for the target words. For ambiguous words, two sentences were selected, one that disambiguates towards the dominant meaning (e.g. for "crane", "While her boss took the unsuspecting Carolyn out to lunch, workers hoisted her car 20ft into the air with a borrowed crane, and parked it neatly on the roof") and another that disambiguates towards the subordinate meaning (e.g. for "crane", "There are many types of bird, for example, the Siberian crane stands two and a half feet tall, its brilliant white plumage offset by a blood-red beak, face and legs"). For unambiguous words, two sentences were selected that conveyed information about the word's meaning (e.g. for "cactus", "The force of its descent has created a natural Jacuzzi in the head pool, surrounded by stands of maidenhair fern, flowering cactus and red lilies", and "The rustlers must arm themselves well, however, to be protected from the cactus spines"). Some of these sentences were edited in minor ways to remove orthographic errors (see Table S1 for the list of sentences selected for ambiguous words, and Table S2 for the list of sentences selected for unambiguous words: https://osf.io/4edpc/).

Comprehension Check Sentences. 112 short comprehension check sentences were created by one non-native English speaker (CG) and checked by two native English speakers

(JR and JT). These sentences contained the target word and were either consistent or inconsistent with the information presented in the previous priming sentence. For example, for the priming sentence related to the dominant meaning of "crane", which was "While her boss took the unsuspecting Carolyn out to lunch, workers hoisted her car 20ft into the air with a borrowed crane and parked it neatly on the roof", the comprehension check sentence was: "Workers used a crane to park Carolyn's car on the roof"), which provides information consistent with the priming sentence. For the priming sentence related to the subordinate meaning of "crane", which was "There are many types of bird, for example, the Siberian crane stands two and a half feet tall, its brilliant white plumage offset by a blood-red beak, face and legs", the comprehension check sentence was: "The Siberian crane has black plumage", which gives information inconsistent with the priming sentence. An equal number of consistent and inconsistent sentences were included across conditions, and for the dominant and subordinate meanings of target words. The comprehension check sentences contained the target word to ensure attention to this word during exposure (see Table S1 for the list of comprehension check sentences created for ambiguous words, and Table S2 for the list of comprehension check sentences created for unambiguous words: https://osf.io/4edpc/).

Probe Words. For the semantic relatedness task, 84 probes were selected from the Wordsmyth dictionary (Parks et al., 1998), one for each unambiguous word (e.g. for "cactus" the probe word was "desert"), and one for each dominant meaning (e.g. for "crane" the probe related to the dominant meaning was "machinery"), and each subordinate meaning (e.g. for "crane" the probe related to the subordinate meaning was "heron") of ambiguous words (see Table S3 for the list of ambiguous words and their probes for dominant and subordinate meanings, and Table S4 for unambiguous words and their probes: https://osf.io/4edpc/). These were matched on length and frequency to the target words. Statistics of frequency for probe words were taken from the "SUBTLEX-UK: A new and improved word frequency

database for British English" (Van Heuven et al., 2014) (see the File S2 for the list of targets, fillers and probe words along with their frequency and length scores: https://osf.io/9jbvk). Table 2.2 shows the mean length and mean frequency for ambiguous words and their matched probe words, as well as the mean length and frequency for unambiguous words and their matched probe words.

Table 2.2

Experiments 1 and 2. Descriptive Statistics for Ambiguous Words, Unambiguous Words, and Their Probe Words.

Classification of words	Mean length	Mean Frequency (Zipf scores)
Ambiguous words	5.04	4.14
Ambiguous probe words dominant meaning	5.07	4.13
Ambiguous probe words subordinate meaning	5.07	4.13
Unambiguous words	5.04	4.12
Unambiguous probe words	5.04	4.13

Note. Mean length (in letters) and mean frequency for ambiguous words, unambiguous words, and their respective probe words. Measures of frequency for ambiguous, unambiguous wordforms, and their probe words were selected from the "SUBTLEX-UK: A new and improved word frequency database for British English" (Van Heuven et al., 2014).

Unrelated Filler Words and Probes. To provide NO responses in the semantic relatedness task, 56 filler-probe pairs were selected. Fillers were words that also occurred in the priming sentences to ensure that these items had also recently been encountered by participants. 14 fillers were selected from sentences describing the dominant meaning of ambiguous words (e.g. for the filler "pollution" its unrelated probe was "rival"), 14 from sentences describing the subordinate meaning of an ambiguous word (e.g. for the filler "error" its unrelated probe was "uncle"), and the remaining 28 from unambiguous word priming sentences (e.g. for the filler "holiday" its unrelated probe was "bonus"). Probe words for these items were selected from the Wordsmyth dictionary (Parks et al., 1998), and matched to ambiguous and unambiguous probe words on length and frequency (see Table S5 for the list of filler words and their probes used in Experiments 1 and 2: https://osf.io/4edpc/).

Statistics of frequency for filler words and their probes were taken from the "SUBTLEX-UK: A new and improved word frequency database for British English" (Van Heuven et al., 2014) (see the File S2 for the list of targets, fillers and probe words along with their frequency and length scores: https://osf.io/9jbvk). Table 2.3 shows the mean length and mean frequency for filler words and their probes.

Table 2.3

Experiments 1 and 2. Descriptive Statistics for Filler Words and Their Probe Words.

Type of words	Mean length	Mean frequency (Zipf scores)
Filler words	6.13	4.42
Probe words	5.02	4.15

Note. Mean length and mean frequency for filler words and their respective probe words. Measures of frequency for filler words and their probe words were selected from the "SUBTLEX-UK: A new and improved word frequency database for British English" (Van Heuven et al., 2014).

Counterbalancing

To ensure that each target (ambiguous and unambiguous words) contributes to both primed and unprimed conditions, and the testing of the dominant or the subordinate meaning of ambiguous words, items were counterbalanced across participants in the priming task and the test task. This counterbalancing gave as a result four versions for this experiment. For the priming task two sets of 14 ambiguous words (Table 2.4: A1 and A2), and two sets of 14 unambiguous words (Table 2.4: U1 and U2) were created. These two sets of words were matched on word frequency and word length. Because we tested one meaning for each

ambiguous word (dominant or subordinate), the two sets of words of the priming task were converted into four sets at test. Specifically, each set of words from the priming task contributed to two sets of words in the test task, where one set tested the dominant meaning and the other tested the subordinate one (see the File S3 that shows the list of words used on each version of the priming and test task: https://osf.io/dq7rw). Table 2.4 shows the counterbalancing across priming and test.

Table 2.4

Experiment 1. Counterbalancing of Items Across Priming and Test.

Version	Number of Participants	Priming Sets for Ambiguous and Unambiguous words	Ambiguous words Test Set 1	Ambiguous words Test Set 2	Unambiguous words Test
1	15	A1 + U1	Dominant	Subordinate	All
2	15	A1 + U1	Subordinate	Dominant	All
3	15	A2 + U2	Dominant	Subordinate	All
4	15	A2 +U2	Subordinate	Dominant	All

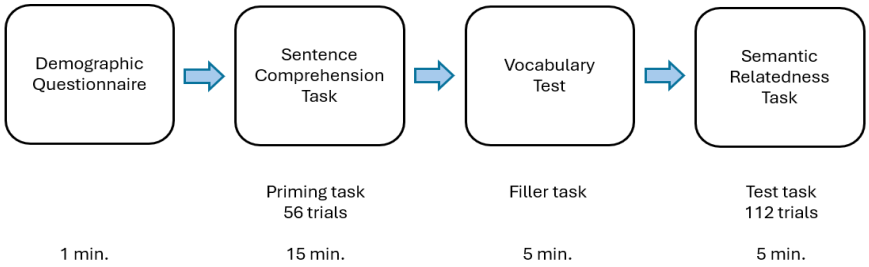
Note. Counterbalancing for the priming and test task of Experiment 1, which resulted in four versions with 15 participants on each of them. In the third column of the table A1 refer to the set of ambiguous words added to versions 1 and 2, A2 refer to the set of ambiguous words added to versions 3 and 4, while U1 refer to the set of unambiguous words added to version 1 and 2, and U2 refer to the set of unambiguous words added to version 3 and 4.

Procedure

The experiment included four parts that were completed by participants in the following order: a Demographic Questionnaire, a Sentence Comprehension Task (Priming task), a Vocabulary Test (Filler task), and the Semantic Relatedness Task (Test task). The sequence of these tasks and the approximate duration can be seen in Figure 2.1.

Figure 2.1

Experiments 1 and 2. Procedure.



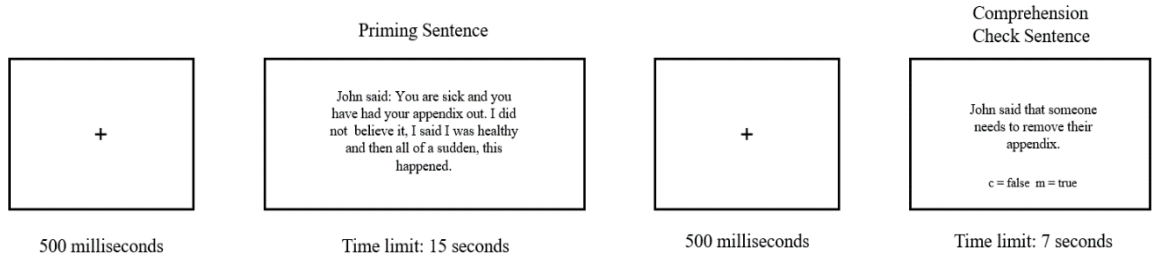
Demographic Questionnaire. First, participants completed a ~5-minute demographic questionnaire where they gave their age, gender, country of residence, native language, the language they use most often, and their educational background. This survey ensured that participants live in the UK, and that their native language is English.

Sentence Comprehension Task. Each participant read 56 sentences, 28 sentences for ambiguous words, of which 14 included the dominant meaning and 14 the subordinate meaning, and 28 sentences for 14 unambiguous words, because they read 2 sentences for each item. After each sentence, subjects responded to a Comprehension Check Sentence and decided if this sentence was true or false according to the information provided in the Priming Sentence. This task was added to secure attention during the priming phase. To begin, participants read the instructions on the screen, then completed two practice trials before starting the main task. Each trial began with a central fixation marker for 500 ms, followed by the Priming Sentence which participants read with a time limit of 15 seconds. Then they saw another 500 ms fixation marker, followed by the Comprehension Check Sentence, which remained on screen until a valid response was given, or until the time limit of 7 second was reached. Participants pressed “m” if the sentence was true or “c” if the sentence was false, with respect to the previous sentence (these reminders appeared at the

bottom of the screen). After they had responded the next trial began automatically. Participants were instructed to respond as quickly and accurately as possible. An example trial of the Priming task is presented in Figure 2.2.

Figure 2.2

Experiments 1 and 2. Example Trial of the Sentence Comprehension Task.



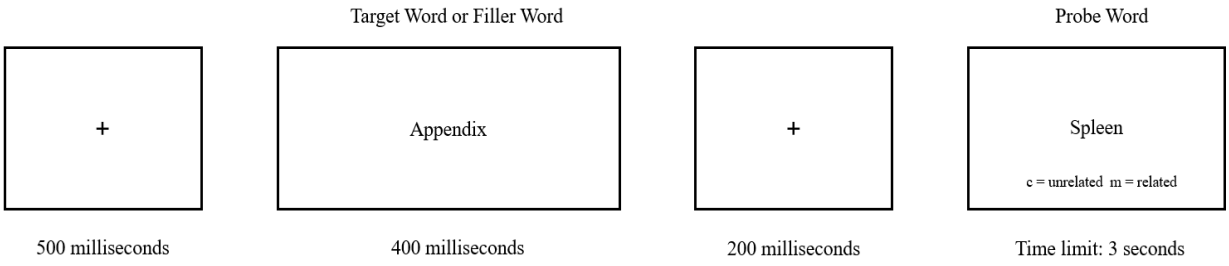
Vocabulary Test. After the Priming task, participants had an optional break of 30 seconds, followed by a Vocabulary Test (Shipley, 1940), which acted as a filler task to secure a short delay between priming and test. Participants first read the instructions on the screen. In each trial subjects read one target word at the top of the screen and four words below. Participants selected one of the four words that had the closest meaning to the target word, by clicking on word 1, 2, 3, or 4. Once participants selected the answer, they moved automatically to the next trial.

Semantic Relatedness Task. After the vocabulary test and an optional 30 second break, participants moved on the test task. On each version this task included 28 probe words for ambiguous words (14 for subordinate meanings and 14 for dominant meanings), 28 probe words for unambiguous words, and 56 probes for filler words to provide NO responses. Half of the targets and half of the fillers were primed, the other halves were unprimed. Participants read a target word (ambiguous, unambiguous, or filler word) followed by a probe word and

decided, as quickly and accurately as possible, whether the two words were related or not. At the beginning of this task, participants completed ten practice trials, followed by the main task. Each trial began with a 500 ms fixation marker, followed by an ambiguous, unambiguous, or filler word for 400 ms. They then saw a 200 ms fixation marker, followed by the probe word which remained on the screen until participants made a response, or until the time limit of 3 seconds was reached. Participants pressed "m" if the probe word was related in meaning or "c" if the probe word was unrelated in meaning to the target/filler word (reminders for the response keys were displayed at the bottom of the screen). Participants were instructed to respond as quickly and accurately as possible. An example trial of the test task can be observed in Figure 2.3.

Figure 2.3

Experiments 1 and 2. Example Trial of the Semantic Relatedness Task.



2.2.3 Results

Sentence Comprehension Task

Participants were accurate at deciding if the check sentence was related or unrelated to the priming sentence. The mean accuracy across participants was 86.79 % (Min = 76.8%,

Max = 96.4%). This suggests that participants were paying an appropriate level of attention during the priming phase of the experiment.

Vocabulary Test

The performance of participants in this task was high. The mean accuracy across participants was 75.71% (Min = 52.5%, Max = 100%). This means that participants completed the task properly, since chance performance is 25%.

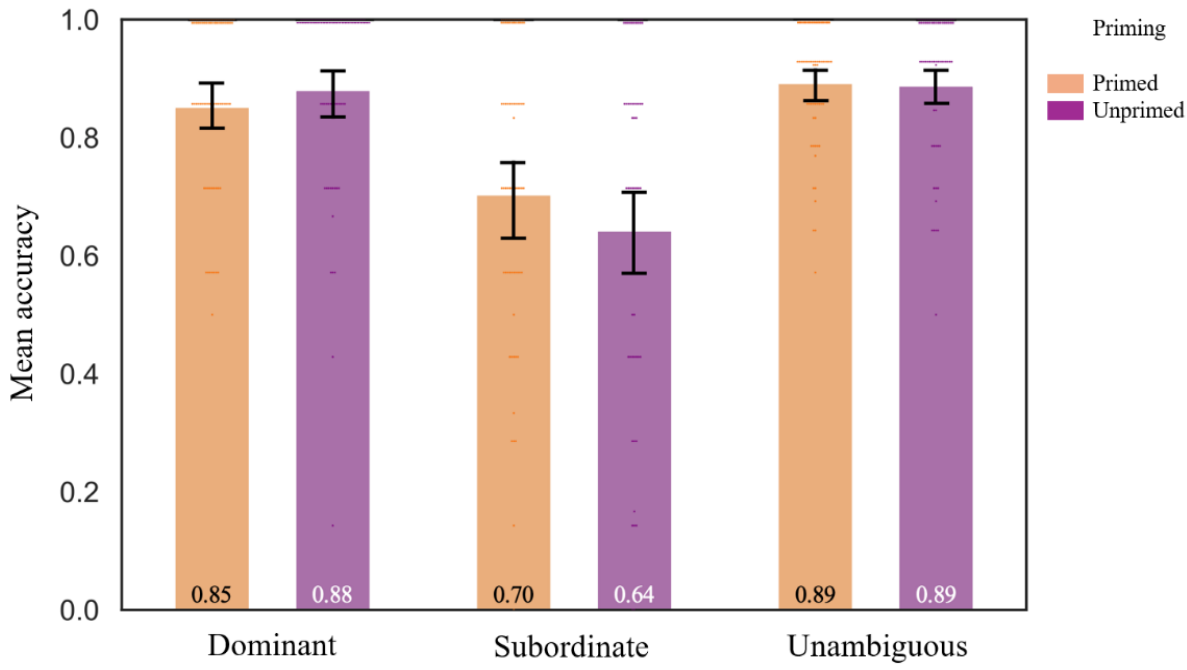
Semantic Relatedness Task

No participants were excluded from the analysis of this task. Response times under 300 ms and above 2500 ms were removed accounting for 0.92% of the total trials. The mean accuracy across participants was 83.03% (Min = 45.5%, Max = 98.2%) on the experimental conditions in this task. Figure 2.4 shows mean accuracy for dominant meanings, subordinate meanings, and unambiguous words in their respective priming conditions. For response times, only correct responses were analysed. The mean response time was 847.84 ms. Figure 2.5 presents mean response times for dominant meanings, subordinate meanings, and unambiguous words in their respective priming conditions.

The data from the three tasks and the R scripts for their analysis are available on the Open Science Framework webpage on the following links: https://osf.io/4akpn/ (data), and https://osf.io/7ah6m/ (R scripts).

Figure 2.4

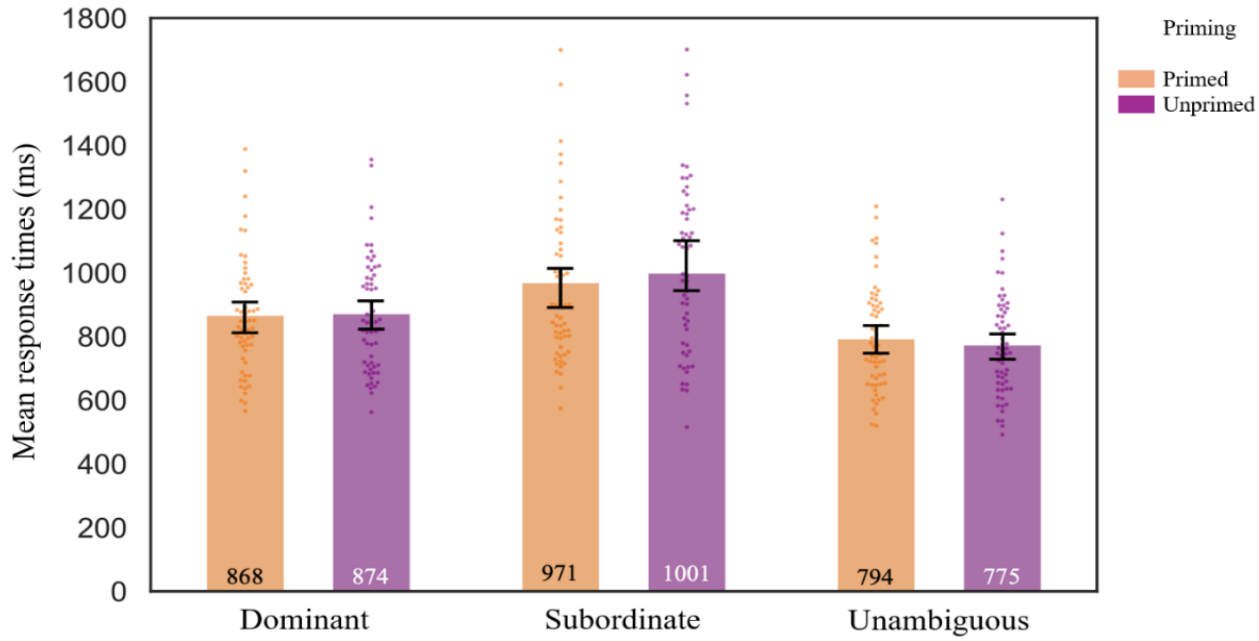
Experiment 1. Bar Plot with the Mean Accuracy for Dominant Meanings, Subordinate Meanings, and Unambiguous Words in their Respective Priming Conditions (Primed and Unprimed).



Note. Error bars represent the 95% within-subject confidence intervals (Morey, 2008). Dots show the mean accuracy for each subject in each condition.

Figure 2.5

Experiment 1. Bar Plot with Mean Response Times (ms.) for Dominant Meanings, Subordinate Meanings, and Unambiguous Words in their Respective Priming Conditions (Primed and Unprimed).



Note. Error bars represent the 95% within-subject confidence intervals (Morey, 2008). Dots show the mean response times (in ms.) for each subject in each condition.

Linear Mixed Effects Analysis

Responses were analysed with linear mixed effects models using the 'lme4' package (Bates Mächler, Bolker & Walker , 2015) and RStudio Team v.4.0.2 (R Core Team, 2019). Models were fit with the glmer () function (with bobyqa optimiser) for accuracy data, and the lmer () function for RTs. The models are based on a 2 x 3 design with fixed effects of Priming (deviation-coded as Primed 1/2 and Unprimed -1/2), and Word Type, expressed as two separate deviation-coded variables; Ambiguity (Subordinate -1/3, Dominant -1/3, and Unambiguous 2/3), and Ambiguous Word Dominance (Dominant 1/2, Subordinate -1/2), and

the interactions between Priming and Word Type, Priming:Ambiguity and Priming:Ambiguous Word Dominance. A maximal model was constructed with a random intercept and random slopes for Priming, Ambiguity, Ambiguous Word Dominance, and their interactions by subjects, and a random intercept and a random slope for Priming by items. The maximal random effects structure was used as this is assumed to decrease the probability of Type I errors (Barr, Levy, Scheepers & Tily, 2013). In the following, it is noted where the random effects structure was modified to achieve convergence.

Statistical inference was based on model comparisons by means of likelihood ratio tests. We report β values, standard errors and z-/t-values for the model parameters, Chi-squared values and p-values (α set to .05) from likelihood ratio tests are reported.

Accuracy

The results observed in Figure 2.4 indicate that the mean accuracy for subordinate meanings was higher for primed (0.70) than unprimed items (0.64). In contrast, for dominant meanings the mean accuracy was higher for unprimed items (0.88) compared to the primed ones (0.85). Lastly, for unambiguous words the mean accuracy for primed and unprimed items was numerically equal (0.89).

The maximal model that converged included a random intercept and random slopes for Priming, Ambiguity, Ambiguous Word Dominance, and their interactions by subjects without accounting for correlations between random effects, and only a random intercept by items.

Model comparisons showed that the main effect of Priming was not significant (β = -0.01, SE = 0.11, z = -0.09; $\chi^2(1) = 0.01$, p = .927). The main effect of Ambiguity (comparing ambiguous and unambiguous words) was significant (β = 1.52, SE = 0.35, z = 4.33; $\chi^2(1) = 17.9$, $p < .001$) with greater accuracy for unambiguous (M = 0.89, SD = 0.31) compared to ambiguous words (M = 0.77, SD = 0.42). The main effect of Ambiguous Word Dominance

(comparing subordinate and dominant meanings) was significant (β = 1.41, SE = 0.15, z = 9.75; $\chi^2(1) = 57.47$, $p < .001$) with greater accuracy for dominant (M = 0.87, SD = 0.34) compared to subordinate meanings (M = 0.67, SD = 0.47).

The interaction between Priming and Ambiguity (comparing the effect of training for ambiguous and unambiguous words) was not significant (β = -0.05, SE = 0.28, z = -0.19; $\chi^2(1) = 0.04$, $p = .852$), nor the interaction between Priming and Ambiguous Word Dominance (comparing the effect of training for subordinate and dominant meanings) (β = -0.69, SE = 0.38, z = -1.80; $\chi^2(1) = 3.12$, $p = .078$).

Response times

Overall, the pattern of results observed in Figure 2.5 indicates faster responses for subordinate meanings that were primed (M = 971 ms.) compared to those unprimed (M = 1001 ms.). For dominant meanings responses were faster for primed (M = 868 ms.) than unprimed items (M = 874 ms.). In contrast, unambiguous items revealed faster responses for unprimed items (M = 775 ms.) compared to the primed ones (M = 794 ms.).

Response times were inverse transformed prior to analysis, based on visual inspection of histograms of model residuals and predicted-vs-residual plots. The maximal model that converged was an intercept-only model. The main effect of Priming was not significant (β = < -0.01, SE = <0.01, t = -0.42; $\chi^2(1) = 0.17$, $p = .677$). The main effect of Ambiguity was significant (ambiguous vs unambiguous words) (β = <0.01, SE = <0.01, t = 6.06; $\chi^2(1) = 28.26$, $p < .001$), with faster responses for unambiguous (M = 784.76, SD = 296.83) compared to ambiguous words (M = 920.56, SD = 356.94). The main effect of Ambiguous Word Dominance (subordinate vs dominant meanings) was also significant (β = 0.0001, SE = 0.00002, t = 6.16; $\chi^2(1) = 37.78$, $p < .001$), with faster responses for dominant (M = 870.89, SD = 322.26) compared to subordinate meanings (M = 985.18, SD = 388.47).

The Interaction between Priming and Ambiguity (comparing the effect of training for ambiguous and unambiguous words) was not significant (β = <-0.01, SE = < 0.01, t = -1.84; $\chi^2(1) = 3.37$, p = .066) nor the interaction between Priming and Ambiguous Word Dominance (comparing the effect of training for subordinate and dominant meanings) (β = <-0.01, SE = <0.01, t = -0.92; $\chi^2(1) = 0.84$, p = .358).

Order Effect Analysis

During Priming, sentences containing the dominant and subordinate meaning of the ambiguous words were presented in a random order. A secondary analysis was conducted on primed dominant and primed subordinate meanings of ambiguous words to investigate whether accuracy and response times in the test phase were influenced by the order of presentation of the dominant and subordinate meanings of ambiguous words during the priming phase. This extra analysis was included because there was evidence of such effect in Betts et al. (2018; Experiment 1). They found that the facilitation effect for subordinate meanings was lost when the exposure to the subordinate meaning was followed with an exposure to the dominant one.

The models were based on a 2 x 2 design with fixed effects of Priming Order (deviation-coded as dominant meaning first 1/2 and subordinate meaning first –1/2), and Ambiguous Word Dominance (Dominant 1/2, Subordinate –1/2) and their interaction. The maximal model included random intercepts and random slopes for Priming Order, Ambiguous Word Dominance, and their interaction by subjects and by items.

Accuracy

The maximal model that converged included a random intercept by subjects, and random slopes for Ambiguous Word Dominance and the Priming Order by Ambiguous Word Dominance interaction, including correlations between random effects by items. The main effect of Priming Order was not significant (β = -0.05, SE = 0.22, z = -0.24; $\chi^2(1) = 0.06$, p =

.809). The main effect of Ambiguous Word Dominance was significant (β = 1.09, SE = 0.40, z = 2.74; $\chi^2(1) = 6.77$, p = .009) with higher accuracy for dominant (M = 0.85, SD = 0.36) compared to subordinate meanings (M = 0.70, SD = 0.46). The interaction between Priming Order and Ambiguous Word Dominance was not significant (β = -0.03, SE = 0.44, z = -0.06; $\chi^2(1) = < 0.01$, p = .952).

Response times

The maximal model that converged was an intercept-only model**.** The main effect of Priming Order was not significant (β = <0.01, SE = <0.01, t = 0.42; $\chi^2(1) = 0.17$, p = .678). The main effect of Ambiguous Word Dominance was significant (β = <0.01, SE = <0.01, t = 4.04; $\chi^2(1) = 16.16$, p < .001) with faster responses for dominant meanings (M = 868.14, SD = 305.05) compared to subordinate meanings (M = 970.88, SD = 370.68). Finally, the interaction between Priming Order and Ambiguous Word Dominance was not significant (β = <0.01, SE = <0.01, t = 1.49; $\chi^2(1) = 2.21$, p = .137).

The data and the R scripts with the LME analysis of the semantic relatedness task, and the LME analysis of the order effect are available on the Open Science Framework webpage on the following links: https://osf.io/4akpn/ (data), and https://osf.io/7ah6m/ (R scripts).

2.2.4 Discussion

The aim of Experiment 1 was to explore what happens to the processing of dominant and subordinate meanings of English ambiguous words when the reader is primed with both meanings. Responses on both dominant and subordinate meanings were compared to an unambiguous word baseline condition. Our only specific prediction was a main effect of Ambiguity – accuracy was expected to be lower and response times longer for ambiguous compared to unambiguous words in the semantic relatedness task. Beyond this, it was of

interest to test three possible outcomes. First, mixed-exposure could cause a facilitation effect in the processing of both meanings, suggesting that these meanings can be boosted independently. Second, mixed-exposure could cause an interference in the processing of both meanings, due to priming both meanings increases their competition. Third, mixed-exposure could cause a null effect, explained by the cancellation of the positive boost from one meaning due to the interference from the other.

As predicted, a main effect of Ambiguity was found, responses were significantly slower and less accurate for ambiguous words compared to unambiguous words. In addition, within the set of ambiguous words, a main effect of Ambiguous Word Dominance was found, responses were significantly slower and less accurate for the subordinate meanings compared with dominant meanings. These patterns replicate numerous eye-tracking (for a review, see Duffy et al., 2001), lexical-decision (Armstrong et al., 2016; Beretta et al., 2005; Hino et al., 2010; Klepousniotou et al., 2007; Mirman et al., 2009), and neuroimaging (Bekinschtein et al., 2011; Blott et al., 2023; Davis et al., 2007; MacGregor et al., 2020; Rodd et al., 2010; Rodd et al., 2012) studies, which show that ambiguous words are more difficult to process than matched unambiguous words, and that this ambiguity effect is particularly strong for subordinate meanings.

A main effect of Priming was not found, neither response times nor the accuracy data showed a significant difference between primed and unprimed conditions. The interaction between Priming and Ambiguity was also absent, the accuracy and speed of the responses given by participants between ambiguous and unambiguous words did not depend significantly on priming conditions. Lastly, the interaction between Priming and Ambiguous Word Dominance was also absent, the accuracy and the speed of the responses to dominant and subordinate meanings did not rely significantly on priming conditions. Thus, we have no

evidence that the prime sentences are changing how the target words are processed, or that this effect of priming is different across conditions.

The aim of Experiment 1 was to explore how mixed-exposure influences the subsequent processing of dominant and subordinate meanings of ambiguous words. In this context, the interaction between Priming and Ambiguous Word Dominance is a key point of analysis. Although this interaction was not significant on accuracy or response times, it is worth considering the numerical pattern of results observed on both dependent measures. First, the accuracy data showed a numerical facilitation effect of Priming for subordinate meanings, where the difference in the mean accuracy for subordinate meanings between primed and unprimed conditions (0.06) was numerically larger than for dominant meanings (-0.03). Additionally, the response time data revealed a larger numerical facilitation effect of Priming on the mean response time for primed compared to unprimed subordinate meanings (30 ms.), facilitation that was much smaller for dominant meanings (6 ms).

The numerical facilitation effect observed for subordinate meanings after mixed-exposure can be explained by Distributed Connectionist models. These models suggest that word frequency plays a key role in the strength of the connections between form and meaning, where high frequency words have strong connections and low frequency words have weak ones. The lower frequency of subordinate meanings (compared to dominant meanings) means that the connection between word-form and the subordinate meaning is weaker and consequently more susceptible to the strengthening after a recent encounter with this meaning. Under Distributed Connectionist models this mixed-exposure will imply that the subordinate meaning can be boosted independently, idea that will be inconsistent with strong claims of semantic competition. Moreover, it is worth noting that the numerical facilitation effect for subordinate meanings revealed here supports the significant facilitation effect observed for subordinate meanings after a single encounter just with this meaning

(Betts et al., 2018; Gaskell et al., 2019; Gilbert et al., 2018 & Gilbert et al., 2021; Rodd et al., 2013 & Rodd et al., 2016).

Overall, the numerical facilitation effect observed for the subordinate meanings of ambiguous words, suggests the possibility to find a significant mixed-exposure benefit for these low-frequency subordinate meanings. No such mixed-exposure facilitation effect was consistently (accuracy and response times) seen numerically for either dominant meanings of ambiguous words or for unambiguous words. One reason that may explain why the benefit of this mixed-exposure for subordinate meanings was not significant is a lack of power. To address this weakness of Experiment 1 and to potentially find a significant facilitation effect for subordinate meanings after a mixed-exposure, Experiment 2 will attempt to find this effect in a pre-registered and well powered experiment.

2.3 Experiment 2

2.3.1 Introduction

This study follows up the numerical but non-significant benefit of mixed-exposure on subordinate meanings seen in Experiment 1. Experiment 2 uses a similar design that secures appropriate statistical power. Although both subordinate and dominant meanings are primed, the effect of mixed-exposure is only tested on subordinate meanings. There are some important differences between these experiments.

First, Experiment 2 uses a 2 x 2 within-subjects design, instead of the 2 x 3 within-subjects design selected for Experiment 1. This main change is explained by the pattern of results shown by Experiment 1, which allow us to remove the testing of the dominant meanings of ambiguous words, because numerically the benefit on accuracy and response time was just observed for subordinate meanings. This situation gives us the chance to remove from the statistical models the third condition of Ambiguous Word Dominance, and

the interaction between Priming and Ambiguous Word Dominance. Consequently, this experiment uses a 2 x 2 within-subjects design that tests the main effects of Priming and Ambiguity along with the interaction between them.

Second, it is worth noting that the number of data points per cell in the design of Experiment 1 was 420, which included data from 60 participants, which is less than the 1600 data points recommended for experiments that measure response times (Brysbaert & Stevens, 2018). Therefore, Experiment 2 increases the number of participants to 182 (1605 data points per cell) to ensure the appropriate power to specifically detect an interaction between Priming and Ambiguity in the accuracy and response time data.

Third, the stimuli were improved. Experiment 1 showed that some items had high error rates at test, perhaps because the semantic relatedness probe was not sufficiently strongly related to the target word. To secure a high semantic association between target and probe words, probes in Experiment 2 were selected from the Edinburgh Associative Thesaurus (Lapalme, 2017). Therefore 51 of 56 probes (25 probes for ambiguous words and 26 probes for unambiguous words) were replaced to reduce such errors and hopefully improve the reliability of the response time data.

Lastly, unlike Experiment 1 this experiment was preregistered on the Open Science Framework (https://osf.io/4an23) with a document that specifies: its theoretical relevance, the main hypotheses, design, stimuli counterbalancing and randomization, sampling plan, sample size, power analysis, analysis plan, transformation applied to the response time data, and data exclusion criteria. The study follows what is described in the preregistration, in the case of any change this will be mentioned accordingly.

Hypotheses

Based on the pattern of results from Experiment 1, the hypotheses for Experiment 2 are:

1. No prediction is made for the main effect of Priming (averaged across word types) because priming is only expected for ambiguous words.
2. Main effect of Ambiguity: more accurate and faster responses for unambiguous words compared to ambiguous words, collapsed across Priming conditions.
3. An interaction between Priming and Ambiguity: more accurate and faster responses for ambiguous words (subordinate meanings) in the primed condition compared to the unprimed condition. This will not be the case for unambiguous words, where the accuracy and response times are predicted to be similar for both Priming conditions.

2.3.2 Method

Participants

189 participants aged between 18 and 40 years were recruited via the online platform Prolific (Palan et al., 2018; www.prolific.co). The inclusion criteria were the same as in Experiment 1. Participants received £6 for taking part in the study. The UCL Department of Experimental Psychology Ethics Committee approved the study.

The number of participants was determined according to Brysbaert et al. (2018) for Linear Mixed Effect Models. Brysbaert et al. suggest a minimum number of 1,600 observations per condition to achieve sufficient power on the analysis on transformed response times (80% of power). After exclusions, 182 participants will provide 2,548 observations on each condition, clearly exceeding the number suggested by Brysbaert et al., but considering an observed error rate of 36% for unprimed subordinate meanings in

Experiment 1 (condition with the highest error rate), and the possibility of an extra data loss of around 1% because of response times under 300 ms and above 2500 ms, it is estimated a reduction of 37% of the 2,548 observations. Given this estimation of data loss the initial number of 2,548 observations on each condition will change to 1,605 correct and filtered observations, number that is similar to that suggested by Brysbaert et al.

Design

The present experiment follows a 2 x 2 within-subjects design, with the independent factors of Priming (Primed/Unprimed) and Ambiguity (Ambiguous/Unambiguous). As in Experiment 1 each participant was primed on half of the ambiguous words and half of the unambiguous words. Like Experiment 1, for ambiguous words participants were primed on both the dominant and subordinate meanings. However, this experiment just tested the subordinate meanings of ambiguous words to increase the power of the study, a decision that also considers results from Experiment 1, which did not reveal a mixed-exposure facilitation effect for dominant meanings.

Stimuli

Ambiguous Words. The ambiguous words were the same as in Experiment 1.

Unambiguous Words. The unambiguous words were the same as in Experiment 1.

Priming Sentences. The priming sentences were the same as in Experiment 1.

Comprehension Check Sentences. The comprehension check sentences were the same as in Experiment 1.

Probe Words. 51 of 56 probe words for ambiguous and unambiguous items in the test task were replaced with better ones, by selecting them from the Edinburgh Associative Thesaurus (EAT) (Lapalme, 2017) to secure a high semantic association with the target words (see Table S6 for the list of ambiguous words and their probes for subordinate

meanings, and Table S7 for the list of unambiguous words and their probes: https://osf.io/4edpc/). Statistics of frequency for targets, fillers and probe words were taken from the "SUBTLEX-UK: A new and improved word frequency database for British English" (Van Heuven et al., 2014) (see the File S4 for the list of targets, fillers and probe words along with their EAT responses, frequency, and length scores: https://osf.io/xmw79). Table 2.5 shows the main descriptives of target and their matched probe words.

Table 2.5

Experiment 2. Descriptive Statistics for Ambiguous Words, Unambiguous Words, and Probe Words.

Classification of words	Mean number of responses target to probe (EAT)	Mean length	Mean frequency (Zipf scores)
Ambiguous words	10.04	5.04	4.14
Ambiguous probe words subordinate meaning		6.25	3.99
Unambiguous words	19.50	5.04	4.12
Unambiguous probe words		6.89	4.12

Note. Mean number of responses from the target word to the probe word, mean length, and mean frequency for target words, and mean length and mean frequency for their matched probe words. Number of responses from target word to probes were taken from the Edinburgh Associative Thesaurus (EAT) (Lapalme, 2017). Measures of frequency for target and probe words were selected from "SUBTLEX-UK: A new and improved word frequency database for British English" (Van Heuven et al., 2014).

Unrelated Filler Words and Probes. Filler words and their probes were the same as those used in Experiment 1.

Counterbalancing

To ensure that each target (ambiguous and unambiguous words) contributed to both primed and unprimed conditions, items were counterbalanced across participants in the

priming task. This counterbalancing gave as a result two versions for this experiment. To avoid the influence of any characteristic of targets or probes between versions, we established two criteria for the counterbalancing of ambiguous and unambiguous words in the priming task. The criteria used for the counterbalancing of ambiguous words were: (i) the number of responses of probe words associated with our target words given by The Edinburgh Associative Thesaurus (Lapalme, 2017), and (ii) the dominance of the subordinate meaning of target words, measures taken from the "New UK-Based Word Association Norm for Spoken Ambiguous Words" (Gilbert et al., 2022). For unambiguous words the criteria used to counterbalance items across versions were: (i) the number of responses of probe words associated with our target words given by The Edinburgh Associative Thesaurus (Lapalme, 2017), and (ii) the frequency of target and probe words, measures taken from the "SUBTLEX-UK: A new and improved word frequency database for British English" (Van Heuven et al., 2014). As a result, two sets of ambiguous words (on Table 2.6 A1 and A2), and two sets of unambiguous words (on Table 2.6 U1 and U2) were created, where each of them included 14 words (see the File S5 that shows the list of words used on each version of Experiment 2: https://osf.io/qdeuw). Table 2.6 shows the counterbalancing for the priming task of Experiment 2.

Table 2.6

Experiment 2. Counterbalancing of Items Across Priming and Test.

Version	Number of Participants	Priming Sets for Ambiguous and Unambiguous words	Ambiguous words Test	Unambiguous words Test
1	91	A1 + U1	Subordinate	All
2	91	A2 + U2	Subordinate	All

Note. Counterbalancing for the priming task of Experiment 2, which resulted into two versions with 91 participants on each of them. In the third column of the table A1 and A2 refer to the set of ambiguous words added to version 1 and 2, respectively, while U1 and U2 refer to the set of unambiguous words added to version 1 and 2, consequently.

Procedure

The procedure and the tasks used in Experiment 2 were the same as in Experiment 1.

2.3.3 Results

Following the criteria set out in the pre-registration, some participants were excluded from the analysis because they: (1) failed to complete the whole experiment or completed it in less than 15 minutes (n = 0); (2) got a mean accuracy lower than 50% in the sentence comprehension task (n = 7) (wrongly the pre-registration established that participants will be excluded if they got a mean accuracy lower than 50% in the semantic relatedness task), and (3) experienced technical difficulties (n = 0). Finally, as also set out in the pre-registration, response times under 300 ms and above 2500 ms were excluded from the analysis because they are too fast or too slow to provide a valid measure during the test task (1.6% of the data).

Sentence Comprehension Task

Participants were accurate at deciding if the check sentence was related or unrelated to the priming sentence. The mean accuracy across participants was 88.71% (Min = 62.5 %, Max = 100%). This suggest that participants completed the task paying enough attention.

Vocabulary Test

The mean accuracy across participants in this task was high 79.04% (Min = 42.5%, Max = 100%). This confirms that participants completed the task adequately.

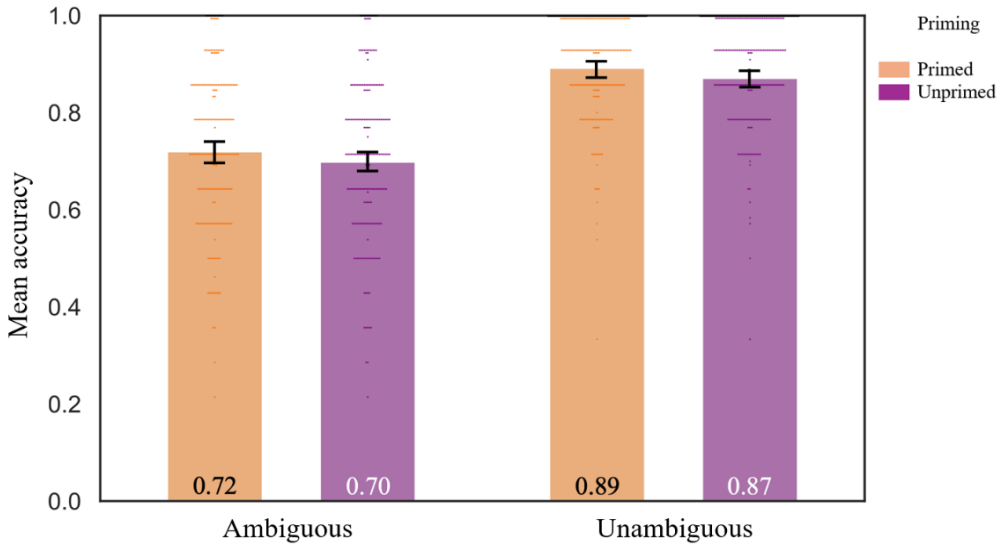
Semantic Relatedness Task

The mean accuracy across participants was 79.54% (Min = 41%, Max = 98%), which is somewhat lower than Experiment 1 (83.03%). However, the selection of better probe words for subordinate meanings in the present experiment slightly increased the mean accuracy on these items (M = 71%), compared to the mean accuracy obtained in Experiment 1 (M = 67%). Figure 2.6 shows mean accuracy for subordinate meanings and unambiguous words in their respective priming conditions. The mean response time of correct responses was 838.67 ms. Figure 2.7 presents mean response times for subordinate meanings and unambiguous words in their respective priming conditions.

The data from the three tasks and the R scripts for their analysis are available on the Open Science Framework webpage on the following links: https://osf.io/4akpn/ (data), and https://osf.io/7ah6m/ (R scripts).

Figure 2.6

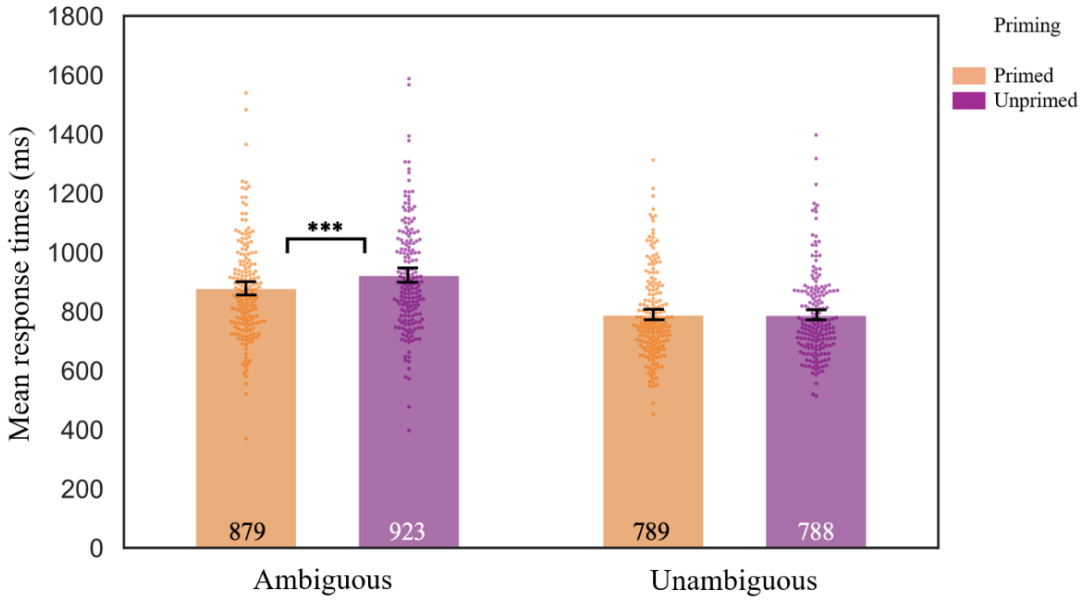
Experiment 2. Bar Plot with Mean Accuracy for Ambiguous and Unambiguous Words in their Respective Priming Conditions (Primed and Unprimed).



Note. Error bars represent the 95% within-subject confidence intervals (Morey, 2008). Dots show the mean accuracy for each subject in each condition.

Figure 2.7

Experiment 2. Bar Plot with Mean Response Times (ms.) for Ambiguous and Unambiguous Words in their Respective Priming Conditions (Primed and Unprimed).



Note. Error bars represent the 95% within-subject confidence intervals (Morey, 2008). Dots show the mean response times (ms.) for each subject in each condition.

Linear Mixed Effects Analysis

Responses were analysed with linear mixed effects models, following the same data transformation and model comparison approach as described in Experiment 1. The models were based on a 2 x 2 within-subjects design with fixed effects for Priming (deviation-coded as Primed 1/2 and Unprimed –1/2), Ambiguity (deviation-coded as Unambiguous 1/2, Subordinate meanings of ambiguous words -1/2), and their interaction. Maximal models included a random intercept and random slopes for Priming, Ambiguity, and the Priming x Ambiguity interaction by subjects, and a random intercept and a random slope for Priming by items. The inclusion of the random slope for Priming by items wasn't included in the pre-

registration, but it was added to the analysis because the effect of Priming can be different for each item.

Accuracy

In general, the results shown in Figure 2.6 reveal a higher mean accuracy for primed ambiguous words (M = 0.72), compared to the unprimed ones (M = 0.70). Unambiguous words also showed a higher mean accuracy on primed (M = 0.89) than unprimed items (M = 0.87). To provide an analysis of this pattern of results, a Linear Mixed Effects Analysis on the accuracy data was applied to the responses given by participants.

The maximal model that converged included a random slope for Ambiguity, the random slope for the Priming by Ambiguity interaction and their correlation by subjects, and a random slope for Priming by items.

There was a significant main effect of Priming ($\beta = 0.16$, SE = 0.06, $z = 2.76$; χ^2 (1) = 7.41, $p = .007$), with greater accuracy in the primed condition (M = 0.81, SD = 0.40) than in the unprimed condition (M = 0.79, SD = 0.41). The main effect of Ambiguity was significant ($\beta = 1.13$, SE = 0.06, $z = 20.1$; χ^2 (1) = 223, $p < .001$), with greater accuracy in the unambiguous (M = 0.88, SD = 0.32) than in the ambiguous condition (M = 0.71, SD = 0.45). The interaction between Priming and Ambiguity was not significant ($\beta = 0.10$, SE = 0.13, $z = 0.79$; χ^2 (1) = 0.62, $p = .431$).

Even though the interaction between Priming and Ambiguity was not significant, post-hoc tests were performed to follow the analysis plan described in the preregistration and clarify whether the priming effects on accuracy are significant or not for each word type. This test was applied using the emmeans() function (Russell V., 2021) in R. Contrary to our prediction, it was found that the priming effect on subordinate meanings of ambiguous words was not significant ($\beta = -0.11$, SE = 0.07, z-ratio = -1.44, $p = .151$). Also contradicting our

prediction, the priming effect was significant for unambiguous words (β = -0.21, SE = 0.1, z-ratio = -2.14, p = .033).

Response times

The mean response times shown in Figure 2.7 indicate faster responses for primed ambiguous words (M = 879 ms.) compared to unprimed ones (M = 923 ms.). In contrast, there was a minimal difference in response times between primed (M = 789 ms.) and unprimed unambiguous words (M = 788 ms.). To test if these effects are statistically significant, a Linear Mixed Effects Analysis on the response time data was applied to the responses given by participants.

The maximal model that converged included a random intercept and a random slope for Ambiguity by subjects including the correlation, and a random intercept by items.

There was a significant main effect of Priming (β = <0.01, SE = <0.01, t = 3.72; χ^2 (1) = 13.80, p < .001), with faster response times in the primed (M = 829.41, SD = 302.28) than in the unprimed condition (M = 848.14, SD = 320.00). The main effect of Ambiguity was significant (β = <0.01, SE = <0.01, t = 3.66; χ^2 (1) = 12.37, p < .001), with faster response times in the unambiguous (M = 788.73, SD = 291.35) compared to the ambiguous condition (M = 900.72, SD = 323.88). Critically, these main effects were qualified by a significant Priming by Ambiguity interaction (β = <-0.01, SE = <0.01, t = -3.49; χ^2 (1) = 12.17, p < .001).

Post-hoc tests were performed to investigate priming effects on response times for each type of word, using the emmeans() function (Russell V., 2021) in R. As predicted, the effect of Priming on subordinate meanings of ambiguous words was significant (β = <-0.01, SE = <0.01, z-ratio = -4.83, p < .001) with faster responses for primed (M = 879.07, SD = 310.57) than for unprimed items (M = 923.00, SD = 335.67). This Priming effect was not

significant for unambiguous words (β = <-0.01, SE = <0.01, z-ratio = -0.17, p = .867), thus supporting our prediction.

Order Effect Analysis

As in Experiment 1, an analysis was conducted on primed subordinate meanings of ambiguous words to investigate whether accuracy and response times at test were influenced by the order of presentation of subordinate and dominant meanings during priming. The models contained a fixed effect of Priming Order (deviation-coded as dominant meaning first 1/2, subordinate meaning first –1/2), a random intercept, and a random slope for Priming Order by subjects and items. Note that this model specification deviates from our preregistration, which erroneously included a fixed effect for Ambiguity.

Accuracy

The maximal model that converged included a random intercept by subjects and a random intercept and random slope for Priming Order by items. The main effect of Priming Order was not significant (β = 0.05, SE = 0.12, z = 0.43; χ^2 (1) = 0.18, p = .675).

Response times

The maximal model that converged was a random intercepts-only model. The main effect of Priming Order was not significant (β = <-0.01, SE = <0.01, t = -1.56; χ^2 (1) = 2.44, p = .119).

The data and the R scripts with the LME analysis of the semantic relatedness task, and the LME analysis of the order effect are available on the Open Science Framework webpage on the following links: https://osf.io/4akpn/ (data), and https://osf.io/7ah6m/ (R scripts).

2.3.4 Discussion

The aim of Experiment 2 was to find how mixed-exposure influences the subsequent processing of subordinate word meanings of English ambiguous words in a well powered experiment. We predicted a significant increase in accuracy and faster responses on the primed compared to the unprimed condition for these items, due to the pattern of results found in Experiment 1, which revealed a numerical benefit of mixed-exposure for subordinate meaning judgements on accuracy and response times.

No prediction was made for the main effect of Priming, but we did observe one, responses were significantly more accurate and faster in the primed than the unprimed condition, collapsed across Ambiguity conditions. As predicted, and consistent with Experiment 1, a significant effect of Ambiguity was found, responses were significantly more accurate and faster for unambiguous words compared to ambiguous words, collapsed across priming conditions.

Our hypothesis regarding the interaction between Priming and Ambiguity found partial support. The accuracy data revealed a non-significant interaction between Priming and Ambiguity. This was tested with planned simple effects, which contradicting our prediction revealed a non-significant difference between primed and unprimed subordinate meanings, and a significant difference between primed and unprimed unambiguous words. In contrast, the response time data found the predicted significant interaction between Priming and Ambiguity, where the benefit of priming was significantly larger for subordinate meanings of ambiguous words (44 ms.) than for unambiguous words (-1ms.). This was confirmed by planned simple effects analyses, which found a significant benefit of priming only for the subordinate meanings of ambiguous words. As in Experiment 1, priming effects for subordinate meanings on accuracy and response times were not influenced by the order of presentation of dominant and subordinate meanings during priming. Overall, the inconsistent

benefit of priming for subordinate meanings suggests that the facilitation effect for these meanings after mixed-exposure is weak.

What is interesting to note is the small facilitation effect for unambiguous words observed on the accuracy data. Although, this effect was not predicted, and current theories cannot account for it, it could be produced due to a baseline type of priming, such as semantic priming. This priming is considered a type of context effect, and happens when word identification is facilitated or inhibited by prior exposure to a word related in meaning (Harley, 2001). For our purpose, it is possible that the two encounters with the same unambiguous words in semantically similar contexts caused a subsequent facilitation for these words, due to these contexts activating highly similar semantic features that are related in meaning to the unambiguous words. In contrast, it is unlikely that semantic priming can account for the facilitation effect observed for ambiguous words, because one sentence disambiguated these towards the subordinate meanings, and the other towards the dominant one, thus excluding the chance of a cumulative effect of similar semantic contexts in the subsequent processing of dominant or subordinate meanings of ambiguous words.

In summary, Experiment 2, by securing appropriate power, provides evidence that mixed-exposure can improve the processing of subordinate meanings; however this mixed-exposure effect is weak because it was observed just in the response time data. The small but significant facilitation effect observed for unambiguous words on the accuracy data could be explained by semantic priming, but this explanation is far from being a solid one and needs to be taken with caution. In this context, further studies are needed to clarify the facilitation effect for subordinate meanings after mixed-exposure, and the facilitation effect for unambiguous words after multiple encounters with the meaning of these words.

2.4 General Discussion

The experiments presented in this chapter aimed to test how mixed-exposure to both dominant and subordinate meanings of ambiguous words influence the subsequent processing of dominant (Experiment 1) and subordinate meanings (Experiments 1 and 2). Testing the effects of a mixed-exposure is relevant because natural language includes exposure to different meanings of ambiguous words. The evidence provided helps us to understand, in a controlled experimental situation, how the language system deals with the semantic competition between the dominant and subordinate meanings of ambiguous words, as well as the potential priming effects of a recent mixed-exposure.

To properly address the main findings of the experiments presented and their implications, the present discussion will provide the general picture of the pattern of results obtained, by analysing the effect of ambiguity, and the effects of a mixed-exposure on the subsequent processing of subordinate and dominant meanings of ambiguous words. Furthermore, the main implications of these results will be identified, and what should be done next to extend our understanding of the effects of a mixed-exposure to ambiguous words.

2.4.1 Effects of Ambiguity

Starting with the effect of Ambiguity, Experiments 1 and 2 revealed a significant main effect of Ambiguity: reduced accuracy and slower responses for ambiguous words compared to unambiguous words. The ambiguity disadvantage observed is consistent with our prediction and a compelling body of evidence showing an increased processing load associated with lexical ambiguity, including behavioural (Armstrong et al., 2016; Hino et al., 2010; Klepousniotou et al., 2007; Mirman et al., 2009; Rodd et al., 2002, 2010), eye-tracking (Duffy, Kambe & Rayner, 2001; Rayner, 1998), and neuroimaging studies (Beretta et al.,

2005; Bekinschtein, et al., 2011; Davis, et al., 2007; Rodd, et al., 2005, 2010, 2012; Vitello, et al., 2014). These effects have typically been interpreted by considering that ambiguity makes language comprehension more difficult because an extra effort is needed to disambiguate words that have more than one meaning or sense. More specifically, there is a competition between the different meanings of ambiguous words, competition that is resolved with the information provided by the context where the word is present. However, this process is costly because of the increased time and cognitive effort required to hopefully select the intended meaning. From a theoretical point of view, for ambiguous words there is a mapping or association, where a single wordform maps forward onto multiple word meanings (Rodd, 2019). Overall, the results presented here characterize ambiguity as a complex process that requires an additional effort to access the intended meaning. However, they also reveal the flexibility that ambiguity adds to the access of the different meanings with the same word, characteristic that makes language comprehension a more rich and dynamic process.

2.4.2 Effects of Mixed-Exposure to Ambiguous Words

To provide a proper analysis of the effects of a mixed-exposure found across Experiments 1 and 2, it is necessary to provide a reminder of the three possible outcomes that were suggested. First, a significant facilitation effect on the processing of both dominant and subordinate meanings, suggesting that both meanings can be boosted independently, evidence that would contradict strong claims of semantic competition. Second, a significant interference in the processing of both meanings, which would support the unlikely idea that semantic competition is stronger than positive priming effects. Third, a null effect on both meanings, which would suggest a cancellation of the positive boost from one meaning due to the interference from the other, thus maintaining the semantic competition between meanings. Taken together, the results of Experiments 1 and 2 provide partial support to the

first possible outcome, a significant facilitation effect on the subsequent processing of both dominant and subordinate meanings. This support is partial because the facilitation effect of a mixed-exposure was only observed on the subsequent processing of subordinate meanings. Specifically, this facilitation was numerical in Experiment 1, and significant in Experiment 2, but only for response times. Moreover, a null effect was found for dominant meanings on both accuracy and response time measures in Experiment 1. To make clear the contribution of these results, the next section will analyse the implications for subordinate and dominant meanings within the semantic competition described by Distributed Connectionist models, providing a better understanding of the effects of mixed-exposure on the subsequent processing of these meanings.

2.4.3 Effects on Subordinate Meanings

The facilitation effect on response times observed for subordinate meanings after mixed-exposure provides weak evidence that this meaning can be boosted independently. This contradicts strong claims of semantic competition, which predict that it is not possible to boost ambiguous word meanings independently of one another because boosting one meaning will come at the expense of other. In contrast, our results suggest that the semantic competition that may come from exposure to the dominant meaning does not overwhelm positive priming effects for subordinate meanings. Importantly, our results extend the growing body of evidence that supports a facilitation effect for subordinate meanings after a single encounter with this meaning (Betts et al., 2018; Gaskell et al., 2019; Gilbert et al., 2018 & Gilbert et al., 2021; Rodd et al., 2013 & Rodd et al., 2016), because now we are providing evidence that subordinate meanings can be boosted even after exposure to both subordinate and dominant meanings of ambiguous words.

Our findings seem to contradict those found by Betts et al. (2018; Experiment 1), who observed a null effect of priming for subordinate meanings after an encounter with this meaning followed by an encounter with the dominant one. However, it is worth noting that Betts et al. (2018; Experiment 1) always primed the subordinate meaning first and then the dominant one, whereas our study randomized the order of priming and revealed that this order does not have a significant influence on priming effects. The null effect on subordinate meanings after mixed-exposure found by Betts et al. (2018; Experiment 1) can be explained considering that this experiment included an average delay between each item in the subordinate prime task and the word association task of approximately 30 minutes. Given that we only observed a weak facilitation effect after 15 minutes, perhaps the increased 30 minutes delay used by Betts et al. made even weaker the facilitation effect for subordinate meanings that we observed in our experiments.

2.4.4 Effects on Dominant Meanings

For dominant meanings, Experiment 1 revealed a null effect after mixed-exposure, where even the numerical difference between primed and unprimed items was small for both accuracy (-0.03) and response times (6 ms.). It is worth noting that this null effect could be explained by the limitations of the measures used, where accuracy and response times in a semantic relatedness task may not be sensitive enough to show any small effect of priming for dominant meanings. Although, these findings should be taken with caution because Experiment 1 was underpowered, and Experiment 2 did not test dominants meanings, they are consistent with Rodd et al. (2013; Experiment 1, Figure 1b), study that found only a small effect of priming on dominant meanings. The reason for this small effect for dominant meanings is that they are already the most available meaning, availability that cannot be further increased. The idea that dominant meanings are less susceptible to priming than

subordinate meanings can explain the null effect for dominant meanings observed in Experiment 1. However, this claim requires further investigation because it seems possible to detect a stronger facilitation effect for dominant meanings at shorter delays, as was observed by Betts et al. (2018; Experiment 1), which found this effect after a delay between prime and test of approximately 9 minutes.

By having described the main implications of the results presented for subordinate and dominant meanings within the semantic competition characterized by Distributed Connectionist models, the following section will identify the limitations of the experiments presented, and it will describe what needs to be done next to fill these gaps.

2.4.5 Limitations and Future Directions

The results obtained in this chapter allow us to take a step forward about the effects of mixed-exposure on the subsequent availability of subordinate meanings of English ambiguous words. However, the procedure used to get these results has some limitations. One limitation is that the tasks used to prime word meanings and test this effect do not completely mimic natural language conditions. The use of ecological methods is relevant since the goal is to better characterize natural language processing, and specifically for our purposes how the language system deals, in our daily lives, with inconsistent exposures to both subordinate and dominant meanings of ambiguous words.

Although, the sentences used to prime word meanings in our experiments were selected from the British National Corpus (Leech & Rayson, 2014), a database that contains natural language passages selected from newspapers, journals, tv programs between others, they just provide strong local disambiguation cues that make possible the selection of the intended meaning. However, natural language also includes distant contextual cues that are part of more extended communicative contexts. To test the effects of mixed-exposure

including these distant cues, it is recommended, for example, the selection of short narratives, such as those employed by Blott et al. (2022), where English ambiguous words were disambiguated by distant rather than local contextual cues. More specifically, the narratives selected by Blott et al. (2022) were composed of three sentences, the first provided a context that disambiguated the ambiguous target word towards the subordinate meaning, the rest of them did not give any information about the intended meaning. Overall, the exposure to texts that include both local and distant contextual cues during priming will secure a better approach to replicate natural language conditions where it is possible to encounter the different meanings of ambiguous words.

Regarding the test phase of our experiments, the use of a semantic relatedness task secured the testing of meaning availability following an exposure to a specific meaning of ambiguous words. However, this meta-linguistic task does not provide a measure of natural language processing during reading. Moving forward to more ecological measures of priming effects after mixed-exposure, the selection of eye-tracking methods seems a viable way to fix this problem. Up to date eye-tracking studies are the most compelling body of evidence that supports the increased cost to process ambiguous words, but just a few have examined the role of previous encounters on the processing of lexical ambiguity during silent reading (Leinenger & Rayner, 2013; Rayner, 1993). Partially fixing this gap, Parker et al. (2023) tested how word-meaning priming supports lexical processing during sentence reading. In this study English-speaking participants read prime and test sentences that included low-ambiguity control words or high ambiguity target words that were disambiguated towards the subordinate meaning. Measures of go-past time (sum of all fixations in a region from first entering the region until moving to the right of the region) and total reading time (total time spent reading a sentence) revealed a greater decrease in the primed condition of high ambiguity words compared to low-ambiguous words. The measures obtained by Parker et al.

(2023) succeed to better characterize word-meaning priming effects on natural language processing, and indeed they will be highly recommended to test in a more natural way how a recent exposure to both subordinate and dominant meanings of ambiguous words influences their subsequent processing.

2.4.6 Conclusions

Overall, the experiments presented in this chapter revealed a weak facilitation effect on the subsequent processing of subordinate meanings after mixed-exposure, and a null effect on the subsequent processing of the dominant ones. To provide strength to the facilitation effect for subordinate meanings observed in Experiment 2, the experiment presented in the next chapter will look for more consistent evidence of it, aiming to detect this facilitation on both accuracy and response time data. To do so, it might be necessary to increase the number of exposures to each item as a viable way to secure its detection. Additionally, the next experiment will test whether the immediate processing benefit for the subordinate meanings persists beyond an immediate test on the same day, to a delayed test the following day. If longer-lasting benefits to subordinate meaning processing are observed, this will make these results even more relevant to better understand and characterize our disambiguation skills.

CHAPTER 3: EFFECT OF MIXED-EXPOSURES TO AMBIGUOUS WORD MEANINGS ON SUBORDINATE MEANING PROCESSING AT IMMEDIATE AND DELAYED TEST

3.1 Introduction

The experiments presented in the previous chapter shed some light on the priming effect of mixed-exposures to the subordinate and dominant meanings of English ambiguous words, and how this effect can be interpreted in the context of semantic competition between unrelated meanings. Results provided partial support to the prediction of a facilitation effect on the subsequent processing of both dominant and subordinate meanings. This support is partial because this facilitation was found just on subordinate meanings, dominant meanings revealed a null effect. These results are relevant because they contradict strong claims of semantic competition, which predict that it is not possible to boost meanings independently, because the boost of one meaning will come at expense of the other. Instead, these findings support the idea of a limited influence of semantic competition after mixed-exposure and provide further support to the claim that recent exposures to a particular meaning of an ambiguous word facilitates its subsequent processing.

To further explore these findings, the pre-registered and well-powered experiment presented in this chapter will test if the immediate processing benefit for subordinate meanings after mixed-exposure persists beyond an immediate test on the same day, to a delayed test the following day. Since Experiments 1 and 2 revealed that this effect was weak, Experiment 3 will attempt to replicate and to boost the effect size of the benefit for subordinate meanings by increasing the number of exposures to each item, and so participants will receive three exposures to both meanings of ambiguous words during the training phase. If longer lasting benefits to subordinate meaning processing are observed, this

will make these results more relevant, suggesting that word-meaning priming effects can be maintained over time even in the context of a mixed-exposure.

Aiming to identify the possible outcomes of a 24 hour delay, and the multiple encounters to the dominant and subordinate meanings of ambiguous words on the subsequent processing of subordinate meanings, the following section will describe the evidence given by the subordinate word-meaning priming literature that directly address the effects of delay, as well as those findings that justify the increased number of exposures to both meanings.

3.1.1 The Effect of Delay on Word-Meaning Priming

Over the last decade the word-meaning priming literature in English (e.g. Betts et al., 2018; Gilbert et al., 2018; Rodd et al., 2013, 2016) has tried to characterize the effect of delay on the observed facilitation effect for subordinate meanings after a recent exposure to this meaning. One of the first studies that tested the effect of delay on word-meaning priming effects was led by Rodd et al. (2013; Experiment 3). This study found that after hearing sentences that disambiguated the meaning of ambiguous words towards their subordinate interpretation, the subordinate meaning associates generated by participants did not differ significantly after 3 and 20 minutes, although a numerical decrease was observed on these associates after 20 minutes. Further exploring the time course of word-meaning priming, Rodd et al. (2016; Experiment 2) tested priming effects after 1, 20, and 40 minutes through a word association task. The results of this experiment showed significant priming effects after 1, 20, and 40 minutes, however the priming effect was significantly higher for the 1 minute delay, compared to the 20 and 40 minutes delays. No difference was observed in priming effects between the 20 and 40 minutes delays. Taken together, these findings indicate that: (i) priming effects are higher at shorter delays, (ii) this effect experiences a fast decay at some point before 20 minutes, and (iii) that after a few minutes and before one hour this effect is

still significantly present. Despite the clarity of these results, the study of priming effects at longer delays (e.g. a few hours or days) provides a better understanding of how this effect influences people's long-term meaning preferences.

To properly address long-term effects of priming, it is necessary to describe the contribution of sleep studies. These studies are relevant because naturally, longer delays include a period of sleep. A growing body of evidence supports the idea that sleep preserves the retention and integration of linguistic knowledge (Bakker et al., 2014; Bakker-Marshall et al., 2018; Dumay et al., 2007; Hulme et al., 2023; Kurdziel et al., 2017; Mak et al., 2023; Tamminen et al., 2010) and, most relevant to the present study, facilitates priming of the subordinate meaning of ambiguous words (Gaskell et al., 2019). Gaskell et al. (2019; Experiment 1), by priming the subordinate meaning of English ambiguous words through sentence listening, found that after a delay of 2 hours the priming effect was larger for those participants who took a nap compared to those assigned to the awake condition. Moreover, this priming effect was also tested after a delay of 12 hours, which included an awake and an overnight sleep conditions. Results showed that the priming effect was larger for those participants in the sleep condition compared to the awake one. Furthermore, Gaskell et al. (2019; Experiment 2), using the same procedure of Experiment 1, observed that overnight sleep preserves the retention and integration of linguistic knowledge after a delay of 24 hours. Specifically, the subordinate word meaning priming effect was bigger in the condition that included exposure in the evening, immediate sleep, and testing in the evening the next day, compared to the condition that included exposure in the morning, sleep that night, and testing in the morning the following day. Overall, this study extends those findings revealed by Gaskell et al. (2019; Experiment 1).

The findings provided about the possible effect of delay are relevant for the following reasons. First, they explore the time course of word-meaning priming for subordinate meanings within a time window of 24 hours, suggesting that this effect tends to decrease over time. Second, they provide evidence that priming can be detected after 24 hours. Third, they suggest that the decrease of priming effects is particularly strong after short delays (up to 20 minutes), then the decrease continues but reducing its intensity. Interestingly, they show that the reduction of the facilitation effect for subordinate meanings after extended periods of time (e.g. 2, 12 or 24 hours) can be decreased after a period of sleep. For the purpose of the experiment presented here, these findings suggest that it would be possible to find a significant facilitation effect for subordinate meanings immediately after training and after a delay of 24 hours, but also a significant reduction in this effect between these two time windows. The reason for the decrease of word-meaning priming effects with time is still unclear. One option will be the influence of time per se (e.g. Rodd et al., 2013, 2016), another one could be the interference of subsequent linguistic stimuli (e.g. Hulme et al., 2023). However, future work will be needed to clarify the mechanisms behind this decrease.

As mentioned previously, the purpose of Experiment 3 is to test if the immediate processing benefit for subordinate meanings after mixed-exposure persists not just after immediate test, but also to a delayed test the following day. This is theoretically relevant because it will reveal if the short-term priming observed in Experiments 1 and 2 can be extended into longer term changes that therefore have the potential to benefit people's comprehension. Both long and short term priming are consistent with both the Immediate Alteration account (i.e. an immediate update of the long-term storage of lexical semantic knowledge) and the Episodic Context account (i.e. the creation of a temporary memory trace, which is subsequently transferred to the long-term storage via hippocampal replay during sleep). To elucidate which account could better explain priming effects, studies are needed

that specifically manipulate the sleep condition between groups (awake/sleep). As a first step towards this goal, Experiment 3 tests whether priming effects are observed after 24 hours, represents a necessary first step to achieve this goal.

3.1.2 Benefit of Repeated Encounters

Aiming to increase the facilitation effect for subordinate meanings after mixed-exposure, the present experiment will increase this mixed-exposure to three encounters for each meaning. The idea to increase the processing benefit for a particular meaning of an ambiguous word after repeated encounters with it is supported by repetition priming. This type of priming is understood as the increased speed of processing of a particular item in response to its repeated presentation. This view is supported by Logan (1990), who suggest that the repeated presentation of an item strengthens the association between its wordform and its interpretation. In sum, repetition priming allows us to expect an increase in priming effects after different encounters to the dominant and subordinate meanings of ambiguous words.

Moreover, the idea to increase the number of exposures is also supported by Betts et al. (2018). This study showed that after 3 exposures to sentences that disambiguated English ambiguous words towards their subordinate meanings, listeners revealed stronger priming effects compared to just one encounter, when this meaning was tested through a word association task. It is worth noting that the additional boost found by Betts et al. (2018) was present just when these encounters were spaced, massed encounters did not provide the additional boost. It is unclear why spaced repetitions (those presented with a 5-minute delay) produce more priming than massed repetitions (those presented in succession). One model that could explain the benefit of space between repetitions is the activation account (Pavlik et al., 2008; 2005). This model suggests that listeners benefit more from spaced repetitions

because the activation of the encountered meaning lasts longer than the one obtained with massed encounters. The second explanation for the benefit of space comes from the consolidation account (e.g. Shadmehr et al., 1997). This account suggests that the benefit of spaced repetitions is explained by the idea that it allows enough time between repetitions to consolidate the meaning of the word after each encounter. Lastly, the benefit of spaced over massed repetitions could be explained by an encoding variability mechanism suggested by Mensix and Raaijmakers (1989) and Raaijmakers (2003). These authors argue that the context of a particular meaning of a word changes over time and this context is encoded with each encounter. The variability between contexts is what allows the integration of different pieces of evidence over time, thus increasing the availability of the primed meaning. Although the experiment presented here does not aim to provide an explanation of the higher benefit of spaced repetitions over the massed ones, it is relevant to consider this factor on the ongoing debate and the future studies that are needed to address it. Despite of this we decided to use spaced rather than massed repetitions since that should be more effective.

By having described the evidence about the effects of delay on word-meaning priming at longer delays, and the theoretical support for the increase in the number of mixed-exposures, the following section will present the current study, which aims to explore if the facilitation effect for subordinate meanings after mixed-exposure can be maintained after 24 hours.

3.2 Experiment 3

3.2.1 Introduction

Following the facilitation effect for subordinate meanings after mixed-exposure observed in Experiments 1 and 2, the present experiment will test if this facilitation persists beyond an immediate test, to a delayed test 24 hours later. To do so, this experiment follows

a similar procedure to the one used in the previous chapter, but it includes multiple exposures during training to both meanings during the exposure phase and a second session that tests the effect of mixed-exposure after one day. Session one include three parts: (i) a sentence comprehension task, where participants are exposed to both meanings of all ambiguous words three times, (ii) a vocabulary test, to secure a short delay between priming and test, and (iii) a semantic relatedness task, where participants are tested on half of the items, deciding if ambiguous words are semantically related to a probe word. Session two includes two parts: (i) a semantic relatedness task, where participants are tested on the other half of the items, and (ii) an exploratory test part, where participants complete an author recognition test, a spelling recognition test, and a sleep quality assessment. These tests were added to explore possible factors that might modulate the magnitude of the observed priming effects, since these were added as part of a separate project, their descriptions will not be included. During the sentence comprehension task, participants are exposed three times to the dominant meanings, and three times to the subordinate meanings of ambiguous words. To match the number of exposures between ambiguous and unambiguous words participants are exposed six times to the single meaning of unambiguous items. As in Experiment 2, they are only tested on the subordinate meanings.

Semantic relatedness judgements for ambiguous and unambiguous control words are analyzed using linear mixed effect models on accuracy and response time data. These models follow a 2 x 2 x 2 within-subjects design with the fixed effects of Training (deviation coded as Trained 1/2 and Untrained –1/2), Ambiguity (deviation-coded as Subordinate -1/2 and Unambiguous 1/2), and Delay (deviation-coded as Immediate -1/2 and Delayed 1/2). The two-way interactions include those between Training and Ambiguity, Training and Delay, and Ambiguity and Delay, the three-way interaction includes the one between Training, Ambiguity and Delay.

Hypotheses

Based on the pattern of results from Experiments 1 and 2, and the evidence and theoretical accounts described in the General Introduction the main hypothesis for this experiment is:

Multiple exposures to both the dominant and subordinate meaning of ambiguous words will improve processing of the subordinate meaning when this is tested immediately and the next day.

More specifically, we make the following predictions for the semantic relatedness (test) task. Note that prediction one will be tested for the whole dataset (ambiguous and unambiguous words). Predictions two, three, and four will be tested by sub-setting the data and analysing just the ambiguous words since they relate only to subordinate meanings:

1. Main effect of Ambiguity: Reduced accuracy and slower response times for the subordinate meaning of ambiguous words compared with unambiguous words, collapsed across training and delay conditions.
2. Main effect of Training for ambiguous words: Increased accuracy and faster response times for the trained items relative to the untrained ones, collapsed across delay conditions.
3. An interaction between Training and Delay for ambiguous words: Driven by a decrease in the magnitude of training effects in the delayed condition compared with the immediate condition, for both accuracy and response times.
4. Simple effects of Training at *both* immediate and delayed test for ambiguous words: Increased accuracy and faster response times in the trained condition compared with the untrained condition.

Note that we make no predictions regarding the effects of training and delay for unambiguous words. While there is currently no strong theoretical reason to expect such

effects, data from Experiments 1 and 2 suggest that these items may show an inconsistent effect of training, they showed either no priming effect or a small facilitation immediately after exposure, outcomes that varied across accuracy and response time measures between experiments.

3.2.2 Method

Experiment 3 was preregistered on the Open Science Framework (https://osf.io/f3b9d), document that specifies: its theoretical relevance, hypotheses, design, stimuli counterbalancing and randomization, sampling plan, sample size, power analysis, procedure, analysis plan, transformation applied to the response time data, and data exclusion criteria. Any change made after the preregistration will be described.

Participants

378 participants aged between 18 and 40 were recruited online through Prolific. The inclusion criteria for participants were the following: (1) aged between 18-40, (2) currently resident in the UK, (3) native UK speaking, (4) no diagnosed reading or language disorders, (5) normal or corrected-to-normal vision. Participants received £7.5 for taking part in the two sessions of this study. The UCL Department of Experimental Psychology Ethics Committee approved the study.

As in Experiment 2, the number of participants for Experiment 3 is determined according to Brysbaert et al. (2018) for linear mixed effect models. After exclusions (described in the results section), a recruitment target of 340 participants will provide 2,380 observations for each of the four crossed conditions (Trained Immediate/Untrained Immediate; Trained Delayed/Untrained Delayed). Although this number exceeds the minimum of 1,600 observations suggested by Brysbaert et al. (2018) to find significant effects in the analysis of transformed data (with 80% of power), it allows us to exclude error

responses in the semantic relatedness task. According to Experiment 2 this error rate will be around 30% for the untrained and immediately tested subordinate meanings, condition that showed the highest number of errors. Moreover, it is estimated an extra data loss of around 1%, due to response times under 300 ms. and above 2500 ms., which will be excluded from the analysis. Taken together, it is expected a total data loss of approximately 31% for those responses in the condition with the highest error rate, which will provide an estimate of 1,642 correct and filtered observations, number that secure the minimum of 1,600 observations suggested by Brysbaert et al. (2018).

Design

This experiment follows a 2 x 2 x 2 within-subjects design, with the independent factors of Training (Trained/Untrained), Ambiguity (Ambiguous/Unambiguous), and Delay (Immediate/Delayed). Given the absence of priming effects for dominant meanings observed in Experiment 1, as with Experiment 2 this experiment just tested the subordinate meanings of ambiguous words. Aiming to extend the facilitation effect for subordinate meanings to 24 hours, the number of exposures was increased to three for each subordinate and each dominant meaning of ambiguous words. To match the number of exposures between ambiguous and unambiguous items participants are exposed six times to the single meaning of unambiguous words.

Stimuli

Ambiguous Words. These were the same as in Experiments 1 & 2.

Unambiguous Words. These were the same as in Experiments 1 & 2.

Priming Sentences. As we increased the number of exposures to three for the subordinate meanings of ambiguous words, three for the dominant meanings of ambiguous words, and six for unambiguous words, 84 training sentences were selected for subordinate

meanings (e.g. for “crane”, “There are many types of bird, for example, the Siberian **crane** stands two and a half feet tall, its brilliant white plumage offset by a blood-red beak, face and legs”), 84 training sentences for dominant meanings (e.g. for “crane”, “While her boss took the unsuspecting Carolyn out to lunch, workers hoisted her car 20ft into the air with a borrowed **crane**, and parked it neatly on the roof”), and 168 training sentences for unambiguous words (e.g. for “cactus”, “The force of its descent has created a natural Jacuzzi in the head pool, surrounded by stands of maidenhair fern, flowering **cactus** and red lilies”). The sentences were taken from Experiments 1 and 2, and the additional ones needed were selected from the British National Corpus (Leech et al., 2014), which provide a natural and rich semantic context to disambiguate our target words. It is worth noting that some of these sentences were edited in minor ways to remove orthographic errors (see Table S8 for the list of sentences selected for ambiguous words: https://osf.io/wzdk2, and Table S9 for the list of sentences selected for unambiguous words: https://osf.io/5ufr2).

Probe Words in the Training Task. Our previous comprehension check sentences used in the priming task of Experiments 1 and 2 were replaced with probe words, to avoid double priming with the same target word present in the comprehension check sentences, and to reduce the time spent in this task. These probes were selected from the Wordsmyth dictionary (Parks et al., 1998). Probes are related or unrelated to the general context of our training sentences, to ensure participants’ attention while reading the priming sentences. For each priming sentence one probe word was selected. Participants needed to decide if the probe was related or unrelated to the general meaning of the priming sentence. For instance, for the sentence “There are many types of bird, for example, the Siberian **crane** stands two and a half feet tall, its brilliant white plumage offset by a blood-red beak, face and legs”, which disambiguated the ambiguous word “crane” towards its subordinate meaning, the probe word selected was “feathers”, which is related in meaning to the sentence; for the

sentence “While her boss took the unsuspecting Carolyn out to lunch, workers hoisted her car 20ft into the air with a borrowed **crane**, and parked it neatly on the roof”, which disambiguated the ambiguous word “crane” towards its dominant meaning, the probe word selected was “clinic”, which is unrelated in meaning to the sentence; and for the sentence “The force of its descent has created a natural Jacuzzi in the head pool, surrounded by stands of maidenhair fern, flowering **cactus** and red lilies”, which included the unambiguous word “cactus”, the probe word selected was “bloom”, which is related in meaning to the sentence (see Table S8 for the list of probe words for ambiguous word sentences: https://osf.io/wzdk2, and Table S9 for the list of probe words for unambiguous word sentences: https://osf.io/5ufr2). The relatedness between priming sentences and probes was counterbalanced across conditions (see the Counterbalancing of related vs unrelated trials during training section for the details of this counterbalancing).

Probe Words in the Test Task. Probe words were the same as in Experiment 2.

Unrelated Filler Words and Probes in the Test Task. These words were the same as in Experiment 2.

Counterbalancing

Counterbalancing of experimental versions: To ensure that each participant encountered each item in either the trained condition or the untrained condition, and that across participants each item contributes to both of these conditions, items were counterbalanced at training. Additionally, to ensure that each participant was tested on each item at immediate or delayed tests, and that across participants each item was tested at both delay conditions, items were counterbalanced at test. This counterbalancing ensured that ambiguous and unambiguous words were evenly split into four lists across training and test, where items were matched on mean frequency and length.

During training, each participant was trained on half of the ambiguous words and half of the unambiguous words (i.e., on two of the four lists). This means that each participant was trained on 14 ambiguous words and 14 unambiguous words. As participants were exposed three times to the dominant meaning, three times to the subordinate meaning of each ambiguous words, and six times to each unambiguous word, they read 42 priming sentences for subordinate meanings, 42 priming sentences for dominant meanings, and 84 priming sentences for unambiguous words. At test, each item was presented to each participant in either the immediate test condition or the delayed test condition (i.e. to eliminate the possibility of any testing effect). Participants were tested on half of the items that were trained/untrained on day one; the other half was tested on day two. The assignment of items to lists required four experimental versions, where each participant was tested on seven items per condition.

Participants were randomly allocated to the four versions of the experiment by the experimental software, such that a total of 85 participants completed each version. To ensure that each version had an equal number of subjects, any participants that were excluded due to technical difficulties or that didn't complete the experiment or that didn't meet our data quality criteria were replaced with new ones. Furthermore, the order in which trained items were presented in the sentences during the training task, and the order of presentation of the test items in both the immediate and the delayed test task were randomized separately for each participant. Table 3.1 shows the counterbalancing across training and test.

Table 3.1

Experiment 3. Counterbalancing of Items Across Training and Test.

Version	Number of Participants	Training Sets	Immediate Test	Delayed Test
1	85	A1 + A2	A1 + B1	A2 + B2
2	85	A1 + A2	A2 + B2	A1 + B1
3	85	B1 + B2	A1 + B1	A2 + B2
4	85	B1 + B2	A2 + B2	A1 + B1

Note. This counterbalancing led to the creation of four experimental versions.

Counterbalancing of related vs unrelated trials during training: As participants received three exposures to the subordinate and three exposures to the dominant meaning of ambiguous words, training trials were balanced across conditions in terms of the number of "related" and "unrelated" responses to probe words. To do so, half of the ambiguous words was paired with two related probes and one unrelated probe, whereas the other half was paired with two unrelated probes and one related probe. For unambiguous items this was not needed, because participants were exposed six times to these items, so they just were exposed to three related and three unrelated probes. The counterbalancing of ambiguous and unambiguous sentences was fixed for all participants (i.e., the pairing of a particular training sentence with a particular probe was held constant for all participants).

Procedure

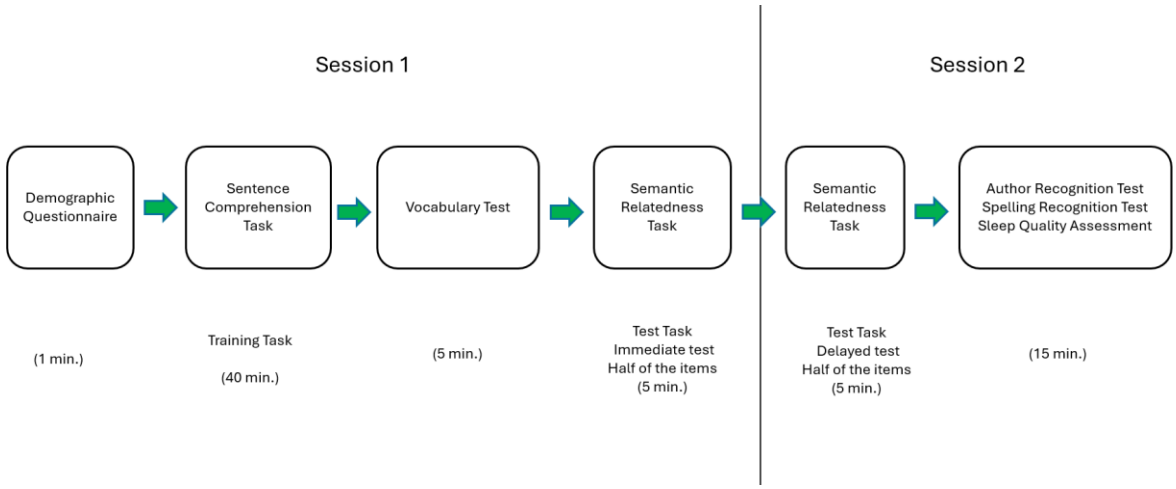
The study included two sessions. In session one participants completed four tasks in the following order: a demographic survey, the training task, a vocabulary test, and immediate test task. Session two, which was completed the following day, included four parts, completed in the following order: the delayed test task, an author recognition test, a spelling recognition test, and a sleep quality assessment. Since the author recognition test, the

spelling recognition test, and a sleep quality assessment took place after all other elements of the experiment were complete and did not relate to the current project, further description will not be included[1].

[1] These tests were added by undergraduate students to further explore individual differences in their respective measures, and how they influence or not the effect of mixed-exposures.

Figure 3.1

Experiment 3. Procedure of Session 1 and Session 2.



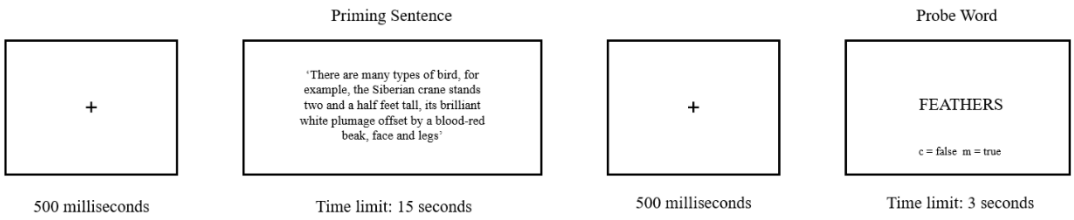
Session One: This session included the following tasks and tests:

Demographic Questionnaire. This was the same as in Experiments 1 and 2.

Sentence Comprehension Task. At the beginning of this task participants read the instructions on the screen, then they completed two practice trials before starting the main task. Each trial began with a central fixation marker for 500 ms., followed by the training sentence which participants read with a time limit of 15 seconds. Then, they saw another 500 ms. fixation marker, followed by a probe word, which remained on screen until a valid response was given, or until the time limit of 3 seconds was reached. Participants pressed "m" if the probe word was related to the general meaning of the sentence or "c" if the probe word was unrelated to the general meaning of the sentence (these reminders appeared at the bottom of the screen). After their response, the next trial began automatically. Participants were instructed to respond as quickly and accurately as possible. A total of 168 trials were completed by each participant.

Figure 3.2

Experiment 3. Example Trial of the Sentence Comprehension Task.



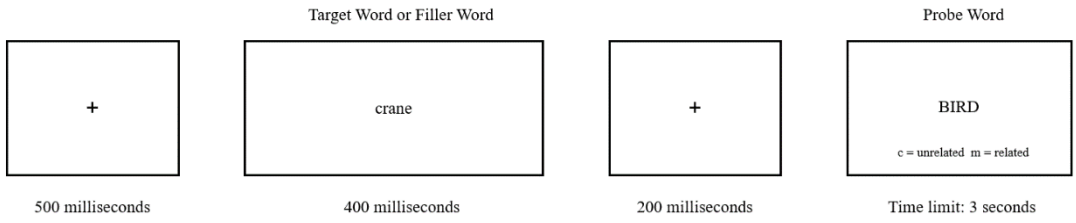
Vocabulary Test. This test is an adapted version of Ooi (2018), which measures vocabulary knowledge. To start participants read the instructions on the screen, then they completed one example trial before completing the test. In each trial participants read on the left side of the screen the target word to be tested, at the same time on the right side appeared four boxes and participants needed to choose which one contained the word that was related to the target word by clicking the correct box. Finally, they moved to the next trial automatically after their response or after 15 seconds if they didn't give any answer. A total of 51 trials were displayed for each participant.

Semantic Relatedness Task. After the vocabulary test participants moved on to the test task. Participants were tested on half of the items that were trained/untrained on day one. Each version of this task included 14 probe words for ambiguous words, 14 probe words for unambiguous words, and 28 filler words and their probes to provide NO responses. Participants read a target word (ambiguous, unambiguous, or filler word) followed by a probe word and decided, as quickly and accurately as possible, whether the two words were related or not. At the beginning, participants completed ten practice trials, followed by the main task. Each trial began with a 500 ms. fixation marker, followed by an ambiguous, unambiguous, or filler word for 400 ms. They then saw a 200 ms. fixation marker, followed by the probe word

which remained on the screen until participants made a response, or until the time limit of 3 seconds was reached. Participants pressed "m" if the probe word was related in meaning or "c" if the probe word was unrelated in meaning to the target/filler word (reminders for the response keys were displayed at the bottom of the screen). Participants were instructed to respond as quickly and accurately as possible. An example trial of the test task can be observed in Figure 3.3.

Figure 3.3

Experiments 1, 2, and 3. Example Trial of the Semantic Relatedness Task.



Session Two: After a 24 hour delay participants started session two, which included the semantic relatedness task, the author recognition test (Stanovic et al., 1989), the spelling recognition test (Burt et al., 2002), and the sleep quality assessment (Hawkins et al., 1992).

Semantic Relatedness Task. This was the same as in session one. Participants were tested on the other half of the items that were trained/untrained on day one.

At the end of session two, individuals were asked to leave any comments, questions, or concerns related to their overall experience in the experiment and if they received any type of help during the study, in order to evaluate whether their responses were valid or not.

3.2.3 Results

As per our pre-registered criteria, participants were excluded from this study if they: (1) failed to complete both sessions of the study (n= 24), (2) got a mean accuracy lower than 70% in the Sentence Comprehension Task (n = 12), securing the required level of attention during priming, or (3) reported technical difficulties (n = 0). Additionally, 2 participants were excluded from the analyses because there was a change in the Public ID for them, this means that their data in session one and session two wasn't possible to join. As a result of this criteria 38 participants were excluded and replaced to ensure adequate power following the guidelines given by Brysbaert et al. (2018). Moreover, responses under 300 ms. and above 2500 ms. also were excluded from the analysis (0.73% of the data).

The data of the vocabulary test, the author recognition test, the spelling recognition test, and the sleep quality assessment will not be analyzed, as they do not relate to the aims of the current experiment.

Sentence Comprehension Task

The mean accuracy across participants was 88.12% (Min = 70.2%, Max = 98.8%). This mean accuracy is similar to Experiment 2 (88.71%), which means that the replacement of the check sentence by a probe word did not change the level of difficulty of this task. The high accuracy suggest that participants were paying an appropriate level of attention during priming.

Semantic Relatedness Task

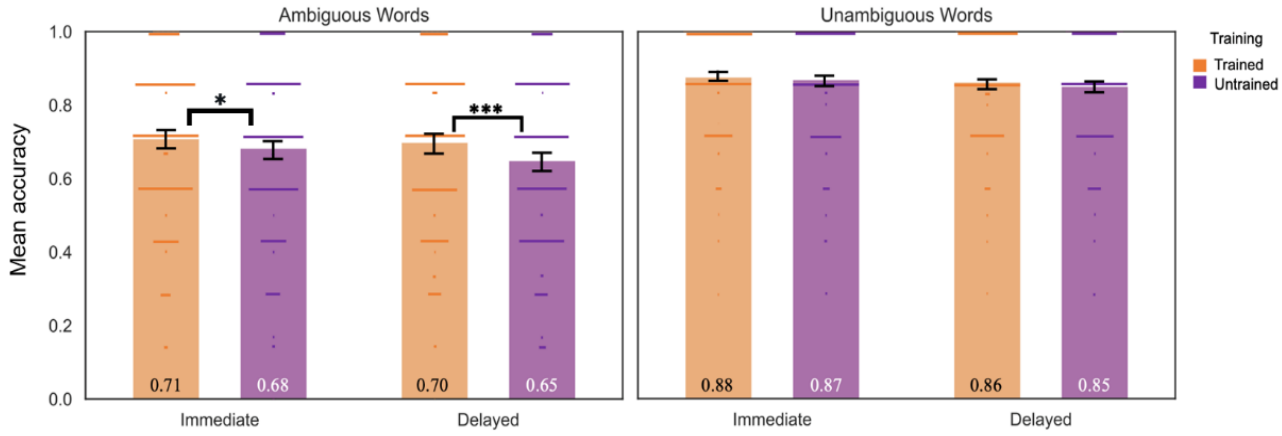
The mean accuracy across participants was 77.51% (Min = 32.14 %, Max = 100%). This mean accuracy is somewhat lower than Experiment 2 (79.54%), probably due to the inclusion of the delayed test condition. Figure 3.4 shows mean accuracy for subordinate meanings and unambiguous words in their respective priming conditions. Moreover, response

times of correct responses were analysed. The mean response time of correct responses was 801.83 ms. Figure 3.5 presents mean response times for subordinate meanings and unambiguous words in their respective priming conditions.

The data from the Sentence Comprehension Task and the Semantic Relatedness Task, along with the R scripts with their analysis are available on Open Science Framework webpage (https://osf.io/ct3p9/).

Figure 3.4

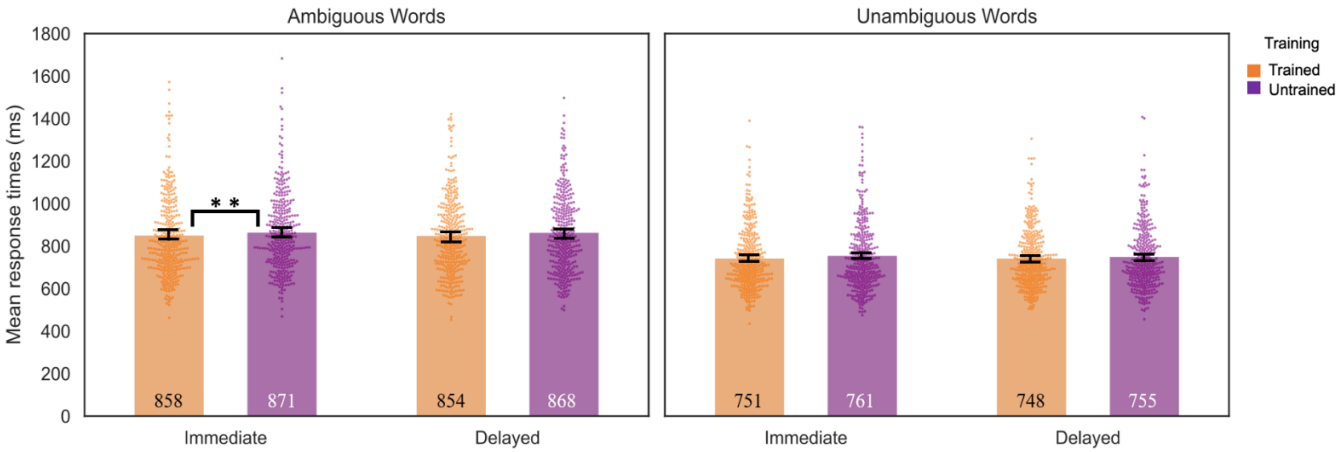
Experiment 3. Bar Plot with Mean Accuracy as a Function of Training (Trained and Untrained), Ambiguity (Ambiguous and Unambiguous), and Delay (Immediate and Delayed).



Note. Error bars represent the 95% within-subject confidence intervals (Morey, 2008). Dots show the mean accuracy for each subject in each condition.

Figure 3.5

Experiment 3. Bar Plot with Mean Response Times (ms.) as a Function of Training (Trained and Untrained), Ambiguity (Ambiguous and Unambiguous), and Delay (Immediate and Delayed).



Note. Error bars represent the 95% within-subject confidence intervals (Morey, 2008). Dots show the mean response time for each subject in each condition.

Linear Mixed Effects Analysis

Responses were analysed with linear mixed effects models, following the same data transformation and model comparison approach as described in Experiments 1 and 2, using the 'lme4' package (Bates et al., 2015) and RStudio Team v.4.0.2 (R Core Team, 2019). Models were fit with the glmer () function (with bobyqa optimiser) for accuracy data, and the lmer () function for response times. The models were based on a 2 x 2 x 2 within-subjects design with fixed effects for Training (deviation-coded as Trained 1/2 and Untrained –1/2) Ambiguity (deviation-coded as Subordinate -1/2 and Unambiguous 1/2), and Delay (deviation-coded as Immediate -1/2 and Delayed 1/2). The two-way interactions include

those between Training and Ambiguity, Training and Delay, and Ambiguity and Delay, the three-way interaction includes the one between Training, Ambiguity, and Delay. Maximal models included a random intercept and random slopes for all fixed effects and all interactions by subjects, and a random intercept and random slopes for Training, Delay, and the Training by Delay interaction by items.

To evaluate main effects and interactions we used Likelihood ratio tests. For both accuracy and response times, the maximal converging model was compared to models where each of the fixed effects were removed. We report β values, standard errors, z-/t-values for the model parameters, and Chi-squared values and p-values (**α** set to .05) from likelihood ratio tests. For RT analyses, RT data was inverse transformed.

Accuracy

The pattern of results revealed by Figure 3.4 indicates that the mean accuracy for ambiguous words was higher for trained than untrained items, a difference (0.04) that was bigger at delayed test (0.05) than at immediate test (0.03). For unambiguous words, the mean accuracy was higher for trained than untrained items, a difference that was equal across Delay conditions (0.01).

Full Dataset: The maximal model that converged included a random intercept and random slopes for Ambiguity, and the interactions between Training and Delay, and Ambiguity and Training and Delay by subjects, without accounting for their correlation, and a random intercept by items.

There was a significant main effect of Training ($\beta = 0.18$, $SE = 0.05$, $z = 4.14$; $\chi^2(1) = 16.65$, $p < .001$), with greater accuracy in the trained ($M = 0.79$, $SD = 0.41$) than the untrained condition ($M = 0.76$, $SD = 0.43$).The main effect of Ambiguity was significant ($\beta = 1.83$, $SE = 0.41$, $z = 4.47$; $\chi^2(1) = 17.25$, $p < .001$), with greater accuracy for unambiguous words ($M = 0.87$, $SD = 0.34$) compared to ambiguous words ($M = 0.69$, $SD = 0.46$). The

main effect of Delay was significant (β = -0.19, SE = 0.05, z = -4.22; χ^2 (1) = 17.32, p < .001), with higher accuracy at immediate test (M = 0.79, SD = 0.41) compared to delayed test (M = 0.77, SD = 0.42). None of the interactions were significant: Training and Ambiguity (β = -0.14, SE = 0.09, z = -1.59; χ^2(1) = 2.45, p = .117), Training and Delay (β = 0.11, SE = 0.09, z = 1.23; χ^2(1) = 1.47, p = .225), Ambiguity and Delay (β = -0.08, SE = 0.09, z = -0.87; χ^2(1) = 0.73, p = .392), Ambiguity and Training and Delay (β = -0.09, SE = 0.18, z = -0.51; χ^2(1) = 0.25, p = .617).

As per our preregistration, to test training effects for ambiguous words and unambiguous words, the data was separated in two datasets, one for each word type, including fixed effects for Training, Delay, and the interaction between Training and Delay. These models include a random intercept and random slopes for Training, Delay, and the interaction for both subjects and items.

Ambiguous Words Data Subset: The maximal model that converged included a random intercept and random slopes for Delay, and the interaction between Training and Delay by subjects, without accounting for their correlation, and a random intercept and random slope for Delay by items, without accounting for their correlation.

The main effect of Training was significant (β = 0.26, SE = 0.05, z = 4.85; χ^2 (1) = 23.00, p < .001), with greater accuracy in the trained condition (M = 0.70, SD = 0.46) than in the untrained condition (M = 0.67, SD = 0.47). There was a significant main effect of Delay (β = -0.15, SE = 0.06, z = -2.64; χ^2 (1) = 6.10, p = .014), with greater accuracy at immediate test (M = 0.70, SD = 0.46) than at delayed test (M = 0.67, SD = 0.47). The interaction between Training and Delay was not significant (β = 0.16, SE = 0.11, z = 1.44; χ^2 (1) = 2.02, p = .155).

Despite the absence of a significant interaction between Training and Delay, post-hoc tests were performed as described in our preregistration using the emmeans () function in R

(Russell V., 2021) to investigate Training effects on accuracy at immediate and delayed test separately. The effect of Training was significant at immediate test (β = -0.18, SE = 0.08, z-ratio = -2.32, p = .021) with higher accuracy in the trained condition (M = 0.71, SD = 0.45) than the untrained condition (M = 0.68, SD = 0.47), and at delayed test (β = -0.33, SE = 0.08, z-ratio = -4.44, p < .001) with higher accuracy in the trained condition (M = 0.70, SD = 0.46) than the untrained condition (M = 0.65, SD = 0.48).

Unambiguous Words Data Subset: The maximal model that converged included a random intercept by subjects and a random intercept and random slopes for Delay and the interaction between Training and Delay by items, without accounting for their correlation.

The main effect of Training was not significant (β = 0.12, SE = 0.07, z = 1.64; χ^2 (1) = 2.55, p = .11). There was a significant main effect of Delay (β = -0.26, SE = 0.09, z = -2.85; χ^2 (1) = 8.34, p = .004), with greater accuracy at immediate test (M = 0.87, SD = 0.33) than at delayed test (M = 0.86, SD = 0.35). The interaction between Training and Delay was not significant (β = 0.07, SE = 0.16, z = 0.41; χ^2 (1) = 0.16, p = .693).

Despite the absence of a significant interaction between Training and Delay, post-hoc tests were performed using the emmeans () function in R (Russell V., 2021) to investigate training effects on accuracy at immediate and delayed test separately. The effect of training was not significant at immediate test (β = -0.09, SE = 0.11, z-ratio = -0.78, p = .437) or delayed test (β = -0.15, SE = 0.11, z-ratio = -1.44, p = .151).

Response Times

Results revealed by Figure 3.5 show faster responses for ambiguous items in the trained than the untrained condition, a difference that was equal across Delay conditions (15 ms.). Similarly, unambiguous words showed faster responses in the trained condition, however the difference between Training conditions (11.5 ms.) was bigger at immediate test (15 ms.) than at delayed test (8 ms.).

Full Dataset: Response times were inverse transformed prior to analysis, based on visual inspection of histograms of model residuals and predicted-vs-residual plots. The maximal model that converged included a random intercept and random slope for Delay by subjects, and a random intercept by items.

There was a significant main effect of Training (β = <0.01, SE = <0.01, t = 4.64; χ^2 (1) = 21.50, p < .001), with faster responses in the trained (M = 797.05, SD = 286.32) than the untrained condition (M = 806.75, SD = 291.33). The main effect of Ambiguity was significant (β = <0.01, SE = <0.01, t = 3.90; χ^2 (1) = 13.86, p < .001), with faster responses for unambiguous words (M = 753.58, SD = 268.01) compared to ambiguous words (M = 862.68, SD = 302.35). The main effect of Delay was not significant (β = <0.01, SE = <0.01, t = 0.18; χ^2 (1) = 0.03, p = .860). The interaction between Training and Ambiguity was significant (β = <-0.01, SE = <0.01, t = -2.31; χ^2 (1) = 5.32, p = .021). The rest of the interactions were not significant: Training and Delay (β = <-0.01, SE = <0.01, t = -0.87; χ^2(1) = 0.76, p = .384), Ambiguity and Delay (β = <-0.01, SE = <0.01, t = -1.23; χ^2(1) = 1.51, p = .219), Ambiguity and Training and Delay (β = <0.01, SE = <0.01, t = 1.05; χ^2(1) = 1.09, p = .296).

To test Training effects for ambiguous words and unambiguous words, the data was separated in two datasets, one for each word type. Response times were inverse transformed prior to analysis, based on visual inspection of histograms of model residuals and predicted-vs-residual plots. Maximal models included fixed effects for Training, Delay, and the interaction between Training and Delay, and a random intercept and random slopes for Training, Delay and the interaction by subjects and items.

Ambiguous Words Data Subset: The maximal model that converged included a random intercept and random slope for Delay by subjects, and a random intercept and random slope for Training by items.

The main effect of Training was significant (β = <0.01, SE = <0.01, t = 2.48; χ^2 (1) = 5.56, p = .018), with faster responses in the trained condition (M = 856.14, SD = 301.35) compared to the untrained condition (M = 869.58, SD = 303.29). The main effect of Delay was not significant (β = <0.01, SE = <0.01, t = 0.85; χ^2 (1) = 0.73, p = .394). The interaction between Training and Delay was not significant (β = <-0.01, SE = <0.01, t = -1.23; χ^2 (1) = 1.50, p = .221).

Despite the absence of a significant interaction between Training and Delay, post-hoc tests were performed using the emmeans () function in R (Russell V., 2021) to investigate training effects on response times at immediate and delayed test separately. The effect of Training was significant at immediate test (β = <-0.01, SE = <0.01, z-ratio = -2.82, p = .005) with faster responses in the trained condition (M = 857.89, SD = 312.84) than the untrained condition (M = 871.24, SD = 293.97), but was not significant at delayed test (β = <-0.01, SE = <0.01, z-ratio = -1.54, p = .124).

Unambiguous Words Data Subset: The maximal model that converged included a random intercept and random slopes for Training, Delay and the interaction between Training and Delay by subjects, not accounting for their correlations, and a random intercept and random slopes for Training and Delay by items, not accounting for their correlations.

The main effect of Training was not significant (β = <0.01, SE = <0.01, t = 1.43; χ^2 (1) = 2.05, p = .152). The main effect of Delay was not significant (β = <-0.01, SE = <0.01, t = -0.37; χ^2 (1) = 0.14, p = .713). The interaction between Training and Delay was not significant (β = <0.01, SE = <0.01, t = 0.10; χ^2 (1) = 0.01 p = .924).

Despite the absence of a significant interaction between Training and Delay, post-hoc tests were performed using the emmeans () function in R (Russell V., 2021) to investigate training effects on response times at immediate and delayed test separately. The effect of

Training was not significant at immediate (β = <-0.01, SE = <0.01, z-ratio = -1.06, p = .291) or delayed test (β = <-0.01, SE = <0.01, z-ratio = -1.17, p = .243).

3.2.4 Discussion

The goal of Experiment 3 was to explore the effects of mixed-exposure to the different meanings of English ambiguous words on the processing of subordinate meanings after a delay of 24 hours. This experiment follows the findings revealed by Experiments 1 and 2, where a facilitation effect for subordinate meanings was observed at immediate test. Aiming to boost the weak facilitation effect observed in the previous experiments, participants were exposed three times to subordinate meanings, and three times to the dominant meanings of ambiguous words. Given the absence of effects for dominant meanings showed by Experiment 1, Experiment 3 just tested priming effects for subordinate meanings.

To analyse the findings and the main contributions of Experiment 3, this discussion will summarise the general pattern of results obtained by focusing on the four key hypotheses set out in the introduction. These hypotheses include a main effect of Ambiguity for ambiguous and unambiguous words, and, for ambiguous words only, a main effect of Training, an interaction between Training and Delay, and simple effects of Training at both immediate and delayed test. Since the purpose of this experiment was to test mixed-exposure effects after 24 hours, the Delay factor will be analysed in more detail than the others, paying special attention to the time-course of mixed-exposure effects.

Effect of Ambiguity

Results observed in Experiment 3 support the hypothesis made about the main effect of Ambiguity. Responses were significantly more accurate and faster for unambiguous words compared to ambiguous words, collapsed across Training and Delay conditions. The

ambiguity disadvantage observed in Experiment 3 is consistent with the results found in Experiments 1 and 2, and the growing body of evidence (e.g. Armstrong et al., 2016; Duffy et al., 1988; Rodd et al., 2002; Vitello et al.,, 2015) that shows the additional cognitive effort needed to resolve the semantic competition between unrelated meanings of ambiguous words.

Effect of Training for Ambiguous Words

The hypothesis made about the main effect of Training for ambiguous words also found support in Experiment 3. A significantly increased accuracy and significantly faster responses were observed for trained ambiguous words, collapsed across delay conditions. The facilitation effect found for the processing of subordinate meanings after mixed-exposure extends those findings revealed by Experiments 1 and 2. Specifically, Experiment 3 provides evidence that this facilitation effect can be found after repeated encounters to the dominant and subordinate meanings of ambiguous words. Furthermore, the analysis of simple effects of Training revealed that the facilitation effect is present immediately after Training and after a delay of 24 hours for accuracy, and just immediately after Training for response times. These findings provide additional support to the claim that the semantic competition that may come from exposure to the dominant meaning does not overwhelm positive priming effects for the subordinate one, suggesting that priming effects have a bigger impact than the semantic competition that naturally occurs between unrelated meanings of ambiguous words.

Effect of Delay for Ambiguous Words

Experiment 3 showed a main effect of Delay, which was significant on accuracy, though not on response times. The reason for the overall decrease in accuracy at delayed test compared to immediate test, irrespective of training, could be explained because in session 1 participants had just been engaged with the training task, which may have focused their

attention on the test task. It is worth noting that the sleep data was not analysed, so the conclusions about the role of sleep in priming effects (after extended delays) is somewhat limited and requires further investigation.

Moreover, the pattern of results showed by Experiment 3 does not support the one made about the interaction between Training and Delay for ambiguous words. The absence of a significant interaction between Training and Delay for accuracy and response times, showed that there was no significant difference in the magnitude of the training effect at the delayed test compared with the immediate test.

The absence of a significant interaction between Training and Delay for ambiguous words is supported by the simple effects of Training for accuracy, which showed that the Training effect is significantly present immediately and after a delay of 24 hours. However, simple effects of Training for response times showed that the Training effect was significantly present immediately after exposure, but just numerically present after 24 hours. Overall, the lack of an interaction between Training and Delay, as well as the simple effects of Training, do not provide evidence of a decay in the facilitation effect for subordinate meanings over 24 hours following repeated mixed-exposures.

These results are valuable for the following reasons. First, they further extend the facilitation effect observed at immediate test for subordinate meanings after mixed-exposure revealed by Experiments 1 and 2, to a delayed test of 24 hours, thus providing consistent evidence of positive priming effects in the context of mixed-exposure, even after an extended delay. Second, they are inconsistent with the evidence that the facilitation effect for subordinate meanings after a recent exposure to this meaning tends to decay over time (Gaskell et al., 2019; Rodd et al., 2013, 2016), because this experiment showed no evidence of a decrease in priming between immediate and delayed test conditions. Finally, they support the body of evidence that suggests that sleep preserves the retention and integration

of linguistic knowledge (Bakker et al., 2014; Bakker-Marshall et al., 2018; Dumay et al., 2007; Hulme et al., 2023; Kurdziel et al., 2017; Mak et al., 2023; Tamminen et al., 2010), and specifically the facilitation effect for the subordinate meaning of ambiguous words (e.g. Gaskell et al., 2019).

Effects for Unambiguous Words

No predictions were made for unambiguous words, but, given the unexpected observation of priming effects for these words in Experiments 1 and 2, it is worth reviewing the pattern of results for these words observed in Experiment 3. In contrast to Experiments 1 and 2, Experiment 3 showed an absence of a main effect of Training effects on both accuracy and response times. This finding supports the idea that weaker lexical-semantic representations (e.g. subordinate meanings) are more susceptible to improvement than stronger ones (e.g. unambiguous words). Regarding the main effect of Delay, this was significant on accuracy, but not on response times, effect that is characterized by a significant decrease in accuracy at delayed test compared to immediate test. The reason for the significant main effect of Delay could be the same as the one suggested for ambiguous words, a maintenance of the level of attention between the training and test task. The interaction between Training and Delay was not significant for accuracy or response times, and the simple effects of Training at both immediate and delayed test conditions revealed no significant differences with untrained items on both accuracy and response times. Overall, the lack of a Training effect for unambiguous words is inconsistent with the results found in Experiments 1 and 2, where this effect was sometimes observed on accuracy and response times measures. In sum, the absence of a significant effect of Training for unambiguous words suggests that the lexical-semantic representations of these words are strong, and consequently less susceptible to improve after recent encounters with them.

Implications for the Immediate Alteration Account and the Episodic Context Account

It is worth noting that the facilitation effect for subordinate meanings after immediate (Experiments 1, 2, and 3) and delayed test conditions (Experiment 3) could be explained by the Immediate Alteration Account, because this account suggests an immediate update of the long-term lexical-semantic knowledge of the word after a recent encounter with it. Under the latest version of this account, mixed-exposures could immediately update the connections in the semantic layer for both dominant and subordinate meanings, thus accounting for Training effects for subordinate meanings at immediate and delayed test conditions. The main drawback of the Immediate Alteration Account is that it cannot integrate those studies that support the idea that sleep preserves the retention and integration of linguistic knowledge (Bakker et al., 2014; Bakker-Marshall et al., 2018; Dumay et al., 2007; Hulme et al., 2023; Kurdziel et al., 2017; Mak et al., 2023; Tamminen et al., 2010), and specifically the facilitation effect of sleep after priming for subordinate meaning of ambiguous words (e.g. Gaskell et al., 2019). These studies suggest that the retention and integration of linguistic knowledge could be explained by a process of consolidation of these recent encounters, a process that is not considered by the Immediate Alteration Account.

In this context, the Episodic Context Account seems to explain the results obtained in Experiment 3 and those revealed by sleep studies. First, the fact that this facilitation was found at immediate and delayed test for trained items maintains the possibility that these items use could use both the long-term lexical-semantic representation of dominant and subordinate meanings, and the temporary representations of these meanings that are created after these recent encounters with them, However, our data cannot make the distinction if this facilitation effect is explained by the use of one of these sources or both of them. Second, since the Episodic Context Account suggests that the consolidation of new episodic memories happens when there is a transfer of hippocampal memories to the neocortex,

process that is facilitated by a period of sleep, the preservation of the facilitation effect for subordinate meanings after 24 hours observed in Experiment 3 could be explained by the presence of overnight sleep. Although Experiment 3 did not include an awake condition to clarify this assumption, this data is consistent with the growing body of evidence revealed by sleep studies (Curtis et al., 2022; Gaskell et al., 2019; Hulme & Rodd, 2023; Mak et al., 2023).

In sum, the key advantage of the Episodic Context Account over the Immediate Alteration Account, is that the first suggests the use of two memory systems, one for knowledge that must be generalized beyond a particular context (semantic representations), and another for unique context-specific representations (episodes), and not just one for long-term semantic representations as the Immediate Alteration Account suggests. The use of a memory system for unique episodes created after a particular experience with a specific word meaning allows the subsequent integration and consolidation of this linguistic experience, processes that are facilitated after a period of sleep. These processes of integration and consolidation are absent under the Immediate Alteration Account because this account suggests an immediate update of the long-term lexical semantic knowledge. Taken together, the findings from Experiments 1, 2, and 3 are consistent with the previous evidence about the facilitation effect for subordinate meanings after an exposure to this meaning (Betts et al., 2018; Gilbert et al., 2018; Rodd et al., 2013, 2016), facilitation that can be preserved in a context of semantic competition between unrelated meanings of ambiguous words, even after an extended delay of 24 hours. By having made clear the contribution of the results of Experiments 1, 2, and 3, and how they are integrated into the word-meaning priming literature, the upcoming section will describe the main limitations of Experiment 3, and what can be done next to further investigate positive priming effects.

Limitations and Future Directions

Overall, Experiment 3 suggests that positive priming effects are stronger than the natural semantic competition between unrelated meanings of ambiguous words, even during extended periods of time. Despite this valuable result, one limitation of this experiment is that it does not completely characterize the time-course of the facilitation effect for subordinate meanings. As mentioned in the introduction to this chapter, this facilitation effect tends to decay at some point before 20 minutes, at least after a single exposure to this meaning, as suggested by Rodd et al. (2013; Experiment 3) and Rodd et al. (2016; Experiment 2). The exploration of the time-course of this facilitation effect at shorter delays (e.g. 3-20-40 minutes) will test whether the pattern of results observed by Rodd et al. (2013; Experiment 3) can be found in a context of mixed-exposure. The exploration of this issue will help to better understand the interaction between priming, delay, and semantic competition effects.

3.2.5 Conclusions

To conclude, the experiments presented in Chapters 2 and 3 revealed that, despite the semantic competition between unrelated meanings of ambiguous words, it is possible to find a facilitation effect for subordinate meanings after a single mixed-exposure (Experiments 1 and 2) and repeated mixed-exposures (Experiment 3). This facilitation effect was also found after one day following three mixed-exposures, as showed by Experiment 3. Taken together, these findings provide evidence that unrelated meanings of ambiguous words can be boosted independently, thus contradicting strong claims of semantic competition, which predict that the boosting of the dominant meaning will overwhelm positive priming effect of the subordinate one. The fact that it is possible to observe a facilitation effect for subordinate meanings after mixed-exposure provides additional evidence of the strength of word-meaning priming effects revealed by several studies (e.g. Betts et al., 2018.; Curtis et al., 2022;

Gaskell et al., 2019; Gilbert et al., 2018, 2021; Mak et al., 2023; Rodd et al., 2013, 2016), and suggests that this effect is stronger than the semantic competition well characterized by Distributed Connectionist models.

CHAPTER 4: THE TIME-COURSE OF WORD-MEANING PRIMING AND SEMANTIC PRIMING

4.1 Introduction

Previous chapters have provided evidence that supports the flexibility of lexical-semantic representations of ambiguous words in English. When adults are exposed to a single or repeated exposures to the dominant and subordinate meanings of ambiguous words, subsequent responses are faster and more accurate to the primed subordinate meaning. This improvement in processing for subordinate meanings can be detected immediately and after a delay of 24 hrs. Despite the consistency of these findings, it is important to note that the word-meaning priming effect seen in these studies has relied on the presentation of the target word in the prime sentence. This chapter will explore whether such effects can be explained by a more general type of semantic priming that doesn't rely on the presentation of the target English ambiguous word itself. This question is theoretically relevant because it will clarify whether word-meaning priming modifies the specific semantic representation of the target word or arises from a more general semantic representation created by the information provided by the context.

Aiming to interpret the findings of the experiment presented in this chapter, the next section provides a recapitulation of the key theories presented in the General Introduction that explain the mechanism(s) behind priming effects.

4.1.1 Immediate Alteration Account and Episodic Context Account

The Immediate Alteration Account suggested by Rodd et al. (2013) and named by Gaskell et al. (2019) argues that word-meaning priming effects should be explained by an immediate updating of long-term connections between a word's written or spoken form and its lexical/semantic representation. This form-to-meaning connection suggests that the form of

a homonym is associated with its different meanings, where dominant meanings have stronger weights than subordinate meanings. Under this account word-meaning priming effects could be explained as alterations to the strengths of the connections between the form of an ambiguous words and the primed meaning.

A second version of the Immediate Alteration Account suggests that word-meaning priming results from a strengthening of the connections among semantic units. This explanation of long-term priming based on semantic information is proposed by Becker and colleagues (1997) who argue that experience with prime words deepens the attractor basins for those words in the semantic layer, consequently semantically related words are affected by this change because of their overlap in semantic space. Similarly, Rodd et al. (2016) argue that equivalent changes to the connections within the semantic layer could potentially make the attractor basin for that meaning more stable, relative to the alternative unprimed meaning. These changes in the semantic layer can explain why during the next encounter with an ambiguous word, even in the absence of any biasing context, the final settled state of the network is more consistent with the primed meaning.

This alternative version of the Immediate Alteration Account may be the preferred one now because recent findings from Gilbert et al. (2018) observed the presence of significant cross-modal priming. This implies that instead of the specific change between the form-to-meaning connections of a particular word, what is being altered are the connections in the semantic layer. Importantly, this possible interpretation of cross-modal word-meaning priming effects makes them more abstract that previously thought. In this context, the second version of the Immediate Alteration Account makes this account more compatible with the idea that word-meaning priming is supplemented by semantic priming, aspect that is not considered by its first version. Overall, the Immediate Alteration Account argues that each experience with an ambiguous word immediately alters its long-term cortical lexical-

semantic connections. Although it is still uncertain whether this alteration is to the connections between form and meaning or among the semantic units themselves, both options explicitly suggest that the stored knowledge of the ambiguous word itself is being altered.

Although, the Immediate Alteration Account offers a viable option to interpret priming effects, the results of the experiment presented here will also be interpreted under the Episodic Context Account. This alternative account has been developed to integrate some recent findings related to the duration of this effect, and the possible influence of a sleep associated consolidation in the subsequent retrieval of a particular meaning of ambiguous words. The Episodic Context Account proposes that when a novel word is encountered in a disambiguating context, a new and temporary memory trace for the comprehension episode is created by the hippocampus. This temporary representation acts as an additional source of information alongside permanent lexical knowledge and influences a word's subsequent interpretation (Gaskell et al., 2019). Instead of immediate changes in connections weights between semantic units, as is suggested by the latest version of the Immediate Alteration Account, the Episodic Context Account argues that when a word is encountered in a sentence context the hippocampus creates a new memory for that episode, combining in a particular way all the elements of the sentence, or creating a new association between words (Eichenbaum et al., 1995).

The results of the experiment presented in this chapter will be interpreted under the Immediate Alteration Account and the Episodic Context Account. The goal is to analyse if word-meaning priming effects are based on the presence of the specific ambiguous word, or if they are based on a more general semantic representation created by the information provided by the context. With this purpose the following section will characterize semantic

priming and provide recent evidence that supports the possibility that word-meaning priming might be supplemented by general semantic priming effects at shorter delays.

4.1.2 Semantic Priming

Semantic priming refers to the facilitation of a faster response to a target due to prior exposure to a stimulus that is related in meaning (Meyer et al., 1971). For more than a century it has been established that word identification can be facilitated by prior exposure to a word related in meaning (Harley, 2001). Meyer and Schvaneveldt (1971) demonstrated that word identification in lexical decision is facilitated if the target word is immediately preceded by a word related in meaning. For instance, it is easier to recognize a word (e.g., “ruler”) if you have just seen a word that is related in meaning (e.g., “leader”). The general idea is that if two linguistic stimuli are semantically similar, they will either assist with or interfere with each other. This effect is called semantic priming. If priming causes processing to be speeded up, we talk about facilitation; if priming causes processing to be slowed down, we talk about inhibition.

One important characteristic of this type of priming is that it has been defined as a short-lived phenomenon, observed across a time-scale of only a few minutes (McNamara, 2005). Aiming to test relatively long-lived effects of semantic priming in English the study led by Becker (1997) offers a valid option to measure the duration of this effect. In Experiment 1 participants were exposed to five semantically related primes for each of the 15 target words. The average delay between primes and targets was 2 minutes. There was an average lag of 10 items between the given prime and the corresponding target word. For each word, participants were instructed to make a lexical decision, by responding “yes” if the item was a word or “no” if otherwise, and a semantic decision, responding “yes” if the item represented something living and “no” if otherwise. The ANOVA for reaction times on

correct responses by subjects showed a significant effect of priming and a significant interaction between priming and type of task. T tests revealed a significant priming effect on the semantic decision task but not on the lexical decision task. On average participants were 43 ms. or 5.7% faster in making semantic decisions for primed than unprimed words. In sum, these results showed the presence of semantic priming after a short delay, but only on a semantic task.

In a second experiment, Becker (1997) used the same materials of Experiment 1 but only one prime was presented for each target word. Since there was no evidence of semantic priming on the lexical decision task in Experiment 1 participants just completed the semantic decision task in Experiment 2. The procedure was similar to Experiment 1, but participants completed just one block where half of the 30 target words were primed. The pause between prime and target list was 2 minutes. There was an average lag of 21.5 items between the given prime and the corresponding target word. As in Experiment 1 semantic priming produced a facilitatory effect on the semantic decision task. The ANOVA for reaction times on correct responses by subjects revealed a significant main effect of priming. On average participants were 35 ms. or 4.9% faster in making semantic decisions for primed than unprimed words. It is important to note that despite the reduction from five semantic primes in Experiment 1 to one semantic prime in Experiment 2 the reduction of semantic priming effects was small (0.8%) which supports the idea that semantic priming is strong at short delays. Interestingly, the increased average in the number of items between prime and target in Experiment 2 (21.5) compared to Experiment 1 (10) did not significantly change the size of semantic priming between both experiments.

Short lived effects of semantic priming are not restricted to studies that use pairs of related words. Using word-meaning priming Rodd et al. (2013: Experiment 3) primed the subordinate meaning of English ambiguous words through spoken sentences. This

experiment aimed to assess: (1) if word-meaning priming is contingent on the presence of the ambiguous word or if its effects reflect a general type of semantic priming, and (2) explore the time-course of word-meaning priming and semantic priming. During priming participants heard sentences that disambiguated ambiguous words towards their subordinate meaning, these sentences either included the target word in the word-meaning priming condition (e.g. "The **ruler** of the country was very popular indeed") or included an unambiguous synonym that replaced it in the semantic priming condition context (e.g. "The **leader** of the country was very popular indeed"). This experiment followed a between subject design where participants were assigned to the primed or unprimed condition. After short (3 min.) and long delays (20 min.) a word association task measured meaning preferences of the target words. In this test task participants heard a spoken word and typed the first word that came to mind that was related to the word just heard. Results showed that the number of associates related to the subordinate meaning was significantly higher in the primed than the unprimed condition across prime types after a short, 3-minute delay. In contrast, after the longer 20-minute delay results showed only a significant effect of word-meaning priming (where the target word is presented in the prime sentence), the effect of semantic priming (where the target word is replaced with a synonym in the prime sentence) was not significant. When the two types of priming were directly compared, there was no significant difference between word-meaning priming and semantic priming at the short delay. In contrast, at the longer delay greater priming was observed in the word-meaning priming condition compared with the semantic priming condition. However, the critical interaction between Prime-Type and Delay did not reach significance, which is likely due to a lack of power. Overall, findings from Rodd et al. (2013: Experiment 3) further support the idea that semantic priming effects are short lived, and that word-meaning priming can be observed at longer delays, thus

providing evidence that semantic priming and word-meaning priming are supported by different mechanisms with different time courses.

In contrast, Curtis et al. (2022) conducted a series of three experiments using spoken sentences to prime a particular aspect of the meaning of English low-ambiguous words (e.g. "luggage-heavy vs. luggage-suitcase") and found evidence for longer-term effects of semantic priming. Across experiments, meaning preferences were measured 20-30 minutes later through a relatedness judgement task, where participants needed to decide whether a probe word was related or not to the target, and a word association task, where they needed to generate a word related in meaning to the one previously seen. Overall, results showed greater word-meaning priming than semantic priming for accuracy in the relatedness judgement. However, no significant differences were found between word-meaning priming and semantic priming in response times in the relatedness judgement task, nor in the number of responses generated that were consistent with the primed meaning in the associate production task. To the best of our knowledge this is the first evidence of the absence of a significant difference between word-meaning priming and semantic priming after a delay of up to 20-30 minutes.

Taken together, there is inconsistent evidence provided by word-meaning priming studies about the effects of semantic priming for high and low ambiguous words at long delays. Rodd et al. (2013: Experiment 3) found semantic priming at a short but not at long delay, however their experiment was very under-powered, and Curtis et al. (2022) showed semantic priming at a long delay but this was not completely consistent across tasks/outcome measures. Further research is therefore necessary to determine if there is a clear distinction between word-meaning and semantic priming effects. To explore this issue the present replication study aims to: (1) discover if word-meaning priming relies on the presentation of the target word in the prime sentence, or if its effects can be explained by a more general type

of semantic priming that doesn't rely on the presentation of the target ambiguous word itself, and (2) find the possible differences in the time-course between word-meaning priming and semantic priming.

4.2 Experiment 4

4.2.1 Introduction

The experiment presented in this chapter is a replication of a previous study by Rodd et al. (2013; Experiment 3) where the aim is to test the possible differences in the effects and the time-course of word-meaning priming and semantic priming in English, running a well-powered experiment.

From a theoretical point of view it is important to determine whether word-meaning priming effects are significantly larger than semantic priming effects at longer delays. Rodd et al. (2013; 2016) argued that each exposure to the ambiguous word changes the representation of that specific word through a change in the stored information about the relative likelihoods of its meanings. They argued that this effect is longer lived than more general semantic priming effects. If this claim is correct then, at the longer delay, priming should be present when the ambiguous word itself is present in the prime sentence, but priming should be significantly reduced (or absent) in the semantic priming condition. In contrast, if word-meaning priming reflects a more general form of semantic priming that does not specifically rely on the presence of the ambiguous word itself but is driven by the overall meaning of the sentence, then the patterns of priming effects should be similar in the two priming conditions.

4.2.2 General Approach to This Replication

A power analysis using the data from Rodd et al. (2013) revealed the need to increase the number of participants to 180 in order to have adequate power to find a significant

interaction between Priming and Delay for the critical comparison between word-meaning priming and semantic priming. The materials, design, and procedure were the same as in the original study, however two main changes were applied to this study. First, the current study was conducted online rather than in person, which may affect the timing of the tasks, the levels of attentiveness, and the quality of the data, issues that were considered in our exclusion criteria described in the method section. Second, the time and the structure of the tasks may somewhat differ from the original experiment mainly because some important details were not fully described in the original study. As in Rodd et al. (2013), the dependent measure is the proportion of consistent associates (words consistent with the primed subordinate meaning of the ambiguous words) generated in the word association task. For example, the primed (subordinate) meaning of "ruler" would be the meaning related to leader, therefore, consistent associates would be those such as "president". Importantly, the present experiment analyses the data from the word association task using logistic mixed effects models with crossed subjects and items random effects, rather than ANOVAs as in the original study. However, the same analysis approach is taken, in which the first analysis compares word-meaning priming and unprimed items, the second compares semantic priming and unprimed items, and the third the key comparison between word-meaning priming and semantic priming, with all analyses also including a factor of Delay (short vs long).

Hypotheses

Based on the pattern of results from Rodd et al.'s original study we make the following predictions:

Comparison between word-meaning priming and unprimed conditions:

1. We predict a main effect of Priming: More consistent associates will be generated for the primed condition compared to the unprimed condition, collapsed across

Delay conditions. Simple effects of Priming are expected after both short and long delays.

2. We do not expect a main effect of Delay: A similar number of consistent associates will be generated at short and long delays, collapsed across Priming conditions. We do not expect simple effects of Delay for both priming conditions.
3. We do not expect an interaction between Priming and Delay: The number of consistent associates generated for each Priming condition won't change as a function of Delay.

Comparison between semantic priming and unprimed conditions:

1. We predict a main effect of Priming: More consistent associates will be generated for the primed condition compared to the unprimed condition. Simple effects of Priming are predicted at the short delay but not at the long delay.
2. We predict a main effect of Delay: More consistent associates will be generated at the short delay than at the long delay, collapsed across Priming conditions. Simple effects of Delay are predicted just for the primed condition.
3. We predict an interaction between Priming and Delay: More consistent associates will be generated for the primed condition at short delay than at the long delay. This won't be the case for the unprimed condition, where the number of associates generated will be similar at both delays.

Comparison between word-meaning priming and semantic priming conditions:

1. We predict a main effect of Priming Condition: More consistent associates will be generated for the word-meaning priming condition compared to the semantic priming condition. Simple effects of Prime Condition are expected after the long delay but not at the short delay.

2. We predict a main effect of Delay: More consistent associates will be generated at the short delay than at long delay, collapsed across Priming Condition. Simple effects of Delay are predicted just for the semantic priming condition.
3. We predict an interaction between Priming Condition and Delay: More consistent associates will be generated for the semantic priming condition at the short delay compared to the long delay. This won't be the case for the word-meaning condition, where the number of associates generated will be similar at both delays.

This study was preregistered on the Open Science Framework (https://osf.io/gpqj3), which specifies: the theoretical relevance of this replication, expected outcomes, design, procedure, main changes made to the experiment compared to Rodd et al. (2013), recruitment method, power analysis that justifies the sample size, coding procedure followed to classify the responses from the word association task, analysis plan, data exclusion criteria that secures the quality of the data collected, and the reasoning behind the exclusion of additional data in the missing data section. Overall, the experiment presented follows what is described in the pre-registration, the only exception being the inclusion of a minimum level of performance of 70% in the repetition of the target word in the word association task for each participant. This was added to protect the quality of the data in this task, since it was found that four participants failed to achieve this criteria and, consequently, they provided associates related to the wrong target word. These participants were excluded from the analysis and replaced with new ones.

4.2.3 Method

Participants

189 participants were recruited online through Prolific (Palan et al., 2018, www.prolific.co), their age range was between 18 and 25 years, all of them were native

speakers of British English, currently U.K. residents, without a report of hearing or reading impairment, and they had normal or corrected to normal vision. These requirements were pre-screened on Prolific and those participants that didn't satisfy them weren't allowed to take part in the experiment. Participants were paid at a rate of £9 per hour for taking part in the study. The UCL Department of Experimental Psychology Ethics Committee approved this experiment.

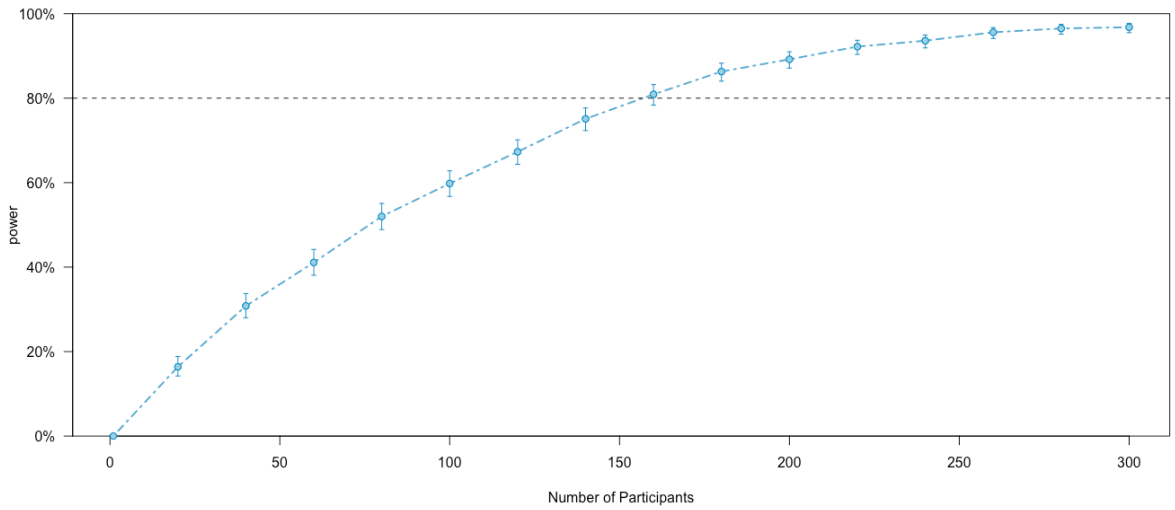
According to our pre-registered criteria some participants were excluded from this experiment if they: (i) misunderstood the instructions, which means that they completed one or more tasks incorrectly, thus providing data that cannot be analysed (n = 0); (ii) didn't provide a complete dataset (those who failed to complete the experiment) (n = 0); (iii) let us know of some technical difficulties during the experiment (n = 0); (iv) had a mean accuracy lower than 70% in the semantic relatedness task (n = 1), to ensure appropriate attention to both types of prime sentences; (v) did not type a digit on more than 25% of trials in the digit span task, to check if participants followed the instructions correctly (n = 2); (vi) had a mean accuracy lower than 31% in the digit span task, securing the correct recall of strings composed of three, four, and five digits (minimum performance expected in this task) (n = 1); (vii) had an average accuracy of less than 70% when repeating the target word in the word association task, to secure the correct hearing of the target word (n = 3) (this criteria wasn't included in the pre-registration but it was added to secure the quality of the data). Lastly, some participants (n = 2) were excluded due to low performance in more than one task, both got a mean accuracy lower than 70% in the semantic relatedness task, one had a mean accuracy lower than 70% when repeating the target word in the word association task, and the other got an average accuracy below 31% in the digit span task. Following these requirements, the data of 9 subjects was excluded, and consequently the performance of each

task and the linear mixed effect analysis of the word association task included the data of 180 participants.

The number of participants in this replication was determined from a power analysis carried out with the data from the word association task from Rodd et al. (2013) (N = 42), which showed the associates generated by participants (across priming conditions) that they thought was related in meaning to the word presented. This analysis was done using the "simr" package (version: 1.0.6; Green & MacLeod, 2016) in R (version: 4.2.0; R Core Team. 2022). A subset of the data was made for the key comparison of interest between word-meaning priming and semantic priming and a logistic linear-mixed effects model was fitted to the subset data. To fit the model we used the glmer() function for the binary measure of consistent associates (1 = consistent, 0 = inconsistent) from the "lme4" package (version: 1.1-29; Bates et al., 2015) in R (version: 4.2.0; R Core Team. 2022). The model contained the fixed effects of Priming (deviation-coded as word-meaning priming 1/2 and semantic priming -1/2), Delay (deviation-coded as short 1/2 and long -1/2), and the interaction between Priming and Delay, and random intercepts by-participants and by-items (but no random slopes). The power calculation indicated that we needed 180 participants to achieve 80% power to find a significant interaction ($\alpha = .05$) between Priming and Delay for the critical comparison between word-meaning priming and semantic priming in terms of the proportion of consistent associates generated in the word association task (Figure 4.2 shows the power curve). The R code with the linear-mixed effects analysis, the power analysis, and the data used to run it is available on the Open Science Framework (https://osf.io/7k4fm/).

Figure 4.1

Experiment 4. Power Curve to Determine the Number of Participants.



Note. Power curve generated using the data taken from Rodd et al. (2013). According to this analysis 180 participants are required to have sufficient power to find a significant interaction between Prime-Type and Delay for the key comparison between word-meaning priming and semantic priming.

Design

The present study replicates the design followed by Rodd et al. (2013; Experiment 3) and is a 3 x 2 design with the within-subject factors of Priming (word-meaning priming/semantic priming/unprimed) and Delay (short/long). This design allows the replication of the analysis approach used by Rodd et. al., which included a series of 2 x 2 factorial designs to make direct pairwise comparisons between the different priming conditions, the effects of delay, as well as the interactions between Priming and Delay.

Stimuli

All stimuli were taken from Rodd et al. (2013; Experiment 3). A total of 54 English ambiguous words (target words), 54 synonyms related to the subordinate meaning of the ambiguous words, and 18 low-ambiguous words (filler words) were included in this experiment. Ambiguous words were either non-homographic homophones (e.g., "prophet/profit") or homonyms (e.g., "deck") and their subordinate meaning was chosen on the basis of dominance norms (Gawlick-Grendell et.al., 1994; Nelson et al., 1980; Sereno et al., 1992; Twilley et al., 1994). 54 word-meaning prime sentences contained the target ambiguous words, which were disambiguated towards their subordinate meaning (e.g. "The **ruler** of the country was very popular indeed"). 54 semantic prime sentences were the same as the word-meaning priming sentences with the exception that the ambiguous word was replaced with a low-ambiguity word with the same meaning in that particular context (e.g. "The **leader** of the country was very popular indeed"). Lastly, 18 low-ambiguous sentences were added to act as fillers, they had similar structure (e.g. "The boy was told that the **ocean** contained many different animals"). These sentences had a mean length of 11.9 words.

This experiment used the original audio files of words and sentences from Rodd et al. (2013), which were recorded by a female speaker of British English (JMR). Written and audio files of words and sentences used in this replication are available on the Open Science Framework (https://osf.io/axd59/).

Counterbalancing

The 54 pairs of sentences were split into six sets of nine sentences, thus creating six versions of the experiment. Each version included each of these sets in one of the six conditions (word-meaning priming at short delay, word-meaning priming at long delay, semantic priming at short delay, semantic priming at long delay, unprimed at short delay, and

unprimed at long delay). These sets were counterbalanced across versions, ensuring that each set was only present in a particular condition in one version of the experiment, but present in all conditions across versions. In other words, each participant (assigned to a particular version of the experiment) was tested on each ambiguous word in just one condition, but across participants (assigned to different versions of the experiment) each ambiguous word was present equally in all conditions. 18 low-ambiguous filler sentences were added to distract from the ambiguity. Nine additional low-ambiguous sentences were included in the practice block and two extra low-ambiguous sentences were added at the beginning of the experimental blocks (one at the beginning of each block) to ensure the correct completion of the task. Table 4.1 shows the counterbalancing across priming and test.

Table 4.1

Experiment 4. Counterbalancing of Items Across Priming and Test.

	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
Set 1	WMP Long	Semantic Long	Unprimed Long	WMP Short	Semantic Short	Unprimed Short
Set 2	WMP Short	Semantic Short	Unprimed Short	WMP Long	Semantic Long	Unprimed Long
Set 3	Semantic Long	Unprimed Long	WMP Long	Semantic Short	Unprimed Short	WMP Short
Set 4	Semantic Short	Unprimed Short	WMP Short	Semantic Long	Unprimed Long	WMP Long
Set 5	Unprimed Long	WMP Long	Semantic Long	Unprimed Short	WMP Short	Semantic Short
Set 6	Unprimed Short	WMP Short	Semantic Short	Unprimed Long	WMP Long	Semantic Long

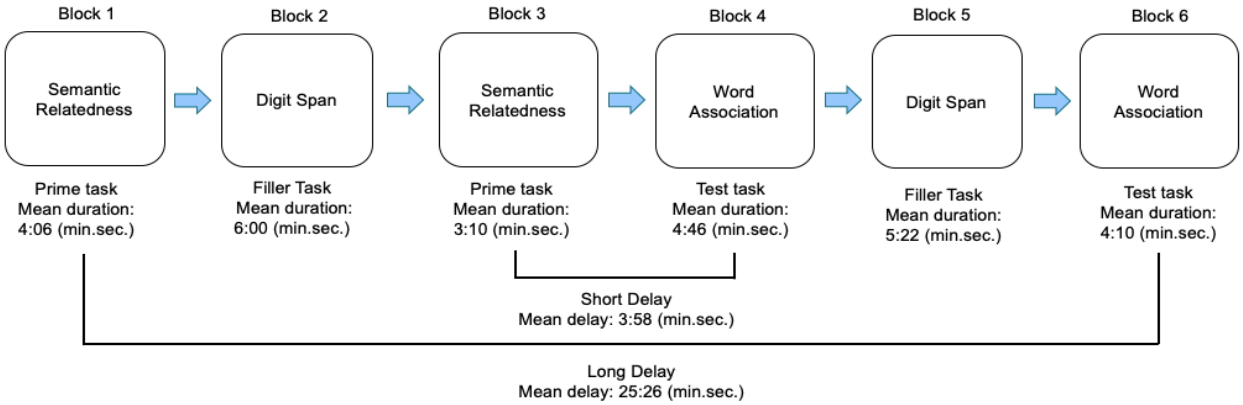
Procedure

This study followed a very similar procedure to Rodd et al. (2013; Experiment 3). All participants completed a single session that included the following parts in a fixed order: a semantic relatedness task (prime task), a digit span (filler task), another semantic relatedness task (prime task), a word association task (test task), another digit span (filler task), and a final word association task (test task). Splitting the semantic relatedness and word association tasks across blocks enabled us to test meaning preferences for half of the items after a short (3 min) and half after a long (20 min) delay. Figure 4.3 shows the procedure followed in Experiment 4. To test meaning preferences after a short delay, participants were exposed to ambiguous words in block three and tested in block four. To test meaning preferences after a long delay they were exposed to ambiguous words in block one and tested in block six.

The complete version of the present experiment is available on Gorilla Open Materials (https://app.gorilla.sc/openmaterials/629234).

Figure 4.2

Experiment 4. Procedure.



Note. Order of the tasks in Experiment 4, where each block includes one task. The average duration of each task, and the average duration of the short and long delays are revealed.

Unintentionally, the duration of each task and the duration of the short and long delays was slightly longer compared to the original study. This may be explained by the fact that these times include the time that participants spent reading the instructions of each task, whereas that likely was not the case in Rodd et al. (2013). It was difficult to match timings exactly because not all details about the structure of each task and the whole experiment were available. In the previous study the mean short delay was 3:06 minutes, while in the current study it was 3:58 minutes, and the long delay in the original study was 19:18 minutes, while in the current study it was 25:26 minutes. The possible implications of time differences at short and long delays will be analysed in the discussion.

Demographic Questionnaire. To begin, participants completed a one-minute demographic questionnaire where they gave their age, gender, country of residence, native language, the language they use the most, and their educational background. This survey aimed to ensure that participants live in the UK, and that their native language is British English.

Semantic Relatedness Task (Prime Task). The aim of this task was to ensure that participants attended to the meaning of the target words in each sentence. In each semantic relatedness task, participants were exposed to nine sentences that included an ambiguous word in the word-meaning priming condition, nine sentences that included a synonym of an ambiguous word in the semantic prime condition, nine sentences containing low-ambiguous word which acted as fillers, meanwhile no exposure was given to nine ambiguous words. Participants heard the spoken sentence (which contained the target or filler word) followed by a probe word and decided, as quickly and accurately as possible, if the probe word was related to the general context of the sentence. Probe words that followed the sentences containing the target ambiguous words were always unrelated in meaning to that sentence and to the meaning of the target ambiguous words. This was to avoid any priming effect at test that would be attributable to participants remembering associated word probes seen during the priming phase. In contrast, the probes selected for the filler low-ambiguous sentences were all strongly related to the sentence meaning. Taking ambiguous and low-ambiguous sentences, the overall relatedness proportion was 33%.

A practice block of nine sentences was completed before participants heard the experimental sentences in the first semantic relatedness task. One lead-in sentence was completed at the beginning of each semantic relatedness task. Each trial began with a 500 ms. fixation marker, followed by the spoken sentence, then participants saw a 200 ms. fixation marker, followed by the probe word which remained on the screen until participants made a

response, or until the time limit of 3 seconds was reached. To provide their responses participants pressed "m" if the probe word was related in meaning to the target/filler sentence, or "c" if the probe word was unrelated in meaning (reminders for the response keys were displayed at the bottom of the screen). Participants were instructed to respond as quickly and accurately as possible. After a 1000 ms. inter-trial pause, the next sentence appeared on the screen.

Digit Span (Filler Task). The purpose of this task was to add a delay between priming and test with a task that involved minimal linguistic exposure to reduce interference with the test task. The task provided a measure of short-term memory capacity through the exposure to strings of numbers ranging from three to nine digits. These digits were visually presented one-digit at a time (500 ms. per digit), then after the presentation of the digit string participants recalled the string by typing their response in a response box that appeared on the screen. After each response, a 500 ms. delay was added before the presentation of the next number string. A total of 35 number strings of different lengths were included across three blocks which were separated by a break of 15 seconds. These timings might be different from those of the original study because this previous work didn't publish the details of the times of this task.

Word Association Task (Test Task). The goal of this task was to measure whether participants preferred the subordinate meanings of the target words, which were primed in the semantic relatedness task. In each word association task, participants heard a total of 27 ambiguous words, nine ambiguous words previously primed in the word-meaning priming condition, nine ambiguous words previously primed in the semantic priming condition, and nine ambiguous words that were not primed before. Participants heard the spoken word and typed it into a text box, to ensure they had heard the words correctly. By pressing "Enter" a new textbox appeared and participants typed the first word that came to mind that was related

to the word that they heard. There was no time limit to type the word heard or to type the word related in meaning, but participants needed to provide a response to move on to the next trial. A 2500 ms. pause preceded the next trial. Experimental items were randomly presented for each participant and were separated into two blocks separated by an optional and self-timed break with a maximum duration of 30 seconds. At the start of each word association task one lead-in word was presented to secure proper attention on the task.

Coding Procedure Used to Code the Associates Generated in the Word Association Task

To describe how the responses generated in the word association task were classified, we will take as an example the homonym "ruler", which was primed towards the subordinate meaning that refers to the person that leads a group of people. In this case, responses were classified as Consistent if the associate was related to the primed meaning (e.g. "president"), alternatively, they were classified as Inconsistent if the associate was related to any other meaning of the target word (e.g. "pencil"), finally responses could be classified as Error if the associate fell into any of the following categories: (a) Unrelated: it does not have a clear relation in meaning to the target word (e.g. "bottle"), (b) Ambiguous: it has a relationship to more than one meaning of the target word (e.g. "long"), (c) Spelling/Typo: it is an error or typo that cannot be unambiguously corrected (e.g. "mayenin"), (d) Misheard: if the target word itself was incorrectly typed (e.g. "ruling"), or (e) No response: no associate was generated. The last classification wasn't included in the preregistration, but it was added because it was found in the data. Unambiguous spelling errors and typos were corrected and classified as Consistent, Inconsistent, or as any type of error accordingly. Table 4.2 shows the codes for each type of response given.

Table 4.2

Experiment 4. Codes Assigned to Each Type of Response Generated by Participants in the Word Association Task.

Type of Associate	Code
Inconsistent	0
Consistent	1
Unrelated	2
Ambiguous	3
Spelling/Typo	4
Misheard	5
No-response	6

To secure the quality, consistency, and efficiency of the coding procedure described before, this process included an automatic coding phase and a manual coding phase.

Automatic coding phase: This coding was completed using a tool developed by Gilbert et. al. (2022), which is an R function to code written word association responses. The function checks for pairs of target words and responses in the coded data set. If a match is found, then the response in the new data set is assigned the same code as that in the coded data set, and a flag variable is set to "1" (i.e. "automatically coded"). If no match is found, then no code is assigned to the response and the flag variable is set to "0" (i.e. "not coded"). Any responses that are flagged with "0" can then be reviewed by the experimenter for manual coding. If there are any target words in the new data set that are not found in the coded data set, then all responses to that cue word are assigned a code of "99" (i.e. "item not present in the coded data") (Gilbert et. al., 2022). The tool matches the associate generated by participants with the associates present in the database that are related to any meaning of the

ambiguous words. After the automatic match was done, we therefore added a function that specified the primed meaning for each ambiguous word. This function added the code "1" when the associate generated was consistent with the primed meaning and added the code "0" when the associate generated was related to any other meaning of the ambiguous word.

According to the developers, it is estimated that around 80% of item-response pairs for which target words are included in the data set can be automatically coded using this tool. Because 10 target items in our experiment are not present in the database and also because some of the associates are not included in this tool the automatic coding rate in the present study was relatively low (58%), meaning that the rest of the responses (42%) were manually coded. The R code for the tool and the database that was used to automatically code the responses of this experiment are available on the Open Science Framework (https://osf.io/uy47w/).

Manual coding phase: The 10 items that are not present in the database used by the automatic tool but that are included in our study, as well as those associates that are not present in the database but that were given as responses to the target items and all error types mentioned before were manually coded (42% of the total data). The procedure followed is available online on the Open Science Framework (https://osf.io/7k4fm/). Responses that required manual coding were coded separately by two coders (JMR and CG) and any discrepancies in this process were resolved on a case-by-case basis through discussion. Information for each item was available during coding, providing accurate definitions for all the meanings of target items and suitable examples of consistent and inconsistent responses.

4.2.3 Results

The data of the three tasks and the R scripts used to conduct all analyses are available on the Open Science Framework (https://osf.io/7k4fm/).

Semantic Relatedness Task

Participants were highly accurate at deciding if the probe word was related or unrelated in meaning to the prime sentence. Across participants the mean accuracy was 95.53% and the lowest mean accuracy for a participant was 87%, suggesting that participants completed the task paying a desirable level of attention. This performance is comparable to Rodd et al.'s (2013) original study, in which the mean accuracy across participants was 95.9% and the lowest mean accuracy for a participant was 89.3%.

Digit Span Task

Participants' digit span performance was lower compared to the original study. In the current study, they recalled a mean of 4.89 digits and the lowest mean number of digits for a participant was 3.74. In contrast, the original study obtained a mean of 7.4 digits recalled and the lowest mean number of digits for a participant was 5. This difference might be explained by the change in the recruitment method used and/or due to demographic differences between participants in these studies.

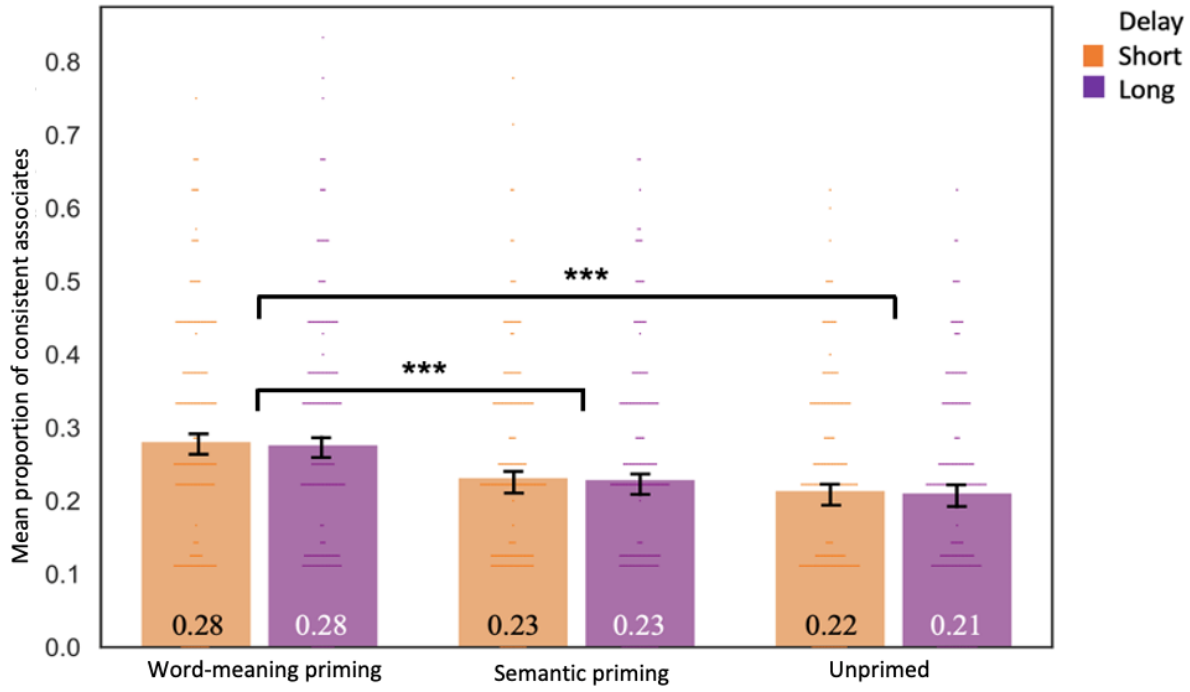
Word Association Task

Errors (4.25% of the data) were removed. One ambiguous word ("hay") was removed from the analysis because in the previous experiment (Rodd et. al., 2013; Experiment 3) its mean consistency score across all conditions was 0.97, showing that instead of the subordinate meaning the meaning was being tested was the dominant one. Figure 4.4 shows the mean proportion of consistent associates generated in each condition in the word association task. It is important to mention that the mean proportion of consistent associates generated in the word association task in this experiment (0.24) was higher than the one found in the original study (0.18). This difference may be explained by the change in the coding procedure followed in this replication which combined automatic and manual coding,

and the possible change in dominance for the subordinate meanings of ambiguous words between the time when the original study was run and when this replication was made.

Figure 4.3

Experiment 4. Bar Plot with the Mean Proportion of Consistent Associates for each Priming Condition.



Note. Error bars represent the 95% within-subject confidence intervals (Morey, 2008). Dots show the mean proportion of consistent associates for each subject in each condition.

Linear Mixed Effects Analysis

Consistent associates from the word association task were analysed with logistic mixed effects models with crossed subjects and items random effects. Models were fitted

using the “glmer()” function (with bobyqa optimiser) from the “lme4” package (version: 1.1-29; Bates et al., 2015) in R (version: 4.2.3; R Core Team. 2023).

To test our hypotheses, the full dataset was divided into three subsets, the first included word-meaning priming and unprimed conditions, the second semantic priming and unprimed conditions, and the third word-meaning priming and semantic priming conditions. The model for each subset took a 2 x 2 within-subjects design including the fixed effects of Priming, Delay, and the interaction. Priming was deviation-coded as 1/2 for word-meaning priming and – 1/2 for unprimed items for the first comparison, 1/2 for semantic priming and – 1/2 for unprimed items for the second comparison, and 1/2 for word-meaning priming and -1/2 for semantic priming for the third comparison, while Delay was deviation-coded as 1/2 for short delay and –1/2 for long delay for all comparisons. These models included random effects by subjects and items with random intercepts and random slopes for Priming, Delay, and the interaction. The “buildmer” package (version; 2.7; Voeten, 2023) was used to find the maximal converging model for each subset, where the appropriate random effects structure was determined using backwards stepwise elimination based on the significance of the change in log-likelihood (likelihood ratio tests) as recommended by Matuschek et al. (2017).

Once the maximal converging model was found, likelihood ratio tests were used to assess significance of the fixed effects and interactions ($\alpha = .05$) for each subset. The maximal converging model was compared to models where each of the fixed effects were removed. We report β values, standard errors, z-/t-values for the model parameters, Chi-squared values and p-values ($\boldsymbol{\alpha}$ set to .05) from likelihood ratio tests.

Word-meaning priming vs. unprimed: The maximal model that converged included a random intercept by subjects and a random intercept by items. The main effect of Priming was significant ($\beta = 0.46$, SE = 0.07, $z = 6.71$; χ^2 (1) = 44.91, $p < .001$), with more consistent associates generated in the word-meaning priming condition (M = 0.28, SD =

0.45) than in the unprimed condition (M = 0.21, SD = 0.41). There was a non-significant main effect of Delay (β = 0.02, SE = 0.07, z = 0.35; χ^2 (1) = 0.12, p = 0.725). The interaction between Priming and Delay was not significant (β = 0.01, SE = 0.14, z = 0.06; χ^2 (1) = 0, p = 0.949).

Semantic priming vs. unprimed: The maximal model that converged included a random intercept by subjects and a random intercept by items. The main effect of Priming was not significant (β = 0.13, SE = 0.07, z = 1.89; χ^2 (1) = 3.51, p = 0.061). The main effect of Delay was not significant (β = 0.02, SE = 0.07, z = 0.25; χ^2 (1) = 0.06, p = 0.803). The interaction between Priming and Delay was not significant (β = 0.01, SE = 0.14, z = 0.05; χ^2 (1) = 0, p = 0.961).

Word-meaning priming vs. semantic priming: The maximal model that converged included a random intercept by subjects and a random intercept by items. The main effect of Prime-Type was significant (β = 0.33, SE = 0.07, z = 4.84; χ^2 (1) = 23.09, p < .001), with more consistent associates generated in the word-meaning priming condition (M = 0.28, SD = 0.45) than in the semantic priming condition (M = 0.23, SD = 0.42). The main effect of Delay was not significant (β = 0.03, SE = 0.07, z = 0.44; χ^2 (1) = 0.19, p = 0.663). The interaction between Prime-type and Delay was not significant (β = 0, SE = 0.14, z = 0; χ^2 (1) = 0, p = 0.999).

4.2.4 Discussion

The experiment presented in this chapter is a replication of Rodd et al. (2013). It aimed to discover if word-meaning priming relies on the presentation of the English target word in the prime sentence or if its effects can be explained by a more general type of semantic priming that doesn't rely on the presentation of the target ambiguous word itself. Moreover, it aimed to find possible differences in the time-course between word-meaning

priming and semantic priming in a well-powered experiment. Although we used the same stimuli and tasks, there were two main differences with the original study that could have influenced the results obtained. The first one was its online presentation. To control this, we specified a detailed exclusion criteria to secure the data quality and consequently the validity of our results. The second was the presence of one extra minute for the short delay and five extra minutes for the long delay in our study compared to Rodd et al., because some of the key experimental details were missing so it was hard to exactly recreate the same timings.

Word-Meaning Priming

The analysis of the first subset that included word-meaning priming and unprimed items showed that the proportion of consistent associates generated in the word-meaning priming condition (0.28) was significantly higher than those generated in the unprimed condition (0.21). Moreover, word-meaning priming effects were not significantly modulated by Delay since the interaction between Priming and Delay was not significant. These results support the hypotheses made for this comparison, where we expected to find a significant word-meaning priming effect after a short and a long delay. This pattern of results replicates the word-meaning priming effects observed by Rodd et al. (2013), where it was found that the proportion of consistent associates generated in the word-meaning priming condition (0.21) was significantly higher than the proportion generated in the unprimed condition (0.15).

One aspect that is worth considering is the typing of the target word after hearing it in the test task, which was added to ensure the recognition of the correct ambiguous word. However, it is relevant to consider if this typing task could have enhanced word-meaning priming by causing a higher level of activation of the primed meaning. Alternatively, it could be argued that because the typing task does not include any semantic information that could

favour the primed meaning it should not boost the word-meaning priming effects. To clarify this issue, further studies are needed, which can contribute to a better characterization of the level of activation achieved when repeating the target word, and its influence on word-meaning priming effects.

Overall, the results observed in this replication support previous English word-meaning priming studies (Rodd et al., 2013, 2016: Gilbert et al., 2018) and consequently they validate the idea that a single exposure to the subordinate meaning of an ambiguous word facilitates the likelihood of retrieval of this meaning in a subsequent encounter.

Semantic Priming

The analysis of the subset of semantic priming and unprimed items revealed no significant difference in the number of associates generated in the semantic priming condition and those generated in the unprimed condition. The main effect of Delay and the interaction between Priming and Delay were also not significant. These results do not support our hypotheses, because we predicted an effect of semantic priming at the short but not at the long delay, whereas we found no semantic priming at either delay. These findings are also inconsistent with those of Rodd et al. (2013), where a marginally significant main effect of semantic priming was found, an effect that was significantly larger after the short delay than after the long delay.

Within the subset of word-meaning priming and semantic priming items, the prediction for the main effect of Prime-Type found support in our results, because more consistent associates were generated in the word-meaning priming condition (0.28) than the semantic priming condition (0.23). However, the predictions of the main effect of Delay, and the interaction between Prime-Type and Delay did not find support, because these effects were absent in our results. When compared to the results found by Rodd et al. (2013) (on

which our predictions were based), our study replicated the bigger effect of word-meaning priming than semantic priming, and the absence of a significant interaction between Prime-Type and Delay, however it failed to replicate the main effect of Delay.

It is important to note that despite we powered appropriately to detect the interaction between Prime-Type and Delay for the critical comparison between word-meaning priming and semantic priming this was absent because the effects of semantic priming were absent at short and long delays. The absence of semantic priming is interesting to observe in this replication because it is inconsistent with our hypotheses and previous findings (Rodd et al., 2013; Curtis et al., 2022) which suggested we would obtain semantic priming effects at least at the short delay. It is well-known that semantic priming effects are short lived, but it is worth analysing why these effects were absent in this study. Considering that this replication used the same design and stimuli one factor to analyse is the duration of the short delay in this replication because compared to the original study there was an increase of approximately one minute. If this slightly longer short delay was enough to lose semantic priming effects, this would indicate how sensitive and short-lived this effect can be. Alternatively, it is possible that the presence of semantic priming at short delay in the original study (Rodd et al. 2013) is not reliable, because that study was underpowered and possibly revealed an effect that at that time point does not exist at the population level.

In this context our results are closer to older findings (e.g. Meyer et al., 1971; Becker et al., 1997) that showed semantic priming effects over a period of seconds or after some intervening items, however these studies didn't test semantic priming effects at longer delays. In two experiments, Meyer and Schvaneveldt (1971) demonstrated that word identification in lexical decision is facilitated if the target word is immediately preceded by a word related in meaning. Similarly, Becker et al. (1997) found semantic priming after an average lag of 21.5 items between primes a targets in a task where participants needed to make a lexical decision

(decide if the item was a word e.g. “butter” or not) or a semantic decision (decided if the item represented something living or part living thing e.g. “whale” or not e.g. “mistake”) for each word presented. The short duration of semantic priming of these earlier studies might be based on the fact that priming was induced through words in isolation. In contrast, this replication showed the absence of semantic priming after a longer delay of approximately 4 minutes using sentences, thus suggesting the idea that the boost of semantic priming though sentence exposure might be limited to a shorter time window or that any effects at longer delays are weak and variable.

Implications for Localist Models and Distributed Connectionist Models of Word Representation

The presence of word-meaning priming and the absence of semantic priming at short and long delays are findings that are worth to analyse under models that characterise how words are represented.

For Localist models, each word is represented by a single entry or unit in our mental lexicon, which contains all the lexical-semantic information of a word (McClelland et al., 1981). When this unit is activated as a consequence of a recent encounter with a word, it is possible to access all the information about that word’s meaning. Having said this, the presence of word-meaning priming and the absence of semantic priming are perfectly addressed by Localist models because it is necessary to specifically encounter the particular ambiguous word to access its semantic information, and update it according to the information provided by the sentence context. Given that each unit represents one concept and to add more concepts it is needed to add more modes for a particular word, it is possible to argue that in the semantic priming condition the information provided by the context

update the representation of the synonym and not the one of the ambiguous word, thus explaining the null effect for semantic priming.

Distinctively, for Distributed Connectionist models each word is represented as a unique pattern of activation across sets of units that represent its form and meaning (Armstrong et al., 2008; Borowsky et al., 1996; Joordens et al., 1994; Kawamoto et al., 1994; Rodd et al., 2004). In this context, the null effect of semantic priming suggests that despite that the synonym probably activates a similar set of semantic units this is not enough to observe priming effects after 4 and 25 minutes. This finding provides support to the specificity of the pattern of activation needed to access and update the lexical-semantic representation of a particular word. It is worth noting that this specificity is found in the word-meaning priming condition, where form and meaning units of the particular ambiguous word are activated, providing the unique pattern of activation required to access its lexical-semantic representation, and consequently update it with the disambiguating information provided by the context.

Finally, it is worth mentioning that if semantic priming effects are present at shorter delays or after a few intervening items as it is revealed by Meyer and Schvaneveldt (1971) and Becker et al. (1997) this type of priming could be better addressed by Distributed Connectionist models than for Localist models. The reason for this assumption is that Distributed Connectionist models consider a lexical-semantic space that is more interconnected and integrated than Localist models, thus providing a better chance to use just the semantic information related to the specific meaning of the ambiguous word. More specifically, encountering a synonym in the same disambiguating context of the ambiguous word probably leads to the activation of similar semantic units, thus accounting for maybe a partial or weaker activation of the lexical-semantic representation of the ambiguous word. The possible overlap in the activation of semantic units between an ambiguous word and its

synonym offered by Distributed Connectionist models, is absent in Localist models because the ambiguous word and the synonym could activate those semantic units that are linked to a specific word and not the ones linked to an item related in meaning.

Implications for Theories of Word-Meaning Priming

The results of this replication are clear, by finding a significant difference between word-meaning priming and semantic priming effects, we can suggest that word-meaning priming relies on the presentation of the specific target word, however we can't rule out that semantic priming might also have a weak additional influence on word-meaning priming effects. Importantly, the absence of semantic priming effects after an average delay of 4 minutes between priming and test reveals the need to measure these effects in future studies because they reveal an alternative pattern of results when compared to what has been revealed by previous experiments (e.g. Rodd et al., 2013; Curtis et al., 2022). Taken together, these findings have direct implications for current theories that aim to explain the mechanism of word-meaning priming as will now be discussed.

The Immediate Alteration Account claims that each experience with an ambiguous word immediately alters the long-term lexical-semantic connections of a particular word. Specifically, this account argues that the stored knowledge of the ambiguous word itself is being altered, and its latest version suggests that this change happens at an abstract lexical-semantic level. In this context the results of our study support the Immediate Alteration Account for two main reasons.

First, we observed word-meaning priming effects that were bigger than semantic priming effects (which were non-significant) at both short and long delays. This supports the idea that what is being changed in the word-meaning priming condition is the specific stored knowledge of the ambiguous word itself and not some general information provided by the

context. Additionally, it is possible to suggest that word-meaning priming effects are not significantly supplemented by semantic priming effects even at short delays because we didn't find semantic priming effects after a delay of 4 minutes, though this doesn't completely rule out the possibility to observe such complementary effects after shorter delays.

Second, since we found word-meaning priming effects at short (4 min.) and long (25 min.) delays and that this effect didn't decrease between these two delays, this seems to support the Immediate Alteration Account's claim that each experience alters the long-term lexical-semantic connections of the word. Perhaps, this is the most intriguing finding of the present study because it not only supports the existence of word-meaning priming effects but also reveals that this effect can be maintained after longer delays. The absence of a decrease in word-meaning priming effects will need to be explored in future studies, which should aim to further characterize its time-course. Despite the clarity of the evidence provided by the current experiment, what cannot be taken for granted from our results is the immediate alteration of these long-term lexical connections because we didn't measure word-meaning priming effects immediately, a condition that will need to be included in future experiments.

Taken together the Immediate Alteration Account can explain our results because we found word-meaning priming effects but not semantic priming , which suggests that word-meaning priming is changing the stored lexical-information of the specific ambiguous word. Furthermore, the absence of a decrease in word-meaning priming effects between 4 and 25 minutes might imply an immediate change among the connections within the semantic layer, making the attractor basin for the primed meaning more stable relative to the alternative unprimed meaning, as it is suggested by Rodd et al. (2016).

Although our results are consistent with the Immediate Alteration Account, as discussed in previous chapters, an alternative explanation has been proposed to explain

priming effects. Gaskell et al. (2019) promotes the idea that when an ambiguous word is encountered in a disambiguating context a new and temporary memory trace for the comprehension episode is created by the hippocampus. This temporary representation acts as an additional source of information alongside permanent lexical knowledge that influences a word's subsequent interpretation. This new theoretical explanation, suggested by the Episodic Context Account, "promotes the idea that there is a division of labour in a complementary systems model between the main long-term repository for established lexical knowledge located in the neocortex, and the network that provides shorter-term plasticity to enable learning located in the hippocampus" (Gaskell et al., 2019, p. 119).

At first sight the presence of word-meaning priming effects in our study are compatible with the Episodic Context Account. According to this account word-meaning priming does not change connection weights in the long-term cortical network as claimed by the Immediate Alteration Account. Instead, it argues that when a sentence is encountered the hippocampus is recruited to bind together a new memory of that sentence or utterance, combining the various components of the sentence in a similar way to the formation of a new association between words (Eichenbaum et al., 1995). As promoted by Gaskell et al. (2019) at short term the creation of this memory trace probably allows listeners to keep track of, and act on, conversations and other forms of dialogue, and presumably it may also provide a source of information that participants can use when they are asked to generate an associate of the word encountered previously. Under these conditions, an unprimed word will only be able to use the cortical long-term lexical network, while a primed word can use both the cortical network and the hippocampal representation of the recent experience with that word (Gaskell et al., 2019). Interestingly, the presence of word-meaning priming effects and the absence of semantic priming suggest that this new episodic memory can be quite specific and that if the primed sentence doesn't include the specific ambiguous word, the combination of

the components of the sentence leads to a slightly different memory trace of the comprehension episode, which may have less of an influence on subsequent encounters.

A second point of analysis for the Episodic Context Account is the absence of a decrease in word-meaning priming effects. The Episodic Context Account explicitly argues that there is a division of labour in a complementary systems model, where the newly created hippocampal (temporal) memories of a particular episode are transferred to the neocortex for their consolidation. This argument assumes that if an episodic memory is not transferred to the neocortex, it will be subject to decay and ultimately to loss. Word-meaning priming studies have showed a rapid decrease of this priming after a few minutes (Rodd et al., 2013, 2016). However, our findings don't support the decrease of word-meaning priming effects at least during the time window tested in the current study (up to 25 min.), which seems to indicate that any contribution of the hippocampus is relatively stable across the time window covered by this experiment.

The hippocampus is involved in a range of online linguistic tasks that contribute to normal everyday conversation beyond simply word learning (Duff et. al., 2017). These include tasks as diverse as the maintenance of common ground (Duff et al., 2011), the use of co-speech hand gesture (Hilverman et al., 2016), the flexible use of language (Duff et al., 2006) and, potentially, the updating of verb biases in syntactic ambiguity resolution (R. Ryskin et al., 2018). Relevant to this idea is the work of Klooster and Duff (2015), who questioned the view that remote semantic memory does not require a functioning hippocampus. They tested a group of patients with hippocampal amnesia on the richness and depth of semantic knowledge for a range of different word types, finding that the amnesic participants performed worse than matched controls in both productive and expressive measures, suggesting that the hippocampus is involved in the maintenance of semantic representations well beyond initial acquisition. Taken together these findings suggest several

possible explanations for why we didn't observe a decrease in word-meaning priming effects in this replication: (1) the transfer of hippocampal memories to the cortex happens before a delay of 4 minutes, (2) the hippocampus is still maintaining the temporary memory of the specific episode after 25 minutes, or (3) the hippocampus doesn't play a role in the update of these lexical-semantic representations because they are directly and immediately updated in the neocortex.

In summary, our findings can be interpreted within the Episodic Context Account in the following ways. First, word-meaning priming effects could be attributed to the creation of a temporary memory trace by the hippocampus. Thus, this hippocampal memory could act as an additional source of information alongside permanent lexical knowledge that influences the subsequent interpretation of the specific ambiguous word. Additionally, our results suggest that this episodic memory is more specific than previously thought considering that we didn't observe priming effects when the ambiguous word was replaced with a synonym in the semantic priming condition. Second, the absence of a decrease in word-meaning priming effects between 4 and 25 minutes could imply that the transfer of hippocampal memories to the cortex happens before 4 minutes, after 25 minutes, or that there is no transfer of hippocampal memories for this particular type of learning.

Future Directions

The experiment reported in this chapter have highlighted some critical issues that warrant further studies. These will be separated into two levels of analysis: (1) improvements for this experiment, and (2) future studies that can address unresolved theoretical issues revealed by this replication.

In terms of possible improvements for the experiment it is important to emphasize that this was a replication of the original study carried out by Rodd et al. (2013), which

means that all the stimuli and tasks were used without any modification. Based on the analysis of priming effects we noticed that some items were not optimal and should be replaced. A few items showed a lot of consistent responses across all conditions, perhaps revealing a change in dominance scores (e.g. the subordinate meaning became the dominant meaning) thus providing no difference between the meanings that were primed and unprimed. These items should be replaced in future studies, preferably based on more recent dominance norms. Another recommended modification is the proper control of the timings of the tasks, this was slightly different in this replication compared to the original study and made both short and long delays longer than in the original study. Specifically, the increased duration of the short delay might be responsible for the absence of semantic priming since this type of priming is considered to be a short lived phenomenon.

Related to future studies these should test both word-meaning priming and semantic priming effects at different time-points (e.g. Rodd et al., 2013, 2016), to see if it is possible to get semantic priming effects at shorter delays (e.g. before 4 minutes) and to test if word-meaning priming decrease after longer delays (e.g. after 25 minutes). Moreover, it is of interest to explore word-meaning priming effects and semantic priming effects using different modalities (e.g. Gilbert et al., 2018) during priming and at test to explore whether these effects are cross-modal.

4.2.5 Conclusions

This chapter has presented a well-powered replication of Rodd et al. (2013; Experiment 3) aiming to explore: (1) if word-meaning priming relies on the presentation of the target word or if its effects can be explained by a more general type of semantic priming and (2) the possible differences in the time-course of both types of priming. The results revealed a significant effect of word-meaning priming at both short and long delays.

Interestingly, there was no decrease in word-meaning priming effects after a long delay (25 min.). We further didn't observe semantic priming effects at either short (4 minutes) or long delays (25 minutes).

Importantly, both the Immediate Alteration Account and the Episodic Context Account can explain this pattern of results. For the former our findings are well accommodated because they support the claim that what is being changed during word-meaning priming is the stored lexical-information of the specific ambiguous word. Moreover, the absence of decrease in word-meaning priming suggests a change in the long-term lexical-semantic connections of the ambiguous word. The Episodic Context Account also provides a plausible explanation for our results because they seem to support the creation of a temporal episodic representation that acts as additional source of information in the update of permanent lexical knowledge, but also, they suggest that this representation is linked to the presence of the specific ambiguous word. Lastly, the most interesting implication for this account is the absence of decrease in word-meaning priming effects, which might imply a difference in the speed of the transfer of hippocampal memories to the cortex or maybe in the entire role of the hippocampus in the update of the stored lexical-semantic knowledge leaving open the question whether the hippocampus plays a role in this process or not.

CHAPTER 5: CONCLUDING REMARKS

5.1 Theoretical Contributions

The research presented in this thesis investigated the flexibility of lexical-semantic representations of English ambiguous words using word-meaning priming. This goal was pursued by testing how recent encounters with particular meanings of ambiguous words in context influence their subsequent disambiguation.

Chapter 2 tested how a single exposure to both the dominant and subordinate meanings of ambiguous words, or what we called mixed-exposure, influenced the subsequent processing of dominant (Experiment 1) and subordinate meanings (Experiments 1 and 2) immediately after test. This is relevant because natural language includes exposures to both meanings, thus its testing helps us to understand how we handle these inconsistent exposures. To do so, participants read sentences that disambiguated ambiguous words towards the subordinate or the dominant meaning. After a filler task, meaning preferences were tested through a semantic relatedness task, where participants decided if a probe word was related or unrelated in meaning to a target/filler word. After mixed-exposure Experiment 1 revealed a numerical facilitation effect for subordinate meanings and a null effect for dominant meanings. Since, Experiment 1 revealed a null effect for dominant meanings, Experiment 2 just tested the effect for the subordinate ones. It is worth noting that Experiment 2 included a bigger sample to secure enough power, and the selection of more carefully selected stimuli compared to Experiment 1. Considering these differences Experiment 2 showed a significant facilitation effect for subordinate meanings after mixed-exposure just on response times. These results are consistent with those studies that show a facilitation effect for subordinate meanings after a single encounter with this meaning (Betts et al., 2018; Gaskell et al., 2019; Gilbert et al., 2018 & Gilbert et al., 2021; Rodd et al., 2013 & Rodd et al., 2016), but also

they extend this facilitation effect to the context of mixed-exposure. These results provide evidence that the meanings of ambiguous words can be boosted independently, which contradicts strong claims of semantic competition.

The aim of Chapter 3 was to explore if the immediate processing benefit for subordinate meanings after mixed-exposure observed in Experiments 1 and 2 can be extended to a delay of 24 hours. Since Experiments 1 and 2 revealed a weak facilitation effect for subordinate meanings, Experiment 3 increased the number of exposures to three for subordinate meanings and three for the dominant ones. Experiment 3 followed a similar procedure to Experiment 2 but included a second session to measure meaning preferences after one day. Semantic relatedness judgements showed a significant facilitation effect for subordinate meanings immediately after training and one day later. Experiment 3 provides additional support to the idea that meanings can be boosted independently, and that this boost can be maintained even after a delay of 24 hours. Overall, findings from Experiments 1, 2, and 3 are in line with the idea that the semantic competition that may come from exposure to the dominant meaning does not overwhelm positive priming effects for subordinate meanings. This suggests that priming effects are stronger than the semantic competition that naturally arises between unrelated meanings of ambiguous words, and that these positive priming effects tend to be relatively stable within a time window of 24 hours.

Lastly, the experiment presented in Chapter 4 was a replication of Rodd et al. (2013) and aimed to (1) assess if word-meaning priming is contingent on the presence of the ambiguous word or if its effects reflect a general type of semantic priming, and (2) explore the time-course of word-meaning priming and semantic priming at short (3 minutes) and longer delays (20 minutes). This is theoretically relevant because it clarifies whether word-meaning priming modifies the specific semantic representation of the target word or if it arises from a more general semantic representation created by the information provided by

the context. This replication tested these issues in a well-powered experiment, using a similar procedure to the original study. During priming, participants heard sentences that disambiguated the ambiguous words toward their subordinate meaning, or sentences in which the target word was replaced with a low-ambiguity synonym. Results from the subsequent word association task showed that the associates generated that were consistent with the subordinate meaning was significantly larger in the word-meaning priming condition than the semantic priming condition at both short and long delays. These findings suggest that word-meaning priming is based on a change in the representation of a particular ambiguous word, rather than a general form of semantic priming.

5.2 Theoretical Contributions for the Immediate Alteration Account and the Episodic Context Account

Although the experiments presented in this thesis did not have the goal to discriminate between the Immediate Alteration Account and the Episodic Context Account, because the second one was absent prior to the creation of Experiments 1 and 2, it is interesting to summarize how their findings can be interpreted by these theories. Under the latest version of the Immediate Alteration Account (Rodd et al., 2013; Rodd et al., 2016), the immediate and delayed facilitation effect found for subordinate meanings after mixed-exposures could be explained by the immediate update in the long-term lexical-semantic knowledge of a particular word for both dominant and subordinate meanings. The absence of the interaction between Training and Delay for ambiguous words showed by Experiment 3, seems to further support the immediate update in the semantic layer described by the Immediate Alteration Account. Additionally, findings from Experiment 4 can also be explained by the Immediate Alteration Account. First, the presence of word-meaning priming and the absence of semantic priming at short and long delays suggest that what is being changed is the lexical-semantic

representation of the specific ambiguous word. Second, the absence of a decrease in word-meaning priming effects between short and long delays could imply an immediate change among the connections within the semantic layer.

Findings from Experiments 1, 2, and 3 could also be explained by the Episodic Context Account (Gaskell et al., 2019). This account suggests that ambiguous words use both the long-term lexical-semantic representation of a word, and the temporary episodic memory trace created after a recent encounter with a particular meaning. Overall, the facilitation effect found for subordinate meanings keeps the possibility that ambiguous words could use both the long-term lexical-semantic representation of dominant and subordinate meanings, and the temporary representations of these meanings created after recent encounters with them. However, our data cannot make the distinction if this facilitation effect is explained by the use of one of these sources or both of them. Regarding the absence of the decrease in the facilitation effect for subordinate meanings between immediate and delayed tests (Experiment 3), this is consistent with the ideas that overnight sleep could facilitate the consolidation of the new episodic memories, or their protection from linguistic interference. Moreover, findings from Experiment 4 are consistent with the Episodic Context Account because they seem to be compatible with the creation and use of a new episodic memory, which allows a subsequent facilitation effect for the previously encountered subordinate meaning. However, these findings also suggest that this episodic memory is quite specific, aspect that is not considered in the actual version of the Episodic Context Account.

To conclude, findings from this thesis can be explained by either the Immediate Alteration Account or the Episodic Context Account. However, the evidence from sleep studies (e.g. Gaskell et al., 2019; Hulme et al., 2023; Mak et al., 2024) and those that investigates word types (e.g. Curtis et al., 2022; Mak et al., 2023) seems to give the advantage to the Episodic Context Account. Although, we can’t discriminate between these

theories, our data helps constrain their details by requiring them to accommodate our findings regarding to the effects of mixed-exposure, time-course of priming effects, and the significant benefit for word-meaning priming over semantic priming.

5.3 Methodological Contributions

This thesis makes clear the advantages of doing web-based research. The 760 participants who took part in the experiments presented in this thesis were recruited online through Prolific (Palan et al., 2018), and completed the experiments using Gorilla (Anwyl-Irvine et al., 2020). Web-based research provides access to a larger and more diverse group of the population than those recruited by lab-based studies. Despite this advantage, online research faces the challenge to maintain data quality.

As identified by Rodd (2024), there are three factors that can affect the quality of the data of web-based research: technology (e.g. internet connectivity), participant identity (e.g. demographic information), and participant behaviour (e.g. understanding of the tasks). Therefore, the experiments presented in this thesis secured data quality by taking the following measures. First, to ensure that technology preserved the quality of the data, some technological requirements were specified: (i) computers/laptops were required phones or tablets were not permitted, (ii) only recognised browsers (e.g. Chrome, Firefox, Safari) were permitted, and (iii) a questionnaire was included at the end of the experiment that asked participants if they experienced any technical difficulties that could interfere with their performance. Second, to ensure that participant identity preserved the quality of the data, it was specified on Prolific a specific demographic criteria (age between 18 and 25 years, native speakers of British English, UK residents, absence of hearing or reading impairment, and normal or corrected to normal vision). Lastly, to ensure an appropriate participant behaviour, the following measures were taken: (i) specific exclusion criteria were specified, which

described the requirements of performance on each specific task, as well as the expected duration on them; (ii) before data collection a pilot phase was added to provide the opportunity to see the likely distribution of performance, thus securing an appropriate exclusion criteria; (iii) the exclusion criteria for Experiments 2, 3, and 4 were preregistered on the Open Science Framework, this is relevant because it describes the expected characteristics of the data to be collected and it secures the trustworthiness of the findings and conclusions (Nosek et al., 2018, 2019); and finally (iv) the exclusion criteria were reviewed after data collection to ensure appropriate exclusions. All the measures described to ensure data quality of web-based research must be included, their absence could generate false findings and wrong conclusions.

Web-based research helped to achieve the aim of conducting well-powered experiments. The purpose of this is to secure a proper replication rate, which should be around 80%. According to Cohen (1962) less than 40% of the experiments in psychology could be replicated, a situation that even a few years ago showed a similar trend (e.g. Dumas-Mallet et al., 2017; Smaldino et al., 2016; Vankov et al., 2014). More specifically, the experiments that motivated the idea to test meaning preferences for subordinate and dominant meanings after mixed-exposure (Betts et al., 2018; Experiment 1) (N = 30), and the original study that tested differences between word-meaning priming and semantic priming (Rodd et al., 2013; Experiment 3) (N = 42), were not properly powered because of the absence of theoretical guidelines, and the absence of proper statistical tools to ensure enough power. Contributing to the solution to this problem, by using recent theoretical recommendations, as well as new statistical tools, Experiments 2, 3, and 4 included a number of participants that secured a proper statistical power. Experiments 2 and 3 followed the theoretical recommendation given by Brysbaert et al. (2018) for linear mixed effect models, which establish a minimum of 1,600 observations per condition to find significant effects in the

analysis of transformed response times. Experiment 4 used the data of the original study (Rodd et al., 2013) to run power analysis simulations to determine the number of participants needed to find a significant interaction between Priming and Delay for the critical comparison between word-meaning priming and semantic priming. The decision to ensure enough power in these experiments contributes to the reduction of the replication crisis in psychology. However, it also highlights the need for researchers to receive more fundings to run experiments with enough power.

Another point of analysis is the selection of the tasks used in the experiments presented, and how they were implemented to measure the effects of interests. The selection of a semantic relatedness task in Experiments 1,2, and 3 is supported by the fact that is a speeded task, this characteristic allows to directly measure the initial processing of words, leaving out the influence of offline or post-access processes that influence word-meaning priming effects. Between these offline processes it can be mentioned the influence of participants' biases, which could favour the selection of responses that are semantically related to the primed meaning, or the opportunity to retrieve episodic memories which could not affect the initial processing of a word. Overall, the time restriction given by a semantic relatedness task allow us to control for such offline processes, thus securing the correct measurement of word-meaning priming effects.

In contrast, the selection of a word association task in Experiment 4 is justified just to secure an exact replication of the original study led by Rodd et al. (2013; Experiment 3)**.** A non-speeded task like a word association task allows the influence of offline processes, because participants can take as long as they like to select the associate related to the meaning that they are considering. This situation causes that the measurement of word-meaning effects reveal the final processing of the words' meanings, which include the

influence of offline processes, thus making unlikely to directly measure the initial processing of these meanings, and consequently to reliably test word-meaning priming effects.

Lastly, to address the findings from the semantic relatedness task, it seems relevant to analyse if the order of presentation of targets and probes influenced the results. In Experiments 1, 2, and 3, participants first saw the ambiguous target (e.g., “crane”) and then the probe word (e.g., “bird”), this allows the activation of the specific pattern that represents the form and meanings of the target, a pattern that is then compared with the pattern of the probe word. If we reverse the order of presentation, meaning that the probe is presented first (e.g., “bird”) and then the target (e.g., “crane”), the probe will constrain the meaning of the target, which can cause a reduction of the ambiguity effect. This idea is supported by the Interactive Activation account, which suggests that semantic relatedness effects arise from the temporal co-activation of related items. Under this account, semantic relatedness impacts working memory at encoding when words are processed, causing the activation of word representations in long-term memory through spreading activation within the long-term memory network, or via redundant feedback between lexical and semantic levels. In this context, the temporal order in which semantically related words are encoded seems to impact this effect.

Analysing the possible mechanism behind word order effects in semantic relatedness, Kowialiewski et al. (2022) carried out a series of three experiments. By manipulating the encoding and recall order of semantic related words, these experiments tested whether the semantic relatedness effect could be explained by a semantic cueing mechanism, which argues that the recall of an item facilitates of other related ones, by an feature overlap account, which suggests that the semantic relatedness effect is promoted by the superposition of semantic features bound to similar contexts, or by the described Interactive Activation account. Results from cue recall tasks, where words were controlled in terms of semantic

relatedness (related, unrelated), temporal proximity (grouped, interleaved), and spatial proximity (grouped, interleaved), showed that semantic relatedness influences working memory at the encoding stage of processing, leaving out the option of a semantic cueing mechanism. Moreover, the temporal order of words was crucial to detect the semantic relatedness effect, thus supporting the Interactive Activation account, and the idea that a word constrains the meaning of a subsequently encountered word.

5.4 Future Directions

Despite the contribution of the findings presented in this thesis some questions remain unanswered. For instance, Experiment 3 showed that the facilitation effect for subordinate meanings after mixed-exposure is present even after 24 hours. This finding is relevant because it suggests that lexical-semantic representation of ambiguous words can preserve the update of the semantic information of a particular meaning for a relatively extended period of time. However, to better characterize the facilitation effect for subordinate meanings after mixed-exposure future studies should test this effect for longer periods of time (e.g. days or weeks). A study that follows this recommendation is Rodd et al. (2016; Experiment 1). In this experiment 1800 English-speaking participants through a radio programme heard short descriptions that included various fully disambiguated ambiguous words. Immediately after or up to a week after this exposure they were invited to complete an online experiment, where their meaning preferences of primed and unprimed items were measured. The creation of studies that test meaning preferences over longer delays will ensure the proper exploration of the duration of the facilitation effect for subordinate meanings after mixed-exposure, and consequently the flexibility of lexical-semantic representations of ambiguous words.

Another recommendation for future studies is to explore the time-course of semantic priming. The literature suggests that this is a short-lived phenomenon observed across a time

window of only a few minutes (McNamara, 2005). This assumption is supported by lexical decision studies (e.g. Becker et al., 1997), and word-meaning priming studies (e.g. Rodd et al., 2013). However, recent evidence has revealed that it is possible to find semantic priming after up to 30 minutes after priming (e.g. Curtis et al., 2022). By replicating the original study of Rodd et al. (2013) (N = 42), Experiment 4 (N = 180) aimed to explore the time-course of word-meaning priming and semantic priming. This study successfully found word-meaning priming effects at short and long delays but failed to find semantic priming at either delay. The absence of semantic priming revealed by Experiment 4 was unexpected, because it contradicts previous findings. Considering the absence of semantic priming shown by Experiment 4, as well as the general assumption that semantic priming is a short-lived phenomenon, it is recommended to run experiments that help us to understand why some find semantic priming at short delays, while others do not. It is unlikely that the absence of semantic priming in Experiment 4 was due to inadequate power. Therefore, these results imply the need to develop theories that better explain this effect, the factors that might modulate it, and they ways on which this effect is trained and tested.

Finally, one suggestion that could help to judge between the Immediate Alteration Account and the Episodic Context Account will be the development of neuroimaging studies. These studies should focus their attention mainly on the role of the hippocampus, which according to the Episodic Context Account is responsible for the transfer of new episodic memories to the neocortex, which allows the consolidation of these new memories. Moreover, the exploration of the role of specific brain regions must be complemented by the exploration of the role of sleep and the time-course of priming effects. Thus, it is recommended to develop experiments that include both sleep recording techniques and the testing of priming effects at both short (e.g. minutes to hours) and long delays (e.g. days to weeks). Although some studies have attempted to do this (e.g. Gaskell et al., 2019; Hulme et

al., 2023; Mak et al., 2024), it is necessary to strengthen and complete the characterization of the priming effects found.

5.5 Conclusions

The findings provided by the experiments presented in this thesis contradict the view that meaning preferences are a stable property of long-term semantic representations, developed incrementally across the lifespan. Instead, our findings provide evidence for the flexibility of lexical-semantic representations of ambiguous words. This flexibility was consistently found across all experiments, suggesting that meaning preferences are influenced by our most recent experiences. Critically, our results suggest that priming effects on subordinate meanings are stronger than the semantic competition between unrelated meanings of ambiguous words, and that word-meaning priming is quite specific relying on the presence of the ambiguous word itself. Our results further validate word-meaning priming effects to update the lexical-semantic representations of ambiguous words, particularly those that are more susceptible to improvement (e.g. subordinate meanings). Future studies should explore the flexibility of lexical-semantic representations by testing it over longer delays and using more naturalistic interventions, aiming to better characterize how meaning preferences are constantly modified by natural language exposure.

REFERENCES

Aljadaan, N., Alzaidi, M., & Alnasser, S. M. (2024). Arabic semantic priming for homographs does not result in a boost to all related material. *Saudi Journal of Language Studies*, *4*(2), 106-124. https://doi.org/10.1108/SJLS-02-2024-0012

Altmann, G. T. M., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition*, *73*(3), 247-264. https://doi.org/10.1016/S0010-0277(99)00059-1

Ahrens, K. (2002). Timing issues in lexical ambiguity resolution. In Nakayama, M. (ed.), Sentence processing in East Asian languages (pp. 1–29) Stanford: Center for the Study of Language and Information Publications. https://www.researchgate.net/profile/Kathleen-Ahrens/publication/262344544_Timing_Issues_in_Lexical_Ambiguity_Resolution/links/57f20e1408ae91deaa56191d/Timing-Issues-in-Lexical-Ambiguity-Resolution.pdf

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2020). Gorilla in our midst: An online behavioural experiment builder. *Behavior Research Methods*, *52*(1), 388-407. https://doi.org/10.3758/s13428-019-01237-x

Armstrong, B. C., & Plaut, D. C. (2008). Settling dynamics in distributed networks explain task differences in semantic ambiguity effects: Computational and behavioral evidence. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (Vol. 30, No. 30). https://escholarship.org/uc/item/6rv2c5hh

Armstrong, B. C., & Plaut, D. C. (2016). Disparate semantic ambiguity effects from semantic processing dynamics rather than qualitative task differences. *Language, Cognition and Neuroscience*, *31*(7), 940-966. https://doi.org/10.1080/23273798.2016.1171366

Bakker, I., Takashima, A., Van Hell, J. G., Janzen, G., & McQueen, J. M. (2014). Competition from unseen or unheard novel words: Lexical consolidation across modalities. *Journal of Memory and Language*, *73*, 116-130. https://doi.org/10.1016/j.jml.2014.03.002

Bakker-Marshall, I., Takashima, A., Schoffelen, J.-M., Van Hell, J. G., Janzen, G., & McQueen, J. M. (2018). Theta-band oscillations in the middle temporal gyrus reflect novel word consolidation. *Journal of Cognitive Neuroscience*, *30*(5), 621-633. https://doi.org/10.1162/jocn_a_01240

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255-278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1). https://doi.org/10.18637/jss.v067.i01

Becker, S., Moscovitch, M., Behrmann, M., & Joordens, S. (1997). Long-term semantic priming: A computational account and empirical evidence. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(5), 1059. https://psycnet.apa.org/buy/1997-06939-001

Bekinschtein, T. A., Davis, M. H., Rodd, J. M., & Owen, A. M. (2011). Why clowns taste funny: The relationship between humor and semantic ambiguity. *Journal of Neuroscience*, *31*(26), 9665-9671. https://doi.org/10.1523/JNEUROSCI.5058-10.2011

Beretta, A., Fiorentino, R., & Poeppel, D. (2005). The effects of homonymy and polysemy on lexical access: An MEG study. *Cognitive Brain Research*, *24*(1), 57-65. https://doi.org/10.1016/j.cogbrainres.2004.12.006

Betts, H. N., Gilbert, R. A., Cai, Z. G., Okedara, Z. B., & Rodd, J. M. (2018). Retuning of lexical-semantic representations: Repetition and spacing effects in word-meaning priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *44*(7), 1130. https://psycnet.apa.org/fulltext/2017-57779-001.html

Blasi, D. E., Henrich, J., Adamou, E., Kemmerer, D., & Majid, A. (2022). Over-reliance on English hinders cognitive science. *Trends in cognitive sciences*, *26*(12), 1153-1170. https://doi.org/10.1016/j.tics.2022.09.015

Blott, L. M., Hartopp, O., Nation, K., & Rodd, J. M. (2022). Learning about the meanings of ambiguous words: Evidence from a word-meaning priming paradigm with short narratives. *PeerJ*, *10*, e14070. https://doi.org/10.7717/peerj.14070

Blott, L. M., Rodd, J. M., & Warren, J. E. (2023). Presentation format affects the behavioural and neural processing costs of sentence reinterpretation. *Language, Cognition and Neuroscience*, *38*(6), 779-801. https://doi.org/10.1080/23273798.2022.2159992

Borowsky, R., & Masson, M. E. J. (1996). Semantic ambiguity effects in word identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(1), 63-85. https://doi.org/10.1037/0278-7393.22.1.63

Branigan, H. (2007). Syntactic priming. *Language and Linguistics Compass*, *1*(1-2), 1-16. https://doi.org/10.1111/j.1749-818X.2006.00001.x

Branigan, H. P., Pickering, M. J., Liversedge, S. P., Stewart, A. J., & Urbach, T. P. (1995). Syntactic priming: Investigating the mental representation of language. *Journal of Psycholinguistic Research*, *24*(6), 489-506. https://doi.org/10.1007/BF02143163

Brysbaert, M., & Stevens, M. (2018). Power analysis and effect size in mixed effects models: A tutorial. *Journal of Cognition*, *1*(1), 9. https://doi.org/10.5334/joc.10

Burt, J. S., & Tate, H. (2002). Does a reading lexicon provide orthographic representations for spelling? *Journal of Memory and Language*, *46*(3), 518-543. https://doi.org/10.1006/jmla.2001.2818

Cai, Z. G., Gilbert, R. A., Davis, M. H., Gaskell, M. G., Farrar, L., Adler, S., & Rodd, J. M. (2017). Accent modulates access to word meaning: Evidence for a speaker-model account of spoken word recognition. *Cognitive Psychology*, *98*, 73-101. https://doi.org/10.1016/j.cogpsych.2017.08.003

Chomsky, N. (2002). An interview on minimalism. *In A. Belletti & L. Rizzi (Eds.), On Nature and Language (pp. 92–161). chapter, Cambridge: Cambridge University Press.* https://doi.org/10.1017/CBO9780511613876.005

Cohen, J. (1962). The statistical power of abnormal-social psychological research: A review. *Journal of Abnormal and Social Psychology*. https://doi.org/10.1037/h0045186

Cruse, A. D. (1986). *Lexical semantics* (1st ed.). *Cambridge university press*. https://philpapers.org/rec/CRULS

Curtis, A. J., Mak, M. H. C., Chen, S., Rodd, J. M., & Gaskell, M. G. (2022). Word-meaning priming extends beyond homonyms. *Cognition*, *226*, 105175. https://doi.org/10.1016/j.cognition.2022.105175

Dautriche, I., Mahowald, K., Gibson, E., & Piantadosi, S. T. (2017). Wordform similarity increases with semantic similarity: An analysis of 100 languages. *Cognitive science*, *41*(8), 2149-2169. https://doi.org/10.1111/cogs.12453

Davis, M. H., Coleman, M. R., Absalom, A. R., Rodd, J. M., Johnsrude, I. S., Matta, B. F., Owen, A. M., & Menon, D. K. (2007). Dissociating speech perception and comprehension at reduced levels of awareness. *Proceedings of the National Academy of Sciences*, *104*(41), 16032-16037. https://doi.org/10.1073/pnas.0701309104

Davis, M. H., Marslen-Wilson, W. D., & Gaskell, M. G. (2002). Leading up the lexical garden path: Segmentation and ambiguity in spoken word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *28*(1), 218-244. https://doi.org/10.1037/0096-1523.28.1.218

Degani, T., & Tokowicz, N. (2010). Semantic ambiguity within and across languages: An integrative review. *Quarterly Journal of Experimental Psychology*, *63*(7), 1266-1303. https://doi.org/10.1080/17470210903377372

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review, 93*(3), 283–321. https://doi.org/10.1037/0033-295X.93.3.283

Dell, G. S. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist model. *Journal of memory and language*, *27*(2), 124-142. https://doi.org/10.1016/0749-596X(88)90070-8

Dell, G. S., Reed, K. D., Adams, D. R., & Meyer, A. S. (2000). Speech errors, phonotactic constraints, and implicit learning: A study of the role of experience in language production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*(6), 1355. https://psycnet.apa.org/record/2000-12254-001

Doyen, S., Klein, O., Simons, D. J., & Cleeremans, A. (2014). On the other side of the mirror: Priming in cognitive and social psychology. *Social Cognition*, *32*(Supplement), 12-32. https://doi.org/10.1521/soco.2014.32.supp.12

Duff, M. C., & Brown-Schmidt, S. (2017). Hippocampal contributions to language use and processing. *The Hippocampus from Cells to Systems* (pp. 503-536). Springer International Publishing. https://doi.org/10.1007/978-3-319-50406-3_16

Duff, M. C., Gupta, R., Hengst, J. A., Tranel, D., & Cohen, N. J. (2011). The use of definite references signals declarative memory: Evidence from patients with hippocampal amnesia. *Psychological Science*, *22*(5), 666-673. https://doi.org/10.1177/0956797611404897

Duff, M. C., Hengst, J., Tranel, D., & Cohen, N. J. (2006). Development of shared information in communication despite hippocampal amnesia. *Nature Neuroscience*, *9*(1), 140-146. https://doi.org/10.1038/nn1601

Duffy, S. A., Kambe, G., & Rayner, K. (2001). The effect of prior disambiguating context on the comprehension of ambiguous words: Evidence from eye movements *On the consequences of meaning selection: Perspectives on resolving lexical ambiguity.* (pp. 27-43). American Psychological Association. https://doi.org/10.1037/10459-002

Duffy, S. A., Morris, R. K., & Rayner, K. (1988). Lexical ambiguity and fixation times in reading. *Journal of Memory and Language*, *27*(4), 429-446. https://doi.org/10.1016/0749-596X(88)90066-6

Dumas-Mallet, E., Button, K. S., Boraud, T., Gonon, F., & Munafò, M. R. (2017). Low statistical power in biomedical science: A review of three human research domains. *Royal Society Open Science*, *4*(2), 160254. https://doi.org/10.1098/rsos.160254

Dumay, N., & Gaskell, M. G. (2007). Sleep-associated changes in the mental representation of spoken words. *Psychological Science*, *18*(1), 35-39. https://doi.org/10.1111/j.1467-9280.2007.01845.x

Eichenbaum, H., & Bunsey, M. (1995). On the binding of associations in memory: Clues from studies on the role of the hippocampal region in paired-associate learning. *Current Directions in Psychological Science*, *4*(1), 19-23. https://doi.org/10.1111/1467-8721.ep10770954

Fang, X., & Perfetti, C. A. (2017). Perturbation of old knowledge precedes integration of new knowledge. *Neuropsychologia*, *99*, 270-278. https://doi.org/10.1016/j.neuropsychologia.2017.03.015

Fang, X., & Perfetti, C. A. (2019). Learning new meanings for known words: Perturbation of original meanings and retention of new meanings. *Memory & Cognition*, *47*(1), 130-144. https://doi.org/10.3758/s13421-018-0855-z

Friedrich, M., Wilhelm, I., Mölle, M., Born, J., & Friederici, A. D. (2017). The sleeping infant brain anticipates development. *Current Biology*, *27*(15), 2374-2380.e3. https://doi.org/10.1016/j.cub.2017.06.070

Frisson, S., Rayner, K., & Pickering, M. J. (2005). Effects of contextual predictability and transitional probability on eye movements during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(5), 862-877. https://doi.org/10.1037/0278-7393.31.5.862

Gaskell, M. G., Cairney, S. A., & Rodd, J. M. (2019). Contextual priming of word meanings is stabilized oversleep. *Cognition*, *182*, 109-126. https://doi.org/10.1016/j.cognition.2018.09.007

Gaskell, M. G., & Dumay, N. (2003). Lexical competition and the acquisition of novel words. *Cognition*, *89*(2), 105-132. https://doi.org/10.1016/S0010-0277(03)00070-2

Gaskell, M. G., & Marslen-Wilson, W. D. (1997). Integrating form and meaning: A distributed model of speech perception. *Language and Cognitive Processes*, *12*(5-6), 613-656. https://doi.org/10.1080/016909697386646

Gawlick-Grendell, L. A., & Woltz, D. J. (1994). Meaning dominance norms for 120 homographs. *Behavior Research Methods, Instruments, & Computers*, *26*(1), 5-25. https://doi.org/10.3758/BF03204557

Gernsbacher, M. A., Varner, K. R., & Faust, M. E. (2015). Investigating differences in general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*(3), 430. https://psycnet.apa.org/record/1990-18933-001

Gilbert, R. A., Davis, M. H., Gaskell, M. G., & Rodd, J. M. (2018). Listeners and readers generalize their experience with word meanings across modalities. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *44*(10), 1533-1561. https://doi.org/10.1037/xlm0000532

Gilbert, R. A., Davis, M. H., Gaskell, M. G., & Rodd, J. M. (2021). The relationship between sentence comprehension and lexical-semantic retuning. *Journal of Memory and Language*, *116*, 104188. https://doi.org/10.1016/j.jml.2020.104188

Gilbert, R. A., & Rodd, J. M. (2022). Dominance norms and data for spoken ambiguous words in British English. *Journal of Cognition*, *5*(1), 4. https://doi.org/10.5334/joc.194

Gómez, R. L., Bootzin, R. R., & Nadel, L. (2006). Naps promote abstraction in language-learning infants. *Psychological Science*, *17*(8), 670-674. https://doi.org/10.1111/j.1467-9280.2006.01764.x

Gottlob, L. R., Goldinger, S. D., Stone, G. O., & Van Orden, G. C. (1999). Reading homographs: Orthographic, phonologic, and semantic dynamics. *Journal of Experimental Psychology*, *25*(2), 561-574. https://psycnet.apa.org/record/1999-10532-017

Green, P., & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, *7*(4), 493-498. https://doi.org/10.1111/2041-210X.12504

Grodner, D., Gibson, E., & Watson, D. (2005). The influence of contextual contrast on syntactic processing: Evidence for strong-interaction in sentence comprehension. *Cognition*, *95*(3), 275-296. https://doi.org/10.1016/j.cognition.2004.01.007

Gutiérrez Silva, C., Blott, L., Taylor, J., & Rodd, J. (2021, July 8-9). A single exposure to both meanings of ambiguous words helps rather than hinders processing of subordinate meanings. [Conference Presentation]. Experimental Psychology Society Meeting, Online. [Not Available Online].

Hagoort, P. (1989). Processing of lexical ambiguities: A comment on Milberg, Blumstein, and Dworetzky (1987). *Brain and language*, *36*(2), 335-348. https://doi.org/10.1016/0093-934X(89)90070-9

Harley, T. (2001). *The psychology of language: From data to theory* (2nd ed.). Psychology press. https://doi.org/10.4324/9781315782942

Hawkins, J., & Shaw, P. (1992). Self-reported sleep quality in college students: A repeated measures approach. *Sleep*, *15*(6), 545-549. https://doi.org/10.1093/sleep/15.6.545

Henderson, L. M., Weighall, A. R., Brown, H., & Gareth Gaskell, M. (2012). Consolidation of vocabulary is associated with sleep in children: Sleep-associated consolidation of vocabulary. *Developmental Science*, *15*(5), 674-687. https://doi.org/10.1111/j.1467-7687.2012.01172.x

Hilverman, C., Cook, S. W., & Duff, M. C. (2016). Hippocampal declarative memory supports gesture production: Evidence from amnesia. *Cortex*, *85*, 25-36. https://doi.org/10.1016/j.cortex.2016.09.015

Hino, Y., Kusunose, Y., & Lupker, S. J. (2010). The relatedness-of-meaning effect for ambiguous words in lexical-decision tasks: When does relatedness matter? *Canadian Journal of Experimental Psychology / Revue Canadienne de Psychologie Expérimentale*, *64*(3), 180-196. https://doi.org/10.1037/a0020475

Hino, Y., Pexman, P. M., & Lupker, S. J. (2006). Ambiguity and relatedness effects in semantic tasks: Are they due to semantic coding? *Journal of Memory and Language*, *55*(2), 247-273. https://doi.org/10.1016/j.jml.2006.04.001

Hockett, C. F., & Hockett, C. D. (1960). The origin of speech. *Scientific American*, *203*(3), 88-97. https://www.jstor.org/stable/24940617

Hoffman, P., & Woollams, A. M. (2015). Opposing effects of semantic diversity in lexical and semantic relatedness decisions. *Journal of Experimental Psychology: Human Perception and Performance*, *41*(2), 385-402. https://doi.org/10.1037/a0038995

Horváth, K., Myers, K., Foster, R., & Plunkett, K. (2015). Napping facilitates word learning in early lexical development. *Journal of Sleep Research*, *24*(5), 503-509. https://doi.org/10.1111/jsr.12306

Hulme, R. C., & Rodd, J. M. (2023). The role of sleep in learning new meanings for familiar words through stories. *Journal of Cognition*, *6*(1), 27. https://doi.org/10.5334/joc.282

Ihara, A. S., Mimura, T., Soshi, T., Yorifuji, S., Hirata, M., Goto, T., ... & Fujimaki, N. (2015). Facilitated lexical ambiguity processing by transcranial direct current stimulation over the left inferior frontal cortex. *Journal of Cognitive Neuroscience*, *27*(1), 26-34. https://doi.org/10.1162/jocn_a_00703

James, E., Gaskell, M. G., Weighall, A., & Henderson, L. (2017). Consolidation of vocabulary during sleep: The rich get richer? *Neuroscience & Biobehavioral Reviews*, *77*, 1-13. https://doi.org/10.1016/j.neubiorev.2017.01.054

Joordens, S., & Besner, D. (1994). When banking on meaning is not (yet) money in the bank: Explorations in connectionist modeling. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(5), 1052-1062. https://doi.org/10.1037/0278-7393.20.5.1051

Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological review*, *87*(4), 329. https://doi.org/10.1037/0033-295X.87.4.329

Kaiser, E., & Trueswell, J. (2004). The role of discourse context in the processing of a flexible word-order language. *Cognition*, *94*(2), 113-147. https://doi.org/10.1016/j.cognition.2004.01.002

Kamide, Y., Altmann, G. T. M., & Haywood, S. L. (2003). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language*, *49*(1), 133-156. https://doi.org/10.1016/S0749-596X(03)00023-8

Kaschak, M. P., & Glenberg, A. M. (2004). This construction needs learned. *Journal of Experimental Psychology: General*, *133*(3), 450-467. https://doi.org/10.1037/0096-3445.133.3.450

Kawamoto, A. H., Iv, W. T. F., & Kello, C. T. (1994). When two meanings are better than one: Modeling the ambiguity advantage using a recurrent distributed network. *Journal of Experimental Psychology: Human Perception and Performance*, *20*(6), 1233.https://psycnet.apa.org/buy/1995-19637-001

Klein, D. E., & Murphy, G. L. (2001). The representation of polysemous words. *Journal of Memory and Language*, *45*(2), 259-282. https://doi.org/10.1006/jmla.2001.2779

Klepousniotou, E., & Baum, S. R. (2007). Disambiguating the ambiguity advantage effect in word recognition: An advantage for polysemous but not homonymous words. *Journal of Neurolinguistics*, *20*(1), 1-24. https://doi.org/10.1016/j.jneuroling.2006.02.001

Klooster, N. B., & Duff, M. C. (2015). Remote semantic memory is impoverished in hippocampal amnesia. *Neuropsychologia*, *79*, 42-52. https://doi.org/10.1016/j.neuropsychologia.2015.10.017

Kowialiewski, B., Krasnoff, J., Mizrak, E., & Oberauer, K. (2022). The semantic relatedness effect in serial recall: Deconfounding encoding and recall order. *Journal of Memory and Language*, *127*, 104377. https://doi.org/10.1016/j.jml.2022.104377

Kurdziel, L. B. F., Mantua, J., & Spencer, R. M. C. (2017). Novel word learning in older adults: A role for sleep? *Brain and Language*, *167*, 106-113. https://doi.org/10.1016/j.bandl.2016.05.010

Lapalme, G. (2017). *Edinbutgh Associative Thesaurus (EAT) [ONLINE].* http://rali.iro.umontreal.ca/rali/?q=en/Textual%20Resources/EAT

Leech, & Rayson. (2014). Word frequencies in written and spoken English. Based on the British National Corpus. Routledge. https://doi.org/10.4324/9781315840161

Leinenger, M., & Rayner, K. (2013). Eye movements while reading biased homographs: Effects of prior encounter and biasing context on reducing the subordinate bias effect. *Journal of Cognitive Psychology*, *25*(6), 665-681. https://doi.org/10.1080/20445911.2013.806513

Levelt, W.J. (1989). *Speaking: From Intention to Articulation*. MIT Press, Cambridge, MA.

Levelt, W. J. (1992). Accessing words in speech production: Stages, processes and representations. *Cognition*, *42*(1-3), 1-22. https://doi.org/10.1016/0010-0277(92)90038-J

Levinson, S. (2000). Presumptive meanings: The theory of generalized conversational implicature. MIT Press, 2000. Pp. xxiii+480. *Journal of Linguistics*, *40*(1), 181–186. doi:10.1017/S0022226703272364

Levy, R. (2008). Expectation-based syntactic comprehension. *Cognition*, *106*(3), 1126-1177. https://doi.org/10.1016/j.cognition.2007.05.006

Li, P., Shu, H., Yip, M. C., Zhang, Y., & Tang, Y. (2002). Lexical ambiguity in sentence processing: Evidence from Chinese. *Sentence processing in East Asian languages*, 111-129. https://blclab.org/wp-content/uploads/2013/02/sp01.pdf

Li, P., & Yip, M. (1996). Lexical ambiguity and context effects in spoken word recognition: Evidence from Chinese. In Cottrell, G. (ed.), Proceedings of the 18th Annual Conference of the Cognitive Science Society (pp. 228–232). Hillsdale, NJ: Lawrence Erlbaum Associates. https://escholarship.org/uc/item/3mg9k0qr

Logan, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? *Cognitive Psychology*, *22*(1), 1-35. https://doi.org/10.1016/0010-0285(90)90002-L

Luke, S. G., & Christianson, K. (2016). Limits on lexical prediction during reading. *Cognitive Psychology*, *88*, 22-60. https://doi.org/10.1016/j.cogpsych.2016.06.002

Lyons, J. (1977). *Semantics: Volume 2* (Vol. 2). Cambridge University Press. https://doi.org/10.1017/CBO9780511620614

Lyons, J. (1981). *Language and linguistics*. Cambridge University Press. https://doi.org/10.1017/CBO9780511809859

MacDonald, M. C., Pearlmutter, N. J., & Seidenberg, M. S. (1994). Lexical nature of syntactic ambiguity resolution. *Psychological review*, *101*(4), 676. https://doi.org/10.1037/0033-295X.101.4.676

MacGregor, L. J., Rodd, J. M., Gilbert, R. A., Hauk, O., Sohoglu, E., & Davis, M. H. (2020). The neural time course of semantic ambiguity resolution in speech comprehension. *Journal of Cognitive Neuroscience*, *32*(3), 403-425. https://doi.org/10.1162/jocn_a_01493

Mak, M. H. C., Curtis, A. J., Rodd, J. M., & Gaskell, M. G. (2023). Episodic memory and sleep are involved in the maintenance of context-specific lexical information. *Journal of Experimental Psychology: General*. https://doi.org/10.1037/xge0001435

Mak, M. H. C., Curtis, A. J., Rodd, J. M., & Gaskell, M. G. (2024). Recall and recognition of discourse memory across sleep and wake. *Journal of Memory and Language*, *138*, 104536. https://doi.org/10.1016/j.jml.2024.104536

Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., & Bates, D. (2017). Balancing type I error and power in linear mixed models. *Journal of Memory and Language*, *94*, 305-315. https://doi.org/10.1016/j.jml.2017.01.001

McClelland, J. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological review*, *102*(3), 419. https://doi.org/10.1037/0033-295X.102.3.419

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: *Psycholinguistics: critical concepts in psychology*, *88*(5), 422. https://doi.org/10.1037/0033-295X.88.5.375

McLeod, P., Plaut, D. C., & Shallice, T. (2001). Connectionist modelling of word recognition. *Synthese*, *129*, 173-183. https://link.springer.com/article/10.1023/A:1013003423323

McNamara, T. P. (2005). Semantic Priming McNamara, T. P. (2005). Semantic priming. Perspectives from memory and word recognition. New York: Psychology Press Ltd. https://doi.org/10.4324/9780203338001

McQueen, J. M., Norris, D., & Cutler, A. (2006). The dynamic nature of speech perception. *Language and Speech*, *49*(1), 101-112. https://doi.org/10.1177/00238309060490010601

Mehler, J., Segui, J., & Carey, P. (1978). Tails of words: Monitoring ambiguity. *Journal of Verbal Learning and Verbal Behavior*, *17*(1), 29-35.https://doi.org/10.1016/S0022-5371(78)90507-8

Mensix, G.-J. M., & Raaijmakers, J. G. W. (1989). A model for contextual fluctuation. *Journal of Mathematical Psychology*, *33*(2), 172-186. https://raaijmakers.edu.fmg.uva.nl/PDFs/Mensink%20and%20Raaijmakers%20JMP%201989.pdf

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words; Evidence of a dependence between retrieval operations. *Journal of experimental psychology*, *90*(2), 227. http://websites.umich.edu/~bcalab/documents/MeyerSchvaneveldt1971.pdf

Mirman, D., Strauss, T. J., Dixon, J. A., & Magnuson, J. S. (2009). Effect of representational distance between meanings on recognition of ambiguous spoken words. *Cognitive Science*, *34*(1), 161-173. https://doi.org/10.1111/j.1551-6709.2009.01069.x

Montazeri, M., Hamidi, H., Hamidi, B., & Yaghoobi, J. (2014). The localist and the distributed models of connectionism. J*ournal of Applied Linguistics and Language Research*, 1(2), 27-33. https://www.jallr.com/index.php/JALLR/article/view/11

Morey, R. D. (2008). Confidence intervals from normalized data: A correction to Cousineau (2005). *Tutorials in Quantitative Methods for Psychology*, *4*(2), 61-64. https://doi.org/10.20982/tqmp.04.2.p061

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review*, *76*(2), 165-178. https://doi.org/10.1037/h0027366

Nelson, D. L., McEvoy, C. L., Walling, J. R., & Wheeler, J. W. (1980). The University of South Florida homograph norms. *Behavior Research Methods & Instrumentation*, *12*(1), 16-37. https://doi.org/10.3758/BF03208320

Norbury, C. F. (2005). Barking up the wrong tree? Lexical ambiguity resolution in children with language impairments and autistic spectrum disorders. *Journal of Experimental Child Psychology*, *90*(2), 142-171. https://doi.org/10.1016/j.jecp.2004.11.003

Norman, K. A., Newman, E., Detre, G., & Polyn, S. (2006). How inhibitory oscillations can train neural networks and punish competitors. *Neural computation*, *18*(7), 1577-1610. https://doi.org/10.1162/neco.2006.18.7.1577

Norman, K. A., & O'Reilly, R. C. (2003). Modeling hippocampal and neocortical contributions to recognition memory: A complementary-learning-systems approach. *Psychological Review*, *110*(4), 611-646. https://doi.org/10.1037/0033-295X.110.4.611

Norris, D. (2013). Models of visual word recognition. *Trends in Cognitive Sciences*, *17*(10), 517-524. https://doi.org/10.1016/j.tics.2013.08.003

Norris, D., McQueen, J., & Cutler, A. (2003). Perceptual learning in speech. *Cognitive Psychology*, *47*(2), 204-238. https://doi.org/10.1016/S0010-0285(03)00006-9

Nosek, B. A., Beck, E. D., Campbell, L., Flake, J. K., Hardwicke, T. E., Mellor, D. T., Van 'T Veer, A. E., & Vazire, S. (2019). Preregistration is hard, and worthwhile. *Trends in Cognitive Sciences*, *23*(10), 815-818. https://doi.org/10.1016/j.tics.2019.07.009

Nosek, B. A., Ebersole, C. R., DeHaven, A. C., & Mellor, D. T. (2018). The preregistration revolution. Proceedings of the National Academy of Sciences, 115(11), 2600–2606. https://doi.org/10.1073/pnas.1708274114

Onifer, W., & Swinney, D. A. (1981). Accessing lexical ambiguities during sentence comprehension: Effects of frequency of meaning and contextual bias. *Memory & Cognition*, *9*, 225-236. https://link.springer.com/article/10.3758/BF03196957

Ooi, N. (2018). Developing a vocabulary test of lexical knowledge and flexibility. [Unpublished bachelor's thesis]. University College London.

O'Reilly, R. C., & Rudy, J. W. (2000). Computational principles of learning in the neocortex and hippocampus. *Hippocampus*, *10*(4), 389-397. https://doi.org/10.1002/1098-1063(2000)10:4<389:AID-HIPO5>3.0.CO;2-P

Palan, S., & Schitter, C. (2018). Prolific.ac—A subject pool for online experiments. *Journal of Behavioral and Experimental Finance*, *17*, 22-27. https://doi.org/10.1016/j.jbef.2017.12.004

Parker, A. J., Taylor, J. S. H., & Rodd, J. M. (2023). Readers use recent experiences with word meanings to support the processing of lexical ambiguity: Evidence from eye movements. https://doi.org/10.31234/osf.io/b49vk

Parks, R., Ray, J., & Bland, S. (1998). Wordsmyth English dictionary—Thesaurus. [ONLINE]. *1998*. [1999, February 1], University of Chicago. Available: http:// www.wordsmyth.net/

Pavlik, P. I., & Anderson, J. R. (2008). Using a model to compute the optimal schedule of practice. *Journal of Experimental Psychology: Applied*, *14*(2), 101-117. https://doi.org/10.1037/1076-898X.14.2.101

Philip I. Pavlik, & Anderson, J. R. (2005). Practice and forgetting effects on vocabulary memory an activation-based model of the spacing effect. *Cognitive science*, *29*(4), 559-586. https://onlinelibrary.wiley.com/doi/abs/10.1207/s15516709cog0000_14

Piantadosi, S. T., Tily, H., & Gibson, E. (2012). The communicative function of ambiguity in language. *Cognition*, *122*(3), 280-291. https://doi.org/10.1016/j.cognition.2011.10.004

Piercey, C. D., & Joordens, S. (2000). Turning an advantage into a disadvantage: Ambiguity effects in lexical decision versus reading tasks. *Memory & Cognition*, *28*(4), 657-666. https://doi.org/10.3758/BF03201255

Pinker, S., & Bloom, P. (1990). Natural language and natural selection. *Behavioral and brain sciences*, *13*(4), 707-727. https://doi.org/10.1017/S0140525X00081061

Plaut, D. C. (1997). Structure and function in the lexical system: Insights from distributed models of word reading and lexical decision. *Language and Cognitive Processes*, *12*(5-6), 765-806. https://doi.org/10.1080/016909697386682

R Core Team. (2019). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Available at http://www.R-project.org/.

Raaijmakers, J. G. W. (2003). Spacing and repetition effects in human memory: Application of the SAM model. *Cognitive Science*, *27*(3), 431-452. https://doi.org/10.1207/s15516709cog2703_5

Rayner, K. (1993). Eye movements in reading: Recent developments. *Current Directions in Psychological Science*, *2*(3), 81-85. https://doi.org/10.1111/1467-8721.ep10770940

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological bulletin*, *124*(3), 372. https://psycnet.apa.org/buy/1998-11174-004

Rodd, J. (2020). Settling into semantic space: An ambiguity-focused account of word-meaning access. *Perspectives on Psychological Science*, *15*(2), 411-427. https://doi.org/10.1177/1745691619885860

Rodd, J., Gaskell, G., & Marslen-Wilson, W. (2002). Making sense of semantic ambiguity: semantic competition in lexical access. *Journal of Memory and Language*, *46*(2), 245-266. https://doi.org/10.1006/jmla.2001.2810

Rodd, J. M. (2022). Word meaning access: The one-to-many mapping from form to meaning. 33. https://doi.org/10.31234/osf.io/yz7c2

Rodd, J. M. (2024). Moving experimental psychology online: How to obtain high quality data when we can't see our participants. *Journal of Memory and Language*, *134*, 104472. https://doi.org/10.1016/j.jml.2023.104472

Rodd, J. M., Berriman, R., Landau, M., Lee, T., Ho, C., Gaskell, M. G., & Davis, M. H. (2012). Learning new meanings for old words: Effects of semantic relatedness. *Memory & Cognition*, *40*(7), 1095-1108. https://doi.org/10.3758/s13421-012-0209-1

Rodd, J. M., Cai, Z. G., Betts, H. N., Hanby, B., Hutchinson, C., & Adler, A. (2016). The impact of recent and long-term experience on access to word meanings: Evidence from large-scale internet-based experiments. *Journal of Memory and Language*, *87*, 16-37. https://doi.org/10.1016/j.jml.2015.10.006

Rodd, J. M., Davis, M. H., & Johnsrude, I. S. (2005). The neural mechanisms of speech comprehension: fMRI studies of semantic ambiguity. *Cerebral Cortex*, *15*(8), 1261-1269. https://doi.org/10.1093/cercor/bhi009

Rodd, J. M., Gaskell, M. G., & Marslen-Wilson, W. D. (2004). Modelling the effects of semantic ambiguity in word recognition. *Cognitive Science*, *28*(1), 89-104. https://doi.org/10.1207/s15516709cog2801_4

Rodd, J. M., Johnsrude, I. S., & Davis, M. H. (2010). The role of domain-general frontal systems in language comprehension: Evidence from dual-task interference and semantic ambiguity. *Brain and Language*, *115*(3), 182-188. https://doi.org/10.1016/j.bandl.2010.07.005

Rodd, J. M., Johnsrude, I. S., & Davis, M. H. (2012). Dissociating frontotemporal contributions to semantic ambiguity resolution in spoken sentences. *Cerebral Cortex*, *22*(8), 1761-1773. https://doi.org/10.1093/cercor/bhr252

Rodd, J. M., Longe, O. A., Randall, B., & Tyler, L. K. (2010). The functional organisation of the fronto-temporal language system: Evidence from syntactic and semantic ambiguity. *Neuropsychologia*, *48*(5), 1324-1335. https://doi.org/10.1016/j.neuropsychologia.2009.12.035

Rodd, J. M., Lopez Cutrin, B., Kirsch, H., Millar, A., & Davis, M. H. (2013). Long-term priming of the meanings of ambiguous words. *Journal of Memory and Language*, *68*(2), 180-198. https://doi.org/10.1016/j.jml.2012.08.002

Rodd, J. (2018). Lexical ambiguity. In Shirley-Ann Rueschemeyer, and M. Gareth Gaskell (eds), *The Oxford Handbook of Psycholinguistics*, 2nd edn, Oxford Library of Psychology (2018; online edn, Oxford Academic, 10 Sept. 2018). https://doi.org/10.1093/oxfordhb/9780198786825.013.5, accessed 29 Nov. 2024.

Roelofs, A. (1997). The WEAVER model of word-form encoding in speech production. *Cognition*, *64*(3), 249-284. https://doi.org/10.1016/S0010-0277(97)00027-9

Rueschemeyer, S.A., & Gaskell, M. G. (2018). *The Oxford Handbook of Psycholinguistics* (2nd ed.). Oxford Library of Psychology (2018; online edn, Oxford Academic). https://doi.org/10.1093/oxfordhb/9780198786825.001.0001

Russell V., L. (2021). *Emmeans: estimated marginal means, aka least-squares means. R package version 1.6.2-1[Computer software].* https://CRAN.R-project.org/package=emmeans

Ryskin, R. A., Qi, Z., Duff, M. C., & Brown-Schmidt, S. (2017). Verb biases are shaped through lifelong learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *43*(5), 781-794. https://doi.org/10.1037/xlm0000341

Ryskin, R., Qi, Z., Covington, N. V., Duff, M., & Brown-Schmidt, S. (2018). Knowledge and learning of verb biases in amnesia. *Brain and Language*, *180-182*, 62-83. https://doi.org/10.1016/j.bandl.2018.04.003

Sandoval, M., Leclerc, J. A., & Gómez, R. L. (2017). Words to sleep on: Naps facilitate verb generalization in habitually and nonhabitually napping Preschoolers. *Child Development*, *88*(5), 1615-1628. https://doi.org/10.1111/cdev.12723

Schvaneveldt, R. W., Meyer, D. E., & Becker, C. E. (1976). Lexical ambiguity, semantic context, and visual word recognition. *Journal of experimental psychology: human perception and performance*, *2*(2), 243. https://researchcollective.com/PFWeb/Roger/Papers/Schvaneveldt_Meyer_Becker_1976.pdf

Sedivy, J. C. (2002). Invoking discourse-based contrast sets and resolving syntactic ambiguities. *Journal of Memory and Language*, *46*(2), 341-370. https://doi.org/10.1006/jmla.2001.2812

Sedivy, J. C., K. Tanenhaus, M., Chambers, C. G., & Carlson, G. N. (1999). Achieving incremental semantic interpretation through contextual representation. *Cognition*, *71*(2), 109-147. https://doi.org/10.1016/S0010-0277(99)00025-6

Sereno, S. C., Pacht, J. M., & Rayner, K. (1992). The effect of meaning frequency on processing lexically ambiguous words: Evidence from eye fixations. *Psychological Science*, *3*(5), 296-301. https://doi.org/10.1111/j.1467-9280.1992.tb00676.x

Shadmehr, R., & Brashers-Krug, T. (1997). Functional stages in the formation of human long-term motor memory. *The Journal of Neuroscience*, *17*(1), 409-419. https://doi.org/10.1523/JNEUROSCI.17-01-00409.1997

Shattuck-Hufnagel, S. (1979). Speech errors as evidence for a serial-order mechanism in sentence production. In: Cooper, W.E., Walker, E.C.T. (Eds.), Sentence Processing: Psycholinguistic Studies Presented to Merrill Garrett. Erlbaum, Hillsdale, NJ.

Shen, W., & Li, X. (2016). Processing and representation of ambiguous words in Chinese reading: Evidence from eye movements. *Frontiers in psychology*, *7*, 1713. https://doi.org/10.3389/fpsyg.2016.01713

Shipley, W. C. (1940). A self-administering scale for measuring intellectual impairment and deterioration. *The Journal of Psychology*, *9*(2), 371-377. https://doi.org/10.1080/00223980.1940.9917704

Simpson, G. B., & Krueger, M. A. (1991). Selective access of homograph meanings in sentence context. *Journal of Memory and Language*. https://doi.org/10.1016/0749-596X(91)90029-J

Smaldino, P. E., & McElreath, R. (2016). The natural selection of bad science. *Royal Society Open Science*, *3*(9), 160384. https://doi.org/10.1098/rsos.160384

Stanovic, K. E., & West, R. F. (1989). Exposure to print and orthographic Processing. *24*(4), 402-433. *Reading Research Quarterly*. https://doi.org/10.2307/747605

Swaab, T., Brown, C., & Hagoort, P. (2003). Understanding words in sentence contexts: The time course of ambiguity resolution. *Brain and Language*, *86*(2), 326-343. https://doi.org/10.1016/S0093-934X(02)00547-3

Swinney, D. A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behaviour*. *18*(6), 645-659.https://doi.org/10.1016/S0022-5371(79)90355-4

Tabossi, P., & Zardon, F. (1993). Processing ambiguous words in context. *Journal of Memory and Language*. *32*(3), 359-372. https://doi.org/10.1006/jmla.1993.1019

Tamminen, J., Payne, J. D., Stickgold, R., Wamsley, E. J., & Gaskell, M. G. (2010). Sleep spindle activity is associated with the integration of new memories and existing knowledge. *The Journal of Neuroscience*, *30*(43), 14356-14360. https://doi.org/10.1523/JNEUROSCI.3028-10.2010

Tooley, K. M., & Traxler, M. J. (2010). Syntactic priming effects in comprehension: A critical review: Syntactic priming effects in comprehension. *Language and Linguistics Compass*, *4*(10), 925-937. https://doi.org/10.1111/j.1749-818X.2010.00249.x

Trott, S., & Bergen, B. (2020). Why do human languages have homophones? *Cognition*, *205*, 104449. https://doi.org/10.1016/j.cognition.2020.104449

Twilley, L. C., & Dixon, P. (2000). Meaning resolution processes for words: A parallel independent model. *Psychonomic Bulletin & Review*, *7*(1), 49-82. https://doi.org/10.3758/BF03210725

Twilley, L. C., Dixon, P., Taylor, D., & Clark, K. (1994). University of Alberta norms of relative meaning frequency for 566 homographs. *Memory & Cognition*, *22*(1), 111-126. https://doi.org/10.3758/BF03202766

Tyler, L. K., & Marslen-Wilson, W. D. (1977). The on-line effects of semantic context on syntactic processing. *Journal of Verbal Learning and Verbal Behavior*, *16*(6), 683-692. https://doi.org/10.1016/S0022-5371(77)80027-3

Van Heuven, W. J. B., Mandera, P., Keuleers, E., & Brysbaert, M. (2014). Subtlex-UK: A new and improved word frequency database for British English. *Quarterly Journal of Experimental Psychology*, *67*(6), 1176-1190. https://doi.org/10.1080/17470218.2013.850521

Vankov, I., Bowers, J., & Munafò, M. R. (2014). Article commentary: On the persistence of low power in psychological science. *Quarterly Journal of Experimental Psychology*, *67*(5), 1037-1040. https://doi.org/10.1080/17470218.2014.885986

Vitello, S., & Rodd, J. M. (2015). Resolving semantic ambiguities in sentences: Cognitive processes and brain mechanisms: Resolving semantic ambiguities. *Language and Linguistics Compass*, *9*(10), 391-405. https://doi.org/10.1111/lnc3.12160

Vitello, S., Warren, J. E., Devlin, J. T., & Rodd, J. M. (2014). Roles of frontal and temporal regions in reinterpreting semantically ambiguous sentences. *Frontiers in Human Neuroscience*, 8, 530. https://doi.org/10.3389/fnhum.2014.00530

Voeten, C. C. (2023). Buildmer: Stepwise elimination and term reordering for mixed-effects regression. 663. https://cran.r-project.org/web/packages/buildmer/index.html

Wasow, T., Perfors, A., & Beaver, D. (2005). The puzzle of ambiguity. *Morphology and the web of grammar: Essays in memory of Steven G. Lapointe*, 265-282. https://perfors.net/files/2005/WasowPerforsBeaver2005.pdf

Wiley, J., George, T., & Rayner, K. (2018). Baseball fans don't like lumpy batters: Influence of domain knowledge on the access of subordinate meanings. *Quarterly Journal of Experimental Psychology*, *71*(1), 93-102. https://doi.org/10.1080/17470218.2016.1251470

Wilson, M. A., & McNaughton, B. L. (1994). Reactivation of hippocampal ensemble memories during sleep. *Science*, *265*(5172), 676-679. https://doi.org/10.1126/science.8036517

Zwitserlood, P. (1989). The locus of the effects of sentential-semantic context in spoken-word processing. *Cognition*, *32*(1), 25-64. https://doi.org/10.1016/0010- 0277(89)90013-9