HEMISPHERIC DIFFERENCES IN EFFECTS OF MEANING SIMILARITY AND MEANING DOMINANCE ON SEMANTIC PRIMING: A DIVIDED VISUAL FIELD STUDY

by

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Hemispheric differences in effects of meaning similarity and meaning dominance on semantic priming: A divided visual field study

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Based predominantly on semantic priming studies with divided visual field (DVF) presentation, current models of hemispheric differences in word semantic processing converge on a proposal that left hemisphere (LH) processes focus word meanings to their core by inhibiting less related meanings, whereas right hemisphere (RH) processes keep less related meanings active. The inhibition process supported by LH processing is assumed to apply to two distinct semantic processes: (a) narrowing of a single word meaning (inhibition of less related features and words), and (b) elimination of incompatible/ conflicting meanings of an ambiguous word.

Semantic priming studies investigating hemispheric differences in these two processes have relied on associated prime-target pairs, which might have been problematic for two reasons. First, association might reflect lexical co-occurrence of word forms rather than effects of semantic relatedness; therefore, these studies might have confounded lexical and semantic priming effects. Second, in studies of ambiguous words dominant items were strongly associated whereas subordinate items were weakly associated; therefore, these studies confounded dominance and degree of relatedness.

To address these confounds, this study conducted two semantic priming experiments with central prime presentation, DVF presentations for targets, and a 750 ms SOA. Experiment 1 investigated the effect of degree of semantic similarity on priming, using non-associated, prime-target pairs that were controlled for lexical co-occurrence. Experiment 2 investigated effects of meaning dominance on priming with non-associated prime-target pairs. Results are consistent with high-similarity priming for left visual field (lvf) and possibly for right visual field (rvf) targets, and with high-dominance priming for rvf and lvf targets, suggesting that LH (and RH) processes mediate effects of semantic similarity and dominance.

However, priming effects in both experiments were very small. Thus, priming effects might have reflected that prime-target relatedness was less than expected, indicating that LH processing does not inhibit less related meanings, which is consistent with other studies using central primes. Additionally/ alternatively, larger priming effects in other studies might derive mainly from association rather than semantic similarity. Finally, the small priming effects could be due to some aspect of the experimental procedure that might have made these experiments less sensitive to semantic priming.

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Preface

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1. INTRODUCTION

1.1. STATEMENT OF THE PROBLEM AND BACKGROUND

Over the last several decades a focused research effort has addressed hemispheric differences in the processing of word meanings. This work relies mainly on semantic priming studies with divided visual field (DVF) presentation. Semantic priming refers to the effect that target words are processed faster if they are preceded by a related prime word, sentence, or text context, and priming effects allow inferences to be drawn about the nature of meaning representations and their underlying processing mechanisms. In divided visual field presentation, words are shown laterally in the visual field so that the visual information initially reaches only one hemisphere. Because priming effects can differ depending on the visual field of presentation, hemispheric differences in meaning processing are inferred.

Based on this evidence, several models of such differences have been suggested (e.g., Burgess & Lund, 1998b; Chiarello, 1998b; Koivisto & Laine, 2000). According to these models, the left cerebral hemisphere (LH) and the right cerebral hemisphere (RH) support distinct cognitive architectures and/or computations that play complementary roles in the representation, activation, and processing of word meanings (For ease of exposition, these distinctions will be referred to as *LH processing* and *RH processing* in the rest of this paper. These terms do not imply that all processes relevant to the function of sustained meaning activation are localized in a single hemisphere).

While the models differ in assumptions of underlying processing mechanisms, they all converge on the proposal that after initial broad activation of a word’s features or meanings, LH processing focuses meaning access to a word’s core meanings through inhibition or decay of less related or inconsistent features or interpretations. Thus, activations only for *strongly related* meanings are sustained for further processing. These "lean" and precise meaning representations are thought to enable efficient processing and representation of the current message. Conversely, RH processing continues to keep *weakly related* features or meanings active to make them available for further processing. These sustained meanings are thought to facilitate the processing of unexpected interpretations, non-literal intent, or inferences. In the rest of this document, this proposal will be referred to as the *standard model* of hemispheric differences in word-level meaning activation.

The standard model has been widely accepted to account for semantic priming data with DVF presentation, and it has been applied to language disorders after brain damage, for example, to explain impairments in comprehending non-literal meanings (Brownell, 2000), in inferencing (Beeman et al., 1994), or in ambiguity resolution after right- and left-hemisphere brain damage (Copland, Chenery, & Murdoch, 2002; McDonald et al., 2005). However, the standard model in its current form might be too limited, because the distinction of “strongly” versus “weakly” related meanings confounds two distinct meaning relationships, which likely reflect theoretically distinct underlying processes: strength of semantic relatedness and meaning dominance (Atchley, Burgess, & Keeney, 1999).

Strength of semantic relatedness refers to the degree to which a prime word is related to a corresponding target word (e.g., <cat> and <dog> versus <cat> and <snake>). In current models of word processing, effects of strength of semantic relatedness on priming emerge from the architectural and computational design features that underlie encoded lexical and semantic relationships (Plaut, 1995; McRae & Boisvert, 1998; Canas, 1990). Thus, studies using word pairs with different degrees of semantic relatedness assess the breadth of activation of the prime’s semantic network.

Meaning dominance refers to the relative frequency of incompatible meanings or features of a single word form. For example, the dominant meaning <sphere> is more frequently evoked for the word *ball* than the subordinate meaning <formal dance>, and the dominant feature <crunchy> of the word *apple* is part of the dominant image of this word, which is more frequently evoked than the subordinate image that includes the subordinate feature <rotten> (Atchley et al., 1999)[1]. In current models of word processing, meaning dominance effects result from mechanisms that underlie the mapping of word form representations onto their respective meaning representations (Gernsbacher & St John, 2001; Kawamoto, 1993; Simpson & Burgess, 1985), and studies using ambiguous primes assess the degree of activation for two incompatible and competing meanings.

Plaut (personal communication, April 9, 2002) proposed an alternative model which incorporates these distinctions and differs from the standard model in its predictions for LH processing. In this model, weakly related meanings prime rather than being inhibited, although to a lesser degree than strongly related meanings. Subordinate meanings are inhibited, consistent with the standard model. Thus, according to this model, LH semantic processing is responsible for eliminating inconsistent and incompatible information, but not for narrowing activated semantic fields. Results from studies that use long stimulus onset asynchronies, central prime presentation, and the priming measure of unrelated versus

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[1] Note that in the article by Atchley and colleagues the terms *dominant* and *subordinate* refer to the frequency with which participants produced features in a feature generation task. This use of the two terms is inconsistent with the way they are used in word ambiguity studies; therefore, the terminology was adapted here to be consistent with other studies investigating meaning dominance.

related prime-target pairs (see below for why these methods provide the most appropriate data) are mainly consistent with this proposal (Atchley, Burgess, Audet, & Arambel, 1996; Atchley et al., 1999; Burgess & Simpson, 1988; Burgess et al., 1998b; Chiarello, Burgess, Richards, & Pollock, 1990; Chiarello, Richards, & Pollock, 1992; Nakagawa, 1991), although the evidence is still sparse and in part conflicting (Anaki, Faust, & Kravetz, 1998; Hasbrooke & Chiarello, 1998).

More importantly, all relevant studies are based on associated prime-target pairs for at least one of their conditions, and none of the conditions was controlled for lexical co-occurrence. This methodological choice is problematic for two reasons. First, several authors have argued that association reflects relationships at the word form level, based on lexical co-occurrence (e.g., Fodor, 1983). Thus, observed differences in priming effects might be attributed to word-form rather than word-meaning processing. A lexical source of priming effects would undermine one of the basic theoretical assumptions underlying the standard model as well as Plaut's model, thus questioning their theoretical basis and proposed explanatory mechanisms.

Second, for investigating meaning dominance, associated targets necessarily confound dominance with degree of relatedness, because the target related to the dominant meaning is highly associated with the prime (e.g., bank – money), whereas the subordinate target is very weakly related with the prime (e.g., bank – river). Matching dominant and subordinate word pairs for strength of relatedness is only possible with weakly related targets (e.g., in Atchley et al., 1999), which might not provide enough power to detect subordinate priming. Thus, the previously observed inhibition for subordinate meanings could be a result of an interaction of the two effects.

Therefore, the proposed study asks the following four questions regarding sustained meaning activation supported by LH processing:

1. Once lexical-level effects are controlled for, is priming predicted by differences in strength of semantic similarity?
2. If so, are only meanings with high semantic similarity primed?
3. Once strength of semantic relatedness is controlled for, is priming predicted by differences in meaning dominance?
4. If so, are only meanings with high meaning dominance primed?

To address these questions, two DVF experiments with central prime and lateral target presentation were conducted in this study. Experiment 1 used prime target pairs (a) for which strength of semantic similarity was the measure of semantic relatedness, because for this relationship there is high confidence that priming effects reflect semantic rather than lexical processing (Chiarello, 1998b;

Chiarello, Liu, Shears, Quan, & Kacinik, 2003)[2], and (b), that were controlled for lexical co-occurrence. Experiment 2 used prime-target pairs with ambiguous primes and non-associated targets that were matched in degree of semantic similarity between the dominant and subordinate conditions. Both experiments measured priming at a long stimulus onset asynchrony (SOA) of 750 ms, because the discussed differences in sustained meaning activation are consistently evident at SOAs of 700ms or longer.

1.2. HYPOTHESES AND PREDICTIONS

There were several possible outcomes for Experiment 1. If the standard model is correct, only highly similar meanings would be primed (high-only priming hypothesis). If Plaut's model is correct, weakly and highly related meanings would be primed, but relative to the degree of semantic relatedness (graded priming hypothesis). If reported priming differences in priming resulting from LH processing are lexical rather than semantic, two further scenarios were possible. First, it would be possible that LH processing results in priming based on pure semantic relatedness without an effect of degree of relatedness. In this case, stronger priming for strongly related meanings would result only from lexical effects. Because lexical effects are controlled for in Experiment 1, weakly and strongly related prime target pairs would prime to the same extent (full priming hypothesis). Second, it is possible that priming resulting from LH processing is completely a lexical effect. This possibility would result in a lack of priming in Experiment 1 (no priming hypothesis).

Priming studies in which prime and target are presented centrally indicate that priming based on pure semantic relatedness most likely is similar to priming based on associative relatedness (e.g., Becker, 1980; McRae et al., 1998), and follows a graded priming pattern. Because these results are consistent with the limited evidence from DVF priming studies, graded priming was considered the most likely outcome for Experiment 1.

With respect to dominance, both the standard model and Plaut's model predict priming only for dominant meanings in Experiment 2 (high-only priming hypothesis). Because existing studies have confounded meaning dominance with strength of semantic relatedness, reported results are also consistent with the proposal that LH processing does support sustained activation for subordinate meanings, but to a

[2] Because in most studies lexical and semantic relatedness cannot be distinguished, this paper will use the term *semantic relatedness* to refer to relationships that include both lexical and semantic relatedness. *Pure semantic relatedness* or *semantic similarity* will be used to designate a purely semantic relationship.

lesser degree. This possibility would predict priming relative to strength of dominance (graded priming hypothesis). Under this hypothesis, the apparent lack of sustained activation for low dominance meanings in previous studies would be a result of the interaction between weak activations for meanings that are low in relatedness and for meanings that are low in dominance. Priming for low dominance meanings with highly related targets would still be evident.

To summarize, available evidence suggests a graded priming pattern for semantic similarity, and either a high-only or a graded priming pattern for meaning dominance. A graded priming pattern for similarity is consistent with Plaut's model, but not with the standard model. High-only priming for dominance is consistent with both the standard model and Plaut's model, whereas graded dominance priming is inconsistent with both of these models.

1.3. SIGNIFICANCE

This study investigated in what ways LH processing supports focusing of word meaning activations: are activations sustained only for narrow unambiguous meaning activations, or can meaning activations be broader, maybe even allow for some ambiguity? The answer to this question will provide a clearer understanding of the function of LH processing in word processing. For example, the paired word priming task does not provide a disambiguating context for ambiguous words. If LH processing supports narrowing of meanings to only one compatible interpretation even if not required by context, this bias to disambiguation and coherent meaning representation can be considered very strong. Similarly, if LH processing supports sustained activation only for highly similar meanings, a bias for a precise and “lean” interpretation can be inferred, possibly for reasons of processing efficiency.

Furthermore, developing more precise models of LH meaning processing will contribute a firmer foundation for the investigation of the generality of the detected LH processing characteristics. For example, divided visual field studies of priming for meanings of ambiguous words in both word and sentence contexts have found that the LH processing supports activation of only one unambiguous meaning over time (e.g., Burgess et al., 1988; Faust & Chiarello, 1998), which appears to suggest that such coherence bias is a general feature of LH processing. However, both word and sentence studies suffer from the same confound of semantic relatedness and dominance, and therefore it is possible that the degree to which LH processing supports meaning disambiguation depends on context strength. The proposed study is an important first step in clarifying whether LH processing has a strong coherence bias that applies equally to processing on the word, sentence, and discourse level, or whether the degree of meaning focus in LH processing is more context dependent.

Gaining a better understanding of LH processing function will aid in developing hypotheses and empirical investigation of how the two hemispheric processing systems collaborate in language comprehension. Moreover, while it is far from straightforward to map between observed cognitive deficits after brain damage and investigations of localization of brain functions from divided visual field or imaging studies (Bates & Dronkers, 1999; Tompkins, Baumgaertner, Lehman, & Fassbinder, 2000), a more accurate model of hemispheric contributions to word meaning processing will provide a better foundation for developing and evaluating hypotheses of the effects of brain damage on language processing.

Finally, strength of semantic relatedness effects and meaning dominance effects, as well as hemispheric differences in meaning activation, might depend on practice, individual differences, age, and task demands (Howard, 1983; Becker, 1980; Canas, 1990). These dependencies can only be investigated once performance is delineated in one set of conditions. Therefore this study uses, as much as possible, a similar population and similar experimental conditions as prior studies. By establishing the pattern of LH meaning activation under typical conditions, further research can explore variations of performance due to experience or task demands.

2. LITERATURE REVIEW

The aim of this study was to investigate the effects of strength of semantic similarity and meaning dominance on sustained activations of word meanings for LH processing, in order to gain a better understanding of the specific role the LH processing plays in word meaning processing. This literature review discusses theory and evidence of both *general* and *hemispheric* models of word meaning processing, which form the basis for the research hypotheses under investigation.

In this paper, *general* models of word meaning processing refer to models that address word comprehension without considering the differential contributions of the two cerebral hemispheres. *Hemispheric* models of word meaning processing refer to models that are specifically concerned with the specific contribution of LH and RH processing to word meaning activation. A considerable part of the literature review is dedicated to general models of word comprehension and word priming, even though the questions under investigation address specifically hemispheric effects in word processing. There are two reasons for this attention to general models.

First, over the last several decades an intense research effort has focused on word recognition and word meaning comprehension, with studies of single word recognition and of word priming being the main research tool. This research effort has yielded a wealth of methodological knowledge and theoretical concepts, and has led to the development of various models of word comprehension. Research investigating hemispheric differences in word comprehension is both theoretically and methodologically directly derived from this extensive work.

The lack of attention to the distinction between strength of semantic relatedness and meaning dominance and its theoretical implications in the standard model of hemispheric differences in sustained meaning activation is the direct result of a superficial application of general models of word comprehension to hemispheric models of word processing. To avoid such a pitfall, this review attempts to carefully apply methodological and theoretical knowledge gained in the development of general models of word meaning processing to studying hemispheric contributions to word comprehension.

Second, as outlined above, one main goal of this area of research is to develop a model that is able to predict the contributions of both hemispheres in normal comprehension processes. In this sense, such a model can be seen as an elaboration of a general model of word meaning processing. For developing such a model, it is important to clarify how the general models account for sustained meaning activation under typical central reading conditions, what proposed processes underlie strength of semantic relatedness and meaning dominance effects on sustained meaning activation in typical reading conditions, and then how the inferred processes relate to differential contributions by LH (and RH) processing to sustained meaning activations.

Models of word meaning activation have been developed from investigations of the word priming effect, and the proposed study will use the same method. Therefore this literature review will discuss models of word meaning processing that account for the priming effect, theoretical and methodological considerations that are important when interpreting this effect, and the relevant priming studies with both central and lateralized presentation that address semantic similarity and dominance effects on sustained meaning activation.

The literature review is divided into nine sections. The first five sections are concerned with general models of word meaning processing and review evidence from word priming studies with central stimulus presentation. Section 1 gives a short summary of the basic priming effect and provides necessary definitions. Section 2 presents the most influential general models of word meaning processing, discusses how these models account for the word priming effect, and outlines the basic theoretical framework on which the proposed study is based. Because the proposed study aims at measuring semantic activation and its time course, Section 3 discusses the conditions under which the word priming effect can be considered to reflect semantic processing, and Section 4 reviews the time course of word meaning activations. Section 5 discusses the specific aspects of semantic processing under investigation: effects of semantic similarity and dominance and their theoretical implications.

The next three sections of this literature review provide the necessary theory, methodological background, and evidence regarding hemispheric differences in word meaning processing. Section 6 summarizes hemispheric models of word meaning activation, and Section 7 discusses the method of divided visual field presentation in priming studies. Section 8 reviews available evidence of semantic similarity and dominance effects obtained in such studies, and, based on this evidence, develops the rationale for the proposed research questions. Section 9 gives a short overview of the proposed study, and presents the predictions for its outcome.

2.1. SEMANTIC PRIMING

As mentioned in the introduction, the semantic priming effect refers to the observation that a word is recognized faster and with higher accuracy if it is preceded by a related word, sentence, or text, compared to an unrelated word, sentence, or text. This effect is thought to reflect basic processes of meaning activation and integration, and therefore has been studied extensively.

When discussing semantic priming, it is necessary to distinguish the process of priming as hypothesized in a model of semantic processing from the observable and measurable effect in the experiment. In this paper, the priming process will be referred to as *priming*, whereas the measurable experimental outcome will be referred to as the *priming effect*. Furthermore, this proposal is concerned specifically with semantic priming effects for word pairs. Thus, *priming effect* is additionally defined as the comparison, usually measured as a difference in response times, of a *related* prime condition with related word pairs and an *unrelated* prime condition with unrelated word pairs (e.g., *dog-cat* vs. *fig-cat*).

The comparison between related and unrelated prime conditions is the most frequent measure used in assessing priming effects. Another measure that has been used is comparing a condition with so-called *neutral* primes, like the word *blank*, with related and unrelated prime conditions. In contrast to the standard priming measure, the use of neutral primes allows an estimation of how much priming is due to facilitation of related words, and how much is due to inhibition of unrelated words.

One problem with using neutral primes is that it has been questioned whether processing after neutral primes can really be compared to processing after related or unrelated primes, because neutral primes might not be processed the same way as meaningful word primes (Jonides & Mack, 1984; Brown, Hagoort, & Chwilla, 2000). Furthermore, in several divided visual field studies, neutral primes have shown results that were problematic to interpret, either because of widely varying reaction times (Burgess et al., 1988) or conflicting results across hemispheres (Shears & Chiarello, 2003; Anaki et al., 1998). Therefore, priming effects with neutral primes have to be interpreted with considerable caution. Moreover, while the differentiation between facilitation and inhibition could be theoretically important, it reflects a level of analysis that is not crucial for the questions under investigation in this proposal. Therefore this review focuses only on the priming effect, and not on the facilitation or inhibition effect.

The term *semantic priming* is frequently used in such a way that refers to priming in both word meaning and word form processing. Because in many experimental contexts these two levels cannot be distinguished, this proposal will use the term the same way, and refer to priming within only the semantic level as *pure semantic priming.*

2.2. MODELS OF WORD MEANING PROCESSING AND SEMANTIC PRIMING

This section reviews current models of word meaning processing and discusses how these models account for semantic priming. Current models of word meaning processing developed from models that began to emerge in the late 1960s. These earlier models were based on the notion that each word is represented as one single entity, either as an abstract word detector (Morton, 1970; Becker, 1980) or as a holistic representation (Forster, 1976). This representation is linked to lexical[3] (phonological and orthographic) and semantic information. In these models, a word is comprehended once enough evidence for it is presented, and its corresponding single word representation or detector is *accessed* or *activated*.

In more recent models of word representation there is no single entity that represents a word. Rather, a word consists of its phonological, orthographic, and semantic information. Each kind of information is represented in separate networks, systems, modules, or layers (e.g., Collins & Loftus, 1975; Ellis & Young, 1988; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2000; Fodor, 1983; Borowsky & Besner, 1993). Thus, word representation is distributed over these different layers. While the distinction between lexical and semantic information is somewhat less clear-cut in parallel distributed processing models (see below), the same principle still applies (Plaut, McClelland, Seidenberg, & Patterson, 1996).

This review will only focus on those aspects of the reviewed models that are relevant to the proposed study, that is, aspects that address word meaning processing in reading, and that account for word priming. However, word meaning processing is intrinsically linked to the perception and recognition of word form information; furthermore, as already mentioned, semantic priming effects can reflect both lexical-level and semantic-level activation. Therefore, some issues of lexical-level processing are incorporated in the models reviewed below.

For simplicity, consideration of lexical-level processing is restricted to orthographic information. Evidence suggests – and several models simulate the effect – that phonological, orthographic, and semantic information interact in word activation in such a way that individual levels like phonology

[3] For the purposes of this discussion, unless otherwise specified, *lexical* will refer to word form information, either phonological or orthographic. Also, because this paper does not address syntactic word information, this part of word information representation and processing will not be included in this review.

cannot be factored out of the process (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Van Orden & Goldinger, 1994; Van Orden, Pennington, & Stone, 1990; Perfetti & Bell, 1991). However, because these effects have no further bearing on the issues addressed in this review, they are not further considered.

Currently, the model that by far is applied most frequently to word priming, both in general and hemispheric models, is an architecture in which word forms and word meanings are represented in a network of interconnected nodes. Because network models are so dominant in the literature, the majority of this section is dedicated to them. At the end, two alternative types of models, the compound cue model and quantitative corpus based models, will be presented. The conclusion summarizes the theoretical aspects of these models that are relevant to the proposed study, and thereby presents the theoretical framework on which the proposed study is based.

2.2.1. Network models

In network architectures nodes represent information, and the connections between nodes represent how information is related. Nodes can be activated, and this activation spreads to connected nodes. Thus, when a word is comprehended, its information in the lexical layer becomes activated, which in turn activates its information in the semantic layer.

While sharing many properties, network models differ considerably in architectures and processing mechanisms (e.g., Collins et al., 1975; Grossberg, 1987; Plaut, 1995). For the purpose of the proposed study the particular differences are not critical, because the investigated priming effects are not tied to a specific architecture or processing mechanism. Therefore this review provides only a general overview of those design features and mechanisms that have been proposed to underlie the investigated patterns of semantic priming. For illustration and clarification, it includes examples of the two main network architectures that have been applied to word meaning processing: localist and distributed network models. On the basis of this overview, the specific mechanisms that have been proposed to underlie semantic priming are discussed.

2.2.1.1. Basic architectures and design features

In a network architecture, nodes have continuous activation levels (McClelland, 1979), reflecting the strength of contribution from each individual node to the overall pattern of activation. The properties of the connections between the nodes are an important characteristic of network design. Usually, connections differ in strength or weight (e.g., Collins et al., 1975; McClelland, 1979). Thus, connections not only encode that nodes are related, but also the strength of that relationship. Connections can be simply feedforward (e.g., Seidenberg et al., 1982), or bidirectional (e.g., Collins et al., 1975; McClelland & Rumelhart, 1981; Borowsky et al., 1993). Such interactive connections allow feedback between levels, for example, activation of semantic nodes can influence activation of lexical nodes.

Many network models include inhibitory connections (Cottrell, 1988; McClelland et al., 1981; Balota, Watson, Duchek, & Ferraro, 1999). Inhibition can be implemented as lateral inhibition, which means that nodes within one layer inhibit each other, for example, all lexical nodes (McClelland et al., 1981). Inhibition can also implement more specific constraints, for example, inhibition between nodes representing different meanings of an ambiguous word (Cottrell, 1988; Simpson, 1994; Balota et al., 1999)[4].

Some network models implement representations by hardwiring nodes, connections, and connection weights (McClelland et al., 1981; Gernsbacher et al., 2001), whereas others are designed in such a way that connection weights are learned based on input or feedback (Masson, 1989; Seidenberg, Waters, Sanders, & Langer, 1984). These networks can differ significantly in their learning algorithms and architectural complexity, including the number of layers. Models that learn often incorporate hidden layers, which consist of nodes that do not have specific information assigned to them. These layers aid in learning more complex mappings from input to output layers.

2.2.1.2. Localist versus distributed representation

One major distinguishing characteristic of different types of network models is whether representations are localist or distributed. In localist network models each individual node represents a concept of interest, that is, a complete word form or a complete word meaning. Conversely, in distributed models, information about word forms or word meanings is represented in a pattern of activation states over a variety of nodes. The crucial characteristic of a distributed representation is that the same resources, that is, nodes and weights, contribute to many different representations (Van Gelder, 1991). Distributed representations have distinct computational advantages, because they allow a rich representation of the internal structure of word information. The relationships between representations are

[4] However, apparent inhibition of a meaning representation can be modeled with different mathematical implementations without active inhibitory connections, for example, with a constraint satisfaction architecture (Duffy & Dale, 1977), or with decay parameters and concurrent active maintenance of other semantic nodes. For the purpose of this literature review, the inhibitory effect rather than the actual implementation is important, therefore, *inhibition* will refer to inhibitory effects on semantic representations regardless of implementation.

not only captured in the strength of connections between them, but can be expressed in the patterns of representation themselves.

It is generally accepted that word semantics are organized in a way that they have some central, or "prototypical" (Rosch & Mervis, 1975), "core" (Miller & Johnson-Laird, 1976), or "ideal" (Jackendoff, 1994) meaning, with other aspects of their meaning being more peripheral, less typical, or in a "gray zone" (Jackendoff, 1994). Several studies suggest that when a word is encountered, the exact meaning that is activated depends on context (Anderson & Ortony, 1975; Barsalou, 1982; Tabossi, Colombo, & Job, 1987). If word meanings are not static and circumscribed entities, what exactly then is a meaning representation, and what is represented in the cognitive system? Many models of word meanings address this issue by conceptualizing word meanings as being represented by distributed features (Smith, Shoben, & Rips, 1974; Collins et al., 1975; Tabossi et al., 1987; Cree, McRae, & McNorgan, 1999), with varying probabilities if and how strongly a feature is active when its associated word form is encountered (Tabossi et al., 1987; Barsalou, 1982; Anderson et al., 1975; Dixon & Twilley, 1999).

Thus, the organizational properties of word meanings suggest that a distributed representation is better than a localist model for word meaning representation. Yet, many models of semantic priming are localist (Seidenberg et al., 1982; Cottrell, 1988; Balota et al., 1999; Gernsbacher et al., 2001; Dixon et al., 1999). One reason for this frequent use of localist representations is that they function as graphical (e.g., Collins et al., 1975) or computational (Cottrell, 1988; Gernsbacher et al., 2001; Dixon et al., 1999) simplifications, but are not meant as theoretical statements about the representation of word meanings. Therefore, a wide consensus exists that word meanings are represented in a distributed fashion. However, because both localist and distributed models have been applied to models of word meaning processing and priming, and explanations of priming effects have used either one of the two architectures, both architectures will be referred to throughout this literature review. Thus, for illustration, examples of a strict localist and a distributed network of word meaning processing are presented next[5].

Figure 1 shows the most basic network model of word activation found in the priming literature, a strict localist feed-forward model (Seidenberg et al., 1982; McNamara, 1994; Neely, 1991). Many articles adopt language and concepts from this type of a model. In such a model (Figure 1), incoming visual information for a word (e.g., “girl”) activates the lexical node which represents the written word form. Activation from this node, in turn, activates the node in the semantic system that represents its respective word meaning.

[5] The clearcut dichotomy between localist and distributed models is a simplification, because models can include both distributed representations of word semantics and additional localist representations (Collins et al., 1975; Page, 2000; Bowers, 2002).

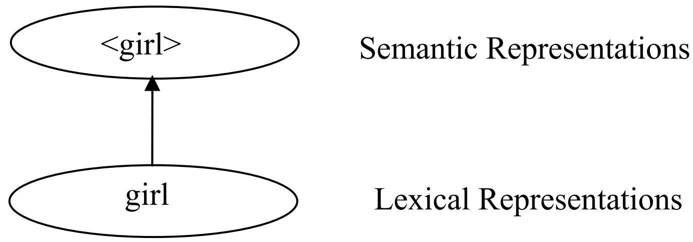

Figure 1 Example of a localist feed-forward model (e.g., Seidenberg, 1982)

For localist models, connections between related word nodes have been proposed for the semantic level (McNamara, 1994), for the lexical level (Fodor, 1983), or for both (Neely, 1991; Williams John N, 1994). It is often proposed that the connections in the semantic level reflect semantic relationships, whereas connections in the lexical level reflect lexical co-occurrence (Williams John N, 1994; Chiarello et al., 2003).

Figure 2 shows an example of a more complex network model, a parallel distributed network model (Cree et al., 1999; Plaut, 1995). Incoming visual information activates a layer of nodes that encodes distributed representations of letters. The nodes in this orthographic layer are connected to nodes in a hidden layer, which in turn are connected to nodes in the semantic layer, representing features of word meanings. These nodes have feedback connections to the hidden layer. The semantic layer is also connected to a semantic hidden layer, which also has feedback connections to the semantic layer. The network learns over many iterations to map orthographic representations onto semantic representations[6] via feedback, which represents the degree of error in prior mapping attempts.

[6] These localist and distributed network models would usually be identified as a spreading activation model and a connectionist model, respectively. It has been argued that localist versus distributed representation distinguishes between these two theoretical frameworks (e.g., Plaut, 1995). However, spreading activation models can also be distributed (Collins et al., 1975), and connectionist models can be localist (Cottrell, 1988). Therefore this review does not differentiate between spreading activation and connectionist frameworks.

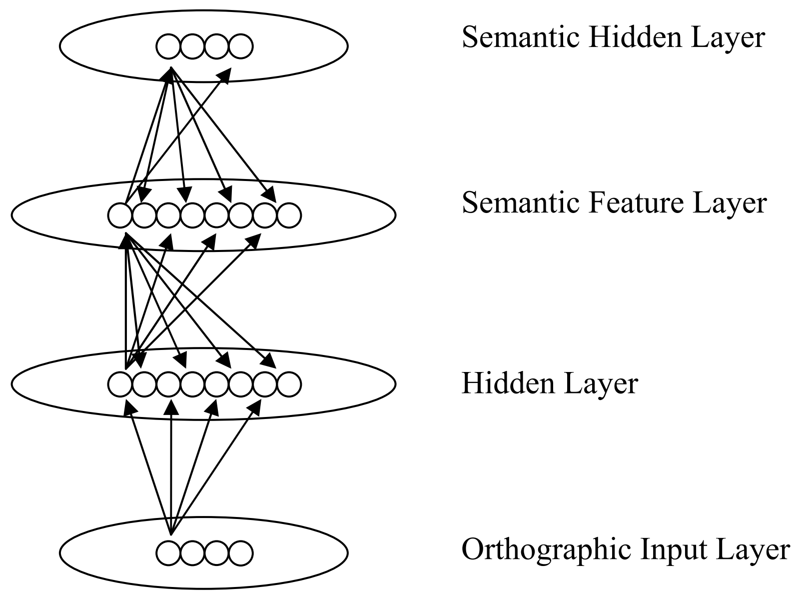

Figure 2 A hypothetical distributed network model of semantic priming, adapted from Plaut (1995) and Cree and colleagues (1999)

A distributed conceptualization of word meanings requires a distinction of two definitions of the term "representation." These two definitions will be distinguished by using the terms representation and instantiated representation. Representations of meanings refer to the knowledge encoded in the cognitive system, that is, the meanings of the feature nodes, the connections between them, and their connection weights. Thus, this knowledge includes the probability with which each part of the meaning becomes activated once the word is perceived. An instantiated representation, on the other hand, refers to an activated state of the network, and to those meanings that are currently active given a word input and a particular context.

2.2.1.3. Mechanisms underlying word priming

Within the framework of network models, five different mechanisms have been proposed to account for priming: spreading activation, semantic feature overlap, short-term changes in connection weights due to semantic feature overlap, learned mappings from a hidden layer, and learned transitions between two network states.

In network models, *spreading activation* refers to the process that activation spreads from one related node to the next via connections that differ in strength or have varying weights. Thus, if a prime word precedes a related target word, activation from the prime's node(s) already activates the target's node(s) to some degree, and the target is recognized faster. The degree of activation, and, by extension, the strength of the measurable priming effect, reflects both the degree of activation of the prime and the degree of relatedness between prime and target. In strict localist models, spreading activation is the only priming mechanism. Spreading activation also plays a role in distributed models, where semantic features can be connected, and thus activate each other.

In distributed models, the second and often principle source of priming is *semantic feature overlap*. If prime and target share features, these features are already activated once the target is encountered, and thus less time is required to activate all features fully (Masson, 1991; Kawamoto, 1993; Plaut, 1995). The third source of priming applies in some models with ongoing learning, where activation of a feature pattern results in *short-term increases in connection weights* for shared features (McClelland & Rumelhart, 1986; Joordens & Becker, 1997). Finally, in some models the sources of priming can be enhanced if a hidden layer is connected to the semantic layer (Figure 2). This layer can encode semantic regularities like feature correlation between related words, and these *learned mappings from the hidden layer* provide the fourth possible mechanism of increasing the speed of activation for related features (Cree et al., 1999).

In complex network models these four priming mechanisms arise from relatedness due to semantic similarity, and thus reflect pure semantic-level priming. The fifth priming mechanism, *learned transitions between two network states*, reflects lexical-level priming due to lexical co-occurrence. For word pairs that co-occur frequently in training, the whole network learns to move more efficiently from one word state to the next (Moss, Hare, Day, & Tyler, 1994; Plaut, 1995)[7].

In distributed models, all these different sources of priming interact and determine how fast the network settles into a stable instantiated representation of the target. The faster the network settles, the faster the meaning is recognized, and the greater the priming effect. The speed of settling into the target activation state depends on the speed with which the features that are shared with the prime can be "turned on," and how fast the incompatible features of the prime can be "turned off" or inhibited (Plaut & Booth, 2000). For pure semantic priming, this depends on the degree of semantic feature overlap, and the

[7] It has to be noted that semantic priming effects have not been modeled consistently over different architectures of distributed models, and the success in simulating specific semantic priming effects has depended on architectural features and the criterion which the priming effect was measured in the simulation (Masson & Borowsky, 1995; Plaut, 1995; Kawamoto, 1993; Dalrymple-Alford & Marmurek, 1999; Cree et al., 1999).

correlations of shared and un-shared features with other features that become active (McRae, de Sa, & Seidenberg, 1997). For lexical-level priming, the degree of lexical co-occurrence is key.

2.2.2. Alternative models

One alternative to network models is the compound cue model of Ratcliff and McKoon (1988; McKoon & Ratcliff, 1992). According to this model, two words that are presented in succession form a compound cue in short-term memory. For this compound cue, familiarity is assessed by a mechanism that evaluates how strongly prime and target are associated with each word in long-term memory. Compound cues are highly familiar if prime and target share many associations in long-term memory. Semantic priming reflects a high degree of familiarity between two items. The compound cue model has not been applied to hemispheric differences in the processing of word meanings, and it cannot account for more complex aspects of priming like expectancy and time course (these effects will be discussed in 1.4.).

Some recent quantitative corpus-based models of word semantics also use lexical co-occurrence data to derive a computational analog of what are proposed to be semantic representations: the Hyperspace Analog to Language (Burgess, Livesay, & Lund, 1998a; Lund & Burgess, 1996). Latent Semantic Analysis (Landauer, Foltz, & Laham, 1998), and the Correlated Occurrence Analog to Lexical Semantics (Rohde, Gonnerman, & Plaut, 2004). Like the compound cue model, these models are based on the assumption that words are similar if they co-occur in similar contexts, but they derive their data from large text corpora (e.g., 1.2 billion word tokens in 9 million articles from Usenet data for the COALS model). The models tabulate co-occurrence in a vector matrix, in which each row vector codes the co-occurrence frequency of one word with every other word in a large text corpus over a 10- or 4-word window (HAL and COALS, respectively), or the frequency with which each word occurs within a single passage or document (LSA).

It is important to emphasize that while the vectors are derived from lexical co-occurrence information, they do not reflect lexical co-occurrence as such. Rather, vectors can be seen as a distributed representation of meaning (Burgess et al., 1998a). The values on the vectors do not code activations of individual meanings or features, but co-occurrence values which represent a certain type of meaning similarity with other words: contextual co-occurrence.

In quantitative models, degree of semantic similarity can be computed as the mathematical distance between word vectors. Semantic priming then can be predicted based on the computed degree of semantic similarity, and several outcomes of priming experiments have been modeled successfully with two of these models (Lund, Burgess, & Atchley, 1995; Landauer et al., 1998). One of the models, HAL

(Burgess et al., 1998b), has also been used to predict hemispheric differences in semantic priming, which will be discussed in Section 1.6.

Quantitative models have the advantage that they do not rely on human (expert) judgments, as do models in which meanings are assigned by the creator of the model (Miller, Beckwith, Fellbaum, Gross & Miller, 1993) or are derived from meaning or feature generation tasks (Cree et al., 1999). Rather, the meaning vectors represent empirical information based on actual language use. Furthermore, given the astonishing facility with which infants learn statistical regularities of language input (Jusczyk, 1999; MacWhinney, 1998), a model that is based on statistical regularities of co-occurrence appears plausible.

A drawback of these models is that because they are solely based on lexical co-occurrence, they do not capture some aspects of human knowledge about word meanings (Perfetti, 1998), and thus provide some results that reflect this lack of knowledge. For example, LSA lists *nurse* to have a higher similarity to *physician* than does *doctor* (Landauer et al., 1998), and COALS list *shimmery* as the most similar word to *lipstick* (Rohde et al., 2004). Another drawback of these quantitative models for word meaning representation is that ambiguous words consist of only a single vector; therefore, individual word meanings are not modeled, and each meaning of the ambiguous word is represented on the same vector. This skews computations of semantic similarity, especially for subordinate meanings (Rohde, personal communication, July 22, 2002).

2.2.3. Basic theoretical framework

The preceding review leads to three decisions and assumptions for the basic theoretical framework for the proposed study. First, because network models are most developed in addressing the various priming effects of interest, have been applied to hemispheric differences in semantic priming, and do not share the drawbacks of quantitative corpus-based models of word semantics, especially with respect to the representation of subordinate meanings, this proposal will use a network model framework as a theoretical background. Second, given the nature of word meanings, word meaning representations will be assumed to be distributed, and effects of strength of semantic relatedness and dominance will be discussed within this theoretical framework.

Third, the different models, architectures, and processing mechanisms that have been proposed to account for priming effects within a network framework could reflect variability in computational simulation and might not have anything to do with actual cognitive processes. However, the diversity of possible mechanisms in the models could also reflect, at least in part, a reality of cognition, in that there are quite likely a variety of sources for priming effects, be they in terms of mechanisms, type of information represented, or processing level (semantic versus lexical).

For example, with regards to semantic information the known characteristics of word meanings strongly suggest a representation that is feature based (e.g., the word *tomato* activates features like <is red>, <can be eaten>, …). This does not rule out that at the same time information about co-occurrence is represented in a way that it can be used to code meaning similarity, or that other types of representations code more explicit, learned knowledge (e.g., <is a fruit>). As discussed for the parallel distributed model with hidden layers, extra layers of representation can encode correlations and higher order systematic relationships between aspects of word meaning information. Therefore it is most likely that word meaning representation is distributed over various types of information, and that pure semantic priming can have several sources. Furthermore, an additional lexical source of semantic priming has been proposed for various architectures and mechanisms (Williams John N, 1994; Plaut, 1995; Joordens et al., 1997), usually thought to reflect direct word co-occurrence information. Again, given the ability of the cognitive system to learn statistical regularities, it is very plausible that such information is learned, represented, and used in word comprehension. Consequently, semantic priming most likely does not have a unitary basis, but rather reflects several characteristics of word meaning representation and processing.

The different sources of priming need to be taken into account in the interpretation of priming data as well as the planning of the proposed study[8]. Fortunately, the different mechanisms that underlie pure semantic priming all result in similar effects and all predict strength of similarity and dominance effects based on feature overlap and patterns of correlation between shared and unshared features. Thus, for the purpose of the proposed study it is assumed that pure semantic priming has these factors at its source. Furthermore, lexical co-occurrence will be assumed as a potential second source of semantic priming. Therefore, lexical co-occurrence needs to be clearly distinguished from pure semantic priming, which is investigated in the proposed study. The next section will discuss under what conditions priming can be assumed to be purely semantic.

2.3. THE SEMANTIC NATURE OF PRIMING EFFECTS

The aim of the proposed study is to investigate semantic processing, and the study will use the semantic priming effect to detect semantic activations in word reading. This section discusses if and under what conditions semantic priming can be considered to reflect semantic rather than lexical processing.

[8] The literature review includes models with characteristics outside of the theoretical framework outlined in this section, because it reviews current models of semantic relatedness and dominance effects, as well as models of hemispheric differences in semantic processing with such characteristics.

Furthermore, it discusses whether the semantic effects detected can be assumed to apply to reading in natural contexts.

Given that researchers propose both lexical-level and semantic-level processing as sources of semantic priming, the question arises whether those two processing levels can be distinguished, and if so, if pure semantic priming has been shown. Two basic factors potentially affect to what extent observed priming reflects semantic-level processing: prime-target relationship and strategic effects. The first subsection below discusses which prime-target relationships can be considered to reflect semantic processing in a priming task. But even when an experiment uses a pure semantic relationship between prime and target, participants will adapt the degree to which they rely on semantic information implicitly or explicitly, depending on task and list conditions. These strategic effects are reviewed in the second subsection below. The third subsection discusses the ecological validity of the semantic priming task and its typical experimental manipulations as an instrument of measuring semantic processing in reading.

2.3.1. Prime-target relationships

To address the question whether semantic priming derives from semantic or lexical processing, many investigators have manipulated the type of relationship between prime and target. For investigating pure semantic priming investigators have tried to identify prime-target relationships that are purely semantic. When selecting such prime-target pairs, investigators first need to rule out any relationship that is lexical in nature. Therefore the first part of this subsection discusses two types of relationships that have been proposed to be lexical: co-occurrence and association. The second part of this subsection discusses meaning relationships that are purely semantic, and argues that meaning similarity is theoretically well motivated as a pure semantic relationship. Finally, available evidence from semantic priming studies is reviewed, and it is concluded that while there are not enough well-controlled studies of pure semantic priming, the evidence available so far is highly suggestive that pure semantic priming exists.

2.3.1.1. Lexical word relationships

Lexical co-occurrence, or the frequency with which words occur with each other, can be considered to reflect lexical-level processing because it is based on word form frequency, and as such is not intrinsically a semantic relationship. However, lexical co-occurrence has not been much investigated in semantic priming studies. This is partially due to the fact that until recently lexical co-occurrence data were difficult to obtain. Furthermore, another word relationship frequently has been considered to be lexical in nature: word association (Fodor, 1983; Shelton & Martin, 1992). Because estimates of association were much easier to obtain, most research investigating lexical priming effects has been directed at studying word association.

Associative relationship is usually not defined beyond its operationalization as the frequency with which the target is given in association norms (McRae & Boisvert, 1998). Most researchers share the assumption that associations are "accidents of contiguity" (Fischler, 1977, p. 335), arising from lexical or conceptual co-occurrence (Fodor, 1983; McNamara, 1992; Williams, 1994; Plaut, 1995), and many suggest that associations are purely lexical co-occurrence effects (Fodor, 1983; Lupker, 1984; Williams, 1994; Shelton et al., 1992). Furthermore, several researchers assume that lexical representations form a network in which word form representations are connected if they are associated (Fodor, 1983; Lupker, 1984; Shelton et al., 1992). Thus, association is seen as a convenient operationalization of co-occurrence or lexical word relationships. Yet, the claim that association is a lexical relationship or reflects lexical co-occurrence needs to be demonstrated empirically.

Two studies (Spence & Owens, 1990; Lund, Burgess, & Audet, 1996) investigated correlations between lexical co-occurrence and association as indexed in association norms. Spence and Owens found a correlation of .42. Lund and colleagues found a correlation of .25. However, when they divided prime-target pairs into those that were semantic neighbors according to the HAL metric (see Section 2.2.2) and those that were not, only the semantic neighbors showed a correlation effect (.48). The authors interpreted this result to mean that lexical co-occurrence is independent of association, and only linked to association as long as words are semantically related, which would suggest that these two variables just co-vary.

However, it is possible that both studies underestimate the correlation between association and lexical co-occurrence because they used absolute measures of co-occurrence, which were not scaled or normalized for word frequency. Thus, they assume that lexical co-occurrence is learned as the absolute frequency of co-occurrence. However, it is quite possible that lexical co-occurrence relationships are learned relative to the absolute frequency of occurrence of each word. Therefore, it would be necessary to test both measures of co-occurrence before firm conclusions can be drawn. Another problem with the study by Lund and colleagues was that semantic neighbors were defined with HAL vectors. In a set of 48 prime-target pairs used for Experiment 1 in this study, stimuli were selected so that semantic similarity did not correlate with relative lexical co-occurrence. For this set of stimuli, relative co-occurrence still correlated with HAL-type vectors with an $r = .6$. Therefore, it is quite possible that a measure of semantic similarity using HAL-type vectors also reflects lexical co-occurrence, which questions the conclusion that the correlation in Lund et al.'s study increased due to semantic factors.

As a result, the available data on association and lexical co-occurrence is inconclusive, and it is unclear to what extent lexical co-occurrence drives association effects. At the same time, semantically-related word pairs that are also associated are rated to have higher feature overlap or shared characteristics than those pairs that are not associated (Fischler, 1977; Chiarello, 1998b). This result raises the possibility that association might reflect a higher degree of semantic relatedness rather than a lexical-level relationship. Based on similar reasoning, McRae and Boisvert (1998) suggest using associated prime-target pairs when investigating the semantic nature of priming.

A look at strongly associated word pairs from association norms (Nelson, Lalomia & Canas, 1991) suggests that association is driven by both lexical co-occurrence and pure semantic relatedness. Lexical co-occurrence seems to underlie the association of word pairs like *jigsaw-puzzle* or *dill-pickle*. Often co-occurrence and semantic similarity go together, for example, for *day-night*. For some associated word pairs co-occurrence does not seem to play a significant role, for example, for *trousers-pants*. Thus, it is most likely that associative relationships represent an amalgam of purely semantic relationships and co-occurrence effects.

Therefore, when the goal is to investigate priming separate from lexical effects, the current state of evidence suggests that associated prime-target pairs need to be excluded. At the same time, excluding prime-target pairs does not necessarily control for all lexical effects. As a result, ideally studies should control for both co-occurrence and association effects when intending to rule out lexical-level effects on semantic priming.

2.3.1.2. Semantic word relationships

Researchers who have tried to identify semantic word relationships have selected a variety of relationships, for example, category-exemplar (bird-robin), category-coordinate (eagle-crow), part-whole (tree-trunk), perceptual similarity (grass-hair), feature overlap (finch-canary), instrument relationships (broom-floor), or script relationships (restaurant-wine) (McRae et al., 1998). These semantic relationships do not represent a coherent theoretical framework of semantic representation, and reflect each author's conceptualization of word semantics. The lack of theoretical clarity as to what constitutes a purely semantic relationship makes it difficult to interpret or design studies that attempt to measure only semantic processing. Furthermore, some of these relationships are likely to covary highly with lexical co-occurrence, for example, instrument relationships.

However, the preceding review of distributed models of word meaning processing suggests that one meaning relationship can be identified that according to these models clearly reflects semantic rather than lexical processing in semantic priming: *meaning similarity*. In the context of distributed models, semantic similarity denotes both semantic feature overlap and correlations of feature patterns, and it is independent of lexical co-occurrence. Meaning similarity has been operationalized in several different ways: similarity judgment of word meanings, (McRae et al., 1998), judgment of how many features two words share (Chiarello, 1998b), or feature generation for word meanings (e.g., McRae et al., 1997).

Many studies have found semantic priming with word pairs based on various semantic relationships that were controlled for association (Lucas, 2000). But, as argued above, association might not be a strict enough control for lexical-level processing effects. Thus, while it is quite possible that many of these studies did measure effects of semantic processing, the evidence cannot be considered conclusive. Only four studies have used semantic similarity to investigate semantic priming, and they found semantic priming at short stimulus onset asynchronies (SOAs) (McRae et al., 1997; McRae et al., 1998; McRae, Cree, Westmacott, & De Sa, 1999; Lund et al., 1996) and at long SOAs (McRae et al., 1998). Three of the four studies controlled for association, (McRae et al., 1998; Lund et al., 1996; McRae et al., 1999), and one controlled for both association and co-occurrence (Cree et al., 1999). These results are highly suggestive that pure semantic priming exists, but further corroboration is needed.

2.3.2. Strategic effects on semantic priming

While semantic processing can be detected with semantic priming tasks, the sensitivity of the task depends on the specific experimental characteristics. Participants adjust the degree to which they rely on semantic information in their responses depending on demands of task and list characteristics. This section (a) summarizes evidence how three such characteristics (response task, relatedness proportion, and degree of relatedness strength) affect the likelihood that priming reflects semantic processing; and (b) discusses theoretical accounts and implications of these strategic effects. Because a lot of the relevant work on strategic effects has been done in single word recognition, the subsequent summary includes evidence from both single word recognition and semantic priming studies.

2.3.2.1. Evidence for strategic effects

The main response tasks used in single word recognition and semantic priming studies are pronunciation, lexical decision, and semantic judgments. In the pronunciation task participants orally read words, in the lexical decision task participants decide whether a string of letters is a word or not, and for semantic judgments participants decide whether target words fulfill a semantic criterion, for example, animacy. In single word recognition studies semantic processing effects are indicated if semantic variables, such as ambiguity or imageability, are reflected in the response times. In semantic priming studies, semantic processing effects are indicated through priming effects for word pairs with pure semantic relationships. Based on these criteria, for single word recognition semantic processing effects have been evidenced in all three response tasks (Hino & Lupker, 1996; Lichacz, Herdman, Lefevre, & Baird, 1999; Azuma & Van Orden, 1997; Rodd, Gaskell, & Marslen-Wilson, 2002; Masson et al., 1995; Hino, Lupker, & Pexman, 2002; Pexman, Lupker, & Hino, 2002). Based on the strictest criteria for pure semantic priming outlined above, priming effects have been shown in lexical decision and semantic judgments (Cree et al., 1999). When considering a wider set of studies that controlled for association, priming has also been shown in pronunciation (Lucas, 2000).

However, semantic processing effects are not the same in each task, for example, they are less reliable for pronunciation. In single word recognition studies using pronunciation, ambiguity effects are reliably shown for only low-frequency words (Hino et al., 1996; Lichacz et al., 1999). Also, semantic priming effects for pronunciation are smaller than in studies that use lexical decision (Neely, 1991; Lucas, 2000), which makes null effects more likely.

Relatedness proportion and degree of relatedness effects reflect additional manipulations that change the sensitivity of word priming to semantic processing effects. *Relatedness proportion* refers to the proportion of related targets to all word targets (related targets/all word targets) in an experiment. Higher relatedness proportions lead to increases in semantic priming. This effect is the most reliable of strategic effects specific to word priming, and has been replicated in pronunciation and lexical decision (Tweedy, Lapinski, & Schvaneveldt, 1977; de Groot, 1984; Hutchison, Neely, & Johnson, 2001; Perea & Rosa, 2002; Stolz & Neely, 1995; Bell, Chenery, & Ingram, 2001).

The *degree of relatedness strength* effect refers to the finding that in experiments that include prime-target pairs with both high and low relatedness, changes in the proportion of high- to low-relatedness stimuli change the priming effects. When high- and low-relatedness stimuli occur equally, both evidence priming (Becker, 1980; Stolz et al., 1995; Canas, 1990; Fischler & Goodman, 1978; McRae et al., 1998). However, when the majority of related stimuli are highly related, there is less or no priming for low-relatedness targets (Becker, 1980; Canas, 1990); and when the majority of related stimuli has low relatedness, priming for both types of stimuli is equal (Canas, 1990). This effect is especially relevant for one of the semantic factors under investigation in the proposed study, that is, strength of semantic similarity.

2.3.2.2. Theoretical accounts and implications

A basic underlying assumption of all models of strategic effects in semantic priming is that, in order to use the information that is most advantageous for a given task, the cognitive system can attentionally control the degree to which certain information or computations affect overall processing (Balota et al., 1999; Plaut et al., 2000; Becker, 1980). This control is often implemented as some sort of gain control mechanism (Cohen, Braver, & O'Reilly, 1996; Kello & Plaut, 2000; Kello, Plaut, & MacWhinney, 2000). Different models of strategic effects converge on two common denominators: they either propose a “semantic model,” that is, *direct* changes to speed, strength, or pattern of the instantiated semantic activations (Balota, Cortese, & Wenke, 2001), or a “sensitivity model,” that is, changes in *sensitivity* to speed, strength, or pattern of such activations by processes that receive activations from the semantic layer, for example, the phonological output representations (Balota, Paul, & Spieler, 1999), lexical representations (Stolz et al., 1995), or processes that determine the response criteria (Plaut et al., 2000). However, for each account it is easy to present another one which uses the opposite model to explain the same effect. To the knowledge of this author, the two models have not been distinguished experimentally, and both possibilities need to be taken into account when interpreting semantic priming results.

2.3.3. Ecological validity

Given that strategic processing effects might change the sensitivity of a particular experimental task to semantic processing in semantic priming experiments, the question arises to what extent semantic priming effects reflect semantic processing in normal reading. For example, reading single words aloud, deciding whether a letter string is a word, or judging whether word is animate is quite different from comprehending a written text. That difference, of course, is in part the point: the typical conditions of semantic priming experiments try to isolate word meaning activation processes within clearly defined and simple semantic contexts, factoring out text-level integration or syntactic processing. However, as the previous subsection indicates, these experimental conditions might introduce processes that do not occur in normal comprehension, which could render the results ecologically invalid. This subsection discusses the ecological validity of response task, relatedness proportion, and degree of relatedness strength effects.

When participants read text for the purposes of comprehension, they need to process each word meaning so it can be integrated with the context. Conversely, pronouncing words can be done with no or minimal semantic input, and even in lexical decision participants can rely more on lexical-level information to perform the task compared with the task of meaning comprehension in normal reading. Therefore, if strategic effects change strength of instantiated semantic activations or task sensitivity to such activation, it is plausible that semantic effects detected in both pronunciation and lexical decision are reduced compared to normal reading, with a stronger reduction for pronunciation.

Several researchers have suggested that lexical decision taps an integration stage in which semantic relatedness between prime and target is checked (Lorch, Balota, & Stamm, 1986; de Groot, 1985; Neely, 1991). This argument suggests that priming effects could reflect a re-activation of the prime by the target that does not occur in normal reading. However, if priming reflects a semantic relatedness check, semantically-related words should always prime in lexical decision regardless of sentential context, because the activations would be induced by the detection of semantic relatedness between adjacent words. This is not the case. For example, the finding that targets related to subordinate word meanings of ambiguous words prime at medium but not at long SOAs (Simpson et al., 1985) suggests that lexical decisions reflect the time course of semantic activation of the prime, rather than a lexically-based post access relatedness check.

Because semantic judgments are explicit and metalinguistic, they might introduce meaning activations that would not occur in normal comprehension. For example, an animacy judgment task might prime animate meanings (Collins et al., 1975). Therefore, semantic judgments might change the pattern of semantic activations, and this possibility needs to be taken into account in semantic judgments tasks. However, such a bias is only problematic if the two semantic factors of interest are differentially affected by the judgment task, for example, if degree of semantic similarity is investigated with an animacy judgment task, and the stimuli in the high- and low- similarity conditions differ in their degree of animacy.

Overall, then, while response tasks affect either the strength of instantiated semantic activations or sensitivity to such activations, there is no obvious reason to assume that these effects result in qualitative changes to semantic activation processes that could invalidate semantic priming as a measure of the semantic dimensions of interest.

Similar arguments apply to the relatedness proportion effect. First, given that in any text context word meanings by definition are related, readers should expect words to be related, which might result in stronger priming. Expectation of relatedness due to a high relatedness proportion could result in the same processes, and therefore be ecologically highly valid. However, if that is not the case, and relatedness proportion effects reflect extraneous factors like changes in decision criteria, they will introduce quantitative changes in priming effects, but there is no obvious reason to believe that they introduce qualitative changes. Therefore, even if the mechanisms underlying the relatedness proportion effect enhance priming effects to levels that do not reflect normal comprehension, they might make it possible to measure functionally relevant activation differences that otherwise would be too small to detect.

Finally, degree of relatedness strength effects differ from response task and relatedness proportion effects in that they clearly introduce qualitative changes in priming patterns. These effects could be ecologically highly valid if they reflect adjustments the cognitive system makes based on whether or not a context is highly constraining. On the other hand, these effects could introduce artifacts that limit their generalizability. Therefore, strength of relatedness effects can only be compared within similar experimental conditions, and only after a more systematic investigation in different experimental contexts can more general conclusions be drawn.

2.3.4. Summary

In order to investigate semantic processing with the semantic priming task, investigators need to ensure that they use stimuli in which the prime-target relationships are purely semantic. Available evidence is highly suggestive that pure semantic priming exists, although further corroboration is necessary. However, semantic priming effects also depend on task and list characteristics, which can affect the sensitivity of the priming task to semantic effects. Because of these strategic processing effects experimental tasks differ in their sensitivity to instantiated semantic activations either quantitatively or qualitatively. It is argued that most strategic effects are quantitative, which might lead to spurious null results, but over several tasks and conditions an interpretable and ecologically valid pattern should emerge. The degree of relatedness effect, however, appears to result in qualitative changes of the priming effect. While it is possible that these such changes to priming might be representative of strategic effects in reading, their ecological validity is unclear, and thus they limit generalizability of results.

1.4. THE TIME COURSE OF WORD MEANING ACTIVATION

The proposed study investigates *sustained activation* of word meanings, that is, effects of semantic similarity or meaning dominance on instantiated meaning representations after initial activation. Instantiated semantic representations change over time depending on strategic effects or context effects. For example, relatedness proportion effects and degree of relatedness effects occur only at SOAs longer than 200 ms (Neely, 1977; Becker, 1980; Canas, 1990; Hutchison et al., 2001). Another example is ambiguity resolution, for which in many experimental conditions context effects come into play only after initial activation (e.g., Swinney, 1979; Gernsbacher, Varner, & Faust, 1990; Gernsbacher & Faust, 1991). This section reviews how models of semantic priming account for general time course effects on sustained meaning activation. Two models are reviewed. The first model is the Three-Process model of Neely and Keefe (Neely, Keefe, & Ross, 1989), which is a localist model based on the distinction of automatic and controlled processing, and the most cited account of time course effects in priming. The second model is a distributed attractor account proposed by Plaut and Booth (2000), which is the most developed model of time course effects that is based on a distributed network account.

2.3.5. The Three-Process model

The Three-Process model is based on the distinction between automatic and controlled processing, which is one of the basic concepts in the study of attention (Shiffrin, 1988; Shiffrin, Dumais, & Schneider, 1975; Posner & Snyder, 1975; Bargh, 1989). Automatic processes are fast, effortless, capacity free, unintentional, and autonomous. Controlled processes are slower, effortful, require capacity, are under intentional control, and are not autonomous (Shiffrin, 1988; Shiffrin et al., 1975; Posner et al., 1975). In the Three-Process model, automatic and controlled processes are separate, and follow specific time courses. The model assumes that at SOAs of 200 ms or less priming is solely due to automatic spreading activation (Neely, 1991) and therefore strategic factors cannot affect priming at short SOAs. Then automatic activation decays, and priming at long SOAs reflects solely the effect of controlled processing, for example, expectancy-based priming (Hutchison et al., 2001).

One problem with the Three-Process model is the assumption that automatic and controlled processes are strictly dichotomous and occur basically sequentially. In the attention literature, this strict distinction is usually not assumed. For example, automatic and controlled processes have been proposed to be completely dichotomous but co-occurring (Shiffrin et al., 1975; Posner et al., 1975), or seen as a continuum (e.g., Cohen, Dunbar, & McClelland, 1990).

Furthermore, the prediction from Neely's model that strategic effects do not influence priming at short SOAs has not been borne out. Semantic priming can be affected when the encoding conditions of the prime are changed, for example, when participants conduct a letter search task on the prime (Maxfield, 1997), when participants are instructed to recall very briefly (40 ms and 90 ms) presented primes (Fischler et al., 1978), or depending on the methods used for determining recognition threshold for very briefly presented primes (Dagenbach, Carr, & Wilhelmsen, 1989).

These three prime encoding effects seriously challenge the notion that all controlled processes have a slow onset. But if strategic processes can affect priming immediately, it becomes very difficult to distinguish between automatic and controlled priming as such. Prime encoding effects have sparked a lively debate on whether automatic semantic priming exists, and on the usefulness of separating automatic and controlled processes in semantic priming (e.g., Mari-Beffa, Fuentes, Catena, & Houghton, 2000; Stolz & Besner, 1999; Neely & Kahan, 2001). As a consequence, the distinction between automatic and controlled priming is not used in this paper, and effects on priming that are attributed to participants adapting to task conditions are referred to as *strategic*.

2.3.6. Distributed network account

The distributed attractor model by Plaut and Booth (2000) provides an alternative model for time course effects without using the automatic and controlled processing distinction. When meaning activation is simulated in this model, it takes time for the network to settle into a complete attractor state of a meaning, because activation changes for all nodes are computed incrementally. Priming derives primarily from the following dynamic. When a prime is presented, the network moves towards the state of the instantiated semantic representation of the prime. When its target is presented at a short SOA, the network has moved toward the semantic state of the prime, which is similar to that of the target, but has not yet settled deeply into it. Thus, at the point at which a related target is presented, the transition to the target state is faster than when the network has to transition from the state of an unrelated word prime. When the target is presented at a longer SOA, the process is somewhat different. The network has moved deeper into the semantic state of the prime, and priming effects depend on two factors. One, the more features are shared between prime and target, the faster is the transition from the prime state to the target state. Two, because the network has settled deeper into a pattern, features incompatible with the target state take longer to be de-activated or otherwise overridden. Thus, the degree of feature compatibility also determines the priming effect. For unrelated targets there are more incompatible features than for related targets, therefore response times are slowed.

In this model, relatedness proportion affects priming at longer SOAs because only at these later points is the differentiation between related and unrelated primes large enough that changes in decision criteria become effective. Plaut and Booth's (2000) model does not require a separate mechanism to account for this effect, and therefore this account of the relatedness proportion effect appears more parsimonious than that of the Three-Process model. Plaut and Booth did not address the degree of relatedness strength effect, and it is unclear whether a similar account could explain this effect, given that the relatedness proportion is the same regardless of how many word pairs are strongly or weakly related.

In sum, neither model can account for the full range of priming phenomena (Fassbinder, 2001), but these two models so far are the best developed models of sustained meaning activation in semantic priming. Their underlying dynamics have been applied to both general and hemispheric models of meaning activation patterns for degree of semantic similarity and meaning dominance. These models and their respective evidence are discussed in the next two sections.

2.4. STRENGTH OF SEMANTIC RELATEDNESS AND MEANING DOMINANCE

Section 5 reviews evidence regarding how sustained meaning activation is affected by differences in strength of semantic relatedness and meaning dominance in semantic priming studies with typical reading conditions, that is, central stimulus presentation. Furthermore, this section reviews how these data can be explained in the context of models of word processing reviewed above. There are two aims for this review. First, it provides the necessary background for the theoretical models that are applied to the interpretation of priming patterns in divided visual field studies. Second, in order to develop hypotheses how left and right hemispheres contribute to semantic processing, it is important to understand the result of interhemispheric integration of semantic processing in reading.

The first part of this section (2.5.1.) briefly reviews the possible priming patterns of semantic activations that were already described in the introduction, that is, *full priming*, *graded priming*, and *high-only priming*. The next part (2.5.2.) of this section summarizes how differences in strength of semantic relatedness affect semantic processing in standard reading conditions. This part discusses evidence from semantic priming studies, and presents how network models can account for these effects. The last part (2.5.3.) addresses the processing of ambiguous words, focusing on how differences in dominance affect semantic priming and on the theoretical implications of such differences.

2.4.1. Priming patterns

The time course of meaning activations is usually investigated by measuring priming effects at different SOAs. When priming is detected at short and long SOAs, meaning activations are sustained. If priming is detected at short but not at long SOAs, meaning activations are inhibited. The proposed study focuses on meaning activation at long SOAs. With respect to the two factors of strength of semantic relatedness and meaning dominance effects, three possible priming patterns are plausible. If these factors have no effect, that is, the degree of similarity or dominance does not influence meaning activation, meanings of high similarity/dominance and low similarity/dominance should prime to the same degree (*full priming)*. If strength of semantic similarity or dominance has an effect, but does not inhibit low-similarity/low-dominance meanings, both types of meanings should prime, with low similarity/dominance meanings showing substantially less priming (*graded priming*). If strength of relatedness has the effect that low similarity/dominance stimuli are inhibited, as proposed in the standard model for words processed in the LH, only high-similarity/high-dominance meanings should prime (*high-only priming*).

Most studies investigate effects of similarity and dominance in factorial designs, treating high and low similarity/dominance as dichotomous variables. Both variables are, of course, continuous, and therefore it is helpful to visualize the effects of these variables accordingly. Figure 3 provides a hypothetical graph of the three potential priming patterns. The three priming patterns differ in their inflection point and the slope of the inflection area. The full priming pattern has a very early inflection point and a steep inflection area, which reflects a threshold function: once meaning representations prime, they are fully activated. The graded priming pattern has a later inflection point and shallower inflection region, which results from an almost linear correspondence between strength of similarity/dominance and degree of priming. The high-only priming pattern has the latest inflection point and again a steep inflection region, which reflects inhibition for low-similarity/low-dominance meanings. Once a certain degree of similarity/dominance is reached, meanings are fully primed.

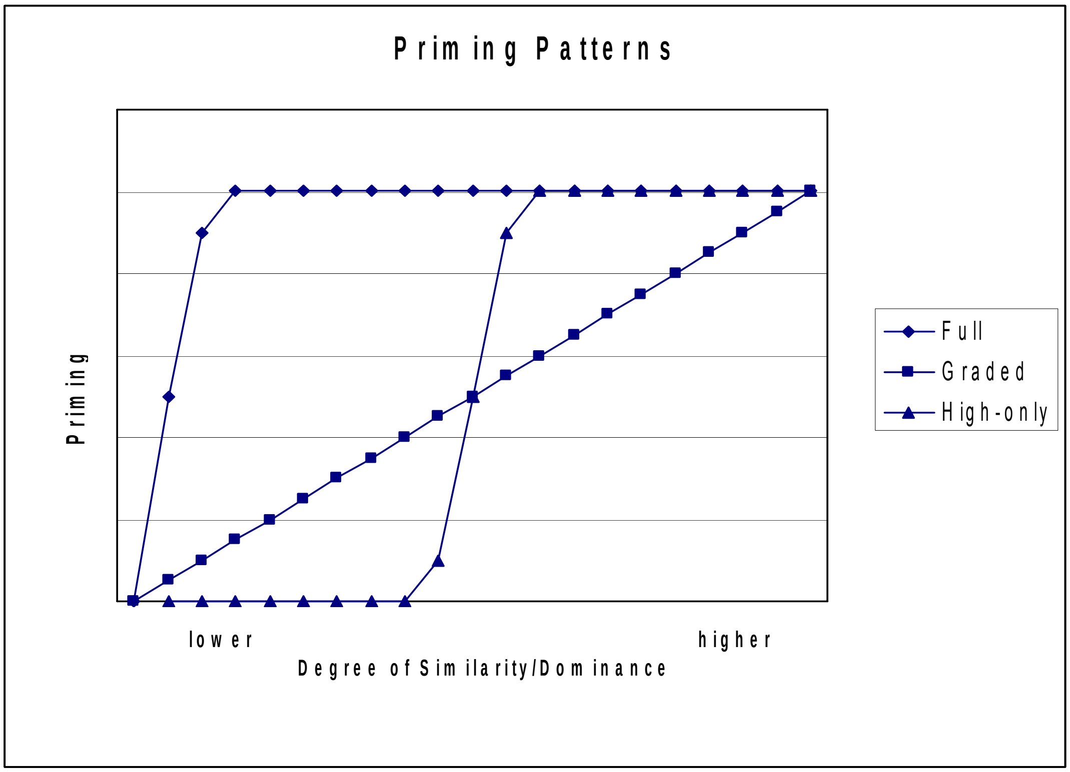

Figure 3   The three priming patterns

2.4.2. Strength of semantic relatedness

This section summarizes evidence for strength of semantic relatedness[9] effects in various studies of semantic priming with central stimulus presentation. These effects have been frequently documented, and results are consistent with a graded priming hypothesis. Strength of semantic relatedness effects can be modulated by different task conditions, and possibly by experience and age. The semantic priming results are discussed within the frameworks of a localist and a distributed network model.

2.4.2.1. Evidence

Under typical priming conditions, that is, with central presentation of prime and target, a relatedness proportion of 50%, and equal distribution of word pairs with low and high relatedness, effects of strength of semantic relatedness have been investigated with three prime-target relationships. These three relationships are superordinate category labels paired with typical and less typical category exemplars (Becker, 1980; Balota et al., 1999; Balota & Duchek, 1988; Lorch, 1982; Howard, 1983), word pairs with high and low strength of association (Becker, 1980; Canas, 1990; Fischler et al., 1978; Lorch, 1982; Balota et al., 1999; Stolz et al., 1995), and word pairs varying in rated degree of semantic similarity (McRae et al., 1998).

The studies used pronunciation, lexical decision, and semantic judgment as response tasks. Almost all studies found strength of semantic relatedness effects, with two main patterns. Several studies found priming for both strongly and weakly related pairs at short and long SOAs, and detected a significant difference for the two levels of strength of relatedness (Becker, 1980; Stolz et al., 1995; Canas, 1990). In other studies the result was similar, but without priming for weakly related pairs at short SOAs (Fischler et al., 1978; McRae et al., 1998). Given that priming effects are often smaller at short than at long SOAs, the lack of priming for weakly related pairs probably reflects an inability for these two studies to detect a very small priming effect. Only one study did not find strength of relatedness effects (Balota et al., 1999). This study used pronunciation as a response task, and is in contrast with two other pronunciation studies that did show an effect (Balota et al., 1988; Lorch, 1982). These different results in pronunciation likely reflect the difficulty of detecting semantic priming effects with pronunciation tasks.

Overall, evidence for strength of semantic relatedness effects is strong. Furthermore, the studies document sustained meaning activation of weakly related meanings and a graded priming pattern, because

[9] Because there is not sufficient evidence for strength of semantic similarity effects, this section also includes data from studies that could reflect either lexical- or semantic-level priming. Limiations to their interpretation are discussed.

priming effects for such meanings were significantly lower than for strongly related meanings. Importantly, nowhere in the available evidence is any indication for inhibition of weakly related meanings.

However, inferences with respect to strength of semantic similarity effects and semantic processing still have to be tentative. MacRae and Boisvert's study is the best controlled study in this regard, because it employed degree of semantic similarity as a measure of semantic relatedness (McRae et al., 1998) and controlled for association. While the results of this study suggest a graded priming effect for semantic similarity, replication with stimulus pairs that are also controlled for co-occurrence is necessary.

As discussed in the previous section, priming patterns with respect to strength of semantic relatedness change based on stimulus list composition. Depending on the amount of stimuli that were strongly or weakly related, full priming and high-only priming were evidenced (Becker, 1980; Canas, 1990). The degree to which participants make use of changes in strength of semantic relatedness might depend on their reading experience and age, which further complicates the interpretation of observed priming patterns. Comparing undergraduates, young adults (around 30 years old) who were not students at the time, and older adults, Howard (1983) found a significant strength of semantic relatedness effect only for the student group. While these results require corroboration, they suggest that the degree to which the cognitive system adapts to, or is able to adapt to, the expected strength of relatedness in verbal material might depend on reading skill, practice, or factors associated with age.

2.4.2.2. Theoretical accounts

Based on the models of word comprehension reviewed above, the potential sources of effects of strength of semantic relatedness are quite straightforward, regardless of the proposed priming mechanism. In localist networks, for which spreading activation is the only processing mechanism that underlies priming, strength of semantic relatedness is encoded as stronger or weaker connection weights (Collins et al., 1975; Anderson, 1983). In distributed models, strength of semantic relatedness effects can also derive from the other priming mechanisms, as reviewed in Section 2.2.1.3. For semantic feature overlap, strength of semantic relatedness is encoded as the number of shared features (Collins et al., 1975; Plaut, 1995). For more complex relationships strength of semantic relatedness is encoded as the degree of correlation, for example through hidden layers (Plaut, 1995; Kawamoto, 1993; McRae et al., 1999). Finally, speed of transition between network states also depends on the frequency of lexical co-occurrence (Plaut, 1995; Moss et al., 1994).

All models predict monotonic strength of semantic relatedness effects in sustained meaning activations of words, and there is no a priori reason why the threshold functions that would be necessary for full or high-only priming would be implemented. Thus, the models are consistent with the evidence that the effect of semantic relatedness on semantic priming is graded.

However, these conclusions only apply to the particular types of subjects tested (undergraduate students), and typical priming conditions. Strategic effects on priming could be accounted for by a gain control mechanism within or subsequent to semantic processing, which would shift priming patterns from graded to full or high-only priming. The "setting" of this gain control mechanism might depend on age and/or reading experience.

2.4.2.3. Summary

The data clearly document a graded priming pattern for semantic relatedness in typical reading conditions. Furthermore, they suggest a similar pattern for semantic similarity, although this result requires further corroboration. The graded priming pattern can easily be accounted for by any of the priming mechanisms discussed in the previous section. The observed priming pattern can change due to differences in list composition or age and reading experience of the participants.

2.4.3. Meaning dominance

This section reviews how differences in meaning dominance affect sustained word meaning activations in typical reading conditions. The first subsection reviews the notion of ambiguity in word meaning, and its representation in distributed network models. The second subsection reviews evidence from semantic priming studies with regards to priming patterns of high- and low-dominance meanings. The third subsection discusses the confound of meaning dominance and strength of semantic relatedness in these studies. The fourth subsection provides theoretical accounts of differences in meaning that arise from meaning dominance effects. Because the evidence cannot conclusively distinguish between a high-only priming pattern and the graded priming pattern, the theoretical accounts of sustained meaning activation take both possible patterns into consideration.

2.4.3.1. Vagueness, polysemy, and homonymy: a continuum of ambiguity

Up to this point, this paper has implicitly discussed meanings of ambiguous words as words with two or more clearly separable meanings that do not overlap. The reality of ambiguity in word meaning is more complicated, with varying degrees of ambiguity and meaning overlap between meanings and senses. These differences are important for models of meaning representation, and need to be taken into consideration when interpreting studies of dominance.

Word meanings are never absolutely specific, but apply to a category of referents by leaving details underspecified. For example, the word *aunt* refers to both the mother's and the father's sister. This lack of meaning specificity is referred to as *vagueness* of word meanings (Tuggy, 1993). Because word meanings are vague, they have core meanings, but their exact meaning is determined through context (e.g., compare the meaning of *eat* in the sentences: "Lord Raleigh ate the soup" and "The dog ate the steak") (Anderson et al., 1975). When the meanings of one word are related but more distinct, for example, *mouth* as a bodily orifice and the river mouth, this is referred to as *polysemy*. Finally, some word forms have completely distinct meanings associated with them, which they share due to historical accident, for example, *bat* as an animal or sports utensil. This is referred to as *homonymy*. To distinguish between polysemy and homonymy, meanings of polysemous words are often referred to as *senses*, whereas meanings of homonymous words are referred to as *meanings* (Durkin & Manning, 1989; Tuggy, 1993).

Theoretically, there is a clear distinction between vagueness, polysemy, and homonymy. In practice, however, these distinctions are not as clear-cut. Standard linguistic tests that are meant to distinguish between vagueness and polysemy are not always conclusive (Geeraerts, 1993; Tuggy, 1993). Furthermore, although theoretically the distinction between polysemy and homonymy can be made by looking at the historical roots of words, speakers/listeners do not necessarily represent the meanings according to this distinction. For example, in Webster's Encyclopedic Unabridged Dictionary (Geeraerts, 1993), the word *plant* has one meaning with several senses, but, as shown in the stimulus validation work for the proposed study, few speakers of English consider the *factory* and *flora* meaning as senses of one word. Furthermore, homonyms can happen to share features, for example, the <animal enclosure> and <penitentiary> meanings of *pen*. Thus, it appears more useful to conceptualize vagueness, polysemy, and homonymy as areas on a continuum with fuzzy boundaries (Tuggy, 1993).

In distributed representations, this continuum is reflected in the degree of pattern overlap between meanings or senses of a word form. For homonymous words, these are completely separate. Polysemous words, on the other hand, share parts of their patterns. The degree of meaning overlap depends on the number of shared features between two senses. The exact meaning of a word sense always depends on context. If two senses are frequently activated in very different contexts, for example, *paper* becoming the meaning of "newspaper," the two different senses become pulled apart in semantic space (Kawamoto, 1993; Klein & Murphy, 2001). Because many features of one sense are incompatible with the other sense, the distance between the two senses in semantic space becomes larger, although it is still closer than for words without any meaning overlap (homonyms).

2.4.3.2. Meaning dominance

Different meanings of ambiguous words can occur with fairly similar frequencies (equibiased ambiguities), or meanings can differ considerably in their relative frequencies (biased ambiguities). The relative meaning frequency of individual meanings of homonyms is referred to as meaning *dominance*. Meanings with high dominance are referred to as *dominant* meanings, and meanings of low dominance are referred to as *subordinate* meanings.

Several studies have investigated how dominance differences affect the time course of sustained activation for meanings of ambiguous words in semantic priming studies with typical reading conditions. The results of these studies suggest that dominance differences affect the time course of priming, and by inference the time course of meaning activation, but the results are not completely consistent. In a frequently cited study, Simpson and Burgess (1985) found that associates of both dominant and subordinate meanings of homonyms showed priming at earlier SOAs (≤ 300 ms), but only high-dominance priming was evident at 750 ms SOA. Simpson and Krueger (1991) reported essentially the same results with neutral, that is, non-biasing sentence contexts. Hino and colleagues (Hino, Lupker, & Sears, 1997), using auditorily presented primes and visually presented targets (cross-modal priming), also found a similar pattern of high-only priming, that is, inhibition of subordinate meanings at a long interstimulus interval (ISI).

Two other studies found continuous priming for dominant and subordinate meanings suggesting a pattern of full priming at long SOAs. Frost and Bentin (1992) attributed this result to a language specific effect. Their study was conducted in Hebrew, which has a lot of ambiguous written forms. They argued that because disambiguation often depends on subsequent context, it is more advantageous for Hebrew readers not to inhibit subordinate meanings. A study by Balota and colleagues (Balota et al., 1999), which used the pronunciation task and investigated dominance effects at three SOAs, found neither an effect of SOA nor of dominance, which is consistent with a full priming pattern. However, given that the average result over all SOAs reflected very small priming effects (5 ms dominant and 8 ms subordinate), it is quite possible that differences due to time course were not detectable.

Thus, it appears that the data are consistent with the proposal that only high-dominance meanings are sustained in semantic priming under typical reading conditions in English. However, there is one problem with this conclusion. In several of the studies reviewed, dominance was confounded with strength of semantic relatedness and vice versa. One study (Hino et al., 1997) attempted to address this confound, and will be discussed in the next subsection.

2.4.3.3. The confound of dominance and strength of semantic relatedness

In three of the studies reviewed above, target words were associates of their primes. However, by definition, the dominant meaning occurs more frequently than the subordinate meaning, and therefore words associated with the dominant meaning of the prime occur far more frequently with the prime than words associated with the subordinate meaning. A typical example is the prime *bank* with its frequently used targets *money* and *river*. According to Nelson's (1991) association norms, the dominant target *money* is the highest associate for *bank*. The subordinate target *river*, on the other hand, was not produced by a single participant in this norming study, and thus has very low associative value. The described time course of activation for ambiguous words therefore not only reflects effects of dominance, but also effects of strength of relatedness, and the two are confounded.

The pattern of meaning activation based on strength of semantic relatedness, which was reviewed above, aids in interpreting this confound. Because meanings with low semantic relatedness are sustained over time in typical reading conditions, the lack of sustained activation for subordinate meanings cannot solely derive from effects of relatedness. This leaves two possible options. First, as commonly proposed (Burgess et al., 1988), subordinate meanings become inhibited over time, resulting in a high-only priming pattern. If complete inhibition is caused by dominance alone, the degree of semantic relatedness is irrelevant for sustained activation of subordinate meanings. The second possibility is that the observed inhibition is an interaction of low dominance and low semantic relatedness. It could be that over time, subordinate meanings lose some of their activation support, but without being completely inhibited. This would be a pattern of graded priming. In many of the studies reviewed above, a graded priming pattern would have been masked, because the subordinate targets were only weakly associated with the prime; thus, the degree of relatedness between prime and target may not have been strong enough to yield a measurable priming effect. If strongly related targets would be used, it should be possible to detect the lower activation of subordinate meanings. Thus, the apparent inhibition effect would in fact be the result of an interaction between graded priming for semantic relatedness and for dominance.

Hino and colleagues (Hino et al., 1997) addressed the question whether inhibition in previous ambiguity studies was due to strength of relatedness effects or dominance effects. They presented ambiguous primes with targets that were either associated words or non-associated semantically related words, for both the dominant and the subordinate meanings. Hino and colleagues matched associated targets for degree of association based on norms. This was only possible with low degrees of association

(.065 for both dominant and subordinate targets), because there are no highly associated words for subordinate meanings. Non-associated pairs were created based on the authors' intuition.

After the experiment was conducted, participants rated word pairs for relatedness in meaning, and were instructed not to base their judgments on "how easily and quickly one word comes to mind when reading the other." This latter rating aimed to measure semantic rather than associative relatedness. Because degree of pure semantic relatedness is independent of co-occurrence frequency, it is independent of dominance. In these ratings, the dominant associated pairs were significantly more strongly related than word pairs in the other three conditions, which did not differ from each other.

Hino and colleagues found that at a 0 ms interstimulus interval (ISI) targets associated with the dominant and the subordinate meanings primed, whereas at 700 ms ISI only targets related to the dominant meanings were primed (associated and non-associated). The measure of meaning relatedness did not affect the results at all. The overall result of the study led the authors to conclude that neither association nor strength of relatedness play a role in sustained meaning activation.

However, this conclusion is at odds with the results of numerous studies discussed above, which found an effect of strength of association and of semantic relatedness on priming at long SOAs. One possible reason for this discrepancy could be that the semantic relatedness rating was not independent of dominance and co-occurrence, as intended. In this author’s experience, when participants are instructed to rate meaning relatedness, they are very prone to include associative relatedness in the ratings even when instructed not to do so. This might be especially true for this study because the instruction asked for meaning *relatedness* ratings rather than meaning *similarity* ratings. Furthermore, the instructions to not base judgments on how likely a participant thinks of one word when the other is read might not be very effective – in fact, these instructions might have induced participants to think of related words. Therefore the validity of these ratings as measures of semantic relatedness is questionable, and the study cannot conclusively differentiate between the two hypotheses of high-only priming or graded priming.

2.4.3.4. Theoretical account

2.4.3.4.1. High-only priming

Localist models that predict high-only priming for dominance rely on a functional inhibition process between semantic nodes that represent the separate meanings of a homonym (Cottrell, 1988; Balota et al., 1999; Duffy, Kambe, & Rayner, 2001). In these models, after initial activation the more strongly activated meaning, which is usually the dominant meaning, inhibits the subordinate meaning. The studies reviewed above did not differentiate between homonymous and polysemous words in their word primes, and it is not clear whether polysemous words would have the same priming pattern. The only way to apply a localist model to polysemous words is to posit that polysemous meanings have separate nodes (Klein et al., 2001).

The most developed distributed model for ambiguity and dominance effects is a model of word recognition and context priming for ambiguous words by Kawamoto (Kawamoto, 1993). In this model, an activated lexical representation of a word activates all sets of features and feature patterns that represent the meanings of that ambiguous word form, depending on the weights of the connections. Over time, the network moves toward the attractor state of one coherent instantiated semantic representation. This is a probabilistic process, and depends on the degree of dominance of the meaning of an ambiguous word; the more frequent a meaning is, the more likely the network will settle into that particular representation.

With regard to priming effects, the process described above is consistent with the high-only priming hypothesis. In the beginning, features of both meanings are active, which results in priming for both meanings. Over time the network moves toward one particular meaning representation, and activation for features of the other representation is inhibited. Because this is a probabilistic process, the majority of participants in an experiment will settle into the dominant representation, thus only the dominant representation appears to be active in the group average.

The process of settling into a single representation has only been modeled for homonymous words. Extrapolating to polysemous words, over time the network again should settle into one coherent sense of a polysemous word, and incompatible features would be inhibited. This would result in a similar time course as for homonymous words. However, those features which are shared between two senses of polysemous words remain active, and if these features are a large enough part of the overall pattern, subordinate senses should prime even at long SOAs.

2.4.3.4.2. Graded priming

The account of dominance effects presented in the previous subsection relies on the assumption that over time semantic representations settle into one coherent representation. However, as discussed above, the priming results are also potentially consistent with the pattern of graded priming. For this pattern, the semantic system must allow incompatible meanings to remain active over time.

The fact that Hebrew shows a full priming pattern for dominance clearly suggests that under certain circumstances, the semantic system sustains incompatible meanings in semantic priming. This cannot be accounted for by Kawamoto's model. One way to accommodate this finding into Kawamoto's model is to propose that the cognitive system has strategic control over the degree to which it settles into a single representation[10]. For speakers of a language like Hebrew, in which sustained activation for

[10] A model of word recognition of ambiguous words by Masson (Masson, 1991) frequently settles into blended representations, that is, representations which incorporate features of both meanings (Masson et al., 1995).

multiple meanings of them because words might be the more effective strategy for comprehension, the system would not settle into one representation without contextual bias. However, even if priming of incompatible meanings in standard paired priming is possible in English, the question is whether it happens. Paired priming studies with equibiased ambiguous primes could provide evidence for this question.

This author is not aware of any studies that have investigated equibiased ambiguities in paired word priming. However, one study investigated equibiased ambiguous words with divided visual field presentation (Atchley et al., 1999). It showed priming for targets related to each meaning in both visual fields. This finding is certainly consistent with the proposal that incompatible meanings can remain active. However, there is another possible explanation. If it is equally probable that the semantic network will settle into either representation, in the group average both meanings would appear to be active simultaneously.

In order to differentiate between the two possibilities, it is necessary to investigate the priming results in more detail. First, the priming effect should be lower for equibiased meanings than for dominant meanings, because only about half of the participants would show priming for each equibiased meaning, but the majority of all study participants would show priming for dominant meanings. Thus, for equibiased meanings the average priming advantage would be reduced. Second, the distribution of priming effects for equibiased meanings should be bimodal, because participants fully activate either the dominant or the subordinate meaning of the ambiguous word, and show a full priming effect for either one. The study report did not provide the necessary data to assess either of these options; therefore, the question of whether activation of incompatible meanings can be sustained cannot be resolved.

2.4.4. Summary

Data from semantic priming studies suggest that under typical priming conditions and with undergraduate participants, semantic relatedness effects result in a graded priming pattern for semantic activations, although further evidence is required to show that this is the case for purely semantic priming effects at long SOAs. This priming pattern is consistent with the predictions from all semantic priming models for both semantic and lexical priming effects. However, strategic list characteristic effects and possibly reading experience and/or age can change these patterns.

While this model can account for the sustained activation of incompatible features, it is incompatible with any evidence for inhibition of subordinate meanings, and requires additional processes to allow for that possibility (Masson et al., 1995).

The evidence summarized in the review of dominance effects is consistent with a high-only priming pattern for dominance effects in typical reading conditions. This priming pattern can be accounted for by the settling dynamics of distributed networks that represent lexical and semantic information, namely, the characteristic of such networks to settle into one single coherent representation. However, a graded priming pattern cannot be ruled out. This pattern requires the assumption of at least partial inhibition of subordinate meanings. At the same time, the semantic system has to allow for ongoing concurrent activation of incompatible meanings. Evidence from Hebrew suggests that the semantic system is able to do so, but evidence from English is not yet available to infer whether incompatible meanings are sustained under typical reading and priming conditions.

2.5. MODELS OF HEMISPHERIC DIFFERENCES IN WORD MEANING PROCESSING

The goal of this study was to investigate the influence of strength of semantic relatedness and meaning dominance on sustained meaning activation for LH processing. This section reviews in more detail current models of hemispheric differences in word meaning processing, and discusses their predictions with regards to the effects of strength of semantic relatedness and meaning dominance on sustained meaning activation. The first section presents the four main models of such differences (Chiarello et al., 2003; Beeman, 2005; Koivisto et al., 2000; Burgess et al., 1998b). These models were summarized as "the standard model" in Section 1, because they make the same predictions for the effects of strength of semantic relatedness and dominance. In addition to these four models, the second part of this section presents a parallel distributed processing account of hemispheric differences in sustained meaning activation that was suggested by David Plaut (personal communication, April 9, 2002). This model differs from the standard model because it predicts a different pattern of strength of semantic relatedness effects for LH processing.

All five models are directly derived from general models of word comprehension. They share the assumption that each hemisphere has its own semantic network, and that meanings are represented separately in each network. Thus, the models assume two parallel independent semantic networks that may share semantic information; however, they process this information differently because they vary in representational or processing characteristics.

2.5.1. Four main models of hemispheric difference in sustained activation for word meanings

The four main models of hemispheric differences in sustained activation of word meanings stem from the work of four research labs that have focused on investigating hemispheric differences in word processing. This section gives a short overview of recent models from each lab. However, before proceeding with those overviews, three issues are addressed to clarify the scope of the review.

First, although the four models are based on different representational and/or processing mechanisms, they each make similar predictions about how strength of semantic relatedness and meaning dominance affect the sustained activation of word meanings for LH and RH processing. In terms of predictions, the models differ in their account of *initial* meaning activation in LH and RH processing. This review does not focus on these differences because the research questions the present study addresses are only concerned with sustained meaning activation *after* initial activation. Thus, this review emphasizes the different mechanisms proposed to account for patterns of sustained meaning activation at long SOAs.

Second, because the proposed study focuses on meaning activation supported by LH processing, this review discusses right hemispheric (RH) processing only to the extent that it illustrates those difference between LH and RH processing that contribute to differing patterns in sustained meaning activations. Finally, because the four models that were summarized in the introduction as the "the standard model" do not explicitly distinguish between effects of semantic relatedness and dominance, the subsequent review does not make this differentiation, and the term "less related" is used to encompass meanings of low semantic relatedness as well as subordinate meanings[11].

2.5.1.1. Chiarello and colleagues' model

For over 20 years, Chiarello's research has focused on the question of hemispheric differences in meaning processing. Recently, Chiarello and colleagues (Chiarello et al., 2003) based their account of hemispheric differences in word meaning activation on representational and processing characteristics of distributed network models, especially on Plaut's (1995) model of pure semantic priming.

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[11] Chiarello and colleagues (Chiarello et al., 2003) pointed out that semantic relatedness and dominance are different word meaning relationships. Because their paper focused on *initial* meaning activation, they did not explore the theoretical implications of the difference between the two relationships for hemispheric differences in *sustained* meaning activation.

The paper by Chiarello and colleagues is mainly concerned with explaining hemispheric differences at the *onset* of semantic activation and not for sustained semantic activation. As a result, their paper makes only brief mention of how such a model predicts hemispheric differences in sustained meaning activation, and does not provide much detail with regard to the processing mechanisms.

In Chiarello and colleagues' account, both hemispheres are parallel distributed semantic networks, each network resembling that in Plaut's (1995) model of pure semantic priming. In Plaut's model, activation for targets with low semantic relatedness dissipates faster than activation for targets with high semantic relatedness, resulting in apparent inhibition of low relatedness meanings. Chiarello and colleagues proposed that this dynamic is evident in LH meaning processing. With regards to the RH, they suggested that meaning representations and/or processing are "noisier," for example, because RH semantic representations are more degraded than LH representations, and/or because "the processes by which the RH accesses lexical-semantic information introduce noise into the system" (Chiarello et al., 2003, p. 729). According to Chiarello and colleagues, such noisier encoded representations or processing lead to slowed activation of meaning representations, and, more importantly, do not *resolve* as easily into precise meanings. This means that for instantiated representations supported by RH processing less-related meanings remain active. In sum, Chiarello and colleagues' model attributes hemispheric differences in sustained meaning activation to noisier representations or processing for RH as compared to LH processing.

2.5.1.2. Beeman's model

Using concepts from proposed hemispheric differences in perceptual processing, Beeman (1993; 1994; 1998; 2005) proposed that for LH processing semantic representations are fine-coded, whereas for RH processing semantic representations are coarse-coded. Fine-coded representations are narrow representations that include only closely-related meanings, whereas coarse-coded semantic representations are broader and therefore include less-related meanings. From the point of view of the model by Chiarello and colleagues, coarse coding could be one way in which the representations sustained by RH processing are noisier compared to representations sustained by LH processing. This aspect of Beeman's model represents one possible implementation of the account by Chiarello and colleagues.

However, in addition to these representational differences, Beeman (1994; 2005) also proposed a selection mechanism for LH processing that inhibits less related meanings. This selection mechanism purportedly aids in the integration of meaning. Thus, in Beeman's model hemispheric differences in word meaning activation derive from two sources: differences between fine and coarse coding, and a selection mechanism supported by LH processing.

2.5.1.3. Koivisto and Laine’s model

Koivisto and Laine (2000) developed their model on the basis of Neely and Keefe's Three-Process model of semantic priming (Neely et al., 1989; Neely, 1991). In Koivisto and Laine's model, word meanings in both hemispheres are represented in two parallel simple localist networks. Hemispheric differences in word meaning activation result from an inhibitory mechanism that is specific to LH processing, and inhibits less-related meaning nodes. The inhibitory process mirrors Beeman’s proposal, and no other source of hemispheric differences is suggested in Koivisto and Laine’s model.

2.5.1.4. Burgess and Lund’s model

Finally, Burgess and Lund (1998b) suggested that differences in speed of activation onset could account for differences in meaning activation between LH and RH processing. In their account, higher degrees of semantic relatedness or dominance lead to both longer and stronger activations of word meanings for both LH and RH processing. As a result, again for both LH and RH processing, less-related meanings decay faster. However, RH processing has a slower onset of speed of activation, and therefore less-related meanings are still activated at a point in time when they have already decayed for LH processing. While Chiarello and colleagues (Chiarello et al., 2003) also proposed that meaning activation for RH processing is slowed compared to LH processing, they did not attribute the difference in sustained meaning activation between the processing types to differences in activation rise time. Thus, Burgess and Lund’s proposal introduces a third possible factor to explain hemispheric differences in sustained meaning activation, that is, slower activation onset for RH processing.

Burgess and Lund (1998b) implemented their proposal with the Hyperspace Analog to Language, a quantitative corpus-based models of word semantics described in Section 2.2.2. Apart from differences in activation onset, this model also incorporated differences in decay based on co-occurrence frequency. The interaction between these two factors was not well explored by the authors.

2.5.1.5. Summary

The four models reviewed above suggest three possible mechanisms that might underlie hemispheric differences in sustained activation of word meanings. First, either representational or processing differences may lead to instantiated meaning representations for LH processing that are less overlapping or narrower than those for RH processing. Second, LH processing may include a mechanism that inhibits less related meanings and that results in more focused instantiated meaning representations. Third, RH processing could have a slower activation onset, which would lead to a later activation onset and later decay of meaning activations. Therefore RH processing would still make wider meaning representations available when LH processing has already focused to narrower representations.

All four models share a central proposal: after initial activation, LH processing sustains only strongly-related meaning activations and inhibits less-related meanings, whereas RH processing keeps less-related meanings active. This central proposal was termed the “standard model” in the introduction. Because the standard model does not distinguish between effects of the strength of semantic relatedness and dominance, for LH processing it predicts a pattern of high-only priming for both semantic similarity and dominance.

2.5.2. Plaut’s model

2.5.2.1. Overview

Plaut’s model is a distributed network model. In this model (Plaut, personal communication, April 9, 2002) LH and RH processing differ in the way semantic information is represented in the network. According to this model, word meanings are coded as vectors, but LH processing codes meanings in sparse vectors, whereas the RH processing codes meanings in crowded vectors. Mathematically, sparse vectors consist of many 0s and few values that are higher than 0. Crowded vectors, on the other hand, consist of few 0s and many values that are higher than 0. When many vectors (or word meanings) need to be distinguished, sparse vectors differentiate information much better, because there is less overlap between patterns. Thus, LH sparse vectors allow instantiated representations to settle into precise and compatible meanings, whereas RH crowded vectors result in more meaning overlap. Plaut’s proposal is similar to Beeman's (1994, 2005), although Plaut’s model differs in its specification of processing dynamics. Again, RH crowded vectors could also be seen as one instantiation of the proposed "noisier" representations in the model of Chiarello and colleagues (Chiarello et al, 2003).

2.5.2.2. Settling dynamics and predictions

Plaut’s model has not been implemented; therefore, the predictions are not based on an actual simulation[12]. According to Plaut (personal communication, July 10, 2002), his model does not predict high-only priming for semantic relatedness and dominance LH. Rather, effects of strength of semantic relatedness and dominance would result in different patterns of sustained meaning activation, based on the settling dynamics of each network.

For strength of semantic relatedness, the model predicts a graded priming pattern for LH processing. That is, meanings with low semantic relatedness sustain activation, but they are active to a lesser degree than meanings with high semantic relatedness. For RH processing, instantiated representations are more diffuse, and therefore differences in activation levels between low and high semantic relatedness might be somewhat weaker than for LH processing. Therefore, while graded priming is still predicted, it might be somewhat harder to detect.

For dominance, the model predicts high-only priming for LH processing, because sparse vectors sustained by LH processing allow the network to settle into one coherent representation without incompatible meanings being active. Conversely, for RH processing, overlapping meaning representations never settle completely into one coherent representation, leaving subordinate meanings active.

Thus, Plaut's model draws a clear distinction between the mechanisms that underlie strength of semantic relatedness effects and dominance effects. Due to this distinction, Plaut's model differs from the standard model in its predictions for the effects of meaning similarity on priming at long SOAs for LH processing; the standard model predicts high-only priming, whereas Plaut's model predicts graded priming.

2.5.2.3. Summary and discussion

Based on their predictions for priming at long SOAs, the various models of sustained meaning activation in the two cerebral hemispheres can be summarized into two distinct groups: the standard model and Plaut's model. Plaut’s model differs from the standard model mainly in its predictions for the effect of strength of semantic relatedness on priming for LH processing. While the standard model predicts a high-only priming pattern, Plaut’s model predicts a graded priming pattern. With regards to

[12] Of course, this is also true for the other models, with the exception of Burgess and Lund’s (1998) model.

dominance, both models predict a high-only priming pattern. Section 2.8. discusses whether the available evidence is conclusive with regards to these predictions. However, before the evidence is addressed, the next section presents in more detail the standard method used in this area of research, divided visual field presentation, and discusses the methodological issues of prime presentation and priming measure.

2.6. DIVIDED VISUAL FIELD PRESENTATION AND PRIMING STUDIES

Divided visual field (DVF) studies have been the main method used to investigate hemispheric differences in reading comprehension. The first part of this section presents the rationale behind this method and addresses questions of validity. The second part discusses methodological variations and interpretational inconsistencies in DVF paired priming studies with respect to prime field of presentation and the choice of the priming measure, proposes which methodological choices are most appropriate for these studies, and outlines the consequences of these choices for the review of evidence.

2.6.1. Divided visual field presentation and its interpretation

DVF presentation makes use of the fact that information from visual stimuli presented toward the side of the vertical midline of a visual field initially reaches only one hemisphere. Therefore this technique can be used to investigate how processing of stimuli differs depending on in which hemisphere incoming information first initiates processing. Of course, after this first step processing will be shared between the hemispheres across the corpus callosum and subcortical structures. Thus, DVF presentation does not measure encapsulated processing within each hemisphere, but it measures processing differences based on which hemisphere initiates processing. It is thought that this initiation gives an advantage to processing supported by the initiating hemisphere, because it is started earlier, and because the contralateral hemisphere receives any information only filtered through the processing of the initiating hemisphere. Therefore, behavioral differences in the two DVF conditions are attributed to the processing styles of LH and RH processing.

In DVF presentation observed differences between the two visual fields can depend on attentional and arousal factors (Kosslyn, Gazzaniga, Galaburda, & Rabin, 1999) or specific stimulus and task conditions (Hellige & Sergent, 1986; Sergent & Hellige, 1986). Not surprisingly, inconsistent results have been reported, leading some to question the validity of the DVF procedure in general (Efron, 1990; Beaumont, 1997). However, several findings are very robust, for example, the right visual field-left hemisphere (rvf-LH) advantage for word recognition. Other DVF effects are substantiated with meta-analysis, for example, the left-visual field (lvf-RH) advantage for visual stimuli with low spatial frequency (Van Kleeck, 1989). These and other findings are consistent with evidence from neuropsychological and imaging studies (Hellige, 1993; e.g., Cabeza & Nyberg, 2000; Robertson & Lamb, 1991; Kosslyn et al., 1999). Thus, DVF presentation is a valid method of investigating hemispheric differences in cognitive processing. But because DVF effects are so susceptible to other influences, results gained in these studies require a high degree of replication and corroboration through other methods (e.g., ERP with source localization, imaging techniques, lesion data).

The validity of many DVF studies has also been criticized from a different point of view. Jordan and colleagues (Jordan, Patching, & Milner, 1998; Jordan, Patching, & Thomas, 2003b) argued that because most DVF studies do not monitor eye movements, the experimenter cannot know if participants follow the instructions for central fixation. In several experiments Jordan and colleagues (Jordan et al., 1998; Jordan, Patching, & Thomas, 2003a) addressed this question; however, conclusions are not straightforward. Jordan and colleagues monitored participants' eye movements in letter search tasks in word context. In three different experiments results varied considerably. While in the first experiment 1%, and in the second experiment 0% of gazes were 1° or more from central fixation (Jordan et al., 1998), in the third experiment this was true for 10% of the gazes (Jordan et al., 2003a). Jordan and colleagues claimed that the final result was "comparable" (Jordan et al., 2003a) to the other two, and it is not clear how they arrived at that evaluation. Judged just on the basis of these three data points, the observed 10% of gaze deviation is the most likely outlier, although the data are certainly not enough for any clear conclusions.

The important question with respect to validity of the DVF method is to what extent these deviations from central fixation invalidate the typical inferences with respect to hemispheric differences. Evidence from animal experiments indicates that an area of 1° visual angle around the center of the visual field projects to both hemispheres (Lavidor & Ellis, 2003; for a recent discussion of this issue, see Lindell & Nicholls, 2003). Because most experiments present their word stimuli at a visual angle of 2°, the observed deviations are unlikely to result in a significant number of trials in which part of the stimulus information reaches both hemispheres.

However, because visual acuity decreases toward the periphery of the visual field, bias toward one direction could change the results meaningfully. In all three experiments discussed here, the majority of gaze deviations were toward the lvf-RH, which raises the possibility that this bias might change the observed "hemispheric differences." Two of the experiments by Jordan and colleagues (Jordan et al., 1998; Jordan et al., 2003a) allow a direct comparison of results when targets were only presented when participants focused in the center (controlled condition) and when eye-movements were just passively monitored (uncontrolled condition).

In the first study (Jordan et al., 1998), results were evaluated for visual field differences based on accuracy. In this study, 1% of gazes were 1° from fixation in the uncontrolled condition, but results were the same as in the controlled condition. The second study (Jordan et al., 2003a) evaluated hemispheric differences in the serial position curve of the letter search task, again based on accuracy. In this study 10% of gazes were 1° or more from fixation in the uncontrolled condition. In the controlled condition, numerical results showed considerably less noise, especially for the lvf-RH. This was reflected in the statistical analysis, where both conditions showed the same result, but it was only marginally significant in the uncontrolled condition ($p = .06$). Thus, gaze deviations of 10% affected the outcome. However, they mainly seemed to introduce noise into the statistical analysis, which could have been addressed by adding more participants. It could be argued that if even this amount of deviation does not change results qualitatively, significant effects from unmonitored studies can be considered valid. However, the numerical results suggested a bias in that the serial position effect was clearly more masked for lvf-RH responses.

Clearly, evidence from these two studies is not enough to extrapolate to all DVF studies. Judged on the basis of this scant data, it appears that in most studies gaze deviations do not affect results enough as to change the outcome with respect to hemispheric differences. However, gaze deviations might increase the likelihood for null results, especially for lvf-RH responses. Jordan and colleagues reported that a subset of participants had considerably more difficulty with maintaining central fixation than the majority of participants (Jordan et al., 2003b). Therefore, this study included a fixation control task to rule out participants who exhibited fixation difficulties over longer periods of the experiment[13].

2.6.2. Methodological Variation

In DVF studies, priming patterns differ depending on the prime field of presentation and the priming measure used. To date, there is no consensus on the theoretical significance of these differences. Such lack of clarity can lead to inconsistencies in the interpretation of results. This section discusses such inconsistencies and suggests that central prime presentation and a comparison of related versus unrelated prime-target pairs are the most appropriate methodological choices for investigating hemispheric differences in word reading with DVF priming studies.

[13] The author thanks Marlene Behrmann for suggesting this approach to the problem of gaze deviations.

2.6.2.1. Prime field of presentation

One important consideration in semantic priming studies with DVF presentation is the method of prime presentation. Primes are presented either centrally, ipsilateral with the target, or contralateral to the target. Chiarello and colleagues (Chiarello et al., 1990) found differential effects for lateral targets of a certain type only if the primes were also presented (ipsi)laterally. They argued that when words are presented in central presentation, each hemisphere initially receives visual information only about parts of the word prime, and therefore the visual information for the word has to be integrated to produce a complete percept. They speculated that this integration of *pre-semantic* information might induce more interhemispheric sharing of *semantic* information, compared to when the visual information of the whole word reaches the same hemisphere in lateralized presentation. According to this argument, lateralized prime presentation leads to less hemispheric interaction in processing pre-semantic information, and also reduces sharing of semantic activation. Therefore, Chiarello and colleagues proposed that ipsilateral presentation is a better measure of within-hemisphere activation. This view has been adopted by other researchers (e.g., Hutchinson, Whitman, Abeare, & Raiter, 2003), and many relevant studies have used lateral prime presentation.

In contrast to this view, the argument can be made that central, rather than lateral prime presentation is ecologically more valid for studying word semantic processing in reading. Lateralized presentation differs from central presentation not only because it changes the hemisphere of visual input, but also because acuity is significantly reduced, and stimulus words are therefore degraded. Although lateralized primes might provide a ‘‘better’’ measure of hemispheric capabilities (Chiarello et al., 2003; Joanette & Goulet, 1998), the extent to which these capabilities play a role in normal, everyday processing conditions is unclear (Joanette & Goulet, 1998). The hemispheric differences in word meaning processing are thought to apply whenever a word is read or heard, that is, under normal processing conditions. For reading, that condition is central presentation. Because the goal in DVF semantic priming studies is to measure semantic activation caused by the *prime*, it is less problematic to have a lateralized *target*. When targets are well controlled, priming differences should be attributable to effects of the prime.

The standard model draws from studies with both central and lateral primes[14]. Thus, excluding studies that have used lateralized prime presentation limits the data from which theoretical inferences can be drawn, compared to what is used as the evidentiary basis for the standard model. This data reduction is

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[14] This use of evidence reflects a selection bias, because evidence from studies with central primes that fit the standard model (Burgess & Simpson, 1988; Nagakawa, 1991) is accepted as valid evidence, but that which does not fit (Chiarello, Burgess, Richards, & Pollock, 1990) is disregarded (e.g., in Chiarello et al., 2003; Koivisto & Laine, 2000).

one reason why the following literature review reaches different conclusions from those found in articles on the standard model.

The discrepancy between the data set that includes only studies with central presentation and the data set that includes both central and lateral prime presentation raises the question as to why these data are at variance. Possible reasons are the previously mentioned degree of interhemispheric pre-semantic interaction, or different degrees of visual degradation of stimuli. However, these reasons lead to more questions than answers (e.g., why do different degrees of pre-semantic interaction affect LH inhibition patterns? Why do different degrees of stimulus degradation affect LH inhibition patterns?), and more research and probably improved theoretical models are needed to gain a better understanding of the implications of these two methods (Coney, personal communication, December 15, 2002). This issue is beyond the scope of the present study.

2.6.2.2. Priming measure

Another area of methodological inconsistency is the choice of priming measure. The most frequently used measure is *priming*, that is, a comparison of the difference in the dependent variable—usually target response time (RT)—between unrelated and related prime-target pairs (e.g., dog–cat; fig–cat). Some studies include a third type of word pair with so-called neutral, semantically empty primes (e.g., blank or xxxx). These studies report two other measures of prime activation: *facilitation* (comparison of neutral vs. related) and *inhibition* (comparison of neutral vs. unrelated). Scrutiny of results shows that these different measures can provide conflicting outcomes (see Fassbinder & Tompkins, 2006, for a review).

For a consistent interpretation of DVF priming study design and analyses of results should be based on only the *priming* measure for three reasons. First, the comparison of unrelated versus related prime-target pairs can be derived from all studies, whereas only studies with neutral primes provide data on facilitation and inhibition. Second, the validity of neutral primes has been questioned because frequently repeated and semantically empty primes might be processed differently from other word primes (e.g., Brown et al., 2000; Jonides et al., 1984). Third, neutral primes can show different effects depending on the visual field to which they are presented (Chiarello, 1998b). In several DVF studies (Anaki et al., 1998; Burgess et al., 1988; Shears et al., 2003) neutral primes have resulted in uninterpretable results. Therefore the following literature review includes only *priming* results, which is the second reason why it reaches different conclusions than those found in articles on the standard model.

2.6.2.3. Summary

In DVF word priming studies, results can differ depending on the prime filed of presentation and the choice of priming measure. It is concluded that for the purpose of investigating hemispheric contributions to normal reading, the most relevant data is obtained in studies using central primes and the comparison of related versus unrelated prime-target pairs. This conclusion results in a different selection of evidence and is the main reason why this author comes to a different interpretation of the available evidence than the authors of the standard model.

2.7. EVIDENCE, THEORETICAL IMPLICATIONS AND RESEARCH QUESTIONS

This section summarizes evidence for effects of strength of semantic relatedness and dominance on sustained semantic priming in studies with targets presented to the rvf-LH and lvf-RH. For each of these two factors, this section first discusses to what extent the evidence is consistent or inconsistent with the two models of hemispheric differences in semantic priming. Against this background, the questions for the current study are developed. A short overview of each experiment is presented, followed by a discussion of possible outcomes and implications.

Because the present study focused on sustained semantic activation, this review includes only studies that report priming effects at SOAs of 600 ms or longer. Only response time data are reported, because they tend to be more sensitive than accuracy data to the cognitive processes under investigation (e.g., Young, 1982). The nine studies included in this review used central primes and the priming measure of semantic activation (for studies in which analyzed facilitation and inhibition rather than priming, raw priming data are reported). Only four out of nine studies supplied relevant information for calculating effect sizes, which makes inter-study comparisons more difficult. Seven studies used lexical decision as the response task, the remaining two (Atchley et al., 1996; Burgess et al., 1998b) used naming.

2.7.1. Semantic relatedness

The standard model and Plaut's model differ in their predictions for the effects of strength of semantic relatedness[15] on sustained meaning activation for LH and RH processing. According to both models, at long SOAs RH processing keeps both high- and low-relatedness meanings active. The models diverge with respect to LH processing at long SOAs: while the standard model predicts high-only priming, Plaut's model predicts graded priming.

Three of the nine DVF studies used paired priming and central primes, and investigated how strength of semantic relatedness affects hemispheric differences in semantic priming. They provide some limited evidence with regards to the divergent predictions from the two models. This subsection of Section 2.8. presents the characteristics of these studies, summarizes their results, and discusses their theoretical implications. Overall, the evidence suggests that LH processing exhibits a graded priming pattern, consistent with Plaut's model. However, none of the studies tested the effect of pure semantic relatedness, which means these effects could be due to lexical level processes rather than semantic processes.

2.7.1.1. Characteristics

The three studies cited above differed in three characteristics: prime-target relationship, time course investigated, and dependent measure. Two studies compared a set of word pair stimuli that included associated and non-associated category coordinates (Chiarello et al., 1990; Chiarello et al., 1992). In this stimulus set, associated word pairs had been rated to have significantly higher feature overlap between prime and target than did the non-associated ones (Chiarello, 1998b). This rating suggests that the stimuli differed in pure semantic relatedness. However, in addition to the difference in semantic strength the stimuli also differed in association. Therefore, effects of association and/or co-occurrence cannot be ruled out. The two studies used different relatedness proportions for related and unrelated word pairs. The first study used a low relatedness proportion (.25), whereas the second used a high relatedness proportion (.70). As previously discussed, stimuli with lower relatedness proportions are probably less sensitive in measuring instantiated semantic activations.

In the third study (Nakagawa, 1991), highly related stimulus pairs were opposites, which by definition are semantically highly similar, but can also be highly associated and might vary in frequency

[15] As a reminder, "semantic relatedness" in this document includes semantic and lexical relatedness.

of co-occurrence. Weakly related stimuli were remote associates, taken from association norms. Again, both meaning relationships probably reflect pure semantic relatedness *and* co-occurrence, and the influence of lexical versus pure semantic factors on priming in this study cannot be determined. Another problem in this study was that as a dependent measure it used facilitation rather than priming. Because Nakagawa also included unrelated primes, numerical results for priming could be calculated and were used in this review instead of facilitation and inhibition results, but no significance testing was available for these measures.

2.7.1.2. Results

All results are shown in Table 1, which reports significant priming effects and effect sizes (ES) when the variance data were available for the contrast of interest. In order to evaluate the models of hemispheric differences in word semantic activation presented in the previous section, the following paragraphs summarize the results of these three studies, guided by three questions:

i. For LH and RH processing, is there evidence for priming of strongly and weakly related meanings at long SOAs?
ii. For LH processing, is there evidence that strength of semantic relatedness affects priming at long SOAs?
iii. For LH processing, is there evidence for partial or complete inhibition of activation for weakly related meanings?

2.7.1.3. Priming at long SOAs

At long SOAs, both studies by Chiarello and colleagues (1990, 1992) showed priming for both high- and low-relatedness targets, regardless of whether they were presented to the right visual field - left hemisphere (rvf-LH) or to left visual field – right hemisphere (lvf-RH). As shown in Table 1., Nakagawa's study (1991) also showed priming at 750ms SOA for high-relatedness targets presented to the both the rvf-LH and lvf-RH. Effect sizes also suggest priming for low-relatedness targets in both presentations, although the low effect size for rvf-LH targets (.17) might be hard to detect. Taken together, the results from the studies by Chiarello and colleagues and Nakagawa suggest that lvf-RH and rvf-LH targets with high and low semantic relatedness may show priming, but for lvf-RH targets activation levels might sometimes be more difficult to detect in low-relatedness conditions.

Table 1 Priming results for prime words paired with strongly vs. weakly related words

(response times and effect sizes)

Study	Strong vs. weak relationship between prime and target	RP[a]	rvf-LH[b] significant priming (effect size)[d]			lvf-RH[c] significant priming (effect size)		
			strong	weak	strong vs. weak	strong	weak	strong vs. weak
Chiarello et al. 1990	Associated vs. non-associated category coordinates	.25	yes	yes	s = w[e]	yes	yes	s=w[f] (26 ms difference)
Chiarello et al. 1992	Associated vs. non-associated category coordinates	.70	yes	yes	s>w	yes	yes	s=w
Nakagawa 1991	Antonyms vs. remote associates	.50	*85 ms*[g] (1.11)	*28 ms* (.33)	*57 ms* (.78)	*57 ms* (.54)	*20 ms* (.17)	*36 ms* (.37)

[a] relatedness proportion (# related targets / # word targets)
[b] right visual field/left hemisphere
[c] left visual field/right hemisphere
[d] significant effect according to priming measure (response time unrelated – response time related prime target pairs). Effect sizes (d = priming/pooled standard deviation) are reported when available.
[e] s = strong, w = weak
[f] it is not quite clear whether the relevant significance test was performed, effect size not calculable
[g] no significance testing available for priming measure. Raw priming effects are reported instead.

2.7.1.3.1. Strength of semantic relatedness effects (LH processing)

The difference between priming for high- and low-relatedness targets in Nakagawa's study (57ms, ES: .78) strongly suggest that there is an effect of strength of semantic relatedness in the LH. Chiarello and colleagues (Chiarello et al., 1992) also documented a significant effect. The exception was the one study by Chiarello and colleagues (Chiarello et al., 1990) that used a low relatedness proportion. Overall, these results suggest that for rvf-LH targets the degree of sustained activation for related meanings depends on the strength of semantic relatedness and reflects a graded priming pattern. Yet, the difference between high and low relatedness might be harder to detect with low relatedness proportions.

2.7.1.3.2. Inhibition of less related meanings (LH processing)

All three studies show evidence of activation for less related meanings at a long SOA in the LH. This suggests that there is no complete inhibition of such meanings. Furthermore, the numerical results in the study by Nakagawa show no indication for any decrease in priming levels for low relatedness targets over time (SOA 67ms: 24 ms, ES: 24; 800ms: SOA 28 ms, ES: .33). This result might suggest that there is not even partial LH inhibition of these meanings. However, because this conclusion is based on a single data point without statistical evaluation, this conclusion is very tentative, and more evidence is needed[16].

2.7.1.3.3. Summary

To summarize, all three studies confound semantic and lexical relatedness. If the observed priming effects, at least in part, are attributable to differences in semantic relatedness rather than lexical relatedness, results overall indicate sustained activation of high- and low-relatedness meanings for both LH and RH processing. Furthermore, evidence shows an effect for strength of semantic relatedness for LH processing, which is more likely to be detected at moderate to high relatedness proportions. Finally, there is no indication that LH processing completely inhibits meanings with low relatedness. Nakagawa's results suggest that there is not even partial inhibition for these meanings. Yet, the lack of statistical analysis and the scarcity of data make this conclusion quite tentative.

[16] If facilitation and inhibition rather than priming would be considered, inhibition for low-relatedness targets is evident in Nakagawa's study. The authors of the standard model only consider the facilitation and inhibition results.

2.7.1.4. Theoretical implications and research questions

The standard model and Plaut's model differ in their predictions for the effects of strength of semantic relatedness for LH processing. Both models predict such effects, but not the same ones. The standard model predicts sustained priming of high-relatedness meanings with complete inhibition of low-relatedness meanings (high-only priming). Plaut's model predicts sustained priming for both types of meanings, but with a significant difference in activation level between the two (graded priming). The minimal data available so far are mostly consistent with Plaut's model, because they show ongoing activation for low-relatedness meanings, and suggest a proportional strength of relatedness effect. The data are inconsistent with the standard model, that is, with the proposal that at long SOAs low-relatedness meanings are completely inhibited. With respect to RH processing, both models predict sustained activation of meanings with low relatedness. Overall, the evidence is consistent with this prediction.

However, it is important to keep in mind that none of the studies tested pure semantic relatedness, because they confounded semantic relatedness with association. Thus, it is still an open question to what extent the available data resulted from effects of pure semantic relatedness rather than lexical relatedness. Therefore, the present study examined the following questions:

For targets presented to the rvf-LH, is priming at long SOAs predicted by differences in strength of semantic similarity once lexical-level effects are controlled for?

If so, are only meanings with high semantic similarity primed?

2.7.2. Dominance

The standard model and Plaut's model do not differ in their predictions for dominance effects on meaning activation for LH and RH processing. Both predict high-only priming for LH processing, concurrent activation of subordinate meanings and for RH processing. Evidence concerning these predictions comes from six DVF studies that used central primes, and investigated how dominance affects hemispheric differences in meaning activation[17] (see Table 2 for results). Of these six studies, four provided results that were consistent with the predictions of both models (Burgess et al., 1988; Atchley et al., 1996; Burgess et al., 1998b; Atchley et al., 1999). The results of the other two studies are inconsistent

[17] One other study (Atchley et al., 1999) also explored hemispheric differences in sustained meaning activation with ambiguous primes, using naming as a response task. However, the study had very low accuracy rates (rvf-LH 76 %, lvf-RH 57.5 %), which led the authors to question the validity of their RT and priming analyses. These results therefore will not be included in this review.

with the hypothesis that RH processing supports sustained activation of subordinate meanings (Hasbrooke et al., 1998; Anaki et al., 1998).

Because the research questions of the present study concern priming patterns for targets presented to the rvf-LH, these inconsistencies might seem less relevant. However, if the priming pattern supported by RH processing differs from the one expected in the two models, the very basic underpinnings of the two models are questionable. Therefore, the inconsistent findings are explored in more detail in the next subsection, which discusses the characteristics and results of these six studies (2.8.2.1). It is tentatively concluded that the results indicate that dominance, as tested in these studies, affects meaning activation for LH processing as predicted in the two models. However, as outlined in Section 2.5.3.3., when evaluating the effects of dominance on semantic priming it is important to distinguish to what extent "dominance" effects are confounded with effects of strength of relatedness. This confound will be addressed in the next subsection (2.8.2.2), and the final subsection presents theoretical implications (2.8.2.3).

2.7.2.1. Characteristics and results

2.7.2.1.1. Studies consistent with the two models

Results consistent with both the standard model and Plaut's model were presented in four studies that involved two different meaning relationships between primes and targets. The most frequent prime-target relationship was ambiguous primes paired with targets associated with either the dominant or one of the subordinate meanings of the prime (Burgess et al., 1988; Atchley et al., 1996; Burgess et al., 1998b). One study investigated "unambiguous" primes with feature targets that were either compatible or incompatible with the dominant interpretation of the prime (Atchley et al., 1999). All four studies investigated the time course of meaning activation.

The study by Burgess and Simpson used association norms to determine whether a word meaning was dominant or subordinate. Meanings were considered dominant if at least 60% of all associates reflected the dominant meaning (Atchley et al., 1996). The study by Atchley and colleagues (1996) used a subset of this stimulus set, and dominant meanings were considered dominant if at least 80% of all associates reflected the dominant meaning. This study was only published as a meeting abstract; therefore a detailed evaluation of the methods and analysis is not possible. Similarly, Burgess and Lund reported results from an earlier, unpublished study in a book chapter, and also did not provide much detail about stimuli and analysis. It is likely they used the same stimuli as the studies by Burgess and Simpson or Atchley and colleagues.

At 750 ms SOA, all three studies found priming for dominant and subordinate lvf-RH targets, and dominant rvf-LH targets. Subordinate rvf-LH targets were inhibited. One study (Atchley et al., 1996) also included equibiased ambiguous primes. The authors defined word meanings as equibiased if less than 60% of their associates reflected the dominant meaning, and at least 30% of their associates reflected the subordinate meaning. All targets primed at all SOAs (35 ms, 50 ms, 300 ms, and 750 ms).

Given that the results of these three studies derived from very similar stimulus sets, similar outcomes might be attributable to some accidental stimulus factor independent of dominance. However, as mentioned above, one other study by Atchley and colleagues (Atchley et al., 1999) used a very different stimulus set and found the same priming patterns for LH and RH processing. In this study, Atchley and co-workers used unambiguous or polysemous nouns as stimuli. Target words were features of these nouns gleaned from a feature generation task. Expert judges generated a mental image of each prime word, and then rated whether target features were or were not compatible with the prime's mental image. The mental image that was generated by the judges was basically the dominant meaning[18] of the prime word. Thus, features rated compatible with this meaning were features of the dominant meaning (e.g., the feature "crunchy" for the word "apple"). Features that were rated incompatible with the mental image were features of the subordinate meaning (e.g., the feature "rotten" for the word "apple")[19]. Results showed that subordinate (incompatible) features were inhibited for LH processing, whereas dominant (compatible) features were primed. For RH processing, both types of features were primed. Therefore, this result converges with those of the previous three studies, and is consistent with the standard model and Plaut's model of meaning activation for LH and RH processing.

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[18] “Meanings” is used here as a superordinate of "meaning" or "sense". Atchley's stimulus set includes words that would probably be considered polysemous as well as words that would be considered vague. Because the underlying principle is the same, these distinctions are not useful to make in the context of this discussion.

[19] Atchley and colleagues used the terms "dominant" and "subordinate" to refer to features that were produced frequently and infrequently, respectively. Thus, they used these two terms to refer to the dimension of degree of relatedness. For the sake of consistency, this document uses the terms "high relatedness" and "low relatedness" instead, and applies "dominant" and "subordinate" to the degree with which the features were compatible with the mental image.

Table 2 Priming results for targets related to a dominant and subordinate prime meaning (response time and effect size)

Study	Dominant vs. subordinate relationship between prime and target		rvf-LH[a] significant priming (effect size)[c]				lvf-RH[b] significant priming (effect size)		
			dominant	subordinate	dominant vs. subordinate		dominant	subordinate	dominant vs. subordinate
Anaki et al, 1998	literal vs. metaphoric adjectives primes of noun targets		*34 ms*[d] (.35)	*- 12 ms* (-.12)	*46 ms* (.47)		*1 ms* (.01)	*-4 ms* (-.03)	*5 ms* (.04)
Atchley et al, 1996	dominant vs. subordinate associates of ambiguous primes		yes	no	d > s[e]		yes	yes	not reported
Atchley et al, 1999	features more vs. less compatible with prime meaning		yes (.23)	no (-.03)	d > s (.26)		yes (.33)	yes (.25)	d = s (.08)
Burgess & Lund, 1998[f]	dominant vs. subordinate associates of ambiguous primes		yes	no	d > s		yes	yes	~ 40 ms
Burgess & Simpson, 1988	dominant vs. subordinate associates of ambiguous primes		yes (.55)	no (-.56)	d > s (1.10)		yes (.41)	yes (.42)	d = s (-.01)
Hasbrooke & Chiarello, 1998	dominant vs. subordinate associates of ambiguous primes		yes	no	d > s		yes	no	d > s

[a] right visual field/left hemisphere
[b] left visual field/right hemisphere
[c] significant effect according to *priming* measure (response time unrelated – response time related prime target pairs). Effect sizes (*d* = *priming*/pooled standard deviation) are reported when available.
[d] no significance testing available for *priming* measure. Raw *priming* effects reported instead.
[e] d = dominant, s = subordinate
[f] These data are only reported in a figure in a book chapter. The chapter text implies that significance tests were conducted on dominant and subordinate priming in each visual field condition.

2.7.2.1.2. Studies inconsistent with the two models

One study that did not find the priming pattern predicted in the two models also used ambiguous word primes and target associates (Hasbrooke et al., 1998). In this study, only a long SOA was investigated. As predicted by the two models, RT and accuracy priming was found for rvf-LH and lvf-RH dominant targets. However, there was no evidence of RT priming for subordinate targets presented to the rvf-LH or lvf-RH. This result was replicated in a separate experiment.

One problem with Hasbrooke and Chairello's study is the dominance criterion chosen. As in the other studies, dominant targets were selected based on association norms. However, in the other studies dominant targets represented meanings that comprised at least 60% or even 80% of all associates. Hasbrooke and Chiarello defined targets as being dominant if they had between 40% - 99% of all associates, and as subordinate if they had 25% associates *fewer* than the dominant targets, and not more than 50% of all associates. Thus, dominance levels as well as degree of relatedness levels were generally low. This might have made it difficult to detect priming for subordinate and weakly-related targets.

The one other study that presented data inconsistent with both models (Anaki et al., 1998) investigated priming for word targets associated with either the literal or metaphoric meaning of the prime. This study was conducted in Hebrew. Anaki and colleagues used neutral primes and ambiguous word primes, and paired both types of primes with a metaphoric, a literal, and an unrelated target. It is notable that this study controlled for strength of association to some degree, based on association ratings of ten participants. The literal and metaphoric targets were rated to be equally highly associated with their primes.

At 800 ms SOA, Anaki and colleagues found facilitation (RT neutral – RT related) for rvf-LH literal targets, and facilitation for metaphoric lvf-RH targets. This result fits the expected priming pattern, and is often cited in support of the standard model. However, the results provide another example of the problematic nature of neutral primes. The observed lvf-RH facilitation for metaphoric targets stemmed from the fact that after neutral primes RTs to these targets were considerably longer (about 45 ms) than in all other conditions. In latencies at 200 ms SOA, metaphor targets showed about 37 ms higher RTs than the literal condition, but they did not differ between SOA. Thus, the hemispheric difference in facilitation effects for metaphoric targets was most likely due to some effect other than activation of a related target. Therefore it is impossible to interpret the facilitation results.

If one looks at the numeric results for the standard priming measure (unrelated- related) in this study, priming is only suggested for the literal targets for rvf-LH stimuli (rvf-LH: literal: 34 ms, metaphoric: -12 ms; lvf-RH: literal: 1ms, metaphoric: -4 ms). The lack of priming for lvf-RH targets does not fit with the expected priming pattern. It also does not fit with Frost and Bentin's (1992) hypothesis that meaning selection is less likely in Hebrew. One difference between the first four studies and the study by Anaki and colleagues is that Anaki and colleagues used prime-target pairs that were collocations (e.g., Rolling-ball, stinging-mosquito; Rolling-laugh, stinging-insult), that is, words with high lexical co-occurrence. Compared to word pairs selected from association norms, these prime-target relationships are likely more lexical, or more based on co-occurrence, and are less likely to reflect semantic processing. It is possible that such lexical and non-semantic priming tends to be mediated by the LH.

However, the data could reflect another pattern. Because the study was not designed for an analysis based on priming results, unrelated, literal, and metaphor targets were only controlled for length and frequency. It is possible that inherent differences in the targets resulted in mean RTs that cannot be directly compared. For example, if targets chosen for the unrelated condition happened to be easier to recognize (which facilitation results seem to indicate, though their interpretation is questionable), part of the priming effect might have been masked. In that case, results in this study could, in fact, have reflected the priming pattern predicted by the standard model and Plaut's model. But obviously, it is impossible to verify whether that was the case.

Thus, an inadequate dominance criterion, the lack of semantic relatedness between prime and target, or an unbalanced target conditions are possible reasons why these latter two studies were not consistent with the expected pattern. But these reasons are speculative, and require validation.

2.7.2.1.3. Summary

Four studies showed high-only priming for dominance for LH processing with concurrent activation of subordinate meanings for RH processing at long SOAs, which is consistent with the standard model and Plaut's model. Furthermore, this evidence encompasses two different meaning relationships between prime and target: ambiguous words with related associates and unambiguous words with related features. These results are consistent with the notion that inhibition of incompatible meanings in the LH is a general principle. However, two of these studies (Atchley et al., 1996; Burgess et al., 1998b) were only published as conference abstracts or a secondary report in a book chapter with limited report of results, and three of the four studies (Burgess et al., 1988; Atchley et al., 1996; Burgess et al., 1998b) used a very similar stimulus set. In addition, two other studies showed results that are inconsistent with this pattern. While there are plausible reasons that might explain these inconsistent results, further research is needed to assess these reasons.

Importantly, all six studies show the same priming pattern for rvf-LH targets: high-only priming. This result raises the same question that was already noted for standard central priming and general models of meaning activation: to what extent is this priming pattern confounded by the degree of semantic relatedness? The already mentioned study by Atchley and colleages (Atchley et al., 1999) addressed this question, as discussed next.

2.7.2.2. The confound of dominance and strength of relatedness

As outlined in the Section 2.4., the confound of dominance with strength of relatedness arises when an ambiguous prime is paired with targets related to its dominant or subordinate meanings, and the targets related to the dominant meaning are more strongly related to the prime because these two words occur more often with each other. This confound applies to all studies that used ambiguous primes and associated targets, and for the study with metaphoric primes. However, the study by Atchley and colleagues (Atchley et al., 1999) attempted to control for degree of semantic relatedness. Yet for reasons discussed below, this study cannot conclusively differentiate between the hypotheses that the observed high-only priming is due only to dominance effects or to an interaction of dominance and strength of semantic relatedness. Thus, it is concluded that while the evidence favors models predicting high-only priming, the possibility of a strength-of-relatedness confound in dominance measures cannot be ruled out as an alternative.

As described above, in the study by Atchley and colleagues primes were unambiguous or polysemous nouns, and targets were features that were either compatible or incompatible with the dominant mental representation, or dominant meaning, of their primes. These features were obtained in a feature generation task. They differed in production frequency, that is, the frequency with which each feature was produced over all participants (N = 50). Thus, for features compatible with the dominant meaning (dominant features), features with high and low production frequency were derived (e.g., for *apple*, *round* has a high production frequency, and *crunchy* has a low production frequency). Higher production frequency indicates a higher degree of relatedness. Features incompatible with the dominant sense (subordinate features, e.g., *rotten* for *apple*) were only of low production frequency. Just as Hino and colleagues (Hino et al., 1997) could only control strength of relatedness for targets with low association, Atchley and colleagues could control for strength of relatedness only for features with low production frequency. Thus, effects of strength of relatedness could be assessed by comparing RTs to dominant feature targets of high and low production frequency. Effects of dominance could be assessed by comparing RTs to dominant features of low production frequency with subordinate features of low production frequency.

Atchley and colleagues (Atchley et al., 1999) found that in both visual fields at 750 ms SOA dominant features primed regardless of production frequency. Subordinate features (with low production frequency) primed only when presented to the lvf-RH. This result mirrors the ones from Hino and colleagues (Hino et al., 1997) in standard reading conditions. Similar to Hino and colleagues, Atchley and colleagues argued that the results showed that only dominance affects sustained meaning activation for LH processing, and that strength of relatedness has no effect on processing for both rvf-LH and lvf-RH stimuli. However, as with the study of Hino and colleagues, this conclusion is problematic in several ways. First, this conclusion is at odds with the evidence summarized above, which suggested that LH processing is associated with graded priming effects for semantic relatedness, though this hypothesis still requires a stronger test. Second, Atchley and colleagues might not have found an effect of strength of semantic relatedness because of the way this factor was operationalized. The targets in this study were not only "features" of the primes, they also were complete meanings on their own, and, as words, related to the primes. Therefore it is possible that other types of relationships, which were not controlled for, influenced the results, or that these relationships have a stronger influence on priming than the fact that the targets were features of the primes.

Third, the factor “production frequency” could reflect semantic similarity or association and co-occurrence, and hence semantic or lexical processing. This author’s post-hoc analysis of most words in the study, using the Nelson (1998) association norms suggests that targets differed only to a small degree in association: dominant strong targets had a degree of association of .06, and both types of weakly related targets had a degree of association of .01. This analysis might suggest that association was a well-controlled variable, and that production frequency of features really reflects the degree with which a feature was related to a concept. However, it is also possible that these associative relationships are good indicators of how strongly related the concepts and their features were overall. In that case, the low degree of relatedness between primes and targets in all conditions, and the small difference between the strongly and weakly related targets might not have been sufficient to detect any effect of semantic relatedness. If so, this study is inconclusive with regards to effects of strength of semantic relatedness.

Furthermore, even if the semantic relatedness manipulation was successful, Atchley and colleagues' (1999) study cannot differentiate whether inhibition of subordinate features is partial, reflecting graded priming, or complete, reflecting high-only priming. The apparent high-only priming pattern could have resulted from an interaction or additive effect of graded priming for semantic relatedness and dominance, because it compared weakly-related features of the dominant meaning with weakly-related features of the subordinate meaning. It is possible that subordinate features with less activation still have activation support, but it is not sufficient to prime weakly-related features. In order to rule out that possibility, the study would have had to test subordinate features with high production frequency. However, that is not possible, because subordinate features by definition are only produced infrequently. Thus, Atchley and colleagues’ study could not conclusively address the confound of dominance and strength of semantic relatedness.

2.7.2.3. Theoretical implications and research questions

The standard model and Plaut's model predict priming only for dominant meanings for LH processing with concurrent priming of subordinate meanings for RH processing. Overall, the evidence is consistent with this prediction. However, none of the available studies conclusively addressed the confound of dominance and strength of semantic relatedness. The evidence suggests that dominance affects meaning activation for LH processing, although there is still the possibility that some other factor influenced the results, and replication is needed. The evidence is inconclusive with regards to the nature of the dominance effect, because it cannot be ruled out that the observed high-only priming pattern results from an interaction of dominance and strength of semantic relatedness effects. Therefore, a graded priming pattern is also a possibility. To investigate the high-only priming versus graded priming hypotheses, the current study examined the following two additional research questions:

For targets presented to the rvf-LH, is priming at long SOAs predicted by differences in meaning dominance once strength of semantic relatedness controlled for?

If so, are only meanings with high meaning dominance primed?

2.8. STUDY OVERVIEW, PREDICTIONS, AND IMPLICATIONS

2.8.1. Semantic Similarity

To review, the current study addressed two questions with respect to the effect of pure semantic relatedness on priming patterns in LH processing:

1) For targets presented to the rvf-LH, is priming at long SOAs predicted by differences in strength of semantic similarity once lexical-level effects are controlled for?
2) If so, are only meanings with high semantic similarity primed?

These two research questions were investigated in a DVF paired priming experiment. Stimuli were 48 non-associated prime-target pairs, which differed in their degree of semantic similarity from dissimilar to highly similar, and which were controlled for co-occurrence. The SOA was 750 ms, and the task was lexical decision. The study questions were addressed by estimating the overall effect of semantic similarity and its interaction with visual field in a general linear model, and calculating confidence intervals and effects sizes at pre-specified values of high and low similarity (see Section 3.4.)

Four possible outcomes were considered: *graded priming*, *high-only priming, full priming*, and *no priming*. An outcome of *graded priming* would be consistent with the results of the studies reviewed above, and with Plaut's model. This result would suggest that meaning activations instantiated in LH processing reflect differences in importance of information through different degrees of activation. However, less central information remains active, and focusing of information is not required. Given that evidence from priming studies with central target presentation suggests that lexical and semantic priming show similar patterns, and that the graded priming pattern was found on the studies reviewed above, this was the expected outcome.

An outcome of *high-only priming* would suggest that LH processing focuses word meanings, possibly for processing efficiency, and it would be consistent with the standard model. Given the evidence reviewed above, this result was not expected.

An outcome of *full priming* could be accounted for by assuming that previous studies showed a graded priming pattern because lexical priming effects provided an "associative boost" (Moss, Ostrin, Tyler, & Marslen-Wilson, 1995, p. 874) for high-relatedness items, but that priming due to semantic similarity for LH processing does not show a degree of relatedness effect. Finally, an outcome of *no priming* would suggest that the "semantic" priming pattern in the studies reviewed above resulted only from lexical priming effects, and that lexical but not purely semantic relationships are mediated with LH processing. There is no evidence in the literature to suggest that either of these latter possibilities is the case, and this outcome was not expected.

2.8.2. Dominance

To review, this study addressed these two questions with respect to the effect of meaning dominance on priming patterns in LH processing:

3) For targets presented to the rvf-LH, is priming at long SOAs predicted by differences in meaning dominance once strength of semantic relatedness controlled for?
4) If so, are only meanings with high meaning dominance primed?

These two questions were addressed in a second DVF experiment, by investigating priming effects with prime-target pairs in which biased ambiguous word primes were paired with targets of high similarity (high relatedness) to either the dominant or subordinate meaning. The same targets also appeared with dissimilar primes (no relatedness). These word pairs were controlled for association, to eliminate the confound between dominance and strength of relatedness. Again, the SOA was 750 ms SOA, and the task was lexical decision. The study questions were addressed by estimating the effect of dominance as the interaction of dominance and relatedness and its interactions with visual field in a general linear model. Confidence intervals and effect sizes were calculated at pre-specified values of high and low dominance (see Section 3.4.).

Two different outcomes were expected: *high-only priming* and *graded priming*. An outcome of *high-only priming* would be consistent with the two theoretical models and the results of the studies reviewed above, and indicate that one role of LH processing is to resolve to and keep activated compatible and coherent meanings. An outcome of *graded priming* would suggest that the apparent high-only priming pattern observed in the studies reviewed above could be attributed to an interaction of dominance and strength of lexical/semantic relatedness effects. This result would be inconsistent with the available theoretical models, and it would suggest that elimination of incompatible meanings is not required for efficient LH processing.

Similar to the results reviewed for strength of semantic relatedness effects, results from lateralized priming studies with rvf-LH targets so far mirror the results from central priming studies. Yet, evidence from central priming studies also has not yet been conclusive with regards to the question of whether dominance effects result in high-only or graded priming. Thus, while the dominance effect was clearly expected, there was no expectation as to whether this effect would be a high-only or graded priming pattern.

3. METHOD

3.1. PARTICIPANTS

One hundred twenty-six undergraduate students participated in the study (see Section 3.4. for the power analysis and other factors that determined participant numbers). All participants fulfilled the following criteria, which are typical for word-based recognition and priming studies that use DVF presentation, including the studies reviewed above:

All participants were undergraduate students. A person's level of education can affect semantic priming (Howard, 1983); therefore, this criterion aimed to control for extraneous effects of education level on the dependent variable.

The age range of the participants was limited to 18-30 years, to control for processing differences between participants due to age.

All participants were right-handed. Using right-handed participants is typical in DVF studies because there is a higher chance of lateralization effects for language in left-handed individuals (Young, 1982). Following Tompkins and colleagues (Tompkins, Bloise, Timko, & Baumgaertner, 1994), participants were included if they reported the use of the right hand on all items in a handedness questionnaire consisting of the 6 most discriminating questions for handedness (Annett, 1970).

Half of the participants were female, and half were male. Lateralization differences based on sex have been shown in DVF studies of single word recognition (for a summary, see Chiarello, 1988) and in one study of semantic priming (Stanick, 2001). When such differences are not of primary research interest, it is standard method to balance participants for gender.

All participants were native speakers of English. Following Tompkins and colleagues (Tompkins et al., 1994), participants were excluded if they had used a language other than English for communication as children or later in life outside of classroom instruction. This criterion was aimed to ensure higher linguistic homogeneity among participants, and to reduce variability with respect to individual word meaning interpretations, meaning dominance, or meaning frequency.

All participants had normal to normal-corrected vision. Binocular visual acuity was first screened with Snellen-type visual acuity cards (Vision Screen, MIS Pocket Vision Guide, 2004, MIS, Inc). As per instructions, participants held the visual acuity cards 14 inches from their eyes. The investigator monitored this distance with a measuring tape. Participants were excluded if they failed the 20/20 screening binocularly.

3.2. STIMULI

3.2.1. Overview

The study investigated meaning similarity and meaning dominance in two experiments. For Experiment I, experimental stimuli consisted of two lists of stimuli: a list of 48 unambiguous prime-target pairs, and a list of the same 48 targets as single word stimuli (see Table 3. for examples). The prime-target pairs reflected a range of meaning similarity, from dissimilar to highly similar. Ratings for prime-target similarity were obtained in a validation study (Similarity Judgments for Prime-Target Pairs (Appendix A.7.), which used a seven-point scale from 1 (not similar) to 7 (highly similar). Ratings between 1 and 2 were considered to reflect dissimilar prime-target pairs. Ratings above 2 were considered to reflect similar prime-target pairs[20]. For ease of exposition, the dichotomous distinction between "similar" and "dissimilar" prime-target pairs will be referred to as "Related" and "Unrelated" from now on. Reference to the "similarity" dimension will only be used for discussion of similarity as a continuous variable for Experiment 1.

For Experiment 2, experimental stimuli were 25 word sets of four *ambiguous* prime- target pairs, consisting of an ambiguous Related prime, an ambiguous Unrelated prime, and two targets. The Related primes were ambiguous words with at least two meanings. The two meanings reflected a range of dominance values, including strongly biased to no-bias (balanced) ambiguities. Meaning Dominance was a continuous variable for all Related primes. Ambiguous Unrelated primes were ambiguous words with meanings unrelated to the two target words.

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[20] This range is derived from the criterion for meaning similarity between different meanings of an ambiguous by Rodd and colleagues (Rodd et al., 2002). These criteria are based on researchers' intuitions; to the knowledge of this author no evidence is available to arrive at more objective criteria.

Table 3 Examples for unambiguous stimuli (Experiment 1)

Prime-Target Pairs				Single Targets
Prime	Target	Similarity Rating[a]	# Participants	Target
Canoe	Raft	6.3 (0.8)	25	Raft
Lice	Moth	4.7 (1.8)	26	Moth
Parsley	Maple	3.1 (1.6)	18	Maple
Zipper	Dog	1.1 (0.7)	19	Dog

[a] Similarity ratings are based on a scale of 1-7, mean[21] (standard deviation)

Table 4 Examples for ambiguous set items (Experiment 2)

Dom[a]	Related				Unrelated			
	Prime	Target	Sim. Rating[b]	# Part[c]	Prime	Target	Sim. Rating	# Part
1st Mng[d]	Log	Timber	6.4 (0.8)	27	Swallow	Timber	1.7 (1.3)	23
2nd Mng[e]	Log	Record	6.8 (0.4)	23	Swallow	Record	1.1 (0.4)	17

[a] Dominance
[b] Similarity Ratings, based on a scale of 1-7, mean (standard deviation)
[c] # Participants
[d] First Meaning of ambiguous prime
[e] Second Meaning of ambiguous prime

[21] Following Chiarello (Chiarello, 1998a)and McRae and Boisvert (1998), means were used. In several studies ordinal scales have been shown to be equivalent to interval scales (Duffy et al., 1977; Schiavetti, Martin, Haroldson, & Metz, 1994; Southwood & Flege, 1999), although to the knowledge of this author this has not been investigated specifically for similarity ratings.

Relatedness between primes and targets was assessed with the same similarity rating scale and with the same criteria as those used for unambiguous prime-target pairs. Based on these criteria, the two targets were highly similar to the first and second meanings of the Related prime but not the Unrelated prime (see Table 4 for examples). Prime-target pairs could be matched in degree of similarity because they were not associated. For a complete list of stimuli and stimulus characteristics for each Experiment, see Appendix A.8.

When experimenters select experimental stimuli, two issues are of concern. First, experimental stimuli need to have characteristics that make them valid measures of the phenomenon under investigation. Second, it is necessary to control for unintended effects of word characteristics on the dependent measure that could potentially confound study outcomes. Avoiding such confounds is challenging in studies of word processing, because the measurable speed of word recognition, and, by inference, the processes underlying activation of lexical and semantic information, depend on various semantic, lexical, and sub-lexical characteristics of the word stimuli employed.

Stimulus validity, that is, the extent to which the stimuli can measure effects of meaning similarity and meaning dominance, was addressed primarily through the specific selection criteria for primes and targets. Control for word characteristics that might confound priming results was addressed primarily though the experimental design, in two ways: through the way primes and targets were combined and by stimulus matching for each experimental condition in each analysis.

The next two subsections describe stimulus selection and validation for the two sets of stimuli. Subsection 3.2.2. presents the selection criteria and psycholinguistic characterizations of prime and target words. Subsection 3.2.3. discusses ways in which the experimental design controls for possible confounds that might be introduced through extraneous word characteristics of the experimental items, and presents the matching data for the planned analyses.

3.2.2. Selection and Characterization of Stimuli

3.2.2.1. General recognition criterion

To reduce the variance for the priming effects intended to reflect meaning similarity and meaning dominance, a preliminary study was conducted to ensure that all relevant word meanings were known by a clear majority of individuals eligible for study participation. Words were only included if at least 15 out of 16 undergraduate validation participants indicated that they knew each relevant meaning of the prime or target words. This recognition criterion was validated within the context of an imageability judgment task (see Appendix A.3).

3.2.2.2. Primes

Primes were selected based on degree of meaning ambiguity and part of speech.

3.2.2.2.1. Meaning Ambiguity

Unambiguous primes. For the best experimental distinction between unambiguous and ambiguous primes, unambiguous primes should be as different from each other as possible on the ambiguity continuum. Furthermore, the more unambiguous "unambiguous" primes are, the better controlled they are in terms of meaning similarity between prime and target. However, as was discussed in Section 2.5., it is difficult to draw the line between ambiguous, polysemous, vague, and unambiguous meanings; in fact, it is debatable whether there are words that are truly unambiguous. Thus, the operationalization of the characteristic of "unambiguous" aimed to select primes that were very low on the ambiguity continuum. Because Unrelated primes do not result in priming, this aim was considered to be more important for Related primes (e.g., *canoe*) than for Unrelated primes (e.g., *zipper*). Thus, the four-step selection and validation process for "unambiguous" word meanings described next was only used for Related primes. Because this process involved more complex metalinguistic ratings than the basic similarity or imageability ratings for single words, raters in this validation process were mainly graduate students or individuals with a graduate degree who were native speakers of English.

First, the investigator selected potential prime words from the Merriam Webster Online Dictionary (2004a). Only words with one single meaning, with conflated noun/verb meanings[22], or with two meanings considered to be highly similar by the investigator, were selected. Second, for each selected word, five raters, generated all meanings they could think of (see Appendix A.2). Third, three raters judged whether the generated meanings reflected the same meaning or represented different meanings (see Appendix A.3). Fourth, two words that were judged to have different meanings (*beer*; *grove*) were given to 10 raters, who judged the similarity of the different meanings on a 1-7 scale (1 = not similar, 7 = highly similar). Only words judged with a mean score of 6 or higher were included in the unambiguous word list (see Appendix A.5). The results for these two words were: *beer* (M = 6.4, range = 4 – 7) and *grove* (M = 6.9, range = 5 – 7).

Many word meanings are also used as product names or metaphors. These could not completely be excluded, and therefore words were only eliminated from the word list if their product names and metaphor uses were generated in the meaning generation task or listed in the dictionary.

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[22] It is a feature of English that many words function both as nouns and verbs, for which the nouns are, e.g., the patient (canoe). Such "noun/verb conflations" could not completely be avoided. In each case, the noun was the more frequent meaning of the unambiguous prime.

Finally, homophones like 'patients' become active when participants read words like 'patience' (e.g., Gernsbacher et al., 1991). Thus, homophony introduces another source of ambiguity. To avoid this ambiguity effect, none of the primes were homophones. Homophony was verified by checking each potential prime against two extensive lists of homophones (Hobbs, 1999; Cooper, 2001).

Words selected as Unrelated primes were considered unambiguous if only one sense was listed in the Merriam Webster Online Dictionary (2004b), including noun/verb conflations. For one Unrelated prime an infrequent second meaning was overlooked: *raven* (to devour, plunder).

Ambiguous Primes. Ambiguous primes were selected from two sets of norms: the University of Alberta norms of relative meaning frequency of 566 homographs (Twilley, Dixon, Taylor, & Clark, 1994) and a second norming study (Gilhooly & Logie, 1980a; Gilhooly & Logie, 1980b) that included 387 ambiguous words. In the study by Twilley and colleagues, undergraduate participants, who were native speakers of English, were asked to write down the first word that came to their minds when reading an ambiguous word. The authors assigned each generated associate to a distinct meaning of the homograph, for which they listed the most frequent associate produced (e.g., *wood* for *log*). These meaning assignments were based on collaborative scoring by two raters, which were checked by a third rater. Gilhooly and Logie (1980a) used a similar procedure. Student volunteers wrote down the first meaning that came to their mind for each ambiguous word. One of the experimenters (Gilhooly & Logie, 1980a) categorized the generated meanings based on entries in the Collins English Gem Dictionary, with an interjudge reliability check for 10% of these ratings by 3 raters (84% interjudge contingency correlation). The words selected for this study came from a follow-up study (Gilhooly & Logie, 1980b) that provided imageability ratings for each meaning of 387 ambiguous words.

For ambiguous Related primes (e.g., *log*), ambiguity and dominance were determined based on the data from the norms by Dixon and Twilley (Twilley et al., 1994). In these norms each word is rated by a high number of participants (192). For the purpose of this study degree of dominance was operationalized as the *proportion* of generated associates of all associates that relate to one meaning of a word (# associates for one meaning / # of associates for all meanings) in the University of Alberta norms. This first associate metric is the same dominance criterion as is used in most of the studies reviewed above.

Using the same criterion has the advantage that the outcomes of the proposed study can be compared more easily to the evidence available in the literature. As discussed previously, a possible disadvantage of using the first associate metric is that it might confound dominance with association. First associates might be named because they are related to the dominant meaning, or because they are highly associated with either of the meanings (Hino et al., 1997). However, this confound was avoided. For the validated stimuli, *Dominance* and *Semantic Similarity* did not correlate (r = .12, p = .39), therefore the two variables were orthogonal.

Norms that are based on first associations do not provide an exhaustive list of all meanings; usually, associates to infrequent meanings do not occur in such norms. To better control the dominance value for second meanings, Related primes (e.g., *log*) were selected only if an associate for the targeted second meaning was provided in the norms. Words for which the norms listed three meanings were included only if the third (ignored) meaning had a dominance criterion not higher than .05 of the participants (N = 10), and the dominance value was not higher than the selected second meaning.

Because not all generated associates could be assigned to meanings by the authors of the norms, first and second meanings together did not add up to 100% in the proportion metric. In this study the selected first and second meanings had at least 80% of all associates assigned to their respective meanings[23]. To further control degree of dominance, stimuli were excluded as Related primes if usage of these words might have changed the relative meaning frequencies since 1994 (e.g., page, palm). Furthermore, it was attempted to exclude homophones. This criterion could not be completely fulfilled because it would have ruled out too many words. Thus, words were included if they had homophones with rather obscure meanings (e.g., pupil/pupal) (for details, see Appendix B.1., Table 48).

As discussed in Section 2.5.3.1., distinct meanings of homographs vary in their degree of semantic similarity. Because the possible inhibition of subordinate meanings in LH processing could derive from a mechanism that eliminates *incompatible* meanings, the two meanings of the ambiguous primes should be clearly distinct from and (incompatible with) each other. Therefore, this study controlled for degree of semantic similarity in the two targeted meanings of each ambiguous word. To verify that the two meanings of each prime were unrelated, similarity ratings of the two meanings for the ambiguous primes were obtained. Ten undergraduate participants rated meaning similarity on a scale of 1 to 7, and only ambiguous words for which the average rating was 2.0 or below (means between 1.0 and 1.8, ranges between 1-1 and 1-5) were included in the validated stimulus set. This criterion is similar to or possibly somewhat stricter than the criterion of 2.64 used in the study by Rodd and colleagues (Rodd et al., 2002).

Ambiguous Unelated primes (e.g., *swallow*) were also ambiguous words, and therefore matched to the ambiguous Related primes in the ambiguity dimension. Words that could be used as Unrelated

[23] The studies reviewed in the literature review do not provide any data with respect to this criterion. Because Hino and colleagues (Hino et al., 1997) published their stimuli, their values can be compared to the stimulus set for the proposed study. Based on the norms by Twilley and colleagues (Twilley et al., 1994), the lowest percentage of meanings accounted for in participant's responses was .45 in Hino and colleagues' study (.8 in this study), and for the stimuli in their study on average .86 associates were assigned to the prime meanings (.93 in this study).

primes were selected from the two sets of ambiguity norms discussed above (Twilley et al., 1994; Gilhooly et al., 1980b). In comparison to the Related primes, the ambiguous Unrelated primes were not as well-controlled for number of meanings and meaning relatedness, because such control is too difficult to achieve. Because no priming was expected for Unrelated pairs, these differences were not expected to substantially influence priming effects.

3.2.2.2.2. Part of speech

Prime selection was also controlled for part of speech to reduce processing differences due to different parts of speech. Unambiguous primes were pure nouns (with the exception of a few noun/verb conflations), as determined by the Merriam Webster Online Dictionary (2004) and definitions produced by five participants in a validation task (see Section 3.2.2.2). Using mainly noun meanings was also another way to ensure that prime meanings were as distinct and unambiguous as possible.

In contrast to the unambiguous primes, ambiguous prime meanings could not be restricted to noun meanings. Many ambiguous words function as nouns, verbs, or adjectives at the same time, and the ambiguity norms did not provide enough pure noun/noun ambiguities that also fulfilled the criteria described above to generate sufficient stimuli for the proposed experiment. In order to achieve some control over part of speech, ambiguous words were selected only if the two meanings as listed in the norms were noun and/or verb meanings. Due to an oversight, one of the 25 ambiguous Related primes had also an adjective meaning (*staple*), but it was expected that this one low-frequency meaning would not affect the overall average priming effect.

3.2.2.3. Targets

Targets were selected to fulfill the requirements of prime-target relatedness for semantic similarity, association, and co-occurrence. As a requirement of DVF presentation, they were also controlled for length.

3.2.2.3.1. Semantic similarity

Meaning similarity was used as the main measure of prime-target relatedness. Meaning similarity, as opposed to association, is a measure of prime-target relatedness that is independent of lexical relatedness. By relying on meaning similarity as a measure of prime-target relatedness, it was possible to minimize lexical-level relatedness for unambiguous prime-target pairs in Experiment 1, and to disambiguate the effects of prime dominance and prime-target relatedness in Experiment 2. Potential targets were selected by the investigator, who consulted native speakers and several online thesauri (Olson, 2006; Lexico Publishing Group, 2004; The Wordsmyth Collaborative, 2004) in this process.

Word selection was based on intuitive judgments of shared meaning between potential Related prime-target pairs, and on the lack of such shared meaning for Unrelated prime-target pairs. For each potential prime-target pair, degree of meaning similarity was validated through the already mentioned meaning similarity judgment task (see Appendix A.7). In this task, an average of 21 undergraduate participants (range 16 – 32) rated the meaning similarity of prime-target pairs on a scale from 1 to 7. As discussed above, scale values between and including 1 to 2 were considered to be unrelated, consistent with the criterion for degree of overlap for ambiguous meanings.

In Experiment 1, semantic similarity values for the 48 prime-target pairs ranged from 1 – 6.3 (for a complete list, see Appendix A.8.). The first 10 pairs were unrelated (similarity values between 1 – 1.8). When the 48 pairs were split into three groups with 16 word pairs each, high-similarity items had a mean of 5.7 (*SD* = .4, range = 5.1 – 6.3), low-similarity items had a mean of 4.2 (*SD* = .5, range = 3.5 – 5.1), and unrelated to very low similarity items had a mean of 1.9 (*SD* = .9, range = 1.0 – 3.4).

In Experiment 2, Related prime-target pairs had a mean of 5.6 (*SD* = .7, range = 3.8 – 6.9), and Unrelated prime-target pairs had a mean of 1.4 (*SD* = .2, range = 1.1 – 1.8). Dominance and Similarity did not correlate significantly ($r = .12$, $p = .42$), which showed that the crucial separation of dominance and strength of semantic similarity was achieved. When Dominance was treated as a dichotomous variable, this results was confirmed. Similarity did not differ between first meanings (*M* = 5.7; *SD* = .6, range = 4.4 – 6.9) and second meanings (*M* = 5.5, *SD* = .8, range = 3.8 – 6.8); $t = .880$; $p = .38$).

Using meaning similarity as a measure of relatedness was primarily based on the findings of McRae and Boisvert (1998), who documented different levels of priming for prime-target pairs with high and low semantic similarity in a central priming task. To increase the likelihood that priming for different levels of similarity would be both detectable and distinguishable, the goal for the construction of prime-target pairs for the proposed study was that similarity levels of the ambiguous Related prime-target pairs were close to those in McRae and Boisvert’s high similarity conditions, and that the range of similarity levels for unambiguous prime-target pairs included enough stimuli that reflected the levels of those in the high and low similarity conditions used in McRae and Boisvert. To attempt such a comparison, items from McRae and Boisvert's study were included in the validation items. However, because of some overlap with the items for the proposed study and elimination of a few items with potentially high affect (e.g., “gun”), only 14 of the original 27 items were used in this comparison. Two further items needed to be eliminated from the analysis because they did not reach the recognition criterion of 15 out of 16. Therefore the intended comparison could only be a rough approximation.

Based on the result of these twelve items, and the scaling of the measure (1-7), the similarity value of 6 was considered to be roughly similar to McRae and Boisvert’s highly similar items, and the similarity value of 4 was considered to be roughly equivalent to McRae and Boisvert’s low similarity items. The means for high- and low-similarity prime-target pairs reported above were slightly under the similarity values for 4 and 6. The initial power analysis (Section 3.4.) attempted to take this difference into account.

3.2.2.3.2. Association

Prime-target pairs were not associated. Association was verified by checking each word against the extensive word association norms (Nelson, McEvoy, & Schreiber, 1998). In these norms, undergraduate students generated associates in a single word association task. For each word, associations were collected from 100 to 200 participants, with the majority of words being presented to approximately 150 participants. The norms include all words with all associates that were produced by more than one participant. Any word pair listed in these norms was excluded in the experimental stimuli.

3.2.2.3.3. Co-occurrence

Co-occurrence values for the unambiguous prime-target pairs (Experiment 1) were generated from a Usenet database consisting of 1.2 billion words (D. Rohde, personal communication, October 10, 2004), based on matrix coding co-occurrence for each word pair within a 10-word window for the complete corpus. Relative co-occurrence values were calculated as the product of all co-occurrences of a word pair and all observations divided by the product of all occurrences of the prime and all occurrences of the target[24]. Because co-occurrence correlates with association (Spence et al., 1990), this author expected that by virtue of selecting non-associated prime-target pairs the remaining correlation between co-occurrence and semantic similarity would not be substantial. This expectation was not confirmed, and the previous larger stimulus set was consequently reduced to the current set of 48 unambiguous prime-target pairs. This stimulus set fulfilled the criterion that meaning similarity and lexical co-occurrence were not correlated (r = .13, p = .37).

Length. While control for target length is important when controlling priming effects (see 3.2.3.), the specific target length criterion used was a requirement of DVF presentation. Because visual acuity decreases as stimulus presentation distance from central fixation increases, longer words would decrease participants' ability to perceive target words in the short presentation time. Therefore, many studies limit word length to six (Chiarello et al., 2003) or seven (e.g., Koivisto, 1997; Abernethy & Coney, 1993)

[24] T is the total number of observations (the sum of all cells in the matrix). The probability of a random window containing the prime is A/T. The probability for a random window containing the target is B/T. The probability of a cell containing both is AB/T. So the actual ratio is (AB/T)/((A/T)*(B/T)), which simplifies to AB*T / A*B.

letters. The validated targets had a mean word length of 4.9 letters (range 3 – 7), and only two targets had seven letters.

3.2.3. Control for other word characteristics

There are many semantic, lexical, and sub-lexical word characteristics that, if uncontrolled, can affect the speed of word processing, and thus bias outcomes of studies that use pronunciation, lexical decision, or semantic judgment tasks. Examples of such word characteristics are: a) semantic: degree of ambiguity and polysemy, dominance (Rodd et al., 2002), imageability (e.g., de Groot, 1989), number of synonyms (Hino et al., 2002), and number of features (Pexman, Holyk, & Monfils, 2003); b) lexical: frequency and length (e.g., Balota & Chumbley, 1984), familiarity (Connine, Mullennix, Shernoff, & Yelen, 1990), and age of acquisition (Morrison & Ellis, 1995); and c) sub-lexical: phonological and orthographic neighborhood (e.g., Huntsman & Lima, 1996). Many of these word characteristics are correlated, and it is impossible to control for all of them.

Most of the effects of different word characteristics on word activation processes have been inferred from reaction time data in single word recognition studies. In semantic priming studies, effects of word characteristics on single word recognition are of concern for several reasons. First, the dependent variable in these studies is the response time to the target words. If recognition times for these words differ based on extraneous semantic, lexical or sub-lexical factors, these differences could confound or mask the effect of interest, that is, priming. Thus, the first source of possible bias in priming studies is the effects of word characteristics on *single word recognition times of the target*. Additionally, effects of word characteristics of prime or target can interact with the priming effect itself. Thus, the second source of possible bias in priming studies is interactions of *target word characteristics* with the priming effect, and the third source of bias is interactions of *prime word characteristics* with the priming effect. Few studies have investigated such interactions.

Interactions between *target word characteristics* and priming have been demonstrated for frequency (Becker, 1979; Stone & Van Orden, 1993). For related prime-target pairs in which targets have low frequency, priming effects are larger than for those in which targets have high frequency. There is some indication that other characteristics that slow the speed of word processing (e.g., lower imageability/abstract nouns, spelling irregularity) increase priming effects, but results are somewhat mixed (for a review, see Imai, 2001).

Even fewer studies have addressed interactions between *prime word characteristics* and the priming effect. These studies have primarily involved factors such as the prime task effect or prime degradation, neither of which is relevant for this study. One finding that is relevant for this study is that primes with higher word frequencies induce larger priming effects (Imai, 2001).

The potential biases that can be introduced by prime and target word characteristics can be addressed in a good research design[25] by stimulus combination, stimulus matching, and/or by using covariate analysis for specific word characteristics. The two experiments in the study differed in experimental design: in Experiment 1, critical stimuli were a single group of prime-target pairs that varied in degree of semantic similarity, from dissimilar to highly similar; in Experiment 2, critical stimuli were two groups of prime-target pairs, Related and Unrelated prime-target pairs. Because of these differences in experimental design the measures taken to control for biases based on individual word characteristics also differed.

3.2.3.1. Stimulus combination

As outlined in the discussion above, there were three sources of potential bias on priming results: (1) effects of target word characteristics on single reaction times for that target, (2) interactions of target word characteristics and priming, and (3), interactions of prime word characteristics and priming. This third interaction is not well understood; however, because prime frequency has been shown to affect priming effects, this study took the conservative approach of controlling more generally for prime word characteristics.

As mentioned in Section 3.2.1., in Experiment 1 participants performed a single word lexical decision task with the same targets that were used in the priming task. Response times for each target from this task were used as a covariate in the analysis of priming results, and thus effects of single word reaction times were controlled. Interactions of prime and target word characteristics with priming were addressed with matching (see below).

In Experiment 2, primes and targets were combined in such a way that the same targets were paired with Related and Unrelated primes (e.g., *log-timber*, *swallow-timber*). This design had two implications. One, it controlled for effects of single word recognition times of the target. Two, the design controlled interactions of prime word characteristics and priming between the Related and Unrelated conditions *within* each ambiguity condition (though not between these conditions).

Furthermore, Related and Unrelated primes were the same between the first and second meaning conditions (e.g., *log-timber, log-record*). As a result, if word selection had led to unintentional biases for

[25] However, even a well-designed experiment cannot control for all possible confounds; therefore, experiments always need to be replicated with diverse stimulus sets.

the Related and Unrelated primes *between* these conditions, the biases would have affected each target condition (Similarity or Dominance conditions) the same way. Thus, prime word characteristic effects would not affect a specific condition, but rather affected only the degree of priming in general.

To summarize, in Experiment 2 prime-target combinations were controlled for single word response time effects and interactions of the prime with priming. However, this design did not control for interaction effects of target word characteristics and priming, which were addressed with matching.

3.2.3.2. Matching

3.2.3.2.1. Overview

To address possible confounds arising from interaction of target word characteristics and priming, matching was applied to primes and targets in both experiments, depending on the specific experimental design. To allow investigation of the specific priming patterns, Meaning Similarity was to be analyzed both as continuous and as a categorical variable (Experiment 1), and Dominance was to be analyzed both as continuous and a dichotomous variable (Experiment 2) (see Section 4.3.). Therefore, both analyses were taken into consideration in the design of the matching procedure. Matching was evaluated with correlation analyses or *t* tests. For correlation analyses the criterion was that each word characteristic variable correlate less than .25 with the dependent variable. For *t* tests the criterion was that for each condition word characteristics not differ significantly from each other at the .05 alpha level in 2-sided *t* tests.

Stimulus selection controlled for prime ambiguity and number of noun/verb meanings between ambiguous Related and Unrelated primes. However, it did not control for number of noun/verb meanings with respect to meaning similarity (Experiment 1) and Dominance (Experiment 2). Therefore, the number of noun/verb meanings was used in the prime matching process.

Additionally, matching for primes and targets used four more word characteristics: Frequency, Imageability, Length in Letters and Length in Syllables, and Orthographic Neighborhood. These word characteristics were selected to include those variables that have been shown to interact with priming, and characteristics from each processing level (semantic, lexical, and sub-lexical). This latter criterion was based on the assumption that word characteristic effects correlate more strongly within processing levels than between them. Because target words were presented in a proportional font, Length in Letters was not necessarily the same as the actual word length. Therefore, word Length in Millimeters was also included as a measure of target word length.

For primes and targets, Frequency (based on the HAL corpus), Length, and Orthographic Neighborhood values were obtained from the E-lexicon website (Balota et al., 2004). Imageability values for single word meanings were obtained from a validation study (see 3.2.2.6.). Imageability ratings for ambiguous word meanings were obtained from a separate validation study (3.2.2.5) and from a published norming study (Gilhooly and Logie, 1980b).

3.2.3.2.2. Matching for analyses of continuous independent variables.

For the purpose of matching for analyses of continuous dependent variables, correlation analyses were used. Histograms of the distribution of Similarity and Dominance values in Experiment 1 and Experiments 2, respectively, were inspected. They suggested that neither variable was distributed normally. The same was true for the other lexical variables except Frequency. Therefore, Spearman correlations were used for all correlations.

For primes, correlation analyses were conducted between the main independent variables (prime-target Meaning Similarity in Experiment 1, prime Meaning Dominance in Experiment 2) and prime Imageability, Number of Noun/Verb Meanings, Length in Letters, Length in Syllables, Frequency, and Orthographic Neighborhood. Furthermore, for Experiment 2, correlations were calculated separately for primes of Related and Unrelated prime-target pairs. Because the Dominance effect is a priming effect that specifically involves Related prime-target pairs, Dominance values were of interest only for Related primes. Therefore, lexical characteristics of the Unrelated primes were correlated with the Dominance value of their corresponding Related primes. Similarly, lexical characteristics for ambiguous targets were correlated with Dominance values of their respective Related primes. These lexical characteristics were Imageability, Length in Letters, Length and Syllables, Length in Millimeters, Frequency, and Orthographic Neighborhood.

Most correlations were below .25 (see Appendix B.3.1.), with three exceptions. In Experiment 2, for ambiguous Related primes, Number of Noun/Verb Meanings correlated weakly with Dominance (r_s = .33, p = .02, N = 50), suggesting that primes with higher dominance were somewhat more likely to have conflated noun/verb meanings. As discussed above, with the exception of frequency, not much is known about the influence of prime word characteristics on priming, including number of noun/verb meanings. Matching for these characteristics was a conservative precautionary measure, based on the reasoning that if prime frequency could affect priming, this might possibly be true for other word characteristics. To address this possibility, prime Number of Noun/Verb Meanings was entered last into the final analysis, to evaluate whether it made a significant contribution to the model.

Also in Experiment 2, for ambiguous Unrelated primes and ambiguous targets Imageability correlated weakly with Dominance (r_s = .33, p = .02, N = 50, and r_s = .30, p = .03, N = 50, respectively). These correlations suggested that Imageability for Unrelated primes and for ambiguous targets was somewhat more likely to increase with increasing Dominance of the Related prime. In the final analysis of experimental results these correlations were addressed by adding target Imageability as a co-variate in the final analysis (see Section 4.3.). Furthermore, prime Imageability was entered last into the final analysis, again to evaluate whether it made a significant contribution to the model.

Finally, the analysis for Experiment 2 also included Relatedness (related vs. unrelated) as a dichotomous variable. Therefore, t-tests were conducted between Related and Unrelated primes for prime Imageability, Length in Letters, Length and Syllables, Frequency, and Orthographic Neighborhood (targets were the same in each condition). None of these t-tests was significant (see Appendix B 3.1.).

3.2.3.2.3. Matching for analyses of categorical and dichotomous independent variables

To investigate specific priming patterns based on Meaning Similarity, the planned analysis for Experiment 1 included a 3-way ANOVA, with Similarity split into three interval classes. To control lexical variables of primes and targets with respect to this analysis, matching for Semantic Similarity and the prime/target lexical characteristics listed in the previous section was also carried out in a three-way ANOVA. None of these comparisons were significant (see Appendix B.3.2.).

For Experiment 2, the independent variable Meaning Dominance was dichotomized between the first and second meaning items. *T* tests were conducted for ambiguous Related primes, ambiguous Unrelated primes, and ambiguous targets for most of the same word characteristic variables used in the correlation analyses. However, because Length in Syllables and Number of Noun/Verb Meanings were quasi-dichotomous variables, Kendall's Tau was used. None of the t-tests or Kendall's Tau tests were significant (for complete results, see Appendix B.3.2), with the same exception as above: for ambiguous Related primes, dominance correlated with number of nouns/verb meanings at $\tau = .28$ ($p = .50$, $N = 50$).

3.3. PROCEDURE

3.3.1. Overview

Participants attended two separate sessions on two different days, with at least three intervening days. The first session contained all unambiguous stimuli, half of the ambiguous stimuli, and fillers. The second session contained the other half of the ambiguous stimuli, fillers, and a separate block for single lexical decision targets for Experiment 1. Primes were presented centrally and targets laterally, with a stimulus-onset asynchrony (SOA) of 750 ms. The following subsections discuss in more detail the different stimulus types and lists, block and session order, randomization, task, apparatus, and experimental procedures.

3.3.2. Stimuli types and stimulus lists

The stimulus lists included five different types of stimuli: unambiguous and ambiguous experimental items, nonword filler items, word filler items, and fixation control items. Filler items served several functions: to control for relatedness proportion, word/nonword proportion, and order biases. Fixation control items provided the basis for a rule-out criterion for participants who had difficulty focusing in the center of the visual field. To create various blocks of trials (practice, four priming blocks, single lexical decision), all items were arranged into six types of stimulus lists, described below.

For ease of exposition, target field of presentation (rvf-LH vs. lvf-RH) is not included in the subsequent description. Within each list and each trial block, target field of presentation was balanced for Experiment Type (unambiguous vs. ambiguous), Relatedness (related vs. unrelated), and Lexicality (word vs. nonword target). For a complete list of all stimulus lists that includes target field of presentation and all balancing data, see Appendix C.1.

For filler items with word targets, stimuli were taken from the validation study (Appendix A.7.) or other meaning similarity ratings for word-pairs (McRae et al., 1998; Chiarello, 1998a). Filler primes were considered to be unambiguous if they had only one main entry in Merriam Webster's Online Dictionary (2004), and ambiguous if they had more than one. All filler primes were nouns or noun/verb conflations, and did not include part of speech meanings beyond nouns and verbs.

Nonword targets had the following criteria (Chiarello et al., 2003). They were orthographically legal and pronounceable letter strings, created by changing one letter of an existing word. This procedure kept nonwords word-like, and the more word-like nonwords are, the likelier it is that reaction times reflect semantic processing (Stone et al., 1993). Each letter position was changed equally often, and nonword targets had the same length in letters as word targets.

Using pseudowords (nonwords that sound like words, e.g. "brane") as nonwords enhances semantic effects in priming even more (Stone et al., 1993). Given that this study aimed to measure semantic activation, pseudowords might have appeared a better choice for nonwords. However, using pseudowords can lead to a higher error rate (Stone et al., 1993). Because error rates are already high in DVF priming studies (averaged over 4 of the studies cited above, between 8 and 20% depending on condition), any experimental condition that might increase error rates was avoided, including the use of pseudowords.

3.3.2.1. Experiment 1

The experimental stimuli consisted of 48 *unambiguous* prime-target stimuli. Of these items, 38 were related and 10 were unrelated. To achieve the targeted relatedness proportion of .5, 28 additional Unrelated filler (UNF) items were created. In this total 76 unambiguous stimuli each prime was presented twice, that is, unambiguous experimental and UNF stimuli together consisted of 38 primes and 76 targets. These 76 unambiguous word-word items were matched with 72 word-nonword filler items (Lexicality Control Filler (LCF) items). Balancing between word and non-word trials minimizes any response bias toward yes- or no-responses based on item distribution. The unambiguous LCF items consisted of 36 primes and 72 targets.

In the first testing session, unambiguous primes repeated, but not ambiguous primes. Therefore prime repetition could predict prime ambiguity and target lexicality (word vs. nonword). Two steps were taken to disguise these correlations. First, for LCF items that were matched to unambiguous experimental items, half of the primes were ambiguous and half were unambiguous. Second, another set of 72 filler stimuli was created, Repetition Control Filler (RCF) items. In these items 36 primes were paired with one word and one non-word target. Twenty-four of the primes were unambiguous, and 12 were ambiguous. Half of the word targets were related and half were unrelated, to preserve the 50% relatedness proportion.

Table 5 Distribution and examples of items in the unambiguous lists (Session 1)

List	Stimulus Type	# of Stimuli	Prime Ambiguity	Relatedness	Lexicality	Prime	Target
A	EXP[a]	19	Un[b]	Related	Word	Canoe	Raft
B	EXP	19	Un	Related	Word	Canoe	Car
A	EXP/UNF[c]	19	Un	Unrelated	Word	Lint	Yacht
B	EXP/UNF	19	Un	Unrelated	Word	Lint	Kayak
A	LCF[d]	18	Un		Nonword	Slippers	Nicket
B	LCF	18	Un		Nonword	Slippers	Bry
A	LCF	18	Amb[e]		Nonword	Tap	Lystem
B	LCF	18	Amb		Nonword	Tap	Lound
A	RCF[f]	6/3	Un/Amb	Related	Word	Temple	House
B	RCF	6/3	Un/Amb		Nonword	Temple	Celk
A	RCF	6/3	Un/Amb	Unrelated	Word	Whale	Vault
B	RCF	6/3	Un/Amb		Nonword	Whale	Larce
A	RCF	6/3	Un/Amb		Nonword	Drill	Mub
B	RCF	6/3	Un/Amb	Related	Word	Drill	Wrench
A	RCF	6/3	Un/Amb		Nonword	Squash	Goam
B	RCF	6/3	Un/Amb	Unrelated	Word	Squash	Jingle

[a] Experimental Item
[b] Unambiguous
[c] Unrelated Filler Item
[d] Lexicality Control Filler Item
[e] Ambiguous
[f] Repetition Control Filler Item

Unambiguous experimental, UNF, LCF, and RCF items were distributed into two lists (A and B) in such a way that primes repeated only between, but not within lists (Table 5). Both lists were used in Session 1. Meaning similarity for the experimental Related items was balanced between the two lists, and each list was balanced for relatedness proportion , lexicality, and prime ambiguity.

The single lexical decision task (SLD) required only a single list, and used target words from the following stimulus sets: the 48 unambiguous experimental items, 16 of the Related word-word RCF items, 48 non-word LCF items, 16 nonword RCF items, and 18 fixation control (FC) items from Session 1 (Table 6). Lexicality was balanced.

Table 6 Distribution and examples of items on the single lexical decision list

List	Stimulus Type	# of Stimuli	Lexicality	Target
SLD	EXP[a]	48	Word	Raft
SLD	RCF[b]	16	Word	House
SLD	LCF[c]	48	Nonword	Lound
SLD	RCF	16	Nonword	Goam
SLD	FC[d]	18		9

[a] experimental item
[b] repetition control filler item
[c] lexicality control filler item
[d] fixation control items

3.3.2.2. Experiment 2

Experimental stimuli consisted of 25 sets, each consisting of four stimulus pairs: a Related ambiguous prime with a dominant and a subordinate target, and an Unrelated prime with the same targets. Thus, the 100 ambiguous stimuli consisted of 50 primes and 50 targets. These 100 ambiguous word-word items were matched with 100 word-nonword LCF items, consisting of 50 ambiguous primes and 50 nonword targets.

The ambiguous items and their associated nonword LCF items were distributed into four lists (1, 2, 3, 4), two for each session (Table 7). One session contained either lists 1 and 2 or lists 3 and 4. The makeup of the experimental ambiguous word sets allowed choosing stimuli in such a way that each ambiguous prime and each target occurred only once in a single session (e.g., List 1: *log-timber,* List 2: *swallow-record;* List 3: *log-record,* List 4 *swallow-timber*). Avoiding prime repetition for ambiguous primes reduced the danger that previous exposure to an ambiguous prime over a short amount of time could change the dominance-based activation processes. Ambiguous Related items within and between lists 1 and 2 and within and between lists 3 and 4 were balanced for dominance. Within each list, items were balanced for Lexicality (word vs. nonword targets) and Relatedness (related versus unrelated).

Table 7 Distribution and examples of items in the ambiguous lists (Sessions 1 & 2)

List	Stimulus Type	# of Stimuli	Prime Type	Relatedness	Lexicality	Mng[a]	Prime	Target
1	EXP[b]	25	Amb[c]	Related	Word	1st	Log	Timber
2	EXP	25	Amb	Related	Word	2nd	Swallow	Record
1	LCF[d]	25	Amb		Nonword		Mass.	Chapet
2	LCF	25	Amb		Nonword		Date	Inswer
3	EXP	25	Amb	Unrelated	Word	1st	Log	Timber
4	EXP	25	Amb	Unrelated	Word	2nd	Swallow	Record
3	LCF	25	Amb		Nonword		Date	Chapet
4	LCF	25	Amb		Nonword		Pound	Inswer

[a] Meaning
[b] Experimental Item
[c] Ambiguous
[d] Lexical Control Filler Item

Because unambiguous stimuli from Experiment 1 were only used in the first testing session, a set of 96 unambiguous word and nonword filler (UF) items were created for the second testing session that contained 100 ambiguous word and nonword items. In this session none of the primes and targets were repeated; therefore, UF items consisted of a single list of 24 unambiguous Related, 24 unambiguous Unrelated, and 48 unambiguous word nonword stimuli. The nonword stimuli used repeated primes and targets from Session 1. Sixteen of these primes were paired with the same targets as in Session 1, and 32 used different targets.

The UF items were assigned to two lists (C and D) with 48 stimuli each (Table 8). Each list was balanced for Lexicality and Relatedness.

Table 8 Distribution and examples of items for unambiguous word/ nonword filler lists (Session 2)

List	Stimulus Type	# of Stimuli	Prime Type	Relatedness	Lexicality	Prime	Target
C	UF[a]	12	Un[b]	Related[c]	Word[d]	Ear	Foot
D	UF	12	Un	Related	Word	Navy	Cider
C	UF	12	Un	Unrelated[e]	Word	Arm	Nose
D	UF	12	Un	Unrelated	Word	King	Trout
C	UF	12	Un		Nonword[f]	Herd	Douth
D	UF	12	Un		Nonword	Wrist	Fush
C	UF	12	Un		Nonword	Sleet	Zove
D	UF	12	Un		Nonword	Ostrich	Lunce

[a] unambiguous word and nonword filler items
[b] unambiguous
[c] similar
[d] word
[e] dissimilar
[f] nonword

3.3.2.3. Fixation Control

Fixation control (FC) fillers were presented on average as every eighth stimulus, adding another 76 stimuli. In these trials, primes were not followed by word targets. Instead, a small numeral was displayed in the center of the visual field. This numeral could only be perceived if the participant fixated the central fixation point (Young, 1982). When participants recognized these numerals correctly, it could be inferred that they had focused on the central fixation point. Forty-eight FC trials were needed for Session 1 and 28 for Session 2. Eighteen primes were repeated between Session 1 and Session 2, 30 were unique to Session 1, and 10 were unique to Session 2. Primes were not as stringently controlled as were the experimental items. Primes consisted of nouns, noun/verb conflations, and noun/adjectives (e.g., *FAT*). Targets were numerals from 0 two 9, equally distributed within a block.

Fixation control items for the FC lists were distributed into four lists (X, Y, x, y), one for each block. The number of items depended on block length: 24 items for each block in Session 1, and 14 items for each block in Session 2 (Table 9).

Table 9 Distribution and examples of items on the fixation control lists (Sessions 1 & 2)

List	Stim Type[a]	# Stim[b]	Prime Type	Prime	Target
X/Y	FC[c]	24	Un/Amb[d]	Station	9
x/y	FC	14	Un/Amb	Cow	2

[a] stimulus type
[b] number of stimuli
[c] fixation control items
[d] unambiguous/ambiguous

3.3.2.4. Practice items

The practice lists (see Appendix C.1.) consisted of four short instructional lists (1, 2, 3, & 4) and two primary lists (A & B). List 1 consisted of three single words and three single nonwords, List 2 consisted of word-word pairs and two word-nonword pairs, List 3 consisted of four FC items, and List 4 consisted of four word-word pairs, five word-nonword pairs, and two FC items. Some of the words and nonwords used in each of the four lists were used in more than one list. The two primary lists (List A & List B) consisted of 18 word-nonword pairs, 18 word-word pairs (6 Related, 12 Unrelated), and 12 FC items. The lists included a high number of FC items because these blocks monitored the participants' ability to focus on the central fixation cross. Both lists used the same words, which were part rearranged to create new word-word and word-nonword pairs. Words in all lists were nouns, but they were not controlled for part of speech of other meanings or ambiguity. The distinction between Related and Unrelated pairs was based on the intuitive judgment of the author.

To summarize, six sets of word lists were constructed: (1) four "ambiguous" lists containing experimental ambiguous items and their associated nonword LCF items; (2) two "unambiguous" lists containing experimental unambiguous items and their associated nonword UNF, LCF, and RCF items for Session 1; (3) two "UF" lists containing the unambiguous word and nonword filler items for Session 2; (4) four "FC" lists containing fixation control items, (5) a single list for the single lexical decision task (SLD) for Experiment 1; and (6), six practice lists for the two practice blocks.

3.3.3. Block and session order

The six different lists were combined to create the 2 practice blocks and five experimental block lists, arranged in the following block and session order (Table 10). Each session started with practice. Session 1 started with practice using practice lists 1-4, practice List A, and, if the participant did not fulfill the criterion for fixation control items, practice List B. Session 2 began with practice List 4 and practice List B (again with the possibility that participants would receive practice List A if they failed the fixation control criterion).

In each session, practice was followed by two priming blocks: blocks S1B1 and S1B2 in Session 1, and blocks S2B1 and S2B2 in Session 2. Block lists for S1B1 and S1B2 consisted of one of the four ambiguous lists, one of the two unambiguous lists, and either fixation control List X or Y. The ambiguous lists had selection restrictions: within one session, either List 1 were 2, or Lists 3 or 4 could be given. Also, unambiguous List A was always combined with FC List X, and the unambiguous List B was always combined with FC List Y. Block lists for S2B1 and S2B2 consisted of one of the same four ambiguous lists, one of the two UF lists (C, D), and one of the other two FC lists (x, y). As in Session 1, each UF list was combined with one of the FC lists (List C with List x, and List D with List y). Finally, Session 2 also included a fifth block for the single lexical decision task, which used the SLD List.

Selection restrictions determined list selection for all blocks except Block S1B1. For example, if for Session 1 the ambiguous List 2 was selected for S1B1, then for S1B2 ambiguous List 1 was selected. This left the choice of ambiguous List 3 or 4 for S2B1, and the remaining list was assigned to S2B2. Similarly, the choice of unambiguous list/FC list combination in S1B1 and the choice of UF list/FClist combination in S2B1 determined which corresponding lists were assigned to blocks S1B2 and S2B2. This experimental set-up meant that each participant was presented with each experimental stimulus. However, half of the stimuli were presented to the rvf-LH, and half to the lvf-RH. Thus, every participant underwent every experimental condition, but contributed only half of the experimental data to each condition.

Table 10 Block order within each session

	List Type	Possible Lists	Example
Session 1			
Practice: Instruction	Short Practice Lists	1-4 (all required)	1 - 4
Primary Practice	Practice List	A (B optional)	A
Block S1B1	Ambiguous Lists	1 – 4	2
	Unambiguous List/FC[a] List	A/X, B/Y	A/X
Block S1B2	Ambiguous Lists	1 – 4	1
	Unambiguous List/FC List	A/X, B/Y	B/Y
Session 2			
Practice: Instruction	Short Practice List	4	4
Primary Practice	Practice List	B (A optional)	B
Block S2B2	Ambiguous Lists	1 – 4	3
	UF[b] Lists/FC Lists	C/x, D/y	D/y
Block S2B2	Ambiguous Lists	1 – 4	4
	UA Lists/FC Lists	C/x, D/y	C/x
Block SLD	SLD[c] List	SLD	SLD

[a] Fixation Control
[b] Unambiguous word and nonword Filler
[c] Single Lexical Decision

3.3.4. Randomization

Each block list was pseudo-randomized individually for each participant according to the following criteria. FC trials occurred on average every eighth trial. Stimulus characteristics –Sound (yes/no), Visual Field (rvf-LH vs. lvf-RH), Prime Type (ambiguous vs. unambiguous), Relatedness (related vs. unrelated) and Stimulus Type (experimental vs. filler) – did not repeat more than three times in a row. A custom computer program generated individual randomized block list and verified each list's adherence to the above constraints. Additionally, for each list a "mirror"-list was created that contained the same stimuli and stimulus order, but with each stimulus presented in the opposite visual field. During the experimental sessions, each individual list was read into an E-Prime (Schneider, Eschmann, & Zuccolotto, 2006) masterfile for presentation.

Block list selection was pseudo-randomized for each participant to meet the constraints outlined above, and to balance the four ambiguous lists, the two unambiguous lists, and the two unambiguous word and nonword filler (UF) lists as mirror and non-mirror lists between and within sessions (see Appendix C.1. for exact list distribution).

3.3.5. Task

Participants performed lexical decisions to the targets in each stimulus. As outlined in the literature review (2.3.2.3), semantic judgments are more sensitive to semantic processing effects than lexical decisions. However, such judgments are also less implicit because they require metalinguistc processing. Furthermore, the current experimental setup is meant to be extended to be used with older adults and adults with left and right hemisphere brain damage. Given that individuals with right hemisphere brain damage on average show significant deficits in metalinguistic judgments (Tompkins et al., 2000), lexical decision was the preferred task. On fixation trials, participants pronounced the numeral they read in the center of the screen.

3.3.6. Apparatus and procedure

3.3.6.1. Apparatus

Participants were tested individually in a room with dimmed lighting. They were seated in front of a computer screen (Gateway EV 910) at a distance of 60 cm. A chin rest (HCRD2R Double Screw Clamp Adjustable chin rest, Richmond Products) ensured consistent viewing distance from the screen, which was necessary to keep the visual angle of presentation constant. For their responses, participants used a response box (Serial Response Box, Psychology Software Tools). From the five response buttons, button 2 was assigned to no-responses, and button 4 to yes-responses. Thus, participants made No-responses with their left hand and Yes-responses with their right hand. Stimulus presentation and collection of reaction time data was controlled with a Sony Laptop (Vaio PCG-GRX500) running E-Prime software (Schneider et al., 2006). The numerals read aloud by participants during fixation trials were recorded by the examiner.

3.3.6.2. Stimulus presentation and divided visual field presentation

Stimuli were presented on a white screen. Primes and targets were presented in uppercase[26], black, bold, 15-point Arial font. Stimulus initiation served to draw the attention of the participants to central fixation with a "flickering" fixation point. Each stimulus trial began with the presentation of a black fixation point (plus-sign) for 600 ms in the center of the screen (Arial, 20-point font), followed by the same fixation point in red for 50 ms, and another black fixation point for 100 ms. The color change gave the appearance of flickering, which was intended to draw attention to that position (Chiarello et al., 2003).

The last fixation point was followed by the central presentation of the prime word for 250 ms (Chiarello et al., 2003). To facilitate central fixation, this screen still showed the black fixation point, and the prime (Arial, 15-point font, black, bold, uppercase) was presented centrally and subtended at .3° below the vertical visual angle. A blank screen of 500 ms followed, resulting in an SOA of 750 ms. The

[26] The few DVF studies that mention case in word presentation all have used uppercase (Chiarello et al., 1990; Chiarello et al., 2003; Koivisto, 1998). Atchley and colleagues (Atchley et al., 1999) also probably used uppercase letters, given that they present the stimulus list and examples in uppercase. Thus, uppercase presentation appears to be the standard method in 3 major labs that have pursued DVF semantic priming studies.

target word appeared for 150 ms in lateralized presentation with the innermost edge of the word subtended at 2° of the horizontal visual angle, and the outmost edge subtended at maximally 5°. On fixation trials, target presentation differed. No fixation point was displayed, and instead a numeral was presented in the center of the screen.

The next trial started either 1000 ms after the participant's response, or after 3500 ms (Chiarello et al., 2003). On fixation trials the next trial was initiated after 2500 ms. This time was shortened in comparison to the lexical decision trials because on these trials participants' responses (pronunciation) would not initiate the next trial; therefore, each trial had a 2500 ms interstimulus interval. This experimenter considered 2500 ms sufficient time for verbal responses by the participants.

The parameters of presentation for the lateralized target stimuli followed the recommendations by Bradshaw (1989) and Young (Young, 1982). Lateralized target stimuli were presented at the visual angle of 2° from central fixation, and did not extend beyond 5°. Evidence from animal experiments indicates that an area of about 1 degree visual angle around the center of the visual field projects to both hemispheres (Lavidor et al., 2003; Lindell et al., 2003), therefore the boundary toward the center of the visual field was meant to ensure that no visual information from the target reached the ipsilateral hemisphere directly. Because visual acuity decreases toward the periphery of the visual field, the lateral boundary for stimulus presentation controls for differences in stimulus degradation. Targets were only presented for 150 ms because this presentation interval is short enough to prevent saccades to the word from the fixation point to the target during target presentation (Bradshaw, 1989).

3.3.6.3. Session begin, practice, and instructions

The first session began with the consent procedure and the screening procedures for inclusion and exclusion criteria outlined in Section 3.1. Then participants entered the testing room and adjusted head/chin rest and the chair to a comfortable position. To explain the experimental setup to participants beforehand without indicating the exact purpose of the experiment, participants were told during the consent process that the goal of the experiment was to investigate how well people can recognize words they are not directly looking at. Furthermore, instructions stated that the prime helped participants to "prepare for" the target stimulus (Chiarello et al., 2003). Because focus on central fixation is key for the DVF method, instructions heavily emphasized the importance of maintaining central fixation. Instructions with respect to speed and accuracy were "respond as quickly and accurately as you can". These instructions and reminders to focus centrally were repeated before every block.

In Session 1, practice included several steps (see Appendix C.2.). Participants first practiced lexical decisions to single targets (practice List 1), then on prime-target pairs presented at the actual speed of presentation (practice List 2). The next step of the instructions emphasized fixating the fixation point and not blinking during trials, and used the same practice items (practice List 2). In the third step participants practiced fixation control trials (practice List 3). The fourth step combined word-word/nonword trials and fixation control trials (practice List 4). During all these four steps the experimenter monitored participants' responses and behaviors, and corrected when difficulties were perceived.

In the last practice step participants completed a list of 48 trials (practice List A or B). This step had two goals. First, it provided participants with an initial learning phase that helped to stabilize response times. Second, it served as a check on participants' ability to fixate the central fixation point. Participants who did not fulfill the central fixation criterion (90% correct or higher) completed a second practice list. If they still could not fulfill the criterion, they were ruled out. However, because all participants passed this criterion, the second list was never used this way. But it was used for one participant when the program crashed during the administration of the first list, and for two participants who evidenced task misunderstandings (e.g., one participant asked whether he always pressed the button after the number). In Session 2 practice started at the fourth step, after which participants again completed the longer practice list (practice List B).

3.4. PLANNED ANALYSIS AND POWER ANALYSIS

3.4.1. Planned analysis

The planned RT analysis for both experiments was based on a general linear model, and the planned accuracy analysis on a logistic mixed regression model. In Experiment 1, Semantic Similarity was the main independent variable which was investigated as a continuous predictor variable. RT to SLD items functioned as a covariate, and Subjects and Targets as random variables. In Experiment 2, Meaning Dominance and Relatedness (related versus unrelated) were independent variables, and Subjects and Targets functioned as random variables. Confidence intervals were calculated at pre-specified values of Similarity and Dominance, chosen to reflect low versus high meaning similarity/dominance (see below).

Thus, the planned analysis addressed research question 1 (effect of Meaning Similarity on priming for rvf-LH) through the predictor variable Semantic Similarity, and it addressed research question 3 (effect of Meaning Dominance on priming for rvf-LH targets) through the interaction of Meaning Dominance and Relatedness. According to the planned analysis, the confidence intervals were used to evaluate presence of priming (research questions 1 and 3), and the presence of priming for low-similarity or low-dominance meanings (research questions 2 and 4).

The planned analysis also included two more investigations of the specific priming patterns for Similarity and Dominance. For Experiment 1, the analysis as described above assumed that Similarity was a linear effect. To test this assumption, relative priming effects for low and high similarity targets would be evaluated in a 3-way ANOVA, with Similarity split into three interval classes. For Experiment 2, the experimental design allowed that Dominance could be evaluated in two separate models as both a continuance and a dichotomous variable. The comparison between these two models served as another test of the graded versus high-only priming hypotheses.

3.4.2. Estimation of effect sizes

Only very limited data was available to estimate effect sizes, which means that there was an unavoidable risk of imprecision. To determine the expected effect sizes and variances, results were considered from all previously reviewed DVF studies that used English-speaking participants. First variance was estimated. Only three out of the eight studies provide numerical variance data (Burgess et al., 1988; Nakagawa, 1991; Atchley et al., 1999); therefore, estimated variance was calculated as the average standard deviation documented in these three studies: 125 ms.

For Experiment 1, the effect of Semantic Similarity was estimated from results of the three relevant studies that investigated semantic relatedness (Nakagawa, 1991; Chiarello et al., 1990; Chiarello et al., 1992). Because neither study by Chiarello and colleagues included variance information, the standard deviation estimate (125 ms) based on other studies was applied to Chiarello's results. Another problem was that the Chiarello and Nakagawa studies differed in relatedness proportion: .29 (Chiarello et al., 1990), .5 (Nakagawa, 1991), and .7 (Chiarello et al., 1992). A study of relatedness proportion effects with centrally presented stimuli that investigated relatedness proportion levels of .125, .5, and .875 suggests that the increase in priming due to higher relatedness proportions is linear (Tweedy et al., 1977). Thus, the estimated effect sizes from the three relevant studies were averaged, yielding effect sizes of .89 for highly related stimuli, and .4 for less related stimuli.

However, the highly related word pairs in the three relevant DVF studies were both semantically similar and associated, whereas the highly similar items in the study by McRae and Boisvert (1998), which underlies the estimation of *high* and *low* similarity in the proposed study, were not associated. Therefore, priming effects were expected to be somewhat smaller than in the three DVF studies (Lucas, 2000). Thus, the estimated effect size of .89 was adjusted to .8 for high similarity priming. As a result, the effect size for high similarity (similarity rating of 6) was estimated as .8, and the effect size for low similarity (similarity rating of 4) was estimated as .4.

To estimate an effect of Dominance for Experiment 2, the four studies that found the predicted high-only maintenance pattern were considered (Burgess & Simpson, 1998; Atchley, 1996; Atchley, 1999; Atchley, 2001). However, one of the studies (Atchley, 1999) used different types of stimuli (unambiguous or polysemous primes with related features) than the other studies. This type of prime-target relationship was considered too different from the one used in this study; therefore, the data from the 1999 study by Atchley and colleagues were disregarded for the purposes of deriving an effect size. Furthermore, two of the three remaining studies were only published as meeting abstracts and provided neither exact RT data nor standard deviations (Atchley et al., 1996; Burgess et al., 1998b). However, Burgess and Lund included a graph with RT results. Based on this graph, and the estimated standard deviation of 125, effect sizes could be calculated. Thus, the estimated effect size for Experiment 2 was based on data from two studies (Burgess et al., 1988; Burgess et al., 1998b)

Dominance values in these two Burgess studies were estimated at .88 and .79 for high dominance items, and .06 and .13 for low dominance items, respectively. These values were estimated based on items selected for the current study by applying the .6 and .8 cutoffs for high-dominance items used in the two studies. These values average to dominance values of .84 for high dominance items, and .1 for low dominance items. Again based on the two studies, the average *effect size* for high dominance priming was .58. This estimated effect size was adjusted for two reasons. First, these two studies used associated prime-target pairs, while the current study used semantically similar ones. Therefore, the estimated effect size was reduced by the same proportion as the effect size estimate for Experiment 1. Second, the similarity value for high dominance items ($M = 5.7$) was somewhat below the similarity value of 6 that was assumed for Experiment 1. Thus, the effect size of .58 was adjusted to an effect size of .44. No data are available to estimate the effect size for low dominance priming, if it exists. Following the estimations for Semantic Similarity, 1/2 of the high dominance effect, that is, .22, was entered into the simulation as the estimated effect size for low dominance (a Dominance value of .1).

3.4.3. Power analysis

An *a-priori* power analysis was conducted for the RT analysis, because RT data are usually more sensitive to the effects under investigation (Young, 1982). This analysis was based on estimated effect sizes for confidence intervals at the pre-specified values of Meaning Similarity and Meaning Dominance described in the previous section. The study was designed in such a way that all participants experienced all experimental conditions, but not every stimulus pair in each condition. Therefore, *a-priori* power and sample size were determined by using a Monte Carlo simulation. The simulation was based on the planned analyses, and the expected effect sizes and variances for the parameters of interest. Based on these parameters, the simulation generated 2000 random outcomes for each experiment, assuming Gaussian distributions for the error terms, on the basis of which power and sample size were estimated.

Because in its original design Experiment 1 had more stimuli than Experiment 2, and effect sizes for Experiment 1 were higher than Experiment 2, the original power analysis was only carried out for Experiment 2. This analysis estimated that a sample size of 90 was required to detect low-dominance effects with an effect size of .22 at a power of .8.

After this analysis was carried out, the experimental design for Experiment 1 had to be changed and stimulus numbers had to be reduced to avoid a relationship between Semantic Similarity and lexical co-occurrence. Because this author misunderstood the effects of this design change on the power for Experiment 1, no new power analysis was carried out for Experiment 1 with the complete changed design. Because of the design change, Experiment 1 was underpowered, in particular because it did not include enough stimuli. Additional stimuli would have been necessary to reduce the noise for inter-stimulus variability and to provide a better estimate of the similarity priming effects in the population of prime-target pairs.

The projected participant number of 90 assumed perfect accuracy. Therefore, subject numbers needed to be augmented for loss of data through ruled-out participants and lower accuracy results. After two thirds of the data were collected, the investigator estimated the accuracy rate for lvf-RH targets at 85%, and the number of ruled out participants for the accuracy criterion at 6. This estimate suggested adding an additional 20 participants to the subject number. Furthermore, the examiner monitored the number of ruled-out participants for technical errors, errors in administration, inability to meet the fixation criterion, or failure to return for the second session, which added up to 16 participants. Therefore, 126participants were included in the study.

4. ANALYSIS AND RESULTS

To prepare data for analysis, invalid observations were removed first. These included responses that were missing, invalid because of administrator or technical error. Furthermore, responses were removed , or came from participants who did not meet the fixation control criterion for specific blocks, did not fulfill the accuracy criterion, or showed excessive response bias. Then data were transformed with a logarithmic transformation, and outliers were replaced with their cutoff values (5.2 MAD). Finally, data files were prepared for the main analysis. For both experiments, effects of the main independent variables (Similarity/Dominance) were estimated as regression lines, and specific priming patterns were investigated with follow-up analyses.

4.1. INITIAL DATA CLEANUP

Data were collected from 121 participants. Two participants completed only Session 1; their data were not included. All other individual data files were merged into a single file. One step of the data preparation the prime values and participant's performance was screened for discrimination and bias. These measures rely on analysis of correct responses to words (hits) and incorrect responses to nonwords (false alarms). To facilitate this analysis, each experimental item was paired with a nonword filler item, and targets were matched for letter length (M (words) = 4.91, M (nonwords) = 4.92, $t = -.104$, $p = .92$, $N = 196$). All other fill a stimuli were removed from the data file, creating a file of 48,749 observations. Because the discrimination and bias analysis for participants was conducted with the cleaned data file, all the steps listed in this section were applied to the matched experimental and filler items.

First, observations with missing response times (RTs) or RTs of 0 were removed. These comprised 251 observations were 0.5% of the data, reducing the file to 47,323 observations. The next step removed all data related to technical or administrative error, that is, crashed files with unrecoverable data or incorrect files presented by the experimenter. If one of the two blocks in Session 1 (S1B1, S1B2) was lost, the participant was removed from the analysis of both unambiguous and ambiguous data. If one of the two priming blocks in session 2 (S2B1, S2B2) was lost, the participant was removed from the analysis of ambiguous data. If the single lexical decision block (SLD) was lost, the participant was removed from the analysis of unambiguous data. This procedure resulted in the removal of two participants from both analyses. Two additional participants were excluded from the analysis of ambiguous data because of technical or administrative errors.

Furthermore, for three participants, the experimenter presented an incorrect block file but noted the error, stopped the file, and initiated the correct file. In these cases, any experimental items that were viewed on the incorrect file before it was stopped were noted, and any items that had matching primes and targets subsequently in that session were erased, resulting in the removal of 22 additional observations. In one case a file crashed at the beginning of the administration in Session 2 and was repeated from the beginning. Because the data from the crashed file were retained, these were used for subsequent analysis, and only the unrepeated items were used for the repeated file. Because this was Session 2, none of the primes and targets repeated, so no subsequent experimental items needed to be deleted. Altogether, technical and administrative error accounted for the removal of 1029 observations, or 2.1% of the data (1.3% of the unambiguous and 3.0% of the ambiguous data).

In the next data preparation step, the fixation control (FC) criterion was applied. The *a priori* criterion was that each participant needed to have 90% of the FC trials correct. S1B1 and S1B2 had 24 FC trials each, S2B1 and S2B2 had 14 FC trials each, and SLD had 18 FC trials. Thus, participants were ruled out if they had three errors or more in S2B1 and S2B2, and two errors or more in S2B1, S2B2, and SLD. Using the same criteria as for the technical and administrative errors, the rule-out procedure resulted in the elimination of three participants for both analyses, an additional four participants for the unambiguous analysis, and one additional participant for the ambiguous analysis. Overall, 1374 observations or 2.8 % of the data were removed (4.2% of the unambiguous and 1.7% of the ambiguous data).

A further step in the initial data clean up applied the *a priori* rule-out criterion that participants who showed accuracy of 65% or less on rvf-LH trials were removed from analysis. This accuracy rate was chosen because it lies above the 99% confidence interval for random performance, but below the lowest *observed average* accuracy rate in the representative DVF studies (Chiarello et al., 1990; Simpson et al., 1985; Atchley et al., 1999). In these studies, accuracy rates varied between 99% and 71%, depending on target field of presentation and relatedness. Given that this is the average observed accuracy, many participants would have performed below this value. In the current study the accuracy criterion was applied to the matched word and nonword stimuli. Five participants did not meet the criterion, and their data consisted of 3275 observations or 6.7 % of the data (8.2 % of the unambiguous and 5.7% of the ambiguous data).

Finally, stimulus timing data were inspected. Based on E-Prime software time log data, minimum, maximum, and average delays were calculated for the presentation times of fixation, the prime, SOA, target, and ISI. For example, SOA delay was the sum of prime duration, SOA fixation onset delay, SOA fixation duration error, and target onset delay. Results were inspected for outlying times, with special attention to the presentation time of prime, SOA, and target.

Three observations had timing errors in target duration and were removed. Otherwise, results (Table 11) showed that prime and target durations were always 250 and 150 ms, respectively, and that SOA presentation delay times varied on average between 2 and 6 ms and maximally between 12 and 13 ms. These ranges should not affect the validity of lateralized presentation.

Table 11 Timing Errors presentation of stimulus elements (in ms)

	# of observations	Minimum	Maximum	Mean	Standard Deviation
Unambiguous data					
Fixation	21002	0	23	14.1	4.85
Prime	21002	0	0	0	0
SOA – rvf-LH[a]	10495	-1	13	1.9	3.71
SOA – lvf-RH[b]	10507	-2	13	1.9	3.70
Target	21002	0	0	0	0
ISI[c]	21002	0	12	4.5	3.10
Ambiguous data					
Fixation	22014	2	23	14.1	4.97
Prime	22014	0	0	0	0
SOA – rvf-LH	11010	-1	12	5.5	4.56
SOA – lvf-RH	11004	-2	13	5.4	4.55
Target	22014	0	0	0	0
ISI	22014	0	12	4.5	3.11

[a] Stimulus Onset Asynchrony – right visual field – Left Hemisphere
[b] Stimulus Onset Asynchrony – light visual field – Right Hemisphere
[c] Interstimulus Interval

4.1.1. Discrimination and bias

To evaluate discrimination and bias for all participants, d' and c[27] (Macmillan, 2002) were calculated for both experiments, for each visual field and over both visual fields. Not surprisingly, discrimination ability was worse for lvf-RH targets than for rvf-LH targets, and responses to lvf-RH targets showed a negative bias (Table 12).

Table 12 Discrimination and bias

	# of participants	Minimum	Maximum	Mean	Standard Deviation
All data					
d'	114	.65	3.77	1.64	.65
c	114	-.76	.70	.03	.24
rvf-LH[a]					
d'	114	.86	4.18	2.00	.68
c	114	-.93	.53	-.11	.26
lvf-RH[b]					
d'	114	-.03	4.41	1.40	.79
c	114	-.64	1.08	.15	.32

[a] Right visual field - Left Hemisphere
[b] Left visual field - Right Hemisphere

The low discrimination values for lvf-RH responses did not derive from outliers, and all values were within two standard deviations of the mean. Instead, they reflect that discrimination in the lvf-RH was a difficult task for many participants, most likely because recognition was more difficult in this condition. This difficulty also accounts for the No-bias. For the purpose of data analysis, Yes-bias was of particular concern because it would result in spurious RTs. One participant showed a Yes-bias of more

[27] c = - ½ [z(hits) + z(false alarms)]. In this measure, 0 represents no bias, negative values correspond to a yes-bias and positive values correspond to a no-bias. Most values are between -1 and 1. Positive values can exceed 1.

than three standard deviations from the mean for rvf-LH data and rvf-LH/lvf-RH data combined, and was excluded from analysis for both experiments in the next data preparation step.

4.1.2. Data reduction and transformation

After calculating discrimination and bias, the data file was reduced to only experimental items and included 21530 observations. The data from the participant with strong yes-bias were removed (97 observations, 0.5 % of the experimental data, leaving 21433 observations. Next, outlier treatment and transformations were considered. Ratcliff (1993) has shown that using fixed RT cutoffs for outlier elimination preserves power well; however, cutoffs are problematic because they can result in asymmetric biases (Ulrich & Miller, 1994; Zandt, 2002). Furthermore, inspection of RT data showed deviations from the normal distribution expected for such data (skewness = 2.2, kurtosis = 10.3). Therefore, inverse and logarithmic transformations were considered. In Ratcliff's (1993) simulation, inverse transformations maintain power better then the logarithmic transformations. However, inspection of the normal quantile plots showed that the logarithmic transformation was the better fit for the assumption of a normal distribution, and data were thus transformed (skewness = .67, kurtosis = 1.3).

Next, a conservative outlier criterion was used: any transformed RT value that was more or less than 5.2 median absolute deviations (MAD) of the median[28] was replaced with this cut-off value. This outlier criterion was calculated individually for each participant. Thirty values were changed (0.1 % of the experimental data). Then the data file was split into two files, one for each experiment. The unambiguous data had 10,503 observations, and the ambiguous data had 10,930 observations.

Finally, data files were prepared for each analysis. For the unambiguous data, new variables were created for SLD RT and accuracy values. Each value was transferred into the same row of its corresponding item from the priming task. Items that did not have corresponding values due to missing data were dropped, so that the new data file consisted of 5.223 pairs of observations (a loss of 57 observations or 0.5% of all unambiguous data). This data file was used for accuracy analysis with Similarity as the continuous independent variable. For RT analysis, incorrect items were removed from this file. Items were only retained if both the priming response and the single target response were correct. This procedure left 3,450 pairs of observations. For the ambiguous data, no new file needed to be created

[28] The MAD is calculated as the median absolute value of the differences of individual values from the median. Given a normal distribution, 5.2 MAD is equivalent to a criterion of 3.5 standard deviations (Davies, 2001), and it has the advantage that in contrast to mean and standard deviation, it is not affected and potentially skewed by outlying values. This criterion has been proposed by Hampel (Hampel F.R., 1985), who showed it to be very effective for outlier elimination in Monte-Carlo simulations.

for the accuracy analysis. For RT analysis, incorrect responses were removed, leaving 8069 observations for both the continuous and the dichotomous analysis.

4.2. PRELIMINARY DATA DESCRIPTION

For general descriptive purposes, and to evaluate the speed-accuracy tradeoff, effects of visual field, block order, and Experiment on accuracy and RT were inspected. For the sake of simplicity, these computations were based on the data file before it was split. Effects for RT were computed only for correct responses. Note that the main analysis was based on logarithmically transformed RTs, which are not reflected in these values. As expected, responses to rvf-LH targets were more accurate and faster than responses to lvf-RH targets (Table 13).

Table 13 Comparison of accuracy and response times (RTs) by visual field

	Number of observations	Mean	Standard Deviation	t-value	p-value
Accuracy					
rvf-LH[a]	10701	84%	36%	27.764	.000
lvf-RH[b]	10731	68%	47%		
Reaction Times (ms)					
rvf-LH	9020	649	198.0	-16.658	.000
lvf-RH	7347	728	213.7		

[a] Right visual field - Left Hemisphere
[b] Left visual field - Right Hemisphere

For the comparison of the two experiments, only data from the priming task were considered. Responses were more accurate and faster for Experiment 1 targets, compared to Experiment 2 targets (Table 14). To explore this observation further, target lexical characteristics were compared between the two experiments. Targets for Experiment 1 on average were more imageable, were slightly shorter, were more frequent, and had a larger orthographic neighborhood. However, these differences were small (see

Appendix, B.3.1.), and were significant only for Imageability. Thus, it is unclear whether differences in target lexical characteristics resulted in the performance differences for accuracy and RT between the two experiment.

Table 14   Comparison of accuracy and reaction times (RTs) between experiments

	Number of observations	Mean	Standard Deviation	t-value	p-value
Accuracy					
Experiment 1	10930	82 %	39 %	- 11.066	.000
Experiment 2	5253	74 %	44 %		
Reaction Times (ms)					
Experiment 1	8067	675	212	9.156	.000
Experiment 2	4291	700	210		

Also as expected, participants evidenced a practice effect, especially in RTs, which decreased over the two testing sessions and within each session (Tables 15 and 16).

Table 15 Block order effects (Accuracy)

Experiment	Blocks					Average over Blocks
	S1B1	S1B2	S2B1	S2B2	SLD	
Experiment 1						
Rvf-LH[a]	89 %	88%			84%	87%
lvf-RH[b]	77%	73%			69%	73%
Experiment 2						
Rvf-LH	82%	78%	85%	85%		82%
lvf-RH	68%	62%	65%	66%		65%
Average over Experiments	79%	75%	75%	75%	76%	

[a] Right visual field - Left Hemisphere
[b] Left visual field - Right Hemisphere

Table 16 Block order effects (Reaction Times in ms)

	Blocks					Average over Blocks
	S1B1	S1B2	S2B1	S2B2	SLD	
Experiment 1						
Rvf-LH[a]	717	695			643	685
lvf-RH[b]	767	741			696	735
Experiment 2						
Rvf-LH	741	713	672	676		701
lvf-RH	815	756	738	719		757
Average over Experiments	760	726	705	698	670	

[a] Right visual field - Left Hemisphere
[b] Left visual field - Right Hemisphere

Finally, the speed accuracy tradeoff was evaluated for each visual field and Experiment. As expected, overall slower RTs were associated with an increase in accuracy (Table 17). However, this tradeoff was small in all conditions. It was somewhat smaller for lvf-RH targets, which probably reflects the high error rate and larger variability in that condition. No difference between the experiments was discernible, which suggests that the speed-accuracy tradeoff was not affected by target characteristics.

Table 17 Speed-accuracy tradeoff for visual field in each experiment

	Number	Reaction Times	Accuracy	Correlation (Spearman)	p-value
Experiment 1					
Rvf-LH[a]	5236	691	86%	-0.20	< .001
lvf-RH[b]	5267	748	72%	-0.15	< .001
Experiment 2					
rvf-LH	5465	721	82%	-0.23	< .001
lvf-RH	5465	780	65%	-0.15	< .001

[a] Right visual field - Left Hemisphere
[b] Left visual field - Right Hemisphere

4.3. MAIN ANALYSIS

For both experiments data were analyzed with accuracy and RT as dependent variables. Accuracy data were modeled with a logistic mixed regression model, and response time data were modeled with a general linear model. Also, for Experiment 2, two models were computed with Dominance as either a continuous or a dichotomous predictor variable. This procedure resulted in six models overall. Parameters were estimated using maximum likelihood methods.

Similarity functioned as the fixed predictor variable in Experiment 1, and Dominance in Experiment 2. Additionally, in both experiments Visual Field was entered as a second predictor variable, and items/targets and participants were entered as random effects. Furthermore, selected target lexical characteristics were entered into the models. First, for Experiment 2 target Imageability needed to be added to the model because of the weak correlation of target Imageability with Dominance. All other target lexical characteristics were considered "nuisance" variables, because they were not correlated with the predictor variables (see Section 3.2.3.2.). Therefore, adding them to the model did not affect the estimation of the dependent variables, but it reduced overall variance of the model. The target word characteristics were selected for inclusion in the models based on their intercorrelations (see Appendix B.1.). Because the goal of the modeling was not to estimate the nuisance variables themselves, it was not problematic if they were somewhat correlated. However, highly correlated variables would not contribute to variance reduction. Inspection of the intercorrelations showed that there was a gap between weak (but significant) to moderate correlations (.33 - .52) and moderate to high correlations (.68 - .93). Thus, significantly correlated variables were included only if they did not correlate in the moderate-high bracket. Finally, ambiguous Related primes Number of Noun/Verb Meanings correlated weakly with Dominance, and for ambiguous Unrelated primes Imageability correlated weakly with Dominance. Therefore, these two lexical variables were entered into the RT and accuracy analysis in a separate step, to evaluated whether they contributed to the models.

Based on predictions for the constellations of interest, point estimators reflecting priming effects were calculated with confidence intervals and effect size measures for pre-specified values for low and high Similarity/Dominance (see Section 3.4). These measures were used to evaluate research questions 1 and 3 (i.e., Does semantic similarity/meaning dominance predict priming for rvf-LH targets?).

Evaluation of research questions 2 and 4 (i.e., Are low-similarity/low-dominance targets primed in rvf-LH presentation?) differed between the two experiments. In Experiment 1, the regression line included dissimilar targets. Because Similarity was estimated as a *linear* effect, priming for high-similarity targets would by definition result in an estimation of a lower priming effect for low-similarity targets. As a result, the specific priming patterns could not be evaluated based on the point estimators. Therefore, if the point estimator for high-similarity showed a significant priming effect, relative priming effects for low and high similarity targets would be evaluated in a 3-way ANOVA, with Similarity split into three interval classes.

In Experiment 2, Similarity priming was investigated as the effect of relatedness for related and unrelated prime-target pairs. Because the estimated linear regression line for this effect did not necessarily have a zero intercept, the point estimators based on a linear regression line provided a valid approach to evaluate the different priming patterns, and could be used to address research question 4. The experimental design for Experiment 2 also allowed a separate evaluation of graded versus high-only priming patterns in the direct comparison of the generated models with Dominance entered either as a continuous or dichotomous variable. The Akaike Information Procedure (AIC) was used to decide whether the continuous or the dichotomous model was more appropriate for this data set. The AIC procedure provides a numerical comparison of models that evaluates the tradeoff between goodness of fit and a model's complexity (Burnham & Anderson, 2004).

The analysis as planned avoided analyzing priming effects directly as the difference of related and unrelated prime-target pairs, or as ratios. This procedure has two advantages. First, if extraneous variables affect the related and unrelated conditions differently, such measures of priming effects, especially for the difference measure, are unreliable. Second, when related and unrelated pairs are yoked in the analysis, only half of the observations made can enter the model, thus losing many degrees of freedom. Furthermore, when a reaction time is missing, the corresponding reaction time of the contrasting target would also be lost. In the approach chosen here, participant and target effects were entered directly into the regression model; therefore individual effects were already considered and evened out when calculating the contrasts.

4.3.1. Experiment 1

Unless stated otherwise, the following description of results reports results to be "significant" if the associated *p*-value had an alpha-level no greater than .05, and to be "marginally significant" if the associated *p*-value had on alpha-level between .1 and .05.

The models for Experiment 1 used Similarity and Visual Field as fixed dependent variables. Similarity was a continuous variable, including similarity values from 1 (unrelated) to 6.3. Accuracy or RT to responses from the SLD Task (SLD ACC and SLD RT, respectively) functioned as a covariate. Random effects were estimated for participants and items.Target Imageability, Frequency, Length in Letters, and their interactions with Visual Field were entered as additional "nuisance" variables. The crucial estimations in all analyses were the coefficients for Similarity and the interaction of Similarity and Visual Field. Visual Field was treated as a dummy variable, with rvf-LH coded as 1, and lvf-RH coded as 0.

4.3.1.1. Estimation of coefficients

4.3.1.1.1. Accuracy Analysis

In the continuous analysis, none of the crucial estimations involving Similarity were significant (Table 18). The positive coefficient for SLD ACC was significant, suggesting, not surprisingly, that targets that were more accurate in the single presentation condition were also more accurate in the priming condition. Otherwise, only the main effect coefficients for the three lexical variables were significant, and the main effect for Visual Field was marginally significant. Coefficients for Imageability and Frequency were positive, suggesting that as imageability values and frequency increased, accuracy increased. The coefficient for Length in Letters was negative, indicating that as word length decreased, accuracy increased.

Table 18 Estimated coefficients for accuracy analysis, Experiment 1

	Estimated Coefficient	Standard Error	Z-Values	P-values
Intercept	-1.4280	1.0335	-1.3817	0.17
Similarity	***0.0717***	***0.0623***	***1.1513***	***0.25***
Imageability	0.2846	0.1292	2.2030	0.03
Length in Letters	-0.3658	0.1024	-3.5705	0.000
Frequency	0.2537	0.0692	3.6671	0.000
Visual Field	1.3688	0.8223	1.6647	0.10
SLD ACC[a]	0.6388	0.0890	7.1787	0.000
Similarity by Visual Field	***-0.0774***	***0.0529***	***-1.4616***	***0.14***
Imageability by Visual Field	-0.1252	0.0976	-1.2827	0.20
Length in Letters by Visual Field	0.1348	0.0883	1.5254	0.13
Frequency by Visual Field	0.0067	0.0568	0.1170	0.91

[a] Single lexical decision - accuracy

4.3.1.1.2. Response Time Analysis

Of the crucial estimators involving Similarity, the interaction of Similarity and Visual Field was significant (Table 19). The coefficient was negative, indicating that for lvf-RH targets, response time decreased as similarity increased. Main effect coefficients for all lexical variables were again significant. They reflected the same basic effects as in the accuracy analysis. Furthermore, the interaction between Length in Letters and Visual Field was marginally significant ($p = .06$). The coefficient of this interaction was negative, indicating that the length effect was attenuated for rvf-LH targets.

Table 19 Estimated coefficients for reaction time analysis, Experiment 1

	Estimated Coefficient	Standard Error	Degrees of Freedom	T-values	P-values
Intercept	6.3524	0.1462	3439	43.4379	0.00
Similarity	***0.0024***	***0.0045***	***3439***	***0.5281***	***0.60***
Imageability	-0.0287	0.0108	3439	-2.6596	0.01
Length in Letters	0.0253	0.0073	3439	3.4846	0.00
Frequency	-0.0289	0.0051	3439	-5.6471	0.00
Visual Field	-0.0348	0.0800	3439	-0.4353	0.66
SLD RT[a]	0.0834	0.0183	3439	4.5652	0.00
Similarity by Visual Field	***-0.0086***	***0.0043***	***3439***	***-2.0056***	***0.05***
Imageability by Visual Field	0.0154	0.0108	3439	1.4287	0.15
Length in Letters by Visual Field	-0.0133	0.0070	3439	-1.903	0.06
Frequency by Visual Field	-0.0055	0.0050	3439	-1.0977	0.27

[a] Single lexical desion task - response time in single lexical decision condition

4.3.1.2. Point estimators

Point estimators for priming effects were calculated as linear contrasts between the Similarity values of 4 and 1 (low-similarity and dissimilar) and 6 and 1 (high similarity and dissimilar), respectively, for each visual field[29]. Confidence intervals were calculated for each point estimator, and confidence intervals were transformed by the exponential function in order to obtain the odds ratio or relative change (ratio of RTs), for accuracy and response time data, respectively. *P*-values were calculated for each contrast with the significance test in the linear model, and the power for this test was calculated *post-hoc*.

[29] Because the Similarity values derived from a scale of 1 – 7 (dissimilar to highly similar), the actual values entered were changed to 3 and 5, so that the value 1 (dissimilar) on the 7-point scale was equivalent to an entered value of 0.

The calculation method for the confidence intervals did not include the intercept, because the goal of the analysis was to estimate priming effects (that is, contrasts), and not to predict RT or accuracy values.

Derivation of effect size measures also depended on the variable in question. For RT data, point estimators were divided by the standard deviation of the residuals. To provide an effect size measure with a comparable scale for accuracy data, the effect size was calculated as the multiple of one standard deviation of the logistic distribution (Chinn, 2000), which can be calculated by dividing the point estimator (in logit scale) by 1.81. Results for accuracy and RTs are presented in Table 20 and Table 21. As a reminder, results for Similarity value 4 are not estimated independently. They can only be interpreted under the *a-priori* assumption of a linear similarity effect.

Table 20 Results for point estimators, accuracy analysis, Experiment 1

Visual Field	Sim [a] Value	PE[b] (logit)	PE (odds ratio)	CI[c] Lower Limit (odds ratio)	CI Upper Limit (odds ratio)	P-Value	Effect Size (PE logit/ 1.81)	Power (post-hoc)
Rvf-LH[d]	4	-0.02	0.98	0.66	1.47	0.93	-0.01	.03
Rvf-LH	6	-0.03	0.97	0.50	1.90	0.93	-0.02	.03
Lvf-RH[e]	4	0.22	1.24	0.86	1.79	0.25	0.12	.21
Lvf-RH	6	0.36	1.43	0.78	2.63	0.25	0.20	.21

[a] Similarity
[b] Point Estimator
[c] Confidence interval. A value < 1 in the lower limit indicates that the confidence interval includes the priming effect of 0.
[d] Right visual field – Left Hemisphere
[e] Left visual field – Right Hemisphere

In the accuracy analysis for Experiment 1, none of the confidence intervals were significant, that is, all confidence intervals included 0, which is equivalent to the Similarity value of 1. For rvf-LH targets, effect sizes showed no indication of priming (Similarity value 4: -.01, Similarity value 6: -.02). For lvf-RH targets, effect sizes showed a small positive slope (Similarity value 4: .12, Similarity value 6: .20), indicating an increase in accuracy with increased semantic similarity (priming). Power to detect these effects was low (.21).

Table 21 Results for point estimators, response times analysis, Experiment 1

Visual Field	Sim[a] Value	PE[b] (logRT[c])	CI[d] Lower Limit (relative change)	CI Upper Limit (relative change)	P-Value	Effect Size (PE/SD residuals[e])	Power (post-hoc)
Rvf-LH[f]	4	-0.02	0.96	1.01	0.15	-0.09	.30
Rvf-LH	6	-0.03	0.93	1.01	0.15	-0.15	.30
Lvf-RH[g]	4	0.01	0.98	1.03	0.60	0.04	.08
Lvf-RH	6	0.01	0.97	1.06	0.60	0.06	.08

[a] Similarity
[b] Point Estimator
[c] Response time, logarithmically transformed
[d] Confidence interval. A value ≥ 1 in the upper limit indicates that the confidence interval includes the Similarity value of 1.
[e] Point Estimator divided by standard deviation of the residuals. A negative effect size denotes a decrease in response times, that is, a positive priming effect.
[f] Right visual field – Left Hemisphere
[g] Left visual field – Right Hemisphere

In the analysis of RTs, again none of the confidence intervals were significant. Effect sizes showed small negative effects for rvf-LH targets (Similarity value 4: -.09, Similarity value 6: -.15), indicating a small reduction in RT with increasing similarity (priming). Power to detect these effects was low (.03). For lvf-RH targets, effect sizes showed a very small positive slope (Similarity value 4: -.04, Similarity value 6: -.06). Because the contrasts for Similarity values of 6 were not significant and showed only small effect sizes, the follow-up 3-way ANOVA was not carried out.

4.3.2. Experiment 2

First, AIC values were compared between the continuous and dichotomous models. In the AIC measure, absolute values are can range widely (between values in the hundreds and in the hundred thousands) and are meaningless. Instead, differences between AIC values are interpreted, and a model with a lower AIC value should be preferred over a model with a higher AIC value. Unfortunately, there are no exact guidelines how to interpret AIC differences. According to Burnham and Anderson's (2004) rule-of-thumb, differences up to 2 are not meaningful, and differences of 4 and higher show a clear meaningful difference.

In Experiment 2, the AIC values for the continuous and dichotomous models for the accuracy analysis were 10,398.0 and 10,398.8, respectively. Thus, the value for the dichotomous model was 0.8 lower, which is probably not a meaningful difference. In the RT analysis the value for the continuous and dichotomous models were -2,198.4 and -2,201.5, respectively. In this case, the value for the continuous model was lower by 3.1, which likely reflects a meaningful effect. Therefore the continuous model was considered to be the better model overall, and was chosen for interpretation.

4.3.2.1. Estimation of coefficients

In Experiment 2, meaning dominance, relatedness, and visual field were used for fixed effects estimation. Dominance was a continuous variable ranging from .1 to .97. Random effects were estimated for participants and targets. Because related and unrelated targets were the same words, targets instead of items were used for the random effect. Target Imageability, Frequency, Length in Letters, Length in Syllables, and their interactions with Visual Field were entered as "nuisance" variables.

The crucial estimations in all analyses were the coefficients for Relatedness (priming), the interaction between Relatedness and Dominance, the interaction between Relatedness and Visual Field, and the three-way-interaction between Relatedness, Dominance, and Visual Field. Visual Field and Relatedness were entered as dummy variables, with rvf-LH and lvf-RH coded as 1 and 0, respectively, and related/unrelated coded as 1 and 0, respectively.

4.3.2.1.1. Accuracy Analysis

The only significant coefficient for the effects of interest was the one for the interaction between Relatedness and Dominance (Table 22). The positive coefficient indicated that as dominance increased, the priming effect increased. This effect did not interact with Visual Field. The coefficients for Imageability, Length of Letters, and Frequency were significant, and reflected the same effects as Experiment 1. Furthermore, the coefficient for Visual Field was marginally significant. This positive coefficient reflected an increase of accuracy for rvf-LH targets compared to lvf-RH targets. The one other significant coefficient was that for the interaction of Imageability and Visual Field. This positive coefficient indicated that the slope of the imageability effect was steeper for lvf-RH than for rvf-LH targets, that is, the imageability effect was stronger for rvf-LH targets. The negative coefficient for the interaction of Frequency and Visual Field was marginally significant, reflecting an attenuation of the frequency effect for rvf-LH targets compared to lvf-RH targets.

Table 22 Estimated coefficients for accuracy analysis, Experiment 2

	Estimated Coefficient	Standard Error	Z-Value	P-values
Intercept	-0.81325	0.973811	-0.8351	0.40
Relatedness	***0.01978***	***0.114799***	***0.1723***	***0.86***
Dominance	0.136726	0.292001	0.4682	0.64
Imageability	0.220547	0.065009	3.3926	0.00
Length in Letters	-0.28416	0.105293	-2.6988	0.01
Frequency	0.23066	0.054332	4.2454	0.00
Length in Syllables	-0.07502	0.170865	-0.4391	0.66
Visual Field	1.168311	0.644059	1.814	0.07
Relatedness by Dominance	***0.458288***	***0.212545***	***2.1562***	***0.03***
Relatedness by Visual Field	***-0.04242***	***0.176119***	***-0.2409***	***0.81***
Dominance by Visual Field	0.146341	0.235339	0.6218	0.53
Imageability by Visual Field	0.089251	0.041347	2.1586	0.03
Length in Letters by Visual Field	-0.00695	0.071533	-0.0972	0.92
Frequency by Visual Field	-0.05997	0.036146	-1.6591	0.10
Length in Syllables by Visual Field	-0.04963	0.106728	-0.465	0.64
Relatedness by Dominance by Visual Field	***0.139736***	***0.335529***	***0.4165***	***0.68***

Table 23 Estimated coefficients for response time analysis, Experiment 2

	Estimated Coefficient	Standard Error	Degrees of Freedom	T-Value	P-Value
(Intercept)	6.8434	0.0864	8053	79.171	0.00
Relatedness	***-0.0057***	***0.0132***	***8053***	***-0.432***	***0.67***
Dominance	-0.0586	0.0272	8053	-2.153	0.03
Imageability	-0.0183	0.0058	8053	-3.150	0.00
Length in Letters	0.0247	0.0092	8053	2.683	0.01
Frequency	-0.0278	0.0048	8053	-5.832	0.00
Length in Syllables	-0.0032	0.0153	8053	-0.210	0.83
Visual Field	-0.0573	0.0572	8053	-1.002	0.32
Relatedness by Dominance	***0.0057***	***0.0233***	***8053***	***0.243***	***0.81***
Relatedness by Visual Field	***0.0050***	***0.0175***	***8053***	***0.288***	***0.77***
Dominance by Visual Field	0.0430	0.0229	8053	1.877	0.06
Imageability by Visual Field	-0.0086	0.0039	8053	-2.189	0.03
Length in Letters by Visual Field	-0.0038	0.0060	8053	-0.631	0.53
Frequency by Visual Field	0.0020	0.0032	8053	0.631	0.53
Length in Syllables by Visual Field	0.0006	0.0105	8053	0.057	0.95
Relatedness by Dominance by Visual Field	***-0.0429***	***0.0310***	***8053***	***-1.385***	***0.17***

4.3.2.1.2. Response Time analysis

None of the coefficients for the crucial interactions were significant (Table 23). The coefficient for the main effect of dominance was significant, and the interaction of Dominance and Visual Field was marginally significant. The coefficient for the main effect was negative, indicating that RTs decreased as dominance increased. It is important to note for the purpose of analysis, the same dominance values were entered for related and unrelated prime-target pairs in the Dominance variable, and reflects some other effect that happens to co-vary with Dominance. Other significant coefficients were those for the main effects of Imageability, Length in Letters, Frequency, and the interaction of Imageability and Visual Field. All of these coefficients indicated the same effects as in previous models.

4.3.2.2. Point estimators

In Experiment 2, priming effects were estimated for low- and high-dominance conditions at pre-specified dominance values of 1 and .84, respectively (see Section 3.4.). Because this experiment included related and unrelated prime-target pairs, point estimators for these priming effects were calculated as linear contrasts between the related and unrelated conditions. Relatedness was set to 0 (unrelated) or 1 (related) for all crucial coefficients, separately for each visual field condition. Thus, a contrast value of 0 was equivalent to no priming.

Again, for each point estimator of a priming effect, confidence intervals, p-values, effect sizes, and *post-hoc* power were calculated for the accuracy and RT models. All calculations followed the same procedures as described for Experiment 1. Tables 24 and 25 present the results of these calculations.

In the accuracy analysis, confidence intervals were significant, that is, they did not include 0, for rvf-LH and lvf-RH targets at a dominance value of .84. Effect sizes for these significant effects were small: .27 and .22 for rvf-LH and lvf-RH targets, respectively, and indicated that priming increased with dominance. Post-hoc power for these effects was high (.95 and .97, respectively). Effect sizes showed no indication of the priming effect at a dominance value of 0.1 (Effect sizes of .02 and .04, for rvf-LH and lvf-RH targets, respectively).

Table 24 Results for point estimators, accuracy analysis, Experiment 2

Visual Field	Dom [a] Value	PE [b] (logit)	PE (odds ratio)	CI [c] Lower Limit (odds ratio)	CI Upper Limit (odds ratio)	P-Value	Effect Size (PE logit/ 1.81)	Power (post-hoc)
Rvf-LH [d]	.10	0.04	1.04	0.83	1.30	0.74	0.02	.05
Rvf-LH	.84	0.48	1.62	1.24	2.10	0.00	0.27	.95
Lvf-RH [e]	.10	0.07	1.07	0.88	1.29	0.50	0.04	.10
Lvf-RH	.84	0.40	1.50	1.22	1.84	0.62	0.22	.97

[a] Dominance
[b] Point Estimator
[c] Confidence interval. A value < 1 in the lower limit indicates that the confidence interval includes the priming effect of 0.
[d] Right visual field – Left Hemisphere
[e] Left visual field – Right Hemisphere

In the response time analysis, the only significant confidence interval was the one for rvf-LH targets at a dominance value of .84. Again, the effect size was small (-.16), and indicated that priming increased with dominance. Post-hoc power for this effect was high (.92). Effect sizes for the other conditions showed no indication of the priming effect (rvf-LH, dominance value .1: -.02; lvf-RH, dominance value .1: -.03, dominance value .84: .00).

Table 25 Results for point estimators, response times analysis, Experiment 2

Visual Field	Dom[a] Value	PE[b] (logRT[c])	CI[d] Lower Limit (relative change)	CI Upper Limit (relative change)	P-Value	Effect Size (PE/SD residuals[e])	Power (post-hoc)
Rvf-LH[f]	.10	0.00	0.98	1.02	0.66	-0.02	.07
Rvf-LH	.84	-0.03	0.95	0.99	0.00	-0.16	.92
Lvf-RH[g]	.10	-0.01	0.97	1.02	0.65	-0.03	.07
Lvf-RH	.84	0.00	0.98	1.02	0.93	0.00	.03

[a] Dominance
[b] Point Estimator
[c] Response time, logarithmically transformed
[d] Confidence interval. A value ≥ 1 in the upper limit indicates that the confidence interval includes the Similarity value of 1.
[e] Point Estimator divided by standard deviation of the residuals. A negative effect size denotes a decrease in response times, that is, a positive priming effect.
[f] Right visual field – Left Hemisphere
[g] Left visual field – Right Hemisphere

4.3.2.3. Effects of prime lexical variables

Accuracy and RT data were re-analyzed in two separate analyses, using prime Number of Noun/Verb Meanings and prime Imageability as additional co-variates. Confidence intervals in both models were the same to two decimals than in original models, and effect sizes for accuracy (ratio of point estimator and 1.81) and RT (d) also did not differ. Therefore, these two prime lexical variables did not influence priming effects.

4.3.3. Summary of main results

For Experiment 1, which addressed the effect of semantic similarity on priming, none of the estimated contrasts were significant. Observed priming effects had small effect sizes: in the high-similarity condition for lvf-RH targets in the accuracy analysis, and for rvf-LH targets in the response time analysis. For Experiment 2, which addressed the effect of dominance on priming, accuracy analysis showed significant estimated contrasts for high-dominance targets, regardless of Visual Field. Analysis of RTs showed significant estimated contrasts only for high-dominance targets presented to the rvf-LH.

In Experiment 2, small effect sizes from about 0.2 to 0.15 resulted in significant estimated contrasts. This was not the case in Experiment 1, where the confidence intervals were considerably larger. The reason for this difference lies in the number of observations: because of the experimental design, twice as many observations were entered into the analysis for Experiment 2 than for Experiment 1. This difference in number of observations was reflected in the results of the post-hoc power analysis: Priming effects in Experiment 1 had low power (.21 and .30), whereas priming effects in Experiment 2 exhibited high power (.92, .95, and .97)

Based on the estimated coefficients, main effects for Visual Field were not significant in the response time analysis, and only marginally significant in accuracy analysis. The rvf-LH advantage for word recognition is very strong, and when it is not found in DVF priming studies it raises a red flag. However, in this case the lack of a significant effect is due to the nuisance variables that were entered into the model. Without these variables, the Visual Field effect is highly significant.

The main effects of the lexical characteristics observed for the estimated coefficients reflected well-known effects: a decrease in performance with increasing imageability and frequency. In Experiment 2, the coefficient for the interaction of Imageability and Visual Field was significant, reflecting an increase in the imageability effect for rvf-LH targets.

5. DISCUSSION

Two DVF paired word priming experiments investigated effects of meaning similarity and meaning dominance on priming for targets presented to the rvf-LH. This section discusses the interpretation and implications of the results of these two experiments, and suggests avenues for further research. The first two subsections present the interpretation of divergent results in RT and accuracy measures and the interpretation of significance tests and effect sizes. The next subsection discusses the results with respect to each study's specific research questions and suggests follow-up studies to better address a subset of the research questions. The final subsections outlines avenues of investigation beyond the specific research questions asked in this study.

5.1. INTERPRETATION OF ACCURACY AND RESPONSE TIME

Most experiments in cognitive psychology use both accuracy and RT as dependent variables when participants' responses are measured, but RTs are usually of primary interest because they tend to be more sensitive, including to hemispheric differences in word and letter recognition (Young, 1982; Babkoff, Genser, & Hegge, 1985). However, DVF priming studies show variable error rates. If error rates are too high, too much data is lost, and even correct responses will include many guesses; therefore, RTs are not interpretable (Hellige et al., 1986). Conversely, if accuracy is too high, it is not a sensitive measure of cognitive processes. While this relationship between accuracy and RT is generally accepted, it is not clear at what cut-off points in accuracy one can decide which of the two measures is more sensitive.

Of the nine DVF studies reviewed above, five report complete accuracy analyses (Atchley et al., 1999; Atchley et al., 1996; Chiarello et al., 1992; Hasbrooke et al., 1998; Anaki et al., 1998). In no study did the results for accuracy match those for RT. (Nor did accuracy and RT results match in the present study.) In these five studies results are interpreted based on the implicit assumption that the most sensitive measure for priming is the one that shows most interactions. However, evidence from two studies of visual recognition and attention (Santee & Egeth, 1982; Prinzmetal, McCool, & Park, 2005) suggest that interpretation of divergent results in accuracy and RT might not be that straightforward. The authors concluded that in their two studies divergent RT and accuracy results reflected that these two measures can be differentially sensitive to perceptual and postperceptual processing stages, respectively.

In both studies these results occurred under data-limited conditions, that is, conditions in which stimuli were presented so they were difficult to detect. The fact that accuracy is lower in priming studies with DVF compared to central presentation means that DVF presentation is a data-limited condition. Therefore, the possibility exists that in DVF studies RT and accuracy reflect different stages of the word recognition process, which could potentially have differential effects on the magnitude of the observed priming. Unfortunately, at this point it is impossible to say whether this is the case, or what such differential effects could be, but these results suggest that divergent results for RT and accuracy need to be interpreted carefully.

If the results of Experiment 1 and 2 are interpreted with the assumption that the most sensitive measure for priming is the one that shows most interactions, it would follow that Experiment 1 shows small but non-significant priming effects for high-similarity targets presented to both visual fields, and that Experiment 2 shows significant priming effects for high-dominance targets presented to the rvf-LH. However, as discussed above, it is questionable that this assumption always holds, and a closer look is warranted.

In Experiment 1, rvf-LH targets showed a small non-significant priming effect in effect size magnitude for high-similarity stimuli in the RT analysis ($d = .15$), but no effect was evident in the accuracy analysis ($d = -.02$). This condition had the highest accuracy rate of all conditions (88%), and thus was the condition in which accuracy had the lowest sensitivity to priming. However, studies with comparable accuracy rates of 86% and 85% (Chiarello et al., 1990; Hasbrooke & Chiarello, 1998), respectively, showed significant accuracy priming. It is possible that in these studies effect sizes were larger than in the current study. In that case, the magnitude of the priming effect in this study might have been too small to be detected with the sample size enrolled.

For lvf-RH targets, accuracy analysis showed a statistically nonsignificant, but modest (d=.20) priming effect. In the RT analysis, there was a tiny effect of negative priming ($d = -.06$), that is, priming slightly decreased with an increase in similarity. This effect reflects a small speed-accuracy tradeoff ($r = .25$). It is unlikely that this effect is meaningful, and even if it were to reflect a speed-accuracy tradeoff, it would only account for 5% of the variance. Therefore, it is unlikely that lack of RT priming can be accounted for by such a tradeoff. Thus, the question remains why no positive RT priming effect was evident. Atchley and colleagues (Atchley et al., 1999) found significant RT priming at accuracy rates of 72% for effect sizes of $d = .33$ and .25. Therefore, the effect size priming results for lvf-RH targets in Experiment 1 are difficult to interpret.

In Experiment 2, results for rvf-LH targets were straightforward because both accuracy and RT data showed significant priming for high-dominance targets. Conversely, results for lvf-RH targets were conflicting because only accuracy data showed significant priming, and there was no evidence for priming in the RT results (effect size: $d = .00$). However, in this condition the mean accuracy rate was very low (65%). Thus, it is quite safe to assume that in this condition RT results were not sensitive to priming, and accuracy priming can be interpreted as the underlying priming effect.

Based on this discussion, the results of this study can be stated as follows. Experiment 1 showed a small and non-significant priming effect for rvf-LH targets, and a questionable small and non-significant priming effect for lvf-RH targets. Experiment 2 showed significant priming for high-dominance targets in both visual fields. The next section will discuss these results with respect to significance testing, effect sizes, and interpretation of small effects.

5.2. SIGNIFICANCE TESTS, EFFECT SIZE MAGNITUDE, AND SMALL EFFECTS

The results section reported both significance tests and effects sizes. The meaningfulness of significance tests on the one hand, and estimation of effect size magnitude on the other hand are matter of intense debate (e.g., Chow, 1998 and commentaries; Rosenthal & DiMatteo, 2002), and only very few of the issues involved will be addressed here. One problem with significance tests is the need for a strict cutoff. Specifying an alpha level of .05 a-priori helps prevent bias in the data interpretation. On the other hand, any cutoff is arbitrary. Accepting a null hypothesis because the p-value is .06 can easily result in losing important study results. Thus, significance tests are meant to minimize the probability of a Type I error, that is, falsely rejecting a null hypothesis when it is true, but they do not prevent Type II errors, that is, failing to reject the null hypothesis when it is not true. In such a case, effect sizes can provide additional information that would be lost if only significance was considered.

Interpretation of the meaningfulness of effect size magnitudes always depends on the effect under investigation. Cohen (1988) proposed rules-of-thumb to interpret effect size measures in the social sciences as small, medium, and large: correlations: .1, ;3, and .5, and d (difference of means/standard deviation): .2, .5, and .8, respectively. The problems with these rules are similar to those of cut-offs for significance values. Any cutoff is, to a certain extent, arbitrary. Considering a d of .19 to be irrelevant again might lead to losing important information. On the other hand, very small effect sizes are likely to be meaningless, and can also easily be spurious.

In the case of semantic priming studies, what effect sizes should be considered meaningful? As discussed and Section 2.3.2, study characteristics and analysis procedures affect calculated priming effects and/or observed variance, which can result in widely differing effect sizes that might reflect the same underlying priming effect. Furthermore, while in medical studies effect sizes can be linked to a direct clinical outcome (e.g., number of deaths), for semantic priming it is not clear what the magnitude of the priming effect reflects in terms of the magnitude of effects in the underlying processes, and it is difficult to determine an a-priori cutoff criterion at which effect sizes become meaningless. Therefore, individual effect sizes from a single semantic priming study are difficult to interpret in themselves. However, interpretation can become more meaningful when effect sizes can be compared between studies, if enough comparative data are available. For the effects investigated in this experiment, comparative data was quite limited. Therefore, while this discussion interprets effect sizes in the context of those from related studies, it needs to be kept in mind that due to data restrictions these effect sizes reflect only imprecise estimates of the effect under investigation.

In Experiment 1, none of the significance tests for the confidence intervals for high- and low-similarity items was significant. Therefore, results of the significance tests reflected a priming pattern of *no priming*, that is, priming for neither high- nor low-similarity targets was different from zero. However, effect sizes for priming effects in Experiment 1 were similar to those in Experiment 2, which had significant confidence intervals. The post-hoc power analysis suggests that the lack of significant priming effects in Experiment 1 can be attributed to a lack of power.

The observed effect sizes in both experiments were small. The effect sizes in Experiment 1 (d = .20 for rvf-LH high-similarity accuracy results, and d = .15 for lvf-RH high-similarity RT results) and Experiment 2 (d = .22 and .27 for high-dominance accuracy for rvf-LH and lvf-RH targets, respectively, and d = .16 for rvf-LH high-dominance RT priming) were in the range of those for lvf-RH weak associates (d = .17) in Nakagawa's (1991) study and for rvf-LH dominant targets (d = .23) in the study by Atchley and colleagues (Atchley et al., 1999). In the latter study the dominant prime-target pairs were main features of the prime, but weakly associated; therefore, they can also be considered weakly related. Thus, contrary to the intentions of the study design, the effect sizes in Experiment 1 and Experiment 2 were at the same level as other priming effects for weak prime-target relationships.

There are two possible reasons why effect sizes were so low. First, as was discussed in Section 2.3.2., specific characteristics of task or procedure can influence how sensitive a task is to priming effects. It is possible that some aspect of the procedure in this study made it less sensitive to priming, so that the only priming effects that emerged were those that would be expected to be the strongest effects. The priming effects reflected in effect sizes are consistent with that possibility (see below). Second, it is possible that the level of similarity for the "highly" similar prime-target pairs in both studies was in fact not very high. The next two subsections examine these two possibilities in more detail.

5.2.1. Small priming effects: procedural considerations

While the overall procedure for stimulus presentation is very similar between extant DVF studies, they differ in several presentation characteristics: length of prime, use of a mask after the prime, display of fixation cross through the prime, length and eccentricity[30] of the target. Given that the specific presentation parameters chosen for this study were within the range of those in the other studies, there is no reason to assume that one of these presentation characteristics reduced sensitivity to priming, compared to the other studies. However, there are other details to stimulus presentation that are generally not reported or controlled in sufficient detail to allow comparison between studies, for example, contrast, the choice of lower-or upper-case letters, or the choice of font. These factors could affect the degree of degradation or discriminability for stimuli. Therefore, it is cannot be ruled out that some unknown factor reduced sensitivity to priming in this study.

One procedural difference between this and the other studies was the use of fixation control trials. The fixation control task could have influenced results in two ways. First, the use of fixation control trials introduced a second task. Participants required probably more processing resources because they had to keep both responses in working memory. Reduced working memory capacity can impair the ability to keep competing word meanings activated (Miyake, Just, & Carpenter, 1994); therefore, it is possible that any reduction in working memory could reduce sustained activation of instantiated representation of word meanings. However, it is difficult to know what the extent of this effect could be. Consequently, interference of the fixation control trials with sensitivity of priming cannot be ruled out as a reason for the low priming effects, but this reason has to remain a speculation.

The second possible influence of the fixation control procedure is that it ruled out a subset of participants that are included in the other studies. Based on this procedure, 4.2% of the data for Experiment 1 and 1.7% of the data for Experiment 2 were removed. For this data removal to result in less sensitivity to priming effects, one would have to posit that out of this small percentage of data, the subset of trials on which these participants showed gaze deviations would show such large priming effects as to influence the overall result. This is highly unlikely.

Another reason why this study might have been less sensitive to priming is that accuracy levels might have been just low enough for RT not to be a sensitive measure for priming, and but not low

[30] Degree of lateralization of target presentation varied between 1.4° to 3° of the visual angle.

enough for accuracy to be very sensitive, either. Again, this possibility is highly unlikely, given that between the two experiments accuracy levels in the different visual field conditions varied between 88% and 65%. Furthermore, other studies with similar accuracy levels show higher priming effects sizes than this study. For example, in Experiment 1 for high-similarity targets presented to the rvf-LH, accuracy was 88%, and the RT effect size was d = .15. In the study by Burgess and Simpson (1988), for dominant targets presented to the rvf-LH accuracy was 68% and the RT effect size was d = .55.

To summarize, it is possible that either some detail of the stimulus presentation or the inclusion of the fixation control task were factors that contributed to reducing the sensitivity to semantic priming in the two experiments of the study. However, available evidence does not allow identification of exactly what such a factor could have been, or the extent to which priming might have been affected.

5.2.1.1. Small priming effects: Prime-target relatedness

The methods to create the "highly" similar prime-target pairs for Experiment 1 and Experiment 2 followed in part procedures used by McRae and Boisvert (1998). They showed that the previous failure to find priming at short SOAs for non-associated prime-target pairs was due to the fact that the stimuli used in previous studies (Shelton et al., 1992; Moss et al., 1995) were not similar enough. McRae and Boisvert constructed a stimulus set in which prime-target pairs were significantly higher in similarity, compared to the pairs used in the other two studies.

McRae and Boisvert's stimuli were taken from a set of stimulus pairs for which participants had generated associated features, and McRae and Boisvert could rely on computed measures of feature similarity when selecting their stimuli. Because this study required that targets were short, it was not possible to use McRae and Boisvert's stimuli directly. Instead, it was attempted to match the similarity strength of high- and low- similarity levels used for the stimuli in this study to that of the stimuli of McRae and Boisvert. However, because of stimulus overlap between the two studies, stimulus strength ratings could only be obtained for 12 of the original 27 items, which makes the comparison dubious. Furthermore, the average similarity value for high-similarity items in both experiments was 5.6, which might already be a meaningful difference from the targeted value of 6. Thus, it is quite possible that "highly" similar prime-target pairs were lower in similarity than McRae and Boisvert's.

Another reason why the priming effects were so small could be that this study, as opposed to McRae and Boisvert's study, controlled for lexical co-occurrence. If the priming effects in McRae and Boisvert's study derived in part from co-occurrence effects, smaller effects would be expected once co-occurrence effects are eliminated. Stimuli in Experiment 2 were not controlled for co-occurrence, and priming effects were similar to those of Experiment 1. This result might suggest that co-occurrence effects did not have a big impact on overall priming. However, this conclusion would only be true if priming levels in both experiments would be expected to be equal. Estimated effect sizes for the *a-priori* power analysis suggest that that might not be the case. Therefore, the small priming effects in Experiment 1 could also derive from the fact that stimuli were controlled for co-occurrence.

5.3. STUDY QUESTIONS

This section discusses the results with respect to the four study questions investigated in this study. It is concluded that the study could address the question of presence of pure semantic similarity priming effects and ambiguity priming effects, but could not address whether low-similarity or low-dominance relations are primed for targets presented to the rvf-LH. Changes to the study design that would make it more sensitive to these effects are suggested.

5.3.1. Experiment 1

Experiment 1 was intended to investigate the following research questions:

1. For targets presented to the rvf-LH, is priming at long SOAs predicted by differences in strength of semantic similarity once lexical-level effects are controlled for?
2. If so, are only meanings with high semantic similarity primed?

Based on the results of the significance tests for the confidence intervals, Experiment 1 showed a priming pattern of no-priming. Taken at face-value, this result would suggest that pure semantic relatedness does not induce priming for targets presented to the rvf-LH. If this were the case, semantic priming for rvf-LH targets observed in previous studies should have derived from relatedness based on association and/or co-occurrence alone, potentially reflecting pure lexical effects. This possibility is inconsistent with the standard model and Plaut's model, because it would suggest that LH processing does not mediate the processing of word meanings, but rather the processing of word forms.

However, this conclusion is unlikely to be correct because this experiment did not include enough observations and was underpowered. Therefore, effect size magnitudes can provide important further information. Based on the premise that the detected effects would be replicated as significant effects in a more powerful study, research question 1 could be answered "Yes". The results suggest that pure semantic relatedness predicts priming effects for targets presented to the rvf-LH, and that priming for such targets is not a purely lexical effect. This result indicates that LH processing supports sustained meaning activation for semantically similar words. Furthermore, this result corroborates previous evidence for pure semantic priming (Cree et al., 1999), and extends this finding to long SOAs.

Because the observed accuracy priming effect for lvf-RH targets is difficult to interpret, similar conclusions cannot be firmly drawn with respect to RH processing. However, the observed RT priming effect for rvf-LH targets was quite small. The previous section provided three possible interpretations for this result. First, some unknown characteristic of the procedure could have made the study less sensitive to semantic priming. In that case, only the largest priming effects would have been detected. Second, the stimulus validation procedure failed to create stimuli that were truly "highly" similar, and therefore this experiment tested priming for moderately/low-similarity and low/very low -similarity stimuli, instead of high- versus low-similarity stimuli. Third, controlling for lexical co-occurrence effects could have reduced overall priming levels. The implications of these three possibilities are discussed next, again under the assumption that the observed effect size priming effects could be replicated as significant effects in a more powerful follow-up study.

If it were true that the study was less sensitive to semantic priming for some procedural reason, no further conclusions could be drawn from the study. Research question 2 could not be addressed, and conclusions about the specific priming patterns for rvf-LH targets based on pure semantic similarity would require further research.

If it were true that this experiment actually measured less-than-high-similarity priming (possibility 2), study question 2 could be answered with a "No". The experiment would reflect the expected outcome: targets presented to the rvf-LH prime in low-similarity conditions, consistent with Plaut's model, and inconsistent with the standard model. Such an outcome would suggest that LH processing does not completely inhibit less-related meanings, and consequently, that LH processing does not have the function to narrow broader meanings to ‘lean’ or highly-focused representations.

Plaut's model and the standard model would also predict that low-similarity targets would prime when presented to the lvf-RH. The observed accuracy priming for lvf-RH targets in this experiment might reflect such an effect, but because of the divergent priming results for RT and accuracy in this condition the accuracy priming effect is not really interpretable.

If it were true that the small priming effects derived from eliminating priming due to lexical co-occurrence, and these prime-target pairs reflected high-similarity priming, results would suggest that pure semantic processing effects do not play a big role in semantic priming for LH processing. However, as discussed in Section 2.3.1, when association is removed from the prime-target relationship, higher levels of semantic relatedness might be excluded (McRae et al., 1998; Chiarello, 1998b). Therefore, while it is important to control for association and lexical co-occurrence to eliminate possible (known) sources of lexical priming, doing so makes it more difficult to test higher levels of semantic similarity. Therefore, the stimulus selection procedure made this study a good test for research question 1, but provided a weaker test for research question 2.

In sum, two main reasons might account for why this experiment resulted in such small priming effects: procedural characteristics and a weaker-than-planned prime-target relationship. One way to determine how changes in procedure could improve sensitivity to priming effects would be to explore experimental procedures that improve response accuracy, because increased response accuracy would result in increased RT sensitivity. It is not necessarily intuitive which presentation characteristics lead to higher accuracy. For example, based on accuracy data from six DVF priming studies (Chiarello et al., 1990; Atchley et al., 1999; Burgess et al., 1988; Anaki et al., 1998; Hasbrooke et al., 1998; Nakagawa, 1991), accuracy correlates negatively with length of prime presentation, although one might have expected that an easier to perceive prime increases detectability for related targets. Of course, these studies do not provide enough data points to draw firm conclusions. Therefore, exploratory investigations are necessary to find ways to improve response accuracy in DVF priming studies.

To provide a better chance that study stimuli are sensitive to different levels of similarity priming, stimuli with higher semantic similarity need to be used, and more stimuli need to be included. One possibility to achieve higher similarity between primes and targets would be to use prime-target pairs that are synonyms or nonassociated antonyms, because these should reflect the highest achievable level of semantic similarity. If such stimuli would still result in small priming effects, it could be concluded that semantic similarity only makes a small contribution to observed priming effects for rvf-LH targets, and that priming is driven mainly by association and/or lexical co-occurrence.

To conclude, results from Experiment 1 showed no significant priming effects, but effect size analysis showed small effects consistent with the hypothesis that semantic similarity predicts priming for targets presented to the rvf-LH. Because of the small priming effects, presence or absence of priming for low-similarity targets could not be evaluated conclusively. It is suggested that follow-up studies investigate how experimental procedures can improve accuracy rates in DVF presentation. Furthermore, follow-up studies should use prime-target pairs with higher semantic similarity.

5.3.2. Experiment 2

Experiment 2 was intended to investigate the following research questions:

3. For targets presented to the rvf-LH, is priming at long SOAs predicted by differences in meaning dominance once strength of semantic relatedness controlled for?
4. If so, are only meanings with high meaning dominance primed?

As expected, significant priming effects indicated high-dominance priming for rvf-LH and lvf-RH targets. Thus, research question 3 can be answered "Yes". The study outcome ruled out the hypothesis that dominance effects are based on effects of strength of relatedness for LH or RH processing. However, because the magnitude of priming effects was small, priming patterns for low-relatedness targets could not be evaluated in this study; therefore, research question 4 could not be addressed.

Research question 4 was motivated by the hypothesis that previous findings of complete inhibition for subordinate meanings in priming studies using central and rvf-LH target presentation might be due to an interaction of low prime dominance with low prime-target relatedness. This study used non-associated prime-target pairs, because once association is used to define prime-target relatedness, the confound between strength of relatedness and dominance cannot be avoided.

If it is true, as explored in the previous section, that prime-target pairs in this study failed to be highly similar, this study was an inadequate test of research question 4. Thus, a follow up study should use stimuli with the highest possible degree of similarity while avoiding association. Again, one possibility for such stimuli might be synonyms or nonassociated antonyms. If such a study would not find priming for subordinate meanings, it might still be the case that inhibition for subordinate targets might derive from an interaction of dominance and relatedness. However, the distinction between the two factors would become irrelevant. Rather, associative relatedness between word meanings should then be considered to be one aspect of meaning dominance.

Finally, priming was not observed for low-dominance targets presented to the lvf-RH. Such priming would have been predicted by the standard model and Plaut's model, and would have been consistent with the majority of the DVF studies investigating meaning dominance. Thus, results of this study appear to be inconsistent with either model. However, results of one of the DVF studies reviewed above (Burgess et al., 1998b) reflected a lower magnitude of priming for subordinate compared to dominant meanings for lvf-RH targets. If priming levels in the current study reflected such a priming differential between dominant and subordinate targets, it is unlikely that subordinate priming would have been detected, given the small priming effect for dominant targets. In addition, accuracy for lvf-RH targets was very low (65%), and accuracy overall might be a less sensitive measure of priming. Therefore, results of the study are not interpretable with respect to the question of priming for subordinate meanings of targets presented to the lvf-RH.

To conclude, Experiment 2 showed that dominance priming for rvf-LH and lvf-RH targets does not underlyingly derive from prime-target relatedness. However, because of the small priming effects more specific questions with respect to rvf-LH priming patterns could not be addressed. Furthermore, because of the small effects and low accuracy for rvf-LH target priming, the lack of priming for low-dominance targets is not interpretable. Overall, however, the results are consistent with the hypothesis that LH processing has strong bias to select meanings so that only coherent and compatible instantiated representations are sustained.

5.3.3. Avenues of further research

This study investigated semantic effects on word priming in LH processing. As presented in the previous section, the study could only address two of the four research questions posed, and follow-up studies were suggested to further investigate the question of low-similarity priming and low-dominance priming for targets presented to the rvf-LH. However, even if such studies could provide more conclusive evidence, such data would provide only a small piece in the overall puzzle. This section discusses further areas of research for the basic questions that motivated the study.

A primary motivation for this study was the question to what extent lexical and semantic factors contribute to hemispheric differences in word priming effects. This study focused on investigating pure semantic priming, that is, priming for stimuli for which lexical effects were excluded. However, as is outlined in Section 2.3.1., for a more complete understanding of how lexical and semantic effects contribute to semantic priming, a better understanding of lexical factors in priming and their interaction in the associative priming effect is needed. As a first step, further research should clarify to what extent lexical co-occurrence contributes to semantic priming, and whether such contribution derives from absolute or relative co-occurrence.

Correlating measures of association with both types of co-occurrence can provide some evidence to address these questions, but such an investigation should be followed up by studies that experimentally separate out these two factors, for example, by comparing the magnitude of priming effects for associated prime-target pairs that do not co-occur with matched associated prime-target pairs that co-occur. These investigations still need to be conducted for central prime-target presentations before specific hemispheric effects can be investigated.

As discussed in Section 2.2.1., because effects investigated with DVF presentation are so susceptible to factors like arousal, attention, stimulus presentation, and task conditions, they require replication, also through the use of other methods like fMRI, ERP with source localization, or MEG. Furthermore, these techniques are crucial when investigating finer-grained functional distinctions for hemispheric contributions to word semantic processing. Models proposing specific neurological networks for activation, maintenance, and selection of word meanings are being developed in the imaging literature (Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997; Wagner, Pare-Blagoev, Clark, & Poldrack, 2001; e.g., Jung-Beeman, 2005).

Because event related fMRI has allowed stimulus presentation in mixed rather than in blocked formats, fMRI has become more conducive to investigating priming effects, and more studies of semantic priming are beginning to emerge (Rossell, Price, & Nobre, 2003; Gitelman, Nobre, Sonty, Parrish, & Mesulam, 2005; Matsumoto, Iidaka, Haneda, Okada, & Sadato, 2005). To the knowledge of this author, no studies are available that have addressed effects of degree of relatedness on priming, or investigated to what extent semantic priming is a lexical or semantic effect. Furthermore, studies of lexical ambiguity resolution and processing of metaphor versus literal meanings, which have used semantic priming designs with sentence context, provide conflicting results as to hemispheric contributions to these effects (Mashal, Faust, & Hendler, 2005; Rodd, Davis, & Johnsrude, 2005; Lee & Dapretto, 2006).

Again, to the knowledge of this author, semantic priming has not been investigated with MEG, but studies of semantic priming using ERP with source localization are beginning to appear in the literature (Frishkoff, Tucker, Davey, & Scherg, 2004). Because these methods combine millisecond temporal resolution with source localization techniques, they have the potential to become powerful tools for investigating the specific contributions of lexical and semantic processes to priming, and for exploring their underlying neurological networks.

A better understanding of these processes and their underlying functional networks might aid in reconciling current inconsistencies between studies using participants with acquired brain lesions and models of word semantic processing developed on the basis of the DVF and imaging literature (Bates et al., 1999; Tompkins et al., 2000; Grindrod & Baum, 2005; Scharp, Tompkins, Fassbinder, & Meigh, 2006). As long as these literatures are inconsistent, gaps in our understanding of cognitive processes, the functional networks that support them, and/or the effects of lesions on these networks and processes will remain.

Another way to develop alternative hypotheses and test computational assumptions of models of hemispheric contributions to semantic priming is to develop computational models. A recently developed connectionist model (Monaghan, Shillcock, & McDonald, 2004) investigated the effect of split foveal vision on semantic priming, and specifically the effects of meaning dominance and degree of relatedness in summation priming. The authors concluded that observed hemispheric differences could at least in part result directly from self-organizing properties of the connectionist model when inputs are split over two input layers. This result suggests that representational differences as proposed by Beeman (2005) and Plaut (personnel communication, April 9, 2002) might not be necessary for hemispheric differences to emerge. This line of research could be extended, for example, to compare models with and without assumed representational differences between the two hemispheres. Furthermore, computational models can model effects of lesions, which again can be a valuable source in generating hypotheses with regard to the effects of lesions on performance (Plaut, 1996).

6. CONCLUSION

In two DVF experiments, this study investigated semantic aspects of word priming mediated by LH processing. More specifically, effects of meaning similarity and meaning dominance were studied. There was no significant effect for semantic similarity. However, a post-hoc power analysis suggests that this result was due to a lack of power, and effect size results are consistent with a small similarity priming effect mediated by LH processing. Furthermore, results showed significant dominance priming, indicating that dominance effects are supported by LH processing. The experiments could not shed light on more specific questions about priming patterns for similarity and dominance.

Results of both experiments were consistent with the proposal that LH processing focuses word meanings to unambiguous and compatible interpretations, but does not narrow meanings in general by fully inhibiting less related meanings, consistent with Plaut's model. At the same time, because of the small priming effects, the experiment could not provide much positive evidence for this view. Further research is needed to evaluate the validity and generality of such a bias for LH (versus RH) processing.

The investigation of semantic processing effects on semantic priming is an important step in building models of comprehension, because activation of word meanings provides the basic building blocks of comprehension from which sentence and discourse meanings are derived. Furthermore, word meaning processing might reflect more general aspects of comprehension processes, both in term of the functional properties of meaning processing (e.g., the interplay of activation and inhibition in meaning maintenance and selection), and in terms of neurological networks underlying these processes. Therefore, research on meaning processing on the word level can provide important insights to comprehension processes in general, and research at the word level has the advantage of being easier to control than on sentence or discourse levels.

For a better understanding of the processes that underlie word meaning activation, the separate contributions of semantic and lexical processing need to be further understood. Furthermore, the models of hemispheric differences in lexical semantic processing derived from DVF studies suggest that the two cerebral hemispheres support different processing systems that play separate and interacting roles in word meaning activation, maintenance, and selection. Extending this research to investigate finer-grained neurological networks will likely provide further insights into the underlying processes of comprehension, and might help to develop a better basis for understanding disorders of comprehension.

APPENDIX A

VALIDATION STUDY

A.1 OVERVIEW

The validation study included five different tasks that validated the stimuli according to their selection criteria outlined in Section 3.2.2.

A.1.1 Tasks

In the first two tasks, Meaning Generation and Meaning Count, participants generated word meanings to stimuli presented in a word list, and another set of participants categorized the generated meanings into distinct meanings. These tasks served to identify words that have only one or possibly very highly overlapping meanings, and were the first two steps in validating unambiguous Related primes. In the third task, Similarity Judgments for Prime Meanings, participants judged the degree of similarity between meanings of potential unambiguous and ambiguous primes. This task identified unambiguous words that had senses with such high meaning overlap that they could be still considered to be unambiguous, and was the final step in the validation of unambiguous Related primes. Furthermore, the task validated that the meanings of the ambiguous Related primes were highly dissimilar and non-overlapping.

In the fourth task, Similarity Judgments for Prime-Target Pairs, participants judged the degree of meaning similarity between primes and targets. This task served to validate the similarity criteria. Furthermore, participants indicated whether they knew the intended meanings of ambiguous primes.

Thus, the task was used to validate the recognition criterion for the ambiguous primes. In the fifth task, Imageability Ratings for Ambiguous Word Meanings, imageability ratings for the two relevant meanings of the ambiguous Related primes were obtained for each targeted meaning for which norms were not available. In the last task, Imageability Ratings for Single Word Meanings, such ratings were obtained for the unambiguous primes and all targets. Furthermore, "Know/don't know"-judgments generated in this task were used to validate the recognition criterion for these stimuli.

A.1.2 Participants

There were two groups of participants for the different stimulus validation tasks. The first group consisted, with three exceptions, of graduate students or individuals with a graduate degree, and all participants were native speakers of English. This group will be referred to as Group 1. Participants from this group took part in tasks that were preparatory and/or required more complex metalinguistic judgments: Meaning Generation, Meaning Count, Imageability Ratings for Ambiguous Word Meanings[31], and Similarity Judgments for Prime Meanings. Twenty-six people participated in Group 1 piloting, several of them more than once, and in more than one task. Of these participants, 18 were female and 8 were male. They have an average age of 28 (range 22-36), and an average education of 20 years (range 14-28).

The second group, which will be referred to as Group 2, consisted of undergraduate students with the same demographic characteristics as the ones described for the participants in the proposed experiment, except that the validation participants were not specifically tested for visual acuity, were not necessarily right-handed, and complete gender balance was not attempted. Many of the students in Group 2 participated in two tasks: Imageability Ratings for Single Word Meanings and Similarity Judgments for Prime-target Pairs. Overall, 97 undergraduate students have participated, 80 female and 17 male.

A.1.3 Procedure

All stimuli were based on the criteria listed above. In all rating tasks most of the instructions, all practice items, and all experimental items were presented to participants through display on a computer screen with E-prime software (Schneider, Eschman, & Zuccolotto, 2002). In Meaning Generation and

[31] This task still requires judgments for 4 ambiguous dissimilar primes. These will be carried out by individuals who have already been part of this validation task.

Meaning Count, additional instructions were presented verbally. Stimuli appeared above the center of the screen. For ambiguous words in Group 1 validation tasks, meaning cues were displayed underneath the stimuli. In the lower half of the screen a rating scale from 1-7 was displayed, with the extreme values marked as "high" and "low." The same rating scale was used for imageability and meaning similarity ratings. All stimuli were presented in random order. Participants were tested either in the investigator's advisor's lab, or in some cases at locations convenient to them, for example, at their homes or at a coffee shop.

To eliminate data from participants who misunderstood the task or rated in a way inappropriate for the task for some other reason, an outlier criterion was established for the rating tasks. First, the difference between a participant's rating and the mean rating was calculated for each item. These differences from the mean ratings (DMR) were averaged for each participant, and outliers were determined for these DMR averages. Data of participants were excluded from further analysis if their DMR average was equal to or higher than the median +/- 5.2 the median absolute deviations (MAD) of the DMR averages[32]. Another issue of concern for the rating tasks is the accuracy of the average ratings. Therefore, a 95% confidence interval was calculated for the average rating of each item, and the average of these confidence intervals over all items will be reported for each task.

A.2 MEANING GENERATION

A.2.1 Participants and stimuli

Two groups of five participants from Group 1 completed this task with two different word lists (Lists MG-1 and MG-2). Table 26 presents the demographic data of the participants.

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[32] The MAD is calculated as the median absolute value of the differences of individual values from the median. Given a normal distribution, 5.2 MAD is equivalent to a criterion of 3.5 standard deviations (Davies, 2001), and it has the advantage that in contrast to mean and standard deviation, it is not affected and potentially skewed by outlying values. This criterion has been proposed by Hampel (1985), who showed it to be very effective for outlier elimination in simulation studies.

Table 26   Demographic data for Meaning Generation task

List	Male	Female	Age (SD) range	Education (SD) range
MG-1	2	3	28 (2.5) (25-32)	19 (3.4) (14-22)
MG-2	2	3	27 (3.7) (22-32)	20 (3.9) (16-25)

Stimuli consisted of unambiguous words, and ambiguous filler words. List MG-1 contained 45 words (33 unambiguous) and List MG-2 contained 38 words (28 unambiguous). Words were lowercase in List MG-1, and uppercase in List MG-2.

Table 27 List of stimuli for Meaning Generation Task (in order of presentation)

MG-1		MG-2	
Words	**Ambiguity**[a]	**Words**	**Ambiguity**
tiger	U	YOGURT	U
litter	A	LETTER	A
hive	U	PELICAN	U
moat	U	IGLOO	U
punch	A	TRIP	A
canoe	U	VILLAGE	U
lice	U	SCISSORS	U
beggar	U	WOOL	U
lapel	U	TUSK	U
show	A	FAN	A
bottle	U	RACCOON	U
breeze	U	HUSK	U
trombone	U	SHAMPOO	U
seal	A	MATCH	A
cabin	U	SPINACH	U
salmon	U	WIFE	U
rope	A	LOG	A
ball	A	BLUFF	A
dancer	U	SOOT	U
candle	U	TENNIS	U
dill	U	NAPKIN	U
ring	A	SWALLOW	A
bench	U	SQUID	U
donor	U	OCEAN	U
game	A	CRAFT	A
fur	U	STEEPLE	U
chimney	U	THIMBLE	U
gavel	U	HAYSTACK	U
hat	U	COFFIN	U
letter	A	MOLE	A
badge	U	TOMATO	U
ink	U	GROVE	U

Table 27 (continued)

second	A	BAT	A
ounce	U	TROUT	U
miss	A	CRATER	U
mirror	U		
cabbage	U		
beer	U		
pupil	A		
donkey	U		
poet	U		
cobra	U		
bark	A		
salad	U		
fog	U		

[a] U: unambiguous, A: ambiguous

A.2.2 Instructions

The written instructions (see below) included three explanatory examples, which consisted of a word with many meanings (“ground”), a word with few meanings (“park”), and a word with a single meaning (“cougar”). Participants were encouraged to ask questions.

INSTRUCTIONS:

Many words have more than one meaning. For example, the words "ground" or "park" could have the following meanings:

ground:
1. the surface of the earth
2. to crush into bits'
3. to punish by not allowing one to go out
4. the lowest part; the bottom
5. the conducting body connected to an electric circuit
6. the logical basis of the conclusion or action
7. to keep from flying.

park:
1. to leave the car in a designated place
2. an open area for public recreation

Other words have only one meaning:

cougar:
a wild animal, mountain lion

In this "Excel"-file you can find a list of about 50 words (+ the 3 examples given above). I would like you to read each word, and then type into the file each meaning that you can think of for that word. You can just follow the format of the examples. If you need more columns, just add them.

Thank you for your help!

A.3 MEANING COUNT

A.3.1 Participants and stimuli

Two sets of three participants from Group 1 categorized all meanings generated from List MG-1 and List MG-2. Stimuli (see Table 28) were presented on a paper form that listed each target word and all meanings generated by the participants in the Meaning Generation task.

Table 28 Demographic data for Meaning Count task

List	Rater	Gender	Age	Education
List 1&2	Rater 1	Female	23	18
List 1&2	Rater 2	Male	28	22
List 1	Rater 3	Female	35	19
List 2	Rater 3	Male	30	23

A.3.2 Instructions

Participants read the following instructions, and were encouraged to ask questions:

"I am giving you a list of words and their meanings, which were generated by 5 participants. I would like to judge how many distinct meanings are listed. Please use the definitions of senses provided by the Webster dictionary as your guide (I'll provide you with the website). That is, map the meanings provided by the participants on the Webster definitions. However, if a listed meaning is not in the Webster, but it makes sense to you, go with your intuition, and list it as a separate meaning."

A.3.3 Results

If all three judges for each List agreed that a word had only one meaning, it was considered unambiguous, and not further validated. If words were judged to have more than one meaning, but these meanings were considered to be highly similar by this investigator, the words were included in the Prime Meaning Similarity Judgment task.

Table 29 Stimuli and results for the Meaning Count Task

MG-1		MG-2	
Words	Validation[a]	Words	Validation
tiger	X	YOGURT	√
hive	X	PELICAN	√
moat	√	IGLOO	X
canoe	√	VILLAGE	Sim
lice	√	SCISSORS	Sim
beggar	Sim	WOOL	Sim
lapel	√	TUSK	√
bottle	X	RACCOON	√
breeze	X	HUSK	√
trombone	√	SHAMPOO	X
cabin	Sim	SPINACH	√
salmon	X	WIFE	√
dancer	√	SOOT	√
candle	√	TENNIS	√
dill	Sim	NAPKIN	√
bench	X	SQUID	√
donor	Sim	OCEAN	√
fur	Sim	STEEPLE	√
chimney	√	THIMBLE	Sim
gavel	√	HAYSTACK	√
hat	X	COFFIN	√
badge	Sim	TOMATO	√
ink	Sim	GROVE	Sim
ounce	Sim	TROUT	X
mirror	X	CRATER	√
cabbage	√		
beer	Sim		
donkey	√		
poet	√		
cobra	X		
salad	√		
fog	X		

[a] X: not validated, √: validated, Sim: potentially highly similar, entered in Similarity Judgment for Prime Meanings.

A.4 IMAGEABILITY RATINGS FOR AMBIGUOUS WORD MEANINGS

A.4.1 Participants

Twenty-seven participants from Group 1 participated in this task. Two lists (IRA-1 and IRA-2) with different words were rated, and each item was rated by 15 participants. Three participants rated both lists. After completion of these ratings another change to the stimulus set required imageability judgments for one more word (List IRA-3). Participants for this List were recruited from both undergraduate and graduate students.

Table 30 Demographic Data for Similarity Judgment for Prime Meaning task

List	Male	Female	Age (SD) Range	Education (SD) Range
IRA-1	2	13	29 ([a]) 22-36	20 ([a]) 14-28
IRA-2	3	12	28 ([a]) 22-36	21 ([a]) 16-28
IRA - 3	5	10	29 (8.2) 20 - 50	19 (3.7) 15 - 26

[a] Unfortunately, the data for this measure was lost.

A.4.2 Stimuli

Stimuli included ambiguous primes, some unambiguous primes, and filler items. Potential unambiguous primes were initially included because this step was aimed at validating all primes. Their results were ignored. The filler items ensure that words with low imageability (Gilhooly & Logie, 1980b) were included in the list, because most of the experimental items were relatively high in imageability.

List IRA-1 included 31 ambiguous potential primes, presented either with their dominant and subordinate meaning cues, 19 unambiguous potential primes, and 37 filler items. List IRA-2 included 24 ambiguous potential primes with their dominant and subordinate meaning cues, 26 unambiguous potential primes, and 14 filler items. List IRA-3 consisted of 14 stimuli: the targeted ambiguous word *fall*, 2 ambiguous filler and 8 unambiguous filler words.

Table 31 Stimulus for Imageability Ratings for Ambiguous Prime Meanings

IRA-1			IRA-2		
Stim Type[a]	Stimulus	Meaning Cue	Stim Type	Stimulus	Meaning Cue
dom	boil	*heat to bubbling*	dom	BAT	*a stout solid stick*
dom	bridge	*man-made structure*	dom	BLUFF	*to deceive, feign*
dom	calf	*young cow*	dom	COUNT	*a European nobleman*
dom	foot	*part of leg*	dom	CRAFT	*ship/boat*
dom	hamper	*basket*	dom	FAN	*an enthusiastic devotee*
dom	harp	*musical instrument*	dom	FILE	*a device to keep papers in order*
dom	nag	*pester*	dom	HAM	*a cut of meat*
dom	nap	*brief sleep*	dom	LACE	*a fabric*
dom	pen	*used for writing*	dom	LETTER	*correspondence*
dom	plant	*foliage*	dom	LITTER	*trash, wastepaper, or garbage*
dom	poker	*card game*	dom	LOG	*a record of performance or day-to-day activities*
dom	riddle	*puzzle*	dom	MATCH	*a person or thing similar to another*
dom	staple	*basic need*	dom	MOLE	*an animal*
dom	story	*building floor*	dom	PALM	*part of hand*
dom	tire	*rubber wheel*	dom	PANEL	*a thin board*

Table 31 (continued)

dom	toast	*(browned) bread*	dom	PITCH	*to throw, toss*
dom	wax	*found in beehives*	dom	PLANE	*a flat or level surface*
dom	bark	*tree covering*	dom	SPELL	*to name/write letters in order*
dom	clog	*to overfill*	dom	STRAIN	*to exert (e.g., oneself) very strongly or excessively*
dom	digit	*number*	dom	SUIT	*matched jacket and pants or skirt*
dom	mold	*fungus*	dom	SWALLOW	*bird*
dom	perch	*sit upon*	dom	TOLL	*a tax or fee*
dom	pupil	*student*	dom	TRAIN	*a connected line of railroad cars*
dom	ruler	*monarch*	dom	TRIP	*fall*
dom	cape	*garment*	sub	BAT	*a flying animal*
dom	China	*country*	sub	BLUFF	*a high steep bank*
dom	drill	*tool*	sub	COUNT	*to say numbers in order*
dom	gear	*equipment*	sub	CRAFT	*manual art*
dom	March	*month*	sub	FAN	*an instrument for producing a current of air*
dom	miss	*young woman*	sub	FILE	*a tool for forming or smoothing surfaces*
dom	organ	*musical instrument*	sub	HAM	*a show-off*
sub	boil	*skin lesion*	sub	LACE	*a cord or string*
sub	bridge	*card game*	sub	LETTER	*unit in alphabet*
sub	calf	*lower leg*	sub	LITTER	*absorbent material for animal waste*
sub	foot	*unit of measure*	sub	LITTER	*animal's newborn offspring*
sub	hamper	*impede*	sub	LOG	*piece of unshaped timber*
sub	harp	*bother repeatedly*	sub	MATCH	*a contest between two or more parties*
sub	nag	*old horse*	sub	MATCH	*device that makes a flame*
sub	nap	*texture of fabric*	sub	MOLE	*a pigmented spot on the human body*
sub	pen	*enclosure*	sub	PALM	*tree*
sub	plant	*factory*	sub	PALM	*type of computer*
sub	poker	*fireplace implement*	sub	PANEL	*group of people*
sub	riddle	*filled with*	sub	PITCH	*the relative level of a sound*

Table 31 (continued)

sub	staple	*metal clip*	sub	PLANE	*for air transportation*
sub	story	*saga*	sub	SPELL	*spoken words held to have magic power*
sub	tire	*exhaust*	sub	STRAIN	*to pass something through a sieve*
sub	toast	*short speech*	sub	SUIT	*action/process in a court*
sub	wax	*to increase*	sub	SWALLOW	*food intake*
sub	bark	*dog's vocalization*	sub	TOLL	*to sound (a bell) by pulling the rope*
sub	clog	*wooden shoe*	sub	TRAIN	*to teach so as to make fit, qualified, or proficient*
sub	digit	*finger or toe*	sub	TRIP	*journey*
sub	mold	*to shape*	unamb	YOGURT	**
sub	perch	*fish*	unamb	VILLAGE	**
sub	pupil	*center of eye*	unamb	WOOL	**
sub	ruler	*measuring tool*	unamb	TUSK	**
sub	cape	*peninsula*	unamb	RACCOON	**
sub	china	*dishes*	unamb	SOOT	**
sub	drill	*exercise*	unamb	SPINACH	**
sub	gear	*mechanical device*	unamb	SQUID	**
sub	march	*walk*	unamb	STEEPLE	**
sub	miss	*make an error*	unamb	TENNIS	**
sub	organ	*internal body part*	unamb	THIMBLE	**
unamb	tiger	**	unamb	TOMATO	**
unamb	candle	**	unamb	WIFE	**
unamb	badge	**	unamb	NAPKIN	**
unamb	trombone	**	unamb	HAYSTACK	**
unamb	chimney	**	unamb	GROVE	**
unamb	cobra	**	unamb	CRATER	**
unamb	dancer	**	unamb	COFFIN	**
unamb	dill	**	unamb	BEER	**
unamb	donkey	**	unamb	BEGGAR	**
unamb	donor	**	unamb	CANOE	**
unamb	fog	**	unamb	LICE	**
unamb	gavel	**	unamb	OCEAN	**
unamb	hat	**	unamb	PARSLEY	**
unamb	hive	**	unamb	POET	**
unamb	lapel	**	unamb	TROMBONE	**
unamb	moat	**	filler	ABILITY	**
unamb	ounce	**	filler	ADVICE	**

Table 31 (continued)

unamb	salmon	**
unamb	cabbage	**
filler	ability	**
filler	advice	**
filler	arbiter	**
filler	ballot	**
filler	budget	**
filler	cause	**
filler	childhood	**
filler	clearance	**
filler	complication	**
filler	convocation	**
filler	debt	**
filler	diadem	**
filler	dowry	**
filler	ease	**
filler	enigma	**
filler	exception	**
filler	flourish	**
filler	foe	**
filler	forfeit	**
filler	glut	**
filler	gramercy	**
filler	haul	**
filler	hobby	**
filler	hygiene	**
filler	impunity	**
filler	incursion	**
filler	magnesium	**
filler	marl	**
filler	nutrient	**
filler	pause	**
filler	precursor	**
filler	recreant	**
filler	scheme	**
filler	slough	**
filler	tax	**
filler	wherewithal	**
filler	worth	**
filler	ARBITER	**
filler	BALLOT	**
filler	BUDGET	**
filler	CAUSE	**
filler	CHILDHOOD	**
filler	CLEARANCE	**
filler	COMPLICATION	**
filler	CONVOCATION	**
filler	DEAL	**
filler	EASE	**
filler	ENIGMA	**
filler	EXCEPTION	**

[a] Stimulus Type: amb: ambiguous; unamb: unambiguous

Table 32 Stimulus List IRA-3 for Imageability Ratings for Ambiguous Prime Meanings

IRA-3		
Stim Type [a]	Stimulus	Meaning Cue
dom	FALL	*the act of falling"
sub	FALL	*a season of the year*
dom	BLUFF	*to deceive, feign*
sub	BLUFF	*a high steep bank*
dom	MOLE	*an animal*
sub	MOLE	*a pigmented spot on the human body*
unamb	CRATER	**
unamb	COFFIN	**
filler	ABILITY	**
filler	CAUSE	**
filler	DEAL	**
filler	EASE	**
unamb	POET	**
unamb	TROMBONE	**

[a] Stimulus Type: amb: ambiguous; unamb: unambiguous

A.4.3 Instructions, task and procedures

The task and procedures follow those used by Gilhooly and Logie (1980b}. Each word was presented with the meaning descriptions (cues) for the intended meanings. These cues were generated by the investigator and another graduate student judge, and checked by a faculty judge. Participants either read or listened to the instructions slightly adapted from Paivio (1969).

> Words differ in their capacity to arouse mental images of things or events. Some words arouse a sensory experience, such as a mental picture or sound, very quickly and easily, whereas others may do so only with difficulty (i.e., after a long delay) or not at all. The purpose of this experiment is to rate a list of words as to the ease or difficulty with which they arouse mental images.
>
> NEW SCREEN
>
> Any word which, in your estimation, arouses a mental image (i.e., a mental picture, or sound, or other sensory experience) very quickly and easily should be given a high imagery rating; any word that arouses a mental image with difficulty or not at all should be given a low imagery rating.

NEW SCREEN

For example, think of the word "apple". You may find that "apple" arouses an image easily and would be rated high on imagery, whereas "exception" arouses a mental image with difficulty, if at all, and would be rated low on imagery.

NEW SCREEN

Make your rating by typing in the appropriate number on the keyboard, and choose the number from 1 to 7 that best indicates your judgment of the ease or difficulty with which the word arouses imagery. Words that arouse mental images most readily for you should be given a rating of 7; words that arouse images with the greatest difficulty or not at all should be rated 1; words that are intermediate in ease or difficulty of imagery, of course, should be rated appropriately between the two extremes.

NEW SCREEN

Your ratings will be made on a seven-point scale, where one is the low imagery end of the scale, and seven is the high imagery end of the scale.

NEW SCREEN

Feel free to use the entire range of numbers, from 1 to 7; at the same time, don't be concerned about how often you use a particular number as long as it is your true judgment. Work fairly quickly, but do not be careless in your ratings.

NEW SCREEN

---

automobile

|--|--|--|--|--|--|
1 4 7
low high

Don't know word? "F1"

From this screen on, instructions were presented verbally to achieve a more interactive presentation that would give the examiner a better indication whether the instructions were understood, and to invite questions:

“OK, then you just type the number for your rating on the number keys.”
[participants makes the rating]

SCREEN after rating (as an example with a rating of "6"):

OK?

automobile

|--|--|--|--|--X--|
1 4 7
low high

Go Back? Press "B"-Key

“As you can see, an "X" appears on the number you have rated. If you decide that you want to change your rating, you can go back pressing the "b"-key. Otherwise just press the space-key.

Now some of the words are rather unusual. If you see a word where you are not sure what it means, just press ‘F1’, and spacebar, and go to the next item.”

The next screen presented the word “democracy”.

Instructions:

“Now, one thing is important, the word you see on the screen might make you think of another word. For example, 'democracy' might bring up 'White House' up for you, and you might end up rating ‘White House' rather than 'democracy'. Please make sure that that does not happen. Only rate the word on the screen, and not another word that it might make you think of.”

NEXT SCREEN

---

column

[written vertical list]

|--|--|--|--|--|--|
1 4 7
low high

Don't know word? "F1"

> “Some words have more than one meaning. When you see a word on the screen that has more than one meaning, there will be a short description of one of those meanings under the word, in brackets. There’s an example on the screen right now. When you see this type of item, I would like you to rate the imageability for that meaning of the word. So, how would you rate the word “column,” if the meaning is ‘vertical written list’?”

Participants rated another 3 practice stimuli, for which accuracy feedback was given: column (column), capital (most important city), capital (wealth). At the end of the practice stimuli, the following instructions were given:

> “Ok, now they will be 120 (91) words for you to rate. Some will be unambiguous words, and some will be ambiguous words. As you just saw in the examples, for the ambiguous words there will be a short description to tell you which meaning of the word you should be rating for that item. Do you have any questions?”

A.4.4 Results

In Lists IRA-1 and List Ira-2, data of one male participant (ID 19 and ID 41), who participated on both lists, was excluded because it was an outlier for both lists. This left 14 ratings for each item for the two lists. The average 95% confidence interval for the mean ratings for each experimental item was +/- .63 for List IRA-1, and +/- .59 for List IRA-2.

Table 33 Imageability Judgment: Ambiguous Prime Meanings, List IRA-1

Stim[a] Type	Stimulus	Participants & Ratings															Mean rating	95 % CI[b]
Part[c] ID		2	5	6	3	4	10	11	12	13	14	15	16	17	18	19		
dom[d]	cape	7	6	5	5	7	6	7	6	7	6	7	6	4	6	1	5.73	0.48
dom	China	4	4	6	7	7	6	7	4	2	7	7	7	4	7	3	5.47	0.89
dom	drill	7	6	5	7	7	7	6	7	7	7	7	6	7	7	3	6.40	0.33
dom	gear	5	6	6	7	5	5	6	5	7	5	6	4	4	4	2	5.13	0.53
dom	march	4	2	7	7	1	2	5	1	2	1	2	6	1	5	3	3.27	1.21
dom	miss	6	6	4	5	6	5	6	4	4	5	5	3	2	4	3	4.53	0.64
dom	organ	7	5	5	7	7	7	7	7	6	7	7	6	6	6	1	6.07	0.40
dom	bark	6	7	3	7	7	7	6	7	7	7	6	7	6	6	3	6.13	0.57
dom	clog	6	3	5	7	6	5	5	4	6	5	6	6	5	4	3	5.07	0.55
dom	digit	6	7	7	7	6	6	4	7	7	7	5	6	5	7	5	6.13	0.51
dom	mold	7	2	7	7	7	7	7	7	6	6	6	6	5	6	4	6.00	0.71
dom	perch	1	4	6	6	7	6	6	5	3	6	6	7	6	3	1	4.87	0.92
dom	pupil	6	7	6	7	6	6	6	6	6	7	6	5	6	5	3	5.87	0.32
dom	ruler	4	7	3	7	7	6	7	3	7	4	5	5	5	7	1	5.20	0.82
dom	boil	6	7	6	7	7	7	7	6	7	6	7	7	6	7	5	6.53	0.26
dom	bridge	7	7	7	7	7	7	7	7	7	7	7	6	7	5	4	6.60	0.30
dom	calf	5	6	6	7	7	7	7	7	7	7	7	6	3	6	3	6.07	0.60
dom	foot	7	6	7	7	7	7	7	7	7	7	7	7	7	4	3	6.47	0.43
dom	hamper	6	7	4	7	7	6	6	6	7	7	7	6	6	6	2	6.00	0.43
dom	harp	6	7	7	7	7	7	7	7	7	7	7	7	6	6	1	6.40	0.22
dom	nag	2	5	6	5	3	2	4	6	2	3	5	5	4	2	6	4.00	0.79
dom	nap	7	7	7	7	4	2	7	6	7	5	7	6	5	4	7	5.87	0.83
dom	pen	7	7	6	7	7	7	6	7	7	7	7	6	6	6	5	6.53	0.26
dom	plant	6	7	7	7	7	7	7	7	7	7	7	7	7	7	6	6.87	0.14
dom	poker	6	6	5	7	7	4	7	3	4	7	5	7	7	7	2	5.60	0.74
dom	riddle	2	2	6	5	2	5	3	5	3	3	2	4	3	4	1	3.33	0.70
dom	staple	2	1	3	2	3	4	2	2	2	3	2	3	6	1	1	2.47	0.67
dom	story	7	7	4	6	6	5	7	5	5	7	2	5	6	6	3	5.40	0.73
dom	tire	7	7	7	7	7	7	6	7	7	7	7	7	5	4	3	6.33	0.49
dom	toast	7	7	5	7	7	7	6	7	7	7	7	7	6	6	6	6.60	0.33
dom	wax	6	4	3	5	6	7	6	6	6	3	7	4	6	7	1	5.13	0.73
sub[f]	cape	3	7	2	5	7	5	5	3	5	4	2	6	5	3	1	4.20	0.86
sub	china	7	6	4	7	7	6	6	5	4	7	7	6	6	6	1	5.67	0.54
sub	drill	5	6	2	3	7	5	3	4	4	4	2	3	3	3	7	4.07	0.76
sub	gear	6	2	3	7	7	6	7	4	3	7	5	5	7	6	2	5.13	0.91
sub	march	6	7	2	5	7	5	7	6	5	7	7	5	5	2	2	5.20	0.89
sub	miss	1	2	4	1	2	2	2	3	7	3	2	4	3	1	6	2.87	0.84
sub	organ	6	3	6	7	3	4	7	6	7	6	7	5	4	6	2	5.27	0.76
sub	bark	5	7	7	7	7	7	7	6	7	5	7	6	7	7	4	6.40	0.40
sub	clog	7	7	6	6	6	7	7	6	7	5	6	7	6	6	1	6.00	0.33
sub	digit	4	7	3	6	5	7	7	7	7	6	6	6	5	6	2	5.60	0.65
sub	mold	6	7	3	6	7	5	6	4	4	5	4	7	5	5	1	5.00	0.66

Table 33 (continued)

sub	perch	7	3	3	7	7	6	7	3	3	4	5	5	4	6	4	4.93	0.87
sub	pupil	7	5	3	7	7	7	7	6	6	7	6	7	6	3	2	5.73	0.74
sub	ruler	6	7	7	7	7	7	7	7	7	7	7	7	5	5	2	6.33	0.39
sub	boil	4	2	4	4	7	7	6	6	6	5	5	7	3	5	2	4.87	0.81
sub	bridge	5	7	4	2	7	5	6	6	4	4	2	7	7	7	1	4.93	0.95
sub	calf	7	7	4	7	7	6	6	6	7	7	7	6	6	7	3	6.20	0.45
sub	foot	4	2	4	7	2	3	4	5	7	7	3	4	4	4	2	4.13	0.88
sub	hamper	1	1	6	5	5	3	2	2	4	3	2	4	1	4	1	2.93	0.86
sub	harp	4	2	3	4	4	2	4	2	2	1	1	3	5	3	1	2.73	0.65
sub	nag	3	1	4	6	7	6	6	2	3	3	2	5	4	6	1	3.93	0.98
sub	nap	6	1	1	2	5	6	2	1	2	1	1	-	5	2	2	2.64	1.08
sub	pen	6	7	2	7	6	7	5	1	6	5	5	6	3	6	1	4.87	0.98
sub	plant	7	5	2	5	7	5	7	4	5	5	5	5	5	5	1	4.87	0.68
sub	poker	6	7	4	5	7	7	7	6	7	5	6	6	5	7	1	5.73	0.52
sub	riddle	1	1	5	3	7	5	6	1	2	1	6	2	2	1	1	2.93	1.17
sub	staple	7	5	6	7	7	7	6	7	7	7	7	6	7	5	3	6.27	0.40
sub	story	5	6	7	4	5	1	5	1	3	4	3	5	5	1	7	4.13	1.00
sub	tire	6	6	3	5	5	2	3	1	2	6	3	5	4	2	6	3.93	0.90
sub	toast	5	6	5	2	7	4	6	4	2	5	3	6	4	6	1	4.40	0.81
sub	wax	2	1	2	5	6	3	5	1	2	2	1	6	7	3	1	3.13	1.10
unam g	tiger	7	7	7	7	7	7	7	7	7	7	7	7	6	7	3	6.67	0.14
unam	candle	7	7	6	7	6	7	7	7	7	7	7	6	7	5	5	6.53	0.33
unam	badge	7	5	6	7	6	6	6	7	5	6	7	6	4	6	2	5.73	0.46
unam	trombone	7	7	4	7	7	7	7	7	7	7	7	7	6	6	1	6.27	0.44
unam	cabbage	7	7	6	7	7	7	7	7	7	5	7	7	7	5	3	6.40	0.39
unam	chimney	7	7	5	7	7	7	7	7	5	7	7	7	6	7	1	6.27	0.39
unam	cobra	7	6	7	7	7	7	7	7	5	7	7	6	6	4	1	6.07	0.49
unam	dancer	7	7	7	7	7	7	7	6	7	7	7	6	5	5	4	6.40	0.40
unam	dill	7	1	6	6	5	7	6	4	1	4	6	5	4	6	1	4.60	1.00
unam	donkey	6	7	7	7	7	7	7	7	7	7	7	7	5	6	1	6.33	0.32
unam	donor	1	2	3	7	6	4	6	2	5	3	6	4	2	2	1	3.60	1.01
unam	fog	6	7	7	7	7	7	7	5	7	7	7	5	7	5	3	6.27	0.45
unam	gavel	7	7	6	7	7	6	6	6	7	6	7	7	4	6	5	6.27	0.44
unam	hat	7	7	7	7	7	7	6	7	7	7	7	7	7	6	7	6.87	0.19
unam	hive	7	4	3	7	7	7	6	7	5	5	6	7	5	6	1	5.53	0.68
unam	lapel	7	5	7	6	7	6	7	6	7	7	6	5	6	4	2	5.87	0.50
unam	moat	7	6	6	7	7	6	7	6	6	3	7	7	5	5	1	5.73	0.60
unam	ounce	2	2	3	3	2	3	2	3	7	1	3	6	4	3	1	3.00	0.84
unam	salmon	7	6	7	7	7	7	7	7	3	7	7	6	7	5	1	6.07	0.61
Average 95% CI for all experimental items																		**0.63**
Average DMR[h] for each participant		**1.0**	**1.2**	**1.2**	**1.0**	**1.2**	**0.9**	**1.0**	**0.9**	**1.1**	**0.9**	**0.9**	**0.8**	**0.9**	**1.0**	**3.0**		

Table 33 (continued)

filler	ability	2	4	2	1	2	2	2	2	1	2	1	3	2	1	6	2.20	0.43
filler	convocation	-	2	7	2	6	4	1	4	5	6	3	-	6	2	1	3.77	1.23
filler	deal	6	1	7	1	2	1	5	2	5	2	3	4	2	2	2	3.00	1.04
filler	diadem	-	1	-	7	7	-	7	-	-	-	-	3	3	-	-	4.67	1.52
filler	dowry	2	4	5	1	3	4	3	5	1	4	2	5	2	2	-	3.07	0.75
filler	ease	3	2	6	1	2	1	2	2	3	2	2	5	5	2	1	2.60	0.81
filler	enigma	1	2	3	1	2	1	1	1	3	2	3	2	2	2	1	1.80	0.40
filler	exception	1	5	6	1	1	2	1	1	3	1	1	2	2	1	3	2.07	0.85
filler	flourish	2	7	4	4	7	4	6	3	5	3	6	5	5	2	1	4.27	0.87
filler	foe	5	6	6	2	7	3	5	1	2	4	6	7	4	1	1	4.00	1.11
filler	forfeit	3	5	6	1	4	2	2	1	4	1	2	3	3	1	3	2.73	0.83
filler	advice	6	6	2	1	2	1	3	2	3	1	3	6	3	2	5	3.07	0.95
filler	glut	-	2	5	3	2	2	5	-	2	1	-	2	4	1	-	2.64	0.88
filler	gramercy	-	1	2	1	3	-	-	1	-	-	-	-	-	1	-	1.50	0.49
filler	haul	6	6	3	1	7	5	4	4	4	4	4	6	5	2	1	4.13	0.86
filler	hobby	6	6	5	1	1	3	2	1	5	3	5	5	3	2	5	3.53	0.98
filler	hygiene	7	2	7	4	2	2	2	4	3	4	2	5	5	2	4	3.67	0.96
filler	impunity	1	-	6	1	3	1	1	-	2	1	-	2	1	1	1	1.75	0.81
filler	incursion	1	5	2	1	4	1	3	1	2	-	-	-	1	1	-	2.00	0.79
filler	magnesium	5	1	1	1	3	3	4	5	3	3	4	5	6	4	1	3.27	0.84
filler	marl	-	1	-	1	-	2	-	-	-	-	-	-	6	-	-	2.50	0.86
filler	arbiter	-	6	1	3	5	3	1	2	-	2	3	5	1	2	-	2.83	0.98
filler	nutrient	6	5	4	1	2	3	2	1	2	1	2	3	5	5	4	3.07	0.90
filler	pause	2	5	3	1	7	1	1	2	3	1	3	6	7	2	1	3.00	1.16
filler	precursor	2	1	2	1	3	2	1	1	2	1	1	7	3	2	-	2.07	0.83
filler	recreant	-	1	-	1	-	-	-	-	2	-	-	4	2	-	-	2.00	0.63
filler	scheme	2	1	4	2	3	1	2	2	4	2	2	5	3	1	1	2.33	0.64
filler	slough	4	2	4	4	7	5	5	2	2	1	-	-	1	4	-	3.42	1.10
filler	tax	5	3	4	3	4	1	5	3	5	2	3	6	3	3	2	3.47	0.70
filler	wherewithal	1	1	2	1	1	1	1	1	2	1	1	-	2	1	1	1.21	0.28
filler		1	2	3	1	3	1	1	1	3	4	1	5	2	2	3	2.20	0.68
filler	ballot	4	7	6	4	6	6	7	6	3	5	6	7	6	6	4	5.53	0.64
filler	budget	2	5	2	2	4	2	5	2	5	5	2	5	5	2	5	3.53	0.79
filler	cause	5	1	3	1	1	1	1	1	3	2	1	4	1	1	1	1.80	0.71
filler	childhood	6	7	7	2	6	2	4	2	4	4	6	5	2	4	6	4.47	0.98
filler	clearance	5	3	4	1	2	4	3	4	4	3	2	4	3	3	1	3.07	0.55
filler	complication	6	5	5	1	2	1	1	3	3	3	4	4	1	1	6	3.07	0.92

[a] Stimulus Type
[b] Absolute value of upper and lower bound of 95% confidence interval for each item
[c] Participant
[d] dominant
[f] subordinate
[g] unambiguous
[h] average differences from mean ratings for each item over all ratings for one participant

Table 34 Imageability Judgment: Ambiguous Prime Meanings, List IRA-2

Stim[a] Type	Stimulus	Participants & Ratings															Mean rating	95 % CI[b]
Part[c] ID		20	24	25	26	27	28	29	30	32	33	34	35	38	40	41		
dom[d]	TRAIN	7	7	7	7	6	7	7	7	7	7	7	7	6	6	6	6.79	0.22
dom	HAM	7	6	7	5	6	6	7	7	7	7	6	7	6	5	7	6.36	0.39
dom	FILE	7	7	7	6	3	5	7	7	7	7	7	7	6	6	6	6.36	0.60
dom	COUNT	6	2	5	4	1	6	7	6	6	6	3	3	4	5	1	4.57	0.94
dom	LACE	7	7	7	6	5	6	7	6	7	7	6	7	5	7	4	6.43	0.40
dom	MATCH	1	2	3	2	3	3	4	2	2	2	4	1	4	2	6	2.50	0.53
dom	LOG	4	6	3	4	2	2	7	4	5	7	4	2	6	4	2	4.29	0.91
dom	BAT	7	7	7	6	7	5	7	7	7	7	7	7	6	7	5	6.71	0.32
dom	TOLL	1	7	2	2	1	4	4	4	3	5	5	3	3	3	4	3.36	0.86
dom	PANEL	6	6	6	4	5	5	6	6	7	7	5	6	6	5	2	5.71	0.43
dom	MOLE	7	4	7	7	3	6	7	7	7	7	7	3	6	6	2	6.00	0.80
dom	FAN	5	6	6	2	7	4	7	4	1	4	6	5	4	2	6	4.50	0.98
dom	LETTER	7	6	7	6	5	3	7	7	7	4	7	7	6	6	5	6.07	0.66
dom	TRIP	5	7	7	5	6	3	7	5	7	6	5	4	5	4	6	5.43	0.67
dom	SWALLOW	6	6	5	6	7	2	7	6	5	7	7	6	6	4	7	5.71	0.72
dom	PLANE	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	6.93	0.14
dom	SUIT	7	6	7	6	5	6	7	7	7	7	7	6	5	6	6	6.36	0.39
dom	PALM	7	6	7	6	6	6	7	7	7	7	7	7	7	7	6	6.71	0.25
dom	CRAFT	7	3	5	7	4	6	7	6	-	7	7	4	4	5	3	5.54	1.06
dom	BLUFF	4	1	3	1	2	2	1	1	1	1	1	5	3	2	2	2.00	0.68
dom	STRAIN	5	6	4	2	4	6	4	2	6	2	5	3	4	3	5	4.00	0.77
dom	SPELL	1	4	2	4	2	2	7	4	2	4	3	2	3	1	7	2.93	0.83
dom	PITCH	6	7	7	4	6	4	7	5	7	6	7	4	6	5	6	5.79	0.62
dom	LITTER	7	5	7	6	4	6	7	7	7	7	7	7	6	4	3	6.21	0.59
sub[e]	MATCH	2	6	7	2	3	4	3	5	5	5	5	3	5	2	3	4.07	0.83
sub	LACE	7	6	7	6	4	5	7	7	7	7	2	5	2	6	1	5.57	0.94
sub	PLANE	5	3	7	4	3	3	5	3	5	7	3	1	2	3	3	3.86	0.92
sub	BAT	7	7	7	7	5	5	7	7	7	7	6	7	6	7	6	6.57	0.40
sub	BLUFF	7	3	7	7	5	6	4	5	7	6	5	7	3	4	3	5.43	0.79
sub	MOLE	7	6	7	6	5	6	6	7	7	7	7	7	6	5	4	6.36	0.39
sub	HAM	7	3	7	4	2	5	1	4	4	3	3	3	3	2	2	3.64	0.91
sub	FILE	7	5	6	6	5	5	7	7	7	7	7	7	6	6	2	6.29	0.43
sub	LITTER	6	5	5	6	7	2	7	6	7	7	6	7	3	3	3	5.50	0.89
sub	SUIT	3	3	1	3	2	1	1	2	2	1	2	2	2	3	6	2.00	0.41
sub	FAN	7	6	7	6	6	6	7	7	7	7	7	7	6	5	6	6.50	0.34
sub	LITTER	7	5	7	6	2	4	7	5	5	7	6	7	3	3	3	5.29	0.91
sub	SWALLOW	7	5	7	6	4	5	7	5	5	7	6	6	7	5	1	5.86	0.54
sub	MATCH	7	7	7	7	6	5	7	7	7	7	7	7	6	7	5	6.71	0.32
sub	PANEL	7	6	4	4	3	3	7	4	6	6	4	4	3	3	1	4.57	0.79
sub	TRIP	2	6	4	3	2	3	7	2	7	2	5	2	4	2	7	3.64	1.00
sub	CRAFT	5	6	6	3	2	3	3	2	7	5	5	2	3	2	3	3.86	0.92
sub	LOG	7	6	7	7	5	6	7	7	7	7	7	7	7	6	6	6.64	0.33
sub	SPELL	4	4	4	3	4	4	4	3	1	1	5	4	6	2	5	3.50	0.73

Table 34 (continued)

sub	PITCH	1	2	2	7	2	4	2	1	2	1	2	1	3	1	2	2.21	0.85
sub	STRAIN	4	6	5	5	2	2	5	3	6	7	6	4	5	3	2	4.50	0.82
sub	COUNT	1	1	3	3	3	5	7	4	1	2	5	1	5	2	7	3.07	1.00
sub	TOLL	5	6	2	3	5	3	4	5	5	7	5	6	2	2	2	4.29	0.86
sub	TRAIN	2	3	2	2	3	1	4	3	1	4	2	1	4	2	4	2.43	0.57
sub	PALM	7	7	7	7	7	6	7	7	7	7	7	7	7	7	5	6.93	0.14
sub	PALM	7	5	5	5	2	5	7	6	7	7	5	7	5	6	2	5.64	0.73
sub	LETTER	4	6	7	6	7	5	7	7	6	7	5	7	5	4	7	5.93	0.60
unam[f]	BEER	7	7	7	7	7	6	7	7	7	7	7	7	7	6	6	6.86	0.19
unam	BEGGAR	5	6	7	6	2	6	7	6	7	7	5	7	6	5	5	5.86	0.71
unam	CANOE	7	7	7	7	6	7	7	7	7	7	7	7	6	6	6	6.79	0.22
unam	COFFIN	7	6	7	7	6	7	7	7	7	7	7	7	7	5	6	6.71	0.32
unam	CRATER	7	5	7	7	3	6	7	6	7	7	5	6	7	5	3	6.07	0.63
unam	GROVE	7	3	6	6	2	6	3	6	7	5	4	5	5	4	2	4.93	0.81
unam	HAYSTACK	7	7	7	7	6	7	7	7	7	7	7	7	6	3	4	6.57	0.57
unam	LICE	6	6	7	7	2	2	6	6	6	7	6	1	6	6	4	5.29	1.06
unam	NAPKIN	7	7	7	6	7	7	7	7	7	7	6	7	7	6	7	6.79	0.22
unam	OCEAN	7	7	7	7	6	6	7	7	7	7	7	7	7	5	7	6.71	0.32
unam	PARSLEY	7	7	7	7	3	5	7	7	7	7	6	7	6	7	2	6.43	0.61
unam	POET	2	2	5	3	2	5	7	3	2	5	2	3	5	3	4	3.50	0.84
unam	RACCOON	7	7	7	7	6	7	7	7	7	7	6	7	7	7	5	6.86	0.19
unam	SOOT	6	6	7	7	5	5	4	4	6	6	6	7	6	5	2	5.71	0.52
unam	SPINACH	7	7	7	7	5	6	7	7	7	7	6	7	7	7	3	6.71	0.32
unam	SQUID	7	7	7	7	4	7	7	7	7	7	7	5	7	6	6	6.57	0.49
unam	STEEPLE	7	7	7	7	6	7	7	6	7	7	7	7	7	7	4	6.86	0.19
unam	TENNIS	6	7	7	7	6	6	5	7	4	7	6	7	7	3	6	6.07	0.66
unam	THIMBLE	7	7	7	6	5	5	7	7	7	7	7	7	6	7	2	6.57	0.40
unam	TOMATO	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	6.93	0.14
unam	TROMBONE	7	7	7	7	7	7	7	7	7	7	7	7	7	7	2	7.00	0.00
unam	TUSK	7	7	7	7	6	6	7	6	4	7	6	7	6	7	2	6.43	0.45
unam	VILLAGE	6	5	7	6	4	7	7	7	7	6	5	3	6	6	5	5.86	0.65
unam	WIFE	7	4	7	7	2	6	5	5	2	6	5	4	6	3	7	4.93	0.91
unam	WOOL	7	7	7	7	6	4	7	5	7	6	5	5	6	5	1	6.00	0.54
unam	YOGURT	6	7	7	7	6	5	7	7	7	7	6	7	7	6	6	6.57	0.34
Average 95% CI for all experimental items																		**0.59**
Average DMR[g] for each participant		**0.9**	**0.9**	**0.9**	**0.8**	**1.2**	**1.0**	**1.0**	**0.6**	**1.0**	**1.0**	**0.7**	**1.0**	**0.7**	**1.0**	**1.9**		

Table 34 (continued)

filler	ABILITY	1	1	1	1	3	2	1	1	1	1	3	1	3	1	5	1.50	0.45
filler	ADVICE	1	3	1	1	1	1	2	2	1	1	2	1	2	2	3	1.50	0.34
filler	ARBITER	4	1	1	2	2	3	3	-	-	-	1	1	1	1	-	1.82	0.64
filler	BALLOT	7	3	2	6	7	5	7	6	7	6	4	4	7	2	5	5.21	0.99
filler	BUDGET	1	2	1	1	3	4	4	3	2	2	2	2	4	2	2	2.36	0.57
filler	CAUSE	1	1	1	2	2	2	1	1	1	1	1	1	1	1	3	1.21	0.22
filler	CHILDHO OD	2	1	2	2	3	1	3	2	1	2	4	2	4	3	6	2.29	0.52
filler	CLEARAN CE	5	5	1	1	3	2	3	2	2	1	2	1	4	1	3	2.36	0.76
filler	COMPLICA TION	1	2	1	2	2	1	2	1	1	1	1	1	2	1	5	1.36	0.26
filler	CONVOCA TION	7	5	2	2	6	1	4	3	1	3	2	3	-	1	3	3.08	1.06
filler	DEAL	3	5	7	2	5	3	2	1	1	7	6	3	4	1	5	3.57	1.12
filler	EASE	1	2	1	1	2	1	2	2	1	1	1	1	3	1	3	1.43	0.34
filler	ENIGMA	1	3	1	1	2	6	1	1	-	2	1	1	2	1	3	1.77	0.76
filler	EXCEPTIO N	1	1	1	1	2	1	1	1	1	1	2	1	1	1	3	1.14	0.19

[a] Stimulus Type
[b] Absolute value of upper and lower bound of 95% confidence interval for each item
[c] Participant
[d] dominant
[e] subordinate
[f] unambiguous
[g] average differences from mean ratings for each item over all ratings for one participant

Table 35 Imageability Judgments: Ambiguous Prime Meanings, List IRA-3

Stim[a] Type	Stimulus	Participants & Ratings															Mean rating	95 % CI[b]
Part[c] ID		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		
filler	ABILITY	3	5	7	3	2	2	2	2	4	1	3	2	1	1	2	2.67	0.83
filler	BLUFF	2	7	1	2	4	7	1	1	3	2	3	2	3	6	4	3.20	1.03
filler	BLUFF	6	7	5	7	1	7	7	7	4	5	2	6	6	7	6	5.53	0.95
filler	CAUSE	3	4	2	1	2	2	1	1	2	1	3	1	1	1	3	1.87	0.50
filler	COFFIN	7	7	7	7	7	7	7	7	6	7	7	6	7	7	7	6.87	0.18
filler	CRATER	7	7	7	7	6	4	6	7	7	4	6	7	6	7	6	6.27	0.52
filler	DEAL	4	3	7	3	5	4	3	6	3	1	3	1	2	3	4	3.47	0.83
filler	EASE	2	4	4	2	3	2	1	2	1	1	3	1	2	3	3	2.27	0.52
dom	FALL	6	7	7	7	6	7	4	6	4	5	2	3	6	7	4	5.40	0.83
sub	FALL	6	7	7	7	3	7	6	7	5	2	7	4	5	7	6	5.73	0.82
filler	MOLE	3	7	5	7	6	7	7	6	7	6	6	6	7	7	4	6.07	0.62
filler	MOLE	6	6	7	7	3	7	7	7	6	5	5	7	7	7	6	6.20	0.58
filler	POET	4	5	7	6	5	7	3	4	5	2	3	3	4	7	3	4.53	0.83
filler	TROMBONE	7	7	7	6	7	7	7	7	7	6	6	5	7	7	7	6.67	0.31

[a] Stimulus Type
[b] Absolute value of upper and lower bound of 95% confidence interval for each item
[c] Participant

A.5 SIMILARITY JUDGMENT FOR PRIME MEANINGS

A.5.1 Participants

Seventeen participants from Group 1 participated in this task. Two lists (SJP-1 and SJP-2) with different words were rated, and each item was rated by 10 participants (see Table 36 for demographic data). Three participants rated both lists.

Table 36 Demographic Data for Similarity Judgment for Prime Meaning task

List	Male	Female	Age (SD) range	Education (SD) range
SJ-1	2	8	29 (4.0) 22-36	22 (3.5) 16-28
SJ-2	3	7	28 23-36 (3.9)	21 17-28 (3.1)

A.5.2 Stimuli

Stimuli for this task included the words from the previous validation steps, for which this investigator judged that they might have potentially close enough senses to be considered unambiguous. This task also included ambiguous words selected from ambiguity norms (see table 37 and 38). List SJP-1 consisted of 10 unambiguous words, 41 ambiguous words, and 13 filler words. The filler words were ambiguous or polysemous words that were judged by this experimenter to have related meanings, and thus could generate intermediate similarity judgments values. List SJP-2 was considerably shorter, and consisted of 7 "unambiguous" words and 13 ambiguous words. No filler were included, because experience in the previous list suggested that some items would be judged intermediate even if this was not expected by the experimenter.

In order to rate meaning similarity of word meanings or senses, participants were provided with meaning descriptions for each meaning or sense. For "unambiguous" words, all descriptions were taken from or adapted (shortened) from definitions appearing in the Merriam Webster Online Dictionary (2004). Because this task included ratings for senses of "unambiguous" words, for which meanings differ in fine details, sometimes longer descriptions were required (moat: "deep/wide trench to protect"; "a little brook that separates or forms protection"). Descriptions for ambiguous words were derived from those generated for the imageability judgment task. However, to disguise which words were ambiguous, some of the descriptions of the ambiguous words used in the imageability task were lengthened, again based on definitions from the Merriam Webster Online Dictionary (e.g., *bridge*: changed from "man-made structure" to "structure carrying a path/roadway over a depression").

Providing meaning descriptions in these ratings was not completely straightforward, because such descriptions might have biased the exact word meaning that participants activated. However, this method was considered the best available means of evaluating meaning similarity, and is an improvement over other studies, which did not control degree of meaning similarity. Furthermore, strict criteria were used to establish what signified a high degree or a lack of meaning similarity for unambiguous and ambiguous words. For "unambiguous" words, sufficient meaning similarity was assumed only if their two senses were rated 6.0 or higher. For ambiguous words, two meanings were only considered unrelated if they have a mean rating of 2.0 or lower. Based on these criteria, stimuli should have been rated as highly similar only if almost all participants agreed in their ratings, and should have detected lack of similarity only if almost all participants failed to detect any similarity.

Table 37 Stimuli for Similarity Judgments for Prime Meanings, List SJ-1

Stimulus Type	Stimulus	Meaning 1	Meaning 2
amb[a]	ball	a round, spherical body	large formal gathering for social dancing
amb	boil	to bring or cook something to the boiling point	a swelling and inflammation of the skin
amb	bridge	structure carrying a path/roadway over a depression	card game for usually four players
amb	calf	the young of the domestic cow	part of the leg below the knee
amb	foot	terminal part of leg	unit of length
amb	game	activity engaged in for diversion or amusement	wild animals hunted for sport or food
amb	hamper	a large basket	to restrict or interfere with
amb	harp	a plucked stringed instrument	to dwell on or recur to a subject tiresomely
amb	nag	to irritate by constant scolding or urging	an old horse
amb	nap	a short sleep especially during the day	texture of fabric
amb	pen	an implement for writing	an enclosure
amb	plant	a young tree, vine, shrub, or herb	a factory or workshop
amb	poker	a card game	a metal rod for stirring a fire
amb	prune	a dried plum	to trim
amb	riddle	a mystifying, misleading, or puzzling question	fill/ be filled with
amb	skirt	garment	to avoid
amb	staff	a long stick	personnel
amb	staple	a sustaining commodity	metal clip
amb	story	the space in a building between two adjacent floor levels	a fictional narrative
amb	tire	part of wheel	to exhaust
amb	toast	(browned) bread	short speech
amb	wax	substance secreted by bees	to increase
amb	bark	outer layer of stem	dog's vocalization
amb	clog	to impede with something, overfill	wooden shoe
amb	digit	number	finger or toe
amb	mold	a fungus	to give shape to
amb	perch	to sit upon	a fish
amb	pupil	a child or young person in school	the contractile aperture in the iris of the eye
amb	ruler	someone who rules	measuring tool
amb	ring	a circular band	a clear resonant sound
amb	cape	a sleeveless outer garment	peninsula
amb	China	a country	earthenware or porcelain tableware

Table 37 (continued)

amb	drill	instrument for making holes	the act or exercise of repetetive training
amb	gear	equipment	mechanical device
amb	march	a month	to move along steadily
amb	miss	young woman	to fail to hit/ fail to obtain
amb	organ	musical instrument	internal body part
amb	pelt	animal hide	to successively strike, hurl
amb	seal	carnivorous marine mammal	to close or make secure
amb	shed	a slight structure built for shelter or storage	to give off/ to cast off
amb	sink	basin for washing and drainage	to go/ fall down
unamb[b]	badge	sign of identification	sign of authority
unamb	beer	fermented alcoholic beverage made from grains	carbonated nonalcoholic or a fermented slightly alcoholic beverage with flavoring from roots or other plant parts
unamb	beggar	a person who begs	a person who is poor
unamb	cabin	a private room on a ship or boat	a small one-story dwelling
unamb	dill	an herb	a type of pickle
unamb	donor	someone who gives something	someone who gives a bodily organ or blood
unamb	fur	hairy coat of an animal	article of clothing made of fur
unamb	ink	fluid used in pens	squid's protective fluid
unamb	moat	deep/wide trench to protect	a little brook that separates or forms protection
unamb	ounce	unit of weight	small amount
filler	sting	to prick or wound	a secret opereation
filler	hide	to conceal for shelter or protection	the skin of an animal whether raw or dressed
filler	faint	weak, dizzy, and likely to faint	to lose consciousness
filler	date	the time at which an event occurs	an appointment to meet at a specified time
filler	land	the solid part of the surface of the earth	to set or put on shore from a ship
filler	rose	a flower	a pinkish, red color
filler	rare	not frequently encountered	only partially cooked
filler	sharp	having a thin edge	to be clever or smart
filler	shake	to tremble	to cause to quake, quiver, or tremble
filler	plot	the plan or main story of a literary work	a secret plan for accomplishing a usually evil or unlawful end
filler	nail	a small, metal spike	the thin, hard substance on the end of fingers
filler	flat	lacking air	lower than the proper pitch
filler	broke	to have no money	to have split into pieces

[a,b] amb: ambiguous; unamb: unambiguous

Table 38 Stimuli for Similarity Judgments for Prime Meanings, List SJ-2

Stimulus Type	Stimulus	Meaning 1	Meaning 2
amb[a]	COUNT	*a European nobleman*	*to say numbers in order*
amb	CRAFT	*ship/boat*	*manual art*
amb	FILE	*a device to keep papers in order*	*a tool for forming or smoothing surfaces*
amb	HAM	*a cut of meat*	*a show-off*
amb	LETTER	*correspondence*	*unit in alphabet*
amb	PARK	*leisure area*	*leave vehicle stationary*
amb	PITCH	*to throw, toss*	*the relative level of a sound*
amb	STRAIN	*to exert (e.g., oneself) very strongly or excessively*	*to pass something through a sieve*
dom	SWALLOW	*bird*	*food intake*
amb	FAN	*an instrument for producing a current of air*	*an enthusiastic devotee*
amb	LOG	*piece of unshaped timber*	*a record of performance or day-to-day activities*
amb	SPELL	*spoken words held to have magic power*	*to name/write letters in order*
amb	TRAIN	*to teach so as to make fit, qualified, or proficient*	*a connected line of railroad cars*
unamb[b]	VILLAGE	*a small town/community*	*a small grouping of habitation for people*
unamb	WOOL	*hair of sheep*	*a fabric made out of hair of sheep*
unamb	SCISSORS	*tool used to cut*	*swimming movement*
unamb	THIMBLE	*small metal cup*	*unit of measure*
unamb	GROVE	*wooded area*	*grouping of fruit trees*
filler	FAINT	*weak, dizzy, and likely to faint*	*to lose consciousness*
filler	DONOR	*someone who gives something*	*someone who gives a bodily organ or blood*
filler	INK	*fluid used in pens*	*squid's protective fluid*

[a,b] amb: ambiguous; unamb: unambiguous

A.5.3 Instructions, Task and Procedures

The task and procedures were similar to those used by Rodd and colleagues (Rodd, 2002). Participants viewed written instructions and the target words and descriptions for each word meaning or sense on the computer screen, and rated meaning similarity on a 7-point scale. The written instructions were as follows:

> In this task again you will see a word at the top of the screen. Underneath this word you will find descriptions of two meanings of this word. Your task is to judge how similar the two meanings are on a 7-point scale. If the two meanings are very similar, the appropriate rating is 6 or 7. If the meanings are not similar at all, the appropriate meaning is 1. If the meanings are somewhat similar, choose an appropriate rating between these numbers.
>
> NEXT SCREEN
>
> Note that the descriptions only point you to the two meanings of the word, and do not necessarily describe them sufficiently. Thus, after reading the descriptions, go back to the word again and think about its meanings. This way you can make sure you are in fact judging the word meanings and not the two descriptions instead.

---

ceiling

1. overhead inside lining of a room
2. an upper usually prescribed limit

|--|--|--|--|--|--|

1 4 7

low high

Don't know word? "F1"

Participants received spoken instructions about the rating procedure, which was carried out as in the Imageability Ratings for Ambiguous Word Meanings task. The examiner then instructed participants to rate the three practice examples, and discussed each rating with the participants (1st example moderately similar, 2nd example not similar at all, 3rd example highly similar).

ceiling:

1. overhead inside lining of a room
2. an upper usually prescribed limit

steer:

1. a male bovine animal
2. to control the course of (e.g., a vehicle)

lamp:

1. a vessel with a wick for burning an inflammable liquid (as oil) to produce light
2. a glass bulb or tube that emits light produced by electricity

Participants were encouraged to ask questions. After rating the practice items, participants rated the experimental items without receiving any feedback.

A.5.4 Results

No participants' ratings reached the outlier criterion (5.2 MAD or higher from the mean of the average difference from mean stimulus ratings, see footnote 22, page 122). On List SJP-1, 32 of the 41 ambiguous words and 3 of the 10 “unambiguous” words validated. On List SJP-2, 12 of the 13 ambiguous words and 4 of the 7 “unambiguous” words validated. The average 95% confidence interval for mean ratings of each validated item was +/- 0.36 over 39 validated items for List SJP-1, and +/- .46 over 14 validated items for List SJP-2. Table 39 presents for each item individual ratings, means, and absolute values for the confidence interval boundaries.

Table 39 Individual Ratings for Similarity Judgment for Prime Meanings, List SJ-1

Stimulus Type	Stimulus	Participants & Ratings										Mean Rating[c]	95% CI
		10	11	12	13	14	15	16	17	18	19		
amb[a]	cape	1	1	1	1	1	2	1	1	1	1	1.10	0.20
amb	China	1	4	1	1	1	3	2	6	2	1	2.20	
amb	drill	3	2	1	1	1	1	4	2	5	1	2.10	
amb	gear	1	2	3	6	6	1	3	3	5	5	3.50	
amb	march	1	1	1	1	1	1	2	1	1	1	1.10	0.20
amb	miss	1	1	1	2	1	1	1	1	1	1	1.10	0.20
amb	organ	1	1	1	2	1	2	2	3	1	1	1.50	0.44
amb	pelt	1	1	1	1	1	2	2	2	1	1	1.30	0.30
amb	seal	1	1	1	3	1	1	1	1	1	1	1.20	0.39
amb	shed	1	1	1	2	1	2	4	1	1	1	1.50	0.60
amb	sink	3	2	1	2	3	2	4	2	1	1	2.10	
amb	bark	1	1	1	2	1	1	1	1	1	1	1.10	0.20
amb	clog	1	1	1	1	1	1	1	1	2	1	1.10	0.20
amb	digit	3	2	1	4	2	2	3	5	6	1	2.90	
amb	mold	1	1	1	1	1	1	1	1	1	1	1.00	0.00
amb	perch	1	1	1	2	1	1	2	2	1	1	1.30	0.30
amb	pupil	1	1	1	2	1	1	1	2	1	1	1.20	0.26
amb	ruler	2	2	1	3	2	1	2	2	5	1	2.10	
amb	ring	2	1	1	1	2	1	3	1	1	1	1.40	0.43
amb	ball	2	1	1	1	1	2	1	3	3	1	1.60	0.52
amb	boil	4	5	1	1	5	3	3	4	2	1	2.90	
amb	bridge	1	1	1	1	1	1	4	1	1	1	1.30	0.59
amb	calf	1	1	1	3	1	1	2	2	1	1	1.40	0.43
amb	foot	3	6	1	7	1	3	4	5	6	1	3.70	
amb	game	4	2	1	4	1	5	4	3	2	6	3.20	
amb	hamper	1	1	1	2	2	1	1	2	1	1	1.30	0.30
amb	harp	1	1	1	2	1	1	1	2	3	1	1.40	0.43
amb	nag	2	1	1	2	1	1	2	3	1	1	1.50	0.44
amb	nap	1	1	1	1	1	1	1	1	1	1	1.00	0.00
amb	pen	1	1	1	1	1	1	2	2	1	1	1.20	0.26
amb	plant	2	3	1	3	1	1	3	2	1	1	1.80	0.57
amb	poker	2	1	1	2	1	1	1	2	1	1	1.30	0.30
amb	prune	1	1	1	3	1	1	1	2	1	1	1.30	0.42
amb	riddle	1	1	1	2	1	1	1	1	2	1	1.20	0.26
amb	skirt	1	2	1	2	1	2	3	4	1	1	1.80	0.64
amb	staff	3	1	1	1	3	1	1	1	1	1	1.40	0.52
amb	staple	1	1	1	2	2	3	1	1	1	1	1.40	0.43
amb	story	1	1	1	2	1	1	1	1	1	1	1.10	0.20

Table 39 (continued)

amb	tire	1	1	1	1	1	1	2	2	1	1	1.20	0.26
amb	toast	1	1	1	1	1	1	1	3	1	1	1.20	0.39
amb	wax	1	1	1	1	1	3	2	1	1	1	1.30	0.42
unamb[b]	badge	6	7	5	6	6	7	5	6	7	3	5.80	
unamb	beer	7	6	7	4	7	7	5	7	7	7	6.40	0.67
unamb	beggar	6	7	6	6	7	7	6	6	6	6	6.30	0.30
unamb	cabin	6	5	5	5	6	3	5	6	3	3	4.70	
unamb	dill	5	6	1	2	6	4	7	6	4	3	4.40	
unamb	donor	6	6	4	7	6	6	7	6	6	5	5.90	
unamb	fur	6	7	3	6	7	6	6	7	5	3	5.60	
unamb	ink	6	6	4	6	5	4	6	5	6	5	5.30	
unamb	moat	7	6	6	4	7	6	6	6	6	6	6.00	0.51
unamb	ounce	6	6	3	7	6	5	5	6	7	4	5.50	
filler	sting	3	1	1	6	4	4	3	3	1	1	2.70	
filler	plot	5	5	6	1	2	6	4	5	5	5	4.40	
filler	nail	1	3	1	4	1	2	4	3	3	3	2.50	
filler	flat	4	5	1	2	1	2	5	6	3	1	3.00	
filler	broke	2	1	1	3	1	3	2	4	2	1	2.00	
filler	hide	4	2	3	5	4	5	3	2	3	1	3.20	
filler	faint	7	6	7	6	7	7	7	7	6	7	6.70	
filler	date	7	7	6	6	7	6	5	6	7	6	6.30	
filler	land	5	5	2	5	5	4	6	5	3	2	4.20	
filler	rose	5	6	1	1	6	5	6	5	5	4	4.40	
filler	rare	1	1	1	2	2	5	2	2	7	1	2.40	
filler	sharp	4	5	1	5	4	2	6	5	6	1	3.90	
filler	shake	6	6	7	7	7	6	7	7	3	7	6.30	
Average 95% CI for all validated items													0.36
Average DMR[d] for each participant		0.50	0.64	0.89	0.96	0.74	0.64	0.70	0.73	0.81	0.85		

[a] amb: ambiguous
[b] unamb: unambiguous
[c] gray background: validated stimuli
[d] average differences from mean ratings for each item over all ratings for one participant

Table 40 Individual Ratings for Similarity Judgment for Prime Meanings, List SJ-2

Stimulus Type	Stimulus	Participants & Ratings										Mean Rating[c]	95% CI
		10	11	12	13	14	15	16	17	18	19		
amb[a]	COUNT	1	1	1	1	1	1	1	1	1	1	1.00	0.00
amb	CRAFT	2	1	1	2	1	3	3	2	2	1	1.80	0.49
amb	FAN	5	1	1	2	1	2	1	1	1	1	1.60	0.78
amb	FILE	3	1	1	2	1	2	1	1	2	1	1.50	0.44
amb	HAM	1	1	1	1	1	1	1	2	2	1	1.20	0.26
amb	LETTER	4	2	3	4	5	5	3	1	3	1	3.10	
amb	LOG	3	1	1	1	1	2	1	1	1	1	1.30	0.42
amb	PARK	2	1	2	2	1	3	3	1	2	1	1.80	0.49
amb	PITCH	4	1	1	1	1	4	1	2	1	1	1.70	0.78
amb	SPELL	2	1	2	2	2	2	1	4	1	3	2.00	0.58
amb	STRAIN	3	2	1	2	1	3	1	1	2	1	1.70	0.51
amb	SWALLOW	2	1	1	1	1	2	1	5	1	1	1.60	0.78
amb	TRAIN	2	1	1	1	1	2	2	2	1	1	1.40	0.32
unamb[b]	DONOR	7	7	7	7	7	7	7	7	6	7	6.90	0.20
unamb	GROVE	6	7	5	7	6	6	7	6	7	5	6.20	0.49
unamb	INK	4	5	4	6	6	3	6	7	6	4	5.10	
unamb	SCISSORS	2	1	1	4	6	3	5	5	5	1	3.30	
unamb	THIMBLE	4	3	1	5	5	5	6	2	5	1	3.70	
unamb	VILLAGE	6	7	6	6	7	6	7	6	7	6	6.40	0.32
unamb	WOOL	6	3	4	7	6	6	7	4	5	6	5.40	
Average 95% CI for all validated items													0.46
Average DMR[d] for each participant		0. 98	0. 74	0. 69	0. 52	0. 67	0. 75	0. 75	0. 95	0. 64	0. 87		

[a] amb: ambiguous
[b] unamb: unambiguous
[c] gray background: validated stimuli
[d] average differences of mean ratings for each item over all ratings for one participant

A.6 IMAGEABILITY RATINGS FOR SINGLE WORD MEANINGS

A.6.1 Participants

Eighty participants from Group 2, 64 female and 16 male, rated the imageability of unambiguous primes and all targets words.

A.6.2 Stimuli, Task, and Procedure

Initially it was planned to use imageability norms whenever possible to obtain imageability ratings for unambiguous primes and target words. However, after 14 participants had been tested, it became apparent that the recognition criterion could be more reliably measured in the imageability ratings task rather than in the similarity judgment task. Therefore it was decided to present all unambiguous primes and targets in the imageability ratings task, and to use the "don't know" decisions from this task for the recognition criterion.

Because prime-target pairs in the Similarity Ratings for Prime-Target Pairs were frequently changed, items in the Imageability Ratings for Single Word Meanings task changed constantly. Therefore an exhaustive list of items would not be very informative, and is not presented here. Items included most of the potential unambiguous primes and targets. Additionally, filler items were used to ensure the presence of low imageability items (see Appendix A.3.2.). Instructions, and procedures were the same as in the Imageability Ratings for Ambiguous Primes (Appendix A.3.4), except that the instructions for using meaning cues and ambiguous words were omitted, items did not include meaning cues, and different practice items were used (automobile, democracy, book, mirror, care).

automobile

|--|--|--|--|--|--|

1 4 7

low high

Don't know word? "F1"

A.6.3 Results

One female participant was excluded because on average her ratings differed more than 5.2 MAD from the average difference from the mean rating for each stimulus. This left 61 female participants. The average 95% confidence interval for mean ratings for each validated item was +/- 0.6 over 152 items with 15 or more ratings. Recognition results and imageability for all validated items are reported in 6.4, tables 21 and 25.

Imageability judgments were carried out mainly by female participants. To evaluate a potential gender bias, mean ratings from male participants were compared with mean ratings from 3 randomly selected subgroups of female participants using the Interclass Correlation for absolute agreement. A two-way fixed-effects model was used, Because not all participants rated each word, the number of participants from which mean ratings were derived differed between items. Inter-rater reliability between the male and female raters groups was high, suggesting that both groups of raters did not differ in their imageability ratings.

Table 41 Comparison of mean imageability ratings between male and female raters (Intraclass correlation for absolute agreement)

	Comparison 1		Comparison 2		Comparison 3	
Group	female	male	female	male	female	male
Participants Mean (Range)	10 (7-14)	12 (8-12)	10 (7-14)	10 (7-12)	10 (7-14)	10 (8-12)
Items	46		47		42	
Intraclass Correlation (p-value)	-.96 (.00)		-.90 (.00)		-.95 (.00)	

A.7 SIMILARITY RATINGS FOR PRIME-TARGET PAIRS

A.7.1 Participants

Ninety-seven undergraduate students, 80 female and 17 male, participated in this task, either for course credit or a payment of $5.

A.7.2 Stimuli

Stimuli consisted of potential unambiguous and ambiguous Related primes and Unrelated primes, and their respective targets, which were chosen based on the criteria described in Chapter 3.2.1. Overall, 289 unambiguous and 833 ambiguous word pairs were entered into the validation process as potential unambiguous and ambiguous stimuli, respectively. Furthermore, 28 items from the stimuli of McRae and Boisvert's (1998) experiment were included (Table A 42).

Table 42 Less similar and highly similar items from McRae and Boisvert (1998)

Less similar		Highly similar	
Prime	Target	Prime	Target
GARLIC	BEANS	PEAS	BEANS
PUMPKIN	BEETS	RADISH	BEETS
OSTRICH	BUDGIE	PARAKEET	BUDGIE
BELT	CAMISOLE	BRA	CAMISOLE
RAT	CANARY	FINCH	CANARY
PONY	CHICKEN	DUCK	CHICKEN
SOFA	DRESSER	CLOSET	DRESSER
TRICYCLE	DUNEBUGGY	JEEP	DUNEBUGGY
DRAPES	PILLOW	CUSHION	PILLOW
TOMAHAWK	PISTOL	RIFLE	PISTOL
SUBWAY	SCOOTER	MOTORCYCLE	SCOOTER
CLAMP	SHOVEL	HOE	SHOVEL
CANNON	SPEAR	SWORD	SPEAR
ROBIN	TURKEY	GOOSE	TURKEY

A.7.3 Instructions, task and procedures

Stimuli presentation and task procedure were similar to the Similarity Judgment for Prime Meanings task (Appendix 4.3.). Participants viewed prime and target pairs on a computer screen, and rated degree of similarity for each stimulus pair. Written instructions told participants to rate on a seven-point scale “how similar […] the things or concepts that these words refer to” were, with detailed instructions as follows:

> In this task you will see A PAIR of words at the top of the screen. Your task is to judge the similarity of the meanings of the two words in each pair.
> Thus, for each pair of words, ask yourself the question: How similar are the things or concepts that these words refer to?

NEW SCREEN

Here are some examples for possible ratings (you might not completely agree with them)

"dolphin-whale" - highly similar
"dolphin-goat" - less similar
"dolphin-fridge" - dissimilar

"breeze-gust" - highly similar
"breeze-flurry" - less similar
"breeze-cup" - dissimilar

"hive-burrow" - highly similar
"hive-house" - less similar
"hive-clock" - dissimilar

Again, you will make your judgments on a 7-point scale, with 7 representing highly similar word pairs, and 1 representing dissimilar word pairs

NEW SCREEN

Note that many of the words have more than one meaning, especially the first word in each pair. Whenever you think that any meaning of one word is similar to any meaning of the other word, rate those meanings you think are similar.
For example, for the pair "BANK - SHORE", rate the similarity of the word SHORE to the 'river bank' meaning of BANK.

NEW SCREEN

Every time when the first word has two meanings, you will see an "*A*" (for "ambiguous") under the word pair. For example:

bank shore

A

In that case, only make your judgment when you are aware of *BOTH* meanings of that word. So you can make sure you do not miss a similar meaning.

NEW SCREEN

Feel free to use the entire range of numbers, from 1 to 7; at the same time, don't be concerned about how often you use a particular number as long as it is your true judgment.

NEW SCREEN

Again, the question is:
How similar are the things or concepts that the two words refer to?

Work fairly quickly, but do not be careless in your ratings.

---

bank shirt
A

|--|--|--|--|--|--|
1 4 7
low high

Don't know word? 1st word "F1", 2nd
word: “F2”

Participants received spoken instructions for the rating procedure as in Appendix 4.3. Participants rated 12 practice stimuli, and were provided with accuracy feedback:

bank	shirt	*A*
bread	knife	**
junk	boat	*A*
box	crate	*A*
kitchen	church	**
bill	command	*A*
boil	desk	*A*
die	chip	*A*
foil	book	*A*
mirror	puddle	**
cabinet	shelf	*A*
badge	button	**

Three of these practice stimuli were also used as examples for further spoken instructions. First, with the example of *bread-knife*, the instructions emphasized that participants should not rate association. Second, participants were directed to seek the help of the examiner whenever they could not think of two meanings for an ambiguous prime. In that case the examiner provided meaning cues, and noted whether the participants knew both meanings or not. This procedure was explained with the example of “junk”-“boat”, for which very few participants knew the “boat” meaning. Another practice stimulus for which many undergraduate did not know the second meaning (“foil”) was used later in the practice set so that this procedure could be practiced a second time. Third, based on the example of *box*, participants were instructed that a verb form of a noun (*box* vs. *boxed* in) should not be considered a second meaning.

When participants could not think of a second meaning of an ambiguous word, the ratings were not included in the final analysis of similarity ratings. However, these meanings were considered to be “recognized” unless participants indicated that they did not know a second meaning when given a meaning cue. After rating the practice items, participants rated the experimental items without receiving any feedback.

A.7.4 Results

This section describes reasons for stimulus exclusion (including the recognition data generated in the “Imageability Judgments of Single Word Meanings Task, Appendix A.6.) and results of the comparison of male and female raters. None of the participants provided ratings that were outside the outlier criterion. Two of the items by McRae and Boisvert were excluded because they did not reach the recognition criterion (budgie, camisole). The recognition criterion was also not met for eight of the 47 ambiguous Related primes (cape, fare, habit, nag, nap, pelt, riddle, wax), five of the potential ambiguous Unrelated primes (corn, lime, port, quiver, tin), and four of the unambiguous primes (gavel, lapel, psalm, wren). Furthermore, 32 targets failed to meet the recognition criterion (assail, bard, cohort, coral, curd, flub, foundry, gauge, glint, hobo, infest, jetty, ladle, lager, lass, lob, mare, prod, quill, resin, rite, rotor, rummy, shank, sonar, spire, steed, sty, stymie, tartan, tram).

Two more ambiguous Related primes were excluded because they were homophones (ring, ball). For five of the ambiguous Related primes, no suitable targets that matched the similarity criterion were identified (bluff, hail, marble, season, scale). Finally, 4 ambiguous word sets (Related primes: skirt, train, pitch, harp) were excluded to achieve the matching criterion for imageability (less than 0.25 correlation between dominance and imageability. Many permutations of prime-target pairs were necessary for many of the ambiguous Unrelated primes to obtain the similarity rating criterion of 2 or lower. For Experiment 1, the stimulus list was further reduced significantly to control the for lexical co-occurrence, leaving 48 final stimuli. For Experiment 2, the final stimulus list included 100 stimuli.

Similarity judgments were carried out mainly by female participants. To evaluate a potential gender bias, mean ratings from male participants were compared with mean ratings from 3 randomly selected subgroups of female participants using the Interclass Correlation for absolute agreement. A two-way fixed-effects model was used. Because not all participants rated each word, the number of participants from which mean ratings were derived differed between items. Inter-rater reliability between male and female raters was high, suggesting that the two groups did not differ in their similarity ratings.

Table 43 mean similarity ratings between male and female raters

(Intraclass correlation for absolute agreement)

	Comparison 1		Comparison 2		Comparison 3	
Group	female	male	female	male	female	male
Participants Mean (Range)	7 (6-9)	7 (6-9)	7 (6-9)	7 (6-9)	7 (6-9)	7 (6-9)
Items	57		57		65	
Intraclass Correlation (p-value)	-.94 (.00)		-.93 (.00)		-.96 (.00)	

A.8 FINAL STIMULUS LISTS

The next tables (Tables 44 and A-45) present all validated stimuli for Experiment 1 and Experiment 2. All stimuli are listed with the similarity ratings for each item, the number of participants who rated similarity for that item, and the absolute value of the upper and lower bound of the 95% confidence interval.

Table 44 Unambiguous word sets: similarity ratings

Prime[a]	Targets	SimRat Sim[b]	# Part SimRat[c]	95% CI[d]
SALAD	POND	1.0	21	0.0
AUTO	CREAM	1.0	19	0.0
COUGAR	DRUM	1.1	18	0.1
ZIPPER	DOG	1.2	18	0.3
RAVEN	DANCER	1.2	17	0.3
PENCIL	BLAZE	1.3	25	0.4
PENCIL	LAMP	1.4	31	0.3
BUCKET	MAGGOT	1.5	23	0.4
UMPIRE	GRIME	1.6	18	0.5
ATHLETE	DOME	1.8	18	0.8
STEEPLE	LID	2.5	19	0.6
POET	CLERK	2.8	19	0.7
BEER	HONEY	2.9	16	0.8
PARSLEY	MAPLE	3.1	18	0.7
YOGURT	BACON	3.4	19	0.7
PARSLEY	SUGAR	3.4	19	0.8
SQUID	SNAKE	3.5	19	0.7
CANDLE	BEACON	3.7	25	0.8
CHIMNEY	STOVE	3.7	19	0.8
SQUID	SPIDER	3.7	19	0.8
CANOE	CAR	3.8	30	0.6
POET	READER	4.0	27	0.7
CANDLE	SUN	4.1	16	0.8
CHIMNEY	FUNNEL	4.1	26	0.7
TENNIS	FRISBEE	4.2	19	0.9
GROVE	JUNGLE	4.2	18	0.9
NAPKIN	APRON	4.4	18	0.7
DONKEY	PIG	4.5	22	0.9
LICE	MOTH	4.5	26	0.7
SOOT	GRIT	4.7	19	1.0
TROMBONE	FIDDLE	5.0	25	0.7
STEEPLE	ROOF	5.1	17	0.7
YOGURT	BUTTER	5.1	18	0.7
DONKEY	BISON	5.2	19	0.5
TOMATO	MANGO	5.2	18	0.7
TUSK	ANTLER	5.4	19	0.9
SOOT	CINDER	5.5	26	0.7

Table 44 (continued)

TOMATO	APPLE	5.6	18	0.6
TROMBONE	GUITAR	5.6	19	0.7
BEER	SODA	5.6	16	0.6
TENNIS	HOCKEY	5.7	18	0.5
LICE	ROACH	5.8	29	0.6
TUSK	FANG	5.9	18	0.7
NAPKIN	BIB	5.9	18	0.6
OCEAN	RIVER	5.9	21	0.5
GROVE	FIELD	5.9	17	0.5
CANOE	RAFT	6.3	25	0.3
OCEAN	BAY	6.3	18	0.4

[a] Similar prime
[b] Similarity rating for similar prime target pairs
[c] Number of participants who rated similarity of prime
[d] Absolute value of upper and lower bound of 95% confidence interval for each item

Table 45 Ambiguous word sets: similarity ratings

Related Prime	Unrelated Prime	Dom[a] Lev	Targets	SimRat Related[b]	# Part SimRat[c]	95% CI[d]	SimRat Unrel[e]	# Part SimRat	95 % CI
MARCH	IRON	dom	JULY	**5.9**	18	0.7	**1.2**	18	0.2
		sub	STROLL	**5.3**	28	0.6	**1.3**	16	0.3
MISS	PLANE	dom	GIRL	**5.6**	25	0.5	**1.1**	22	0.2
		sub	FUMBLE	**6.0**	18	0.8	**1.3**	21	0.3
ORGAN	MARBLE	dom	GLAND	**5.7**	27	0.5	**1.3**	25	0.3
		sub	TUBA	**4.8**	18	0.9	**1.3**	26	0.4
SEAL	TOLL	dom	SHARK	**5.4**	17	0.8	**1.1**	21	0.2
		sub	PLUG	**6.1**	18	0.5	**1.3**	20	0.4
SHED	BLUFF	dom	BARN	**6.1**	17	0.5	**1.6**	16	0.5
		sub	OOZE	**4.2**	19	0.9	**1.3**	20	0.6
COUNT	LITTER	dom	TALLY	**6.9**	23	0.1	**1.4**	21	0.3
		sub	DUKE	**6.1**	18	0.7	**1.2**	22	0.3
STRAIN	FILE	dom	STRETCH	**5.1**	19	0.9	**1.5**	20	0.5
		sub	RINSE	**5.3**	23	0.8	**1.6**	23	0.4
BARK	POT	dom	GROWL	**6.8**	16	0.2	**1.2**	19	0.2
		sub	CRUST	**4.6**	18	0.7	**1.5**	17	0.4
CLOG	PANEL	dom	IMPEDE	**5.1**	25	0.8	**1.8**	20	0.6
		sub	SANDAL	**6.0**	21	0.5	**1.2**	20	0.2
MOLD	TRIP	dom	MOSS	**5.2**	17	0.8	**1.3**	16	0.4
		sub	SCULPT	**6.1**	23	0.6	**1.4**	26	0.4
PERCH	CRAFT	dom	SQUAT	**4.7**	17	1.0	**1.5**	22	0.5
		sub	TROUT	**5.5**	25	0.9	**1.4**	23	0.5
PUPIL	DART	dom	NOVICE	**5.0**	17	0.8	**1.5**	22	0.4
		sub	CORNEA	**6.7**	17	0.3	**1.3**	23	0.4
FAN	CASE	dom	BLOWER	**6.3**	19	0.4	**1.2**	18	0.3
		sub	PATRON	**5.3**	23	0.6	**1.6**	21	0.6
BRIDGE	HAIL	dom	LINK	**5.4**	18	0.8	**1.2**	22	0.2
		sub	SPADES	**5.1**	24	0.9	**1.3**	18	0.4
CALF	PARK	dom	LAMB	**5.3**	18	0.8	**1.3**	17	0.4
		sub	ANKLE	**5.1**	16	1.0	**1.2**	23	0.2
HAMPER	MOLE	dom	BAG	**5.5**	18	0.7	**1.1**	21	0.1
		sub	HOBBLE	**3.8**	24	0.9	**1.3**	21	0.3

Table 45 (continued)

PLANT	MATCH	dom	SHRUB	**6.3**	26	0.5	**1.5**	21	0.6
		sub	MILL	**5.7**	23	0.8	**1.1**	21	0.1
PRUNE	LAND	dom	PEACH	**6.1**	17	0.7	**1.5**	26	0.4
		sub	TRIM	**6.0**	17	0.9	**1.2**	18	0.3
STORY	BLADE	dom	SAGA	**6.4**	16	0.4	**1.5**	21	0.4
		sub	LEVEL	**5.9**	18	0.7	**1.7**	21	0.6
TIRE	LETTER	dom	HOOP	**4.4**	24	0.7	**1.7**	18	0.5
		sub	WEAKEN	**5.9**	20	0.8	**1.1**	24	0.2
TOAST	SOIL	dom	MUFFIN	**5.3**	26	0.5	**1.2**	18	0.2
		sub	PRAISE	**6.1**	20	0.6	**1.3**	16	0.3
LOG	SWALLOW	dom	TIMBER	**6.4**	27	0.3	**1.7**	23	0.5
		sub	RECORD	**6.8**	23	0.2	**1.1**	17	0.1
PEN	LACE	dom	CRAYON	**5.9**	27	0.5	**1.2**	18	0.2
		sub	CORRAL	**4.8**	25	1.0	**1.4**	19	0.5
STAFF	FALL	dom	TEAM	**5.8**	25	0.5	**1.7**	16	0.5
		sub	WAND	**5.7**	18	0.7	**1.3**	16	0.2
STAPLE	PALM	dom	PIN	**5.2**	16	0.6	**1.7**	18	0.5
		sub	GOODS	**4.8**	27	0.8	**1.3**	19	0.3

[a] Dominance level: dominant and subordinate. Note that these terms are a simplification, because dominance is a continuous variable, and includes equibiased ambiguous words.
[b] Similarity rating for related prime target pairs
[c] Number of participants who rated similarity of prime
[d] Absolute value of upper and lower bound of 95% confidence interval for each item
[e] Similarity rating for unrelated prime target pairs

The average 95% confidence interval for mean ratings for each validated item was +/- 0.5 over 148 items with 16 or more ratings. Given that the difference between high and low similarity is around a rating of 2, this result suggests that a difference between high and low Similarity was sufficiently discriminated.

APPENDIX B

LEXICAL CHARACTERISTICS AND MATCHING RESULTS

B.1 PRIME LEXICAL CHARACTERISTICS

The next three tables (Tables 46, 47, 48) present in detail the lexical characteristics for each prime in Experiment 1 and 2. For ambiguous Related primes F homophony could not be completely excluded too many words would have been ruled out. Thus, words that were homophones with rather obscure meanings were included. These homophones and their meanings are listed in Table 48.

Table 46 Experiment 1: Prime lexical characteristics

Prime	Image[a]	# Raters[b]	95 % CI[c]	Recog crit[d]	Lengt[e] (letters)	Length[f] (syllables)	Freq[g]	OrthN[h]
ATHLETE	5.11	18	0.87	0.000	7	2	7.2	0
AUTO	4.50	20	0.96	0.000	4	2	9.65	1
BEER	6.00	18	0.82	0.000	4	1	10.11	15
BUCKET	6.39	18	0.55	0.000	6	2	8.11	2
CANDLE	6.67	18	0.32	0.000	6	2	7.91	2
CANOE	6.44	18	0.45	0.000	5	2	7.45	1
CHIMNEY	6.78	37	0.21	0.000	7	2	6.28	0
COUGAR	6.60	20	0.41	0.000	6	2	7.24	0
DONKEY	6.80	40	0.21	0.000	6	2	7.87	1
GROVE	4.41	17	0.90	0.059	5	1	8.27	6
LICE	5.78	18	0.72	0.000	4	1	5.98	14
NAPKIN	6.50	18	0.48	0.000	6	2	5.76	0
OCEAN	6.78	18	0.25	0.000	5	2	9.31	0
PARSLEY	6.00	20	0.55	0.000	7	2	6.66	1
PENCIL	6.78	18	0.25	0.000	6	2	8.01	0
POET	4.39	18	0.95	0.000	4	1	8.15	5
RAVEN	6.60	20	0.44	0.000	5	2	8.13	6
SALAD	6.56	18	0.53	0.000	5	2	7.82	0
SOOT	4.94	18	0.73	0.000	4	1	5.65	17
SQUID	6.53	17	0.84	0.059	5	1	7.03	2
STEEPLE	6.35	17	0.88	0.059	7	2	4.45	1
TENNIS	6.22	18	0.58	0.000	6	2	8.77	1
TOMATO	6.50	18	0.40	0.000	6	3	7.67	0
TROMBONE	6.56	18	0.45	0.000	8	2	6.56	0
TUSK	5.50	18	0.89	0.000	4	1	5.38	9
UMPIRE	6.22	18	0.60	0.000	6	3	6.96	1
YOGURT	6.50	18	0.40	0.000	6	2	7.15	0
ZIPPER	6.50	18	0.58	0.000	6	2	7.13	5

[a] Prime imageability
[b] Number of participants who rated imageability of prime
[c] Absolute value of upper and lower bound of 95% confidence interval of imageability ratings for each item
[d] Recognition criterion: if more than 1 out of 16 participants did not recognize a word (values greater than .0625), it was eliminated as a potential prime
[e] Length in letters
[f] Length in syllables
[g] Frequency
[h] Orthographic Neighborhood

Table 47 Experiment 2: Prime lexical characteristics

Prime	Prime Type	Dom/ Dom[a]	Dom/ Sub[b]	D-Im[c]	95% CI D-Im[d]	S-Im[e]	95% CI S-Im[f]	# D-PoS[g]	# S-PoS[h]	LL[i]	SL[j]	Freq[k]	orthN[l]
MARCH	Rel[m]	0.51	0.47	4.25		5.58		1	2	5	1	11.22	5
MISS	Rel	0.43	0.42	4.64	0.64	2.64		2	1	4	1	10.34	11
ORGAN	Rel	0.50	0.47	6.03		4.76		1	1	5	2	9.86	0
SEAL	Rel	0.50	0.40	6.41		4.03		2	2	4	1	8.77	17
SHED	Rel	0.52	0.40	5.92		3.75		1	1	4	1	8.74	9
COUNT	Rel	0.71	0.21	4.57	0.94	3.07		2	1	5	1	10.45	3
STRAIN	Rel	0.69	0.25	4.33		3.11	4.61	2	1	6	1	9.18	2
BARK	Rel	0.68	0.26	6.36	0.57	6.57	0.40	2	1	4	1	7.8	19
CLOG	Rel	0.74	0.18	5.21	0.55	6.36	0.33	1	1	4	1	6.73	7
MOLD	Rel	0.67	0.27	6.14	0.71	5.29	0.66	2	2	4	1	8.23	13
PERCH	Rel	0.66	0.32	4.78		4.32		2	1	5	1	6.65	4
PUPIL	Rel	0.67	0.33	6.07	0.32	6.00	0.74	1	1	5	2	6.94	1
FAN	Rel	0.75	0.19	4.50	0.98	6.50	0.34	2	1	3	1	10.53	23
BRIDGE	Rel	0.60	0.20	6.79	0.30	5.21	0.95	2	1	6	1	9.87	2
CALF	Rel	0.81	0.11	6.29	0.60	6.43	0.45	1	1	4	1	7.3	5
HAMPER	Rel	0.84	0.03	6.29	0.43	3.07	0.86	1	1	6	2	6.14	6
PLANT	Rel	0.93	0.02	6.93	0.14	5.14	0.68	2	1	5	1	10.14	5
PRUNE	Rel	0.92	0.03	5.94		4.62		1	1	5	1	6.61	2
STORY	Rel	0.97	0.02	5.57	0.73	3.93	1.00	2	1	5	2	11.48	4
TIRE	Rel	0.87	0.05	6.57	0.49	3.79	0.90	1	1	4	1	8.73	16
TOAST	Rel	0.88	0.09	6.64	0.33	4.64	0.81	2	2	5	1	8.03	3
LOG	Rel	0.8	0.09	4.29	0.91	6.64	0.33	2	2	3	1	9.99	21
PEN	Rel	0.91	0.04	6.64	0.26	5.14	0.98	2	2	3	1	8.97	24
STAFF	Rel	0.8	0.11	5.28		5.38		2	1	5	1	10.62	2
STAPLE	Rel	0.81	0.11	2.57	0.67	6.50	0.40	2	2	6	2	7.01	1
IRON	Unrel[n]			6.05		4.95				4	2	9.86	3
PLANE	Unrel			6.93		3.86				5	1	9.84	6
MARBLE	Unrel			5.97		5.73				6	2	8.31	2
TOLL	Unrel			3.36		4.29				4	1	8.93	14
BLUFF	Unrel			2.00		5.43				5	1	7	1
LITTER	Unrel			6.21		5.50				6	2	8.12	9
FILE	Unrel			6.36		6.29				4	1	12.65	16
POT	Unrel			5.89		4.85				3	1	9.49	22
PANEL	Unrel			5.71		4.57				5	2	9.89	1
TRIP	Unrel			4.95		5.41				4	1	10.25	8
CRAFT	Unrel			5.22		5.44				5	1	8.84	4
DART	Unrel			5.92		4.43				4	1	7.41	12
CASE	Unrel			5.27		3.60				4	1	12.2	14
HAIL	Unrel			5.95		4.00				4	1	8.08	15
PARK	Unrel			5.73		5.14				4	1	10.75	15
MOLE	Unrel			6.22		4.54				4	1	7.34	22

Table 47 (continued)

MATCH	Unrel	5.24		5	1	10.47	11
LAND	Unrel	5.46	5.80	4	1	11.23	15
BLADE	Unrel	6.00	5.08	5	1	9.17	6
LETTER	Unrel	5.92	4.27	6	2	10.97	7
SOIL	Unrel	6.36	2.00	4	1	8.94	7
SWALLOW	Unrel			7	2	8.07	1
LACE	Unrel			4	1	8.1	17
FALL	Unrel			4	1	10.74	13
PALM	Unrel	5.94	6.08	4	1	8.7	6

[a] Dominance Value for "dominant" primes (this includes equibiased meanings)
[b] Dominance Value for "subordinate" primes (this includes equibiased meanings)
[c] Imageability ratings for "dominant" meanings. Ratings were generated in the "Imageability Ratings for Ambiguous Meanings" task, or taken from the norms by Gilhooly & Logie, 1980b
[d] Absolute value of upper and lower bound of 95% confidence interval for "dominant" meanings rated in the "Imageability Ratings for Ambiguous Meanings" task
[e] Imageability ratings for "subordinate" meanings. Ratings were generated in the "Imageability Ratings for Ambiguous Meanings" task, or taken from the norms by Gilhooly &Logie, 1980b
[f] Absolute value of upper and lower bound of 95% confidence interval for "subordinate" meanings rated in the "Imageability Ratings for Ambiguous Meanings" task
[g] Number of noun and verb meanings (part of speech) for the "dominant" meaning
[h] Number of noun and verb meanings (part of speech) for the "subordinate" meaning
[i] Length in letters
[j] Length in syllables
[k] Frequency
[l] Orthographic Neighborhood
[m] Related prime
[n] Unrelated prime

Table 48 Homophones of unambiguous and ambiguous primes

Prime	Homophone	Meaning
lice	lyse	to cause to undergo the gradual decline of a disease process
calf	kaph	11th letter of the Hebrew alphabet
pitch	pich	a West Indian shrub or small tree
pupil	pupal	related to pupa stage of insect life cycle
seal	ceil	to make a ceiling
	seel	to close a hawk's eyes by drawing thread through its eyelids
staff	staph	short for staphlococcus
tire	tier	a person who binds or fastens things together

B.2 TARGET LEXICAL CHARACTERISTICS

Table 49 Experiment 2: Target lexical characteristics

Target	Image[a]	# Raters[b]	95 % CI[c]	Recog[d]	LL[e]	LS[f]	Freq[g]	OrthN[h]
POND	6.45	20	0.5	0.0000	4	1	8.19	8
CREAM	5.67	18	0.7	0.0000	5	1	9.20	3
DRUM	6.55	20	0.5	0.0000	4	1	9.02	4
DOG	6.90	20	0.1	0.0000	3	1	10.97	19
DANCER	6.45	20	0.3	0.0000	6	2	8.00	7
BLAZE	4.68	40	0.7	0.0000	5	1	8.43	7
LAMP	6.76	37	0.2	0.0000	4	1	8.80	12
MAGGOT	6.15	40	0.5	0.0250	6	2	6.21	1
GRIME	4.15	20	0.8	0.0000	5	1	5.73	5
DOME	5.89	18	0.7	0.0000	4	1	7.71	15
LID	5.85	20	0.7	0.0000	3	1	7.97	18
CLERK	6.02	41	0.4	0.0000	5	1	7.91	1
HONEY	6.38	16	0.4	0.0000	5	2	9.12	8
MAPLE	5.65	20	0.6	0.0000	5	2	8.31	0
BACON	6.55	20	0.5	0.0000	5	2	8.05	3
SUGAR	6.39	18	0.5	0.0000	5	2	9.57	0
SNAKE	6.75	20	0.3	0.0000	5	1	8.56	6
BEACON	3.41	54	0.6	0.0556	6	2	7.48	1
STOVE	6.39	18	0.6	0.0000	5	1	7.52	8
SPIDER	6.72	18	0.3	0.0000	6	2	8.85	0
CAR	6.80	20	0.2	0.0000	3	1	11.37	23
READER	5.23	53	0.5	0.0000	6	2	10.05	7
SUN	6.88	16	0.3	0.0000	3	1	11.21	21
FUNNEL	6.40	53	0.3	0.0000	6	2	6.67	3
FRISBEE	6.65	20	0.4	0.0000	7	2	6.47	0
JUNGLE	6.61	18	0.3	0.0000	6	2	8.61	5
APRON	6.28	18	0.6	0.0000	5	2	6.29	2
PIG	6.70	20	0.4	0.0000	3	1	8.76	16
MOTH	6.42	19	0.5	0.0000	4	1	6.24	6
GRIT	3.45	20	0.8	0.0000	4	1	6.98	10
FIDDLE	6.15	20	0.6	0.0000	6	2	7.64	6
ROOF	6.19	16	0.7	0.0000	4	1	8.64	9

Table 49 (continued)

BUTTER	6.39	18	0.6	0.0000	6	2	8.83	11
BISON	6.16	19	0.9	0.0526	5	2	6.99	0
MANGO	6.40	20	0.4	0.0000	5	2	6.77	6
ANTLER	6.46	28	0.6	0.0357	6	2	4.44	2
CINDER	4.76	17	0.9	0.0588	6	2	6.17	7
APPLE	6.85	27	0.1	0.0000	5	2	11.10	2
GUITAR	6.83	40	0.2	0.0000	6	2	10.12	0
SODA	6.06	16	0.7	0.0000	4	2	8.12	6
HOCKEY	6.22	18	0.5	0.0000	6	2	9.41	2
ROACH	6.63	41	0.3	0.0000	5	1	6.69	3
FANG	5.89	18	0.7	0.0000	4	1	6.82	12
BIB	5.56	18	0.7	0.0000	3	1	6.66	14
RIVER	6.80	20	0.2	0.0000	5	2	10.21	13
FIELD	6.15	20	0.5	0.0000	5	1	11.29	3
RAFT	6.65	40	0.2	0.0000	4	1	6.73	8
BAY	6.15	20	0.6	0.0000	3	1	10.40	25

[a] Imageability
[b] Number of participants who rated imageability of prime
[c] Absolute value of upper and lower bound of 95% confidence interval of imageability ratings for each item
[d] Recognition criterion: if more than 1 out of 16 participants did not recognize a word (values greater than .0625), it was eliminated as a potential prime
[e] Length in letters
[f] Length in syllables
[g] Frequency
[h] Orthographic Neighborhood

Table 50 Experiment 2: Target lexical characteristics

Target	Dominance Level	Image[a]	# Part Image[b]	95 % CI[c]	Recog[d]	LL[e]	SL[f]	Freq[g]	OrthN[h]
JULY	dom	3.45	20	.6741	0.0000	4	1	10.06	3
GIRL	dom	6.71	21	.2753	0.0000	4	1	10.61	4
GLAND	dom	4.50	26	.8119	0.0385	5	2	6.61	3
SHARK	dom	6.88	25	.1300	0.0000	5	1	8.09	9
BARN	dom	6.75	20	.3447	0.0000	4	1	7.85	16
TALLY	dom	3.90	20	.8400	0.0000	5	1	7.01	8
STRETCH	dom	5.44	27	.6392	0.0000	7	1	9.15	1
GROWL	dom	4.70	23	.9175	0.0000	5	1	6.42	3
IMPEDE	dom	2.58	24	.7168	0.0000	6	1	6.26	0
MOSS	dom	6.17	18	.5073	0.0000	4	1	8.22	22
SQUAT	dom	4.96	23	.7840	0.0000	5	1	7.40	3
NOVICE	dom	3.27	22	.8386	0.0455	6	2	8.56	1
BLOWER	dom	4.69	26	.7933	0.0385	6	1	6.28	3
LINK	dom	3.86	21	.9398	0.0000	4	1	10.57	15
LAMB	dom	6.68	19	.3687	0.0000	4	1	8.14	7
BAG	dom	6.60	20	.4121	0.0000	3	2	9.71	25
SHRUB	dom	6.33	21	.6247	0.0000	5	1	5.63	2
PEACH	dom	6.80	20	.2698	0.0000	5	1	7.50	7
SAGA	dom	2.65	20	.7561	0.0000	4	2	7.94	7
HOOP	dom	6.27	41	.4221	0.0000	4	1	7.15	8
MUFFIN	dom	6.85	40	.1653	0.0000	6	1	6.90	1
TIMBER	dom	5.24	21	.8327	0.0000	6	1	8.37	1
CRAYON	dom	6.90	53	.0957	0.0000	6	1	5.73	0
TEAM	dom	5.95	20	.5594	0.0000	4	1	11.59	11
PIN	dom	6.43	21	.4796	0.0000	3	2	10.12	19
STROLL	sub	4.70	23	.8121	0.0000	6	2	6.33	1
FUMBLE	sub	5.04	27	.7792	0.0000	6	1	5.81	6
TUBA	sub	6.38	32	.6824	0.0625	4	2	6.03	5
PLUG	sub	6.10	21	.5043	0.0000	4	1	9.67	3
OOZE	sub	5.30	23	.8121	0.0000	4	1	7.81	2
DUKE	sub	4.21	19	.8631	0.0526	4	2	9.40	9
RINSE	sub	5.10	21	.7396	0.0000	5	1	7.44	0
CRUST	sub	6.13	23	.6320	0.0000	5	1	7.30	5
SANDAL	sub	6.68	19	.3017	0.0000	6	2	4.98	1
SCULPT	sub	5.13	23	.8109	0.0000	6	1	5.14	0
TROUT	sub	6.65	20	.7246	0.0500	5	1	7.57	2
CORNEA	sub	5.52	27	.7686	0.0370	6	1	5.61	3
PATRON	sub	3.60	20	.9259	0.0000	6	1	7.42	3
SPADES	sub	5.79	24	.6567	0.0000	6	1	6.82	4
ANKLE	sub	6.35	20	.4982	0.0000	5	1	7.90	1
HOBBLE	sub	4.53	30	.7263	0.0000	6	1	4.91	4
MILL	sub	5.42	24	.7547	0.0000	4	1	8.49	18
TRIM	sub	3.00	20	.6966	0.0000	4	1	8.33	9

Table 50 (continued)

LEVEL	sub	2.89	19	.7013	0.0000	5	1	11.78	4
WEAKEN	sub	2.93	41	.5048	0.0000	6	2	7.11	1
PRAISE	sub	2.94	18	.8153	0.0000	6	1	8.70	1
RECORD	sub	6.10	21	.6330	0.0000	6	2	11.03	2
CORRAL	sub	5.38	40	.5534	0.0250	6	1	5.83	0
WAND	sub	5.90	20	.7644	0.0000	4	1	8.60	11
GOODS	sub	4.56	16	.9118	0.0000	5	1	9.41	9

[a] Imageability
[b] Number of participants who rated imageability of prime
[c] Absolute value of upper and lower bound of 95% confidence interval of imageability ratings for each item
[d] Recognition criterion: if more than 1 out of 16 participants did not recognize a word (values greater than .0625), it was eliminated as a potential prime
[e] Length in letters
[f] Length in syllables
[g] Frequency
[h] Orthographic Neighborhood

B.3 MATCHING FOR PRIME AND TARGET LEXICAL CHARACTERISTICS

B.3.1 Matching for the continuous analysis

Table 51 Experiment 1: Correlations for prime lexical characteristics (N = 48)

		SIM	IM	NNVM[c]	LL	LS	FREQ	ORTHN
SIM[a]	Spearman Correlation	1						
	Sig. (2-tailed)	.						
IM[b]	Spearman Correlation	-0.08	1					
	Sig. (2-tailed)	*0.61*	.					
NNVM[c]	Spearman Correlation	-0.21	0.08	1				
	Sig. (2-tailed)	*0.16*	*0.59*	.				
LL[d]	Spearman Correlation	-0.18	.48(**)	-0.24	1			
	Sig. (2-tailed)	*0.24*	*0.00*	*0.10*	.			
LS[e]	Spearman Correlation	-0.19	.54(**)	-0.10	.70 (**)	1		
	Sig. (2-tailed)	*0.21*	*0.00*	*0.48*	*0.00*	.		
FREQ[f]	Spearman Correlation	-0.12	0.05	-0.12	-0.26	0.04	1	
	Sig. (2-tailed)	*0.44*	*0.73*	*0.427*	*0.08*	*0.770*	.	
ORTHN[g]	Spearman Correlation	0.08	-.60(**)	.37(*)	-.67(**)	-.75(**)	0.02	1
	Sig. (2-tailed)	*0.60*	*0.00*	*0.01*	*0.00*	*0.00*	*0.91*	.

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
[a] Similarity
[b] Imageability
[c] Number of Noun/Verb Meanings
[d] Length in Letters
[e] Length in Syllables
[f] Frequency
[g] Orthographic Neighborhood

Table 52 Experiment 2: Correlations lexical characteristics: ambiguous *Related primes*

(N = 50)

		DOM	IM	NNVM	LL	SL	FREQ	ORTHN
DOM[a]	Spearman Correlation	1.00						
	Sig. (2-tailed)	.						
IM[b]	Spearman Correlation	0.25	1.00					
	Sig. (2-tailed)	0.09	.					
NNVM[c]	Spearman Correlation	.33(*)	0.10	1.00				
	Sig. (2-tailed)	0.02	0.50	.				
LL[d]	Spearman Correlation	0.01	-0.18	-0.24	1.00			
	Sig. (2-tailed)	0.93	0.23	0.10	.			
SL[e]	Spearman Correlation	0.03	-0.06	-0.24	.46(**)	1.00		
	Sig. (2-tailed)	0.86	0.66	0.09	0.00	.		
FREQ[f]	Spearman Correlation	-0.01	-0.14	0.12	-0.11	-0.17	1.00	
	Sig. (2-tailed)	0.93	0.32	0.40	0.44	0.25	.	
ORTHN[g]	Spearman Correlation	-0.02	0.13	.31(*)	-.82(**)	-.47(**)	0.08	1.00
	Sig. (2-tailed)	0.89	0.36	0.03	0.00	0.00	0.57	.

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
[a] Dominance
[b] Imageability
[c] Number of Noun/Verb Meanings
[d] Length in Letters
[e] Length in Syllables
[f] Frequency
[g] Orthographic Neighborhood

Table 53 Experiment 2: Correlations lexical characteristics: ambiguous *Unrelated primes* (N = 50)

		DOM	IM	LL	LS	FREQ	ORTHN
DOM[a]	Spearman Correlation	1.00					
	Sig. (2-tailed)	.					
IM[b]	Spearman Correlation	.33(*)	1.00				
	Sig. (2-tailed)	0.02	.				
LL[c]	Spearman Correlation	-0.02	0.02	1.00			
	Sig. (2-tailed)	0.90	0.87	.			
LS[d]	Spearman Correlation	0.00	0.15	.62(**)	1.00		
	Sig. (2-tailed)	0.99	0.29	0.00	.		
FREQ[e]	Spearman Correlation	0.09	-0.155	-0.18	-0.05	1.00	
	Sig. (2-tailed)	0.95	0.28	0.20	0.72	.	
ORTHN[f]	Spearman Correlation	0.00	0.05	-.70(**)	-.54(**)	0.20	1.00
	Sig. (2-tailed)	0.99	0.73	0.00	0.0	0.17	.

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
[a] Dominance
[b] Imageability
[c] Length in Letters
[d] Length in Syllables
[e] Frequency
[f] Orthographic Neighborhood

Table 54 Experiment 1: Correlations for *target* lexical characteristics (N = 48)

		SIMST	IM	LL	Lmm	SL	FREQ	ORTHN
SIMST[a]	Spearman Correlation	1						
	Sig. (2-tailed)	.						
IM[b]	Spearman Correlation	0.06	1					
	Sig. (2-tailed)	0.71	.					
LL[c]	Spearman Correlation	0.02	-0.08	1				
	Sig. (2-tailed)	0.88	0.61	.				
Lmm[d]	Spearman Correlation	0.16	0.04	.75 (**)	1			
	Sig. (2-tailed)	0.27	0.81	0.00	.			
SL[e]	Spearman Correlation	-0.10	-0.08	.93(**)	.72(**)	1		
	Sig. (2-tailed)	0.48	0.59	0.00	0.00	.		
FREQ[f]	Spearman Correlation	-0.05	.37(**)	-0.21	-0.08	-0.24	1	
	Sig. (2-tailed)	0.71	0.01	0.15	0.61	0.11	.	
ORTHN[g]	Spearman Correlation	0.04	0.05	-.68(**)	-.56(**)	-.65(**)	0.22	1
	Sig. (2-tailed)	0.82	0.72	0.00	0.00	0.00	0.13	.

** Correlation is significant at the 0.01 level (2-tailed).
[a] Strength of Similarity
[b] Imageability
[c] Length in Letters
[d] Length in millimeters
[e] Length in Syllables
[f] Frequency
[g] Orthographic Neighborhood

Table 55 Experiment 2: Correlations for *target* lexical characteristics (N = 50)

		DOM	IM	LL	Lmm	LS	FREQ	ORTHN
DOM[a]	Spearman Correlation	1						
	Sig. (2-tailed)	.						
IM[b]	Spearman Correlation	.30(*)	1					
	Sig. (2-tailed)	0.03	.					
LL[c]	Spearman Correlation	-0.17	-0.20	1				
	Sig. (2-tailed)	0.23	0.18	.				
Lmm[d]	Spearman Correlation	-0.19	-0.17	.93(**)	1			
	Sig. (2-tailed)	0.20	0.24	0.00	.			
LS[e]	Spearman Correlation	-0.07	-0.24	.49(**)	.51(**)	1		
	Sig. (2-tailed)	0.65	0.09	0.00	0.00	.		
FREQ[f]	Spearman Correlation	-0.06	-0.06	-.52(**)	-.53(**)	-.33(*)	1	
	Sig. (2-tailed)	0.67	0.71	0.00	0.00	0.02	.	
ORTHN[g]	Spearman Correlation	0.11	0.14	-.73(**)	-.64(**)	-.39(**)	.43(**)	1
	Sig. (2-tailed)	0.47	0.34	0.00	0.00	0.01	0.00	.

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

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

[a] Dominance
[b] Imageability
[c] Length in Letters
[d] Length in millimeters
[e] Length in Syllables
[f] Frequency
[g] Orthographic Neighborhood

Table 56 Experiment 2: *t* tests for lexical characteristics related/unrelated primes (N = 50, 25 in each Relatedness condition)

	Prime Type	Mean	Std. Deviation	*t*-value	*p*-value
Im [a]	Related	5.5	1.10	0.090	0.93
	Unrelated	5.5	1.20		
LL [b]	Related	4.6	0.91	0.155	0.88
	Unrelated	4.6	0.92		
SL [c]	Related	1.2	0.41	-0.335	0.74
	Unrelated	1.2	0.44		
Freq [d]	Related	8.8	1.60	-1.370	0.18
	Unrelated	9.4	1.49		
OrthN [e]	Related	8.2	7.59	-0.871	0.39
	Unrelated	9.9	6.31		

[a] Imageability
[b] Length in letters
[c] Length in syllables
[d] Frequency
[e] Orthographic Neighborhood

B.3.2 Matching for the dichotomous analyses

Table 57 Experiment 1: 1-way ANOVA for lexical characteristics of primes and targets (N = 48, 16 in each group)

	Group	Mean	Standard Deviation	Minimum	Maximum	*F*-Value	*p*-value
Prime-Target Similarity	1	1.9	0.9	1.5	2.4	147.801	0.00
	2	4.2	0.5	4.0	4.4		
	3	5.7	0.4	5.5	5.9		
Primes							
IM[a]	1	6.1	0.8	4.4	6.8	0.031	0.97
	2	6.1	0.8	4.4	6.8		
	3	6.1	0.7	4.4	6.8		
NNVM[b]	1	1.4	0.6	1	3	0.517	0.60
	2	1.4	0.5	1	2		
	3	1.3	0.4	1	2		
LL[c]	1	5.8	1.1	4	7	0.930	0.40
	2	5.7	1.2	4	8		
	3	5.3	1.1	4	8		
LS[d]	1	1.9	0.4	1	3	1.301	0.28
	2	1.6	0.5	1	2		
	3	1.8	0.7	1	3		
FREQ[e]	1	7.6	1.3	4.5	10.1	0.941	0.40
	2	7.0	1.2	4.5	8.8		
	3	7.4	1.5	5.4	10.1		
ORTHN[f]	1	2.4	3.9	0	15	0.725	0.49
	2	3.4	5.1	0	17		
	3	4.6	6.2	0	17		
Targets							
Im	1	6.0	0.7	4.2	6.9	0.322	0.73
	2	6.1	1.1	3.4	6.9		
	3	6.2	0.5	4.8	6.9		
LL	1	4.6	0.9	3	6	0.375	0.69
	2	4.9	1.3	3	7		
	3	4.9	1.0	3	6		
LS	1	1.4	0.5	1	2	0.978	0.38
	2	1.5	0.5	1	2		
	3	1.6	0.5	1	2		

Table 57 (continued)

Lmm	1	2.1	0.5	1	3	0.017	0.98
	2	2.1	0.5	1	3		
	3	2.1	0.5	1	3		
FREQ	1	8.3	1.2	5.7	11.0	0.036	0.96
	2	8.2	1.6	6.2	11.4		
	3	8.2	2.0	4.4	11.3		
ORTHN	1	6.9	6.2	0	19	0.056	0.95
	2	7.7	6.9	0	23		
	3	7.1	6.6	0	25		

[a] Imageability
[b] Number of Noun/Verb Meanings
[c] Length in Letters
[d] Length in Syllables
[e] Frequency
[f] Orthographic Neighborhood

Table 58 Experiment 2: Comparison lexical characteristics of 1st and 2nd meaning targets (t –tests)

	Meaning	N	Mean	Std. Deviation	t -value	*p*-value
IM [a]	First	25	5.4	1.43	0.880	0.38
	Second	25	5.1	1.21		
LL [b]	First	25	4.8	1.04	-1.477	0.15
	Second	25	5.2	0.87		
Lmm [c]	First	25	2.1	0.49	-1.649	0.11
	Second	25	2.3	0.43		
FREQ [d]	First	25	8.1	1.64	1.018	0.31
	Second	25	7.6	1.82		
ORTHN [e]	First	25	7.1	7.16	1.753	0.09
	Second	25	4.2	4.25		

[a] Imageability
[b] Length in letters
[c] Length in millimeters
[d] Frequency
[e] Orthographic Neighborhood

B.3.3 Comparison between experiments

Table 59 Experiment 2: *t* tests for lexical characteristics related/unrelated primes

	Experiment	Mean	Standard Deviation	*t*-value	*p*-value
IM [a]	1	6.11	0.81	4.026	0.00
	2	5.22	1.32		
LL [b]	1	4.81	1.07	-0.912	0.36
	2	5.00	0.97		
Lmm [c]	1	1.50	0.51	0.758	0.45
	2	1.42	0.54		
SL [d]	1	2.11	0.50	-1.304	0.20
	2	2.24	0.47		
FREQ [e]	1	8.24	1.63	1.203	0.23
	2	7.83	1.73		
ORTHN [f]	1	7.25	6.45	1.295	0.20
	2	5.62	6.01		

[a] Imageability
[b] Length in letters
[c] Length in millimeters
[d] Length in syllables
[e] Frequency
[f] Orthographic Neighborhood

APPENDIX C

STIMULUS LISTS

C.1 EXPERIMENT 1

Experiment 1 used three main stimulus lists: Lists A and B, which included experimental prime-target pairs and fillers, and List SLD for the single lexical decision task. Lists A and B are presented in the next two tables, followed by a table that shows counterbalancing for Visual Field. List SLD consisted of experimental and filler targets from List A and B, and items for the fixation control task. For List SLD, 33 words and 31 nonwords were presented to the left visual field, and 31 words and 33 nonwords were presented to the right visual field.

Table 60 List A (Word list for Experiment 1)

Stimulus Type	Prime	Target	Prime Ambiguity	Response	Exp vs. Filler[a]	Relatedness	Visual Field
EXP/UNF[b]							
	CANOE	RAFT	un[c]	yes	exp[d]	rel[e]	lvf[f]
	LINT	YACHT	un	yes	fill[g]	unrel[h]	lvf
	BEER	HONEY	un	yes	exp	rel	rvf[i]
	TERMITE	LIQUOR	un	yes	fill	unrel	rvf
	CANDLE	BEACON	un	yes	exp	rel	rvf
	PENCIL	LAMP	un	yes	exp	unrel	rvf
	TROMBONE	GUITAR	un	yes	exp	rel	lvf
	COUGAR	DRUM	un	yes	exp	unrel	lvf
	CHIMNEY	STOVE	un	yes	exp	rel	lvf
	TULIP	VENT	un	yes	fill	unrel	lvf
	PARSLEY	SUGAR	un	yes	exp	rel	rvf
	MAGNET	SALT	un	yes	fill	unrel	rvf
	DONKEY	BISON	un	yes	exp	rel	rvf
	ZIPPER	DOG	un	yes	exp	unrel	rvf
	OCEAN	RIVER	un	yes	exp	rel	lvf
	SALAD	POND	un	yes	exp	unrel	lvf
	LICE	MOTH	un	yes	exp	rel	lvf
	BUCKET	MAGGOT	un	yes	exp	unrel	lvf
	POET	READER	un	yes	exp	rel	rvf
	RAVEN	DANCER	un	yes	exp	unrel	rvf
	TENNIS	HOCKEY	un	yes	exp	rel	rvf
	RACCOON	POLO	un	yes	fill	unrel	rvf
	STEEPLE	LID	un	yes	exp	rel	lvf
	ATHLETE	TOWER	un	yes	fill	unrel	lvf
	SQUID	SNAKE	un	yes	exp	rel	lvf
	THIMBLE	EEL	un	yes	fill	unrel	lvf
	SOOT	CINDER	un	yes	exp	rel	rvf
	UMPIRE	TAR	un	yes	fill	unrel	rvf
	TUSK	ANTLER	un	yes	exp	rel	rvf
	GULLY	MOLAR	un	yes	fill	unrel	rvf
	YOGURT	BACON	un	yes	exp	rel	lvf
	AUTO	CREAM	un	yes	exp	unrel	lvf
	NAPKIN	APRON	un	yes	exp	rel	lvf
	VILLAGE	TOWEL	un	yes	fill	unrel	lvf
	TOMATO	MANGO	un	yes	exp	rel	rvf
	CRATER	TURNIP	un	yes	fill	unrel	rvf
	GROVE	FIELD	un	yes	exp	rel	lvf
	VODKA	MEADOW	un	yes	fill	unrel	rvf

Table 60 (continued)

RCF[j]							
	PETAL	LODIE	un	no	fill	non	lvf
	CART	RADGE	un	no	fill	non	lvf
	CLAMP	ROLIE	un	no	fill	non	rvf
	RICE	TORM	un	no	fill	non	rvf
	SLEET	GEALM	un	no	fill	non	rvf
	COUNTER	GLAY	amb[k]	no	fill	non	rvf
	SQUASH	GOAM	amb	no	fill	non	lvf
	VASE	VIND	un	no	fill	non	lvf
	CAPE	DUT	amb	no	fill	non	rvf
	BEGGAR	SCRELL	un	no	fill	non	lvf
	DRILL	MUB	amb	no	fill	non	lvf
	ACT	ENBOW	amb	no	fill	non	rvf
	FAULT	RINCH	amb	no	fill	non	rvf
	EAGLE	MAIDER	un	no	fill	non	rvf
	ROBIN	SNORP	un	no	fill	non	rvf
	SOFA	SHEP	un	no	fill	non	lvf
	CIGAR	BLOOG	un	no	fill	non	lvf
	PONY	OIN	un	no	fill	non	rvf
	COINS	BIN	un	yes	fill	unrel	lvf
	NIGHT	MOOSE	un	yes	fill	unrel	lvf
	WING	GRASS	un	yes	fill	unrel	rvf
	COPPER	HANDLE	amb	yes	fill	unrel	rvf
	SEASON	KENNEL	amb	yes	fill	unrel	rvf
	SPRING	FISH	amb	yes	fill	unrel	rvf
	WHALE	VAULT	un	yes	fill	unrel	lvf
	CRUMB	LEAF	un	yes	fill	unrel	lvf
	NUMBER	BLOUSE	un	yes	fill	unrel	lvf
	CLUB	STICK	amb	yes	fill	rel	lvf
	GARLIC	BEANS	un	yes	fill	rel	lvf
	TEMPLE	HOUSE	amb	yes	fill	rel	rvf
	BOTTLE	JAR	un	yes	fill	rel	rvf
	DRAPES	PILLOW	un	yes	fill	rel	rvf
	RADISH	BEETS	un	yes	fill	rel	rvf
	SWORD	SPEAR	un	yes	fill	rel	lvf
	COACH	LEADER	amb	yes	fill	rel	lvf
	TOMAHAWK	PISTOL	un	yes	fill	rel	rvf

Table 60 (continued)

LCF[l]							
	HORN	KILE	un	no	fill	non	lvf
	VACUUM	ZOVE	un	no	fill	non	rvf
	SKY	YOUP	un	no	fill	non	rvf
	HERD	PON	un	no	fill	non	rvf
	WRIST	TUGER	un	no	fill	non	lvf
	RUIN	OLOUR	un	no	fill	non	lvf
	OPERA	STIRE	un	no	fill	non	rvf
	HILL	SKELL	un	no	fill	non	lvf
	STAIRS	BLICK	un	no	fill	non	lvf
	SPOON	FORG	un	no	fill	non	rvf
	SILK	GASK	un	no	fill	non	rvf
	FINGER	FOURET	un	no	fill	non	rvf
	MOUNTAIN	LIZALD	un	no	fill	non	lvf
	EDITOR	LUNCE	un	no	fill	non	lvf
	ROSE	WINDAW	un	no	fill	non	rvf
	WATER	BARREG	un	no	fill	non	rvf
	MAYOR	PLURAG	un	no	fill	non	lvf
	SLIPPERS	NICKET	un	no	fill	non	lvf
	STAGE	MINEN	amb	no	fill	non	rvf
	TAP	LYSTEM	amb	no	fill	non	lvf
	WAVE	ANCH	amb	no	fill	non	lvf
	SPEAKER	BOBLE	amb	no	fill	non	rvf
	POOL	PLARL	amb	no	fill	non	lvf
	NET	GLIVE	amb	no	fill	non	rvf
	RESORT	DEVAY	amb	no	fill	non	rvf
	RIGHT	DRIG	amb	no	fill	non	rvf
	PAGE	FLUG	amb	no	fill	non	lvf
	PARTY	SQUORE	amb	no	fill	non	rvf
	GRADE	PARELT	amb	no	fill	non	rvf
	FENCE	MOOST	amb	no	fill	non	lvf
	MEAL	PLAIR	amb	no	fill	non	lvf
	CRANK	MOTHEN	amb	no	fill	non	lvf
	COURT	TETLE	amb	no	fill	non	lvf
	DROP	SPING	amb	no	fill	non	lvf
	BAND	PLINE	amb	no	fill	non	lvf
	WATCH	HABIS	amb	no	fill	non	rvf

[a] Experimental vs. Filler Item
[b] Experimental items, Unambiguous Filler items
[c] Unambiguous
[d] Experimental
[e] Related
[f] Left visual field
[g] Filler
[h] Unrelated
[i] Right visual field
[j] Repetition Control Filler items
[k] Ambiguous
[l] Lexicality Control Filler items

Table 61   List B (Word List for Experiment 1)

Stimulus Type	Prime	Target	Prime Ambiguity	Response	Exp vs. Filler[a]	Relatedness	Visual Field
EXP/UNF[b]							
	CANOE	CAR	un[c]	yes	exp[d]	rel[e]	lvf[f]
	LINT	KAYAK	un	yes	fill[f]	unrel[h]	rvf[i]
	BEER	SODA	un	yes	exp	rel	lvf
	TERMITE	MILK	un	yes	fill	unrel	rvf
	CANDLE	SUN	un	yes	exp	rel	rvf
	PENCIL	BLAZE	un	yes	exp	unrel	lvf
	TROMBONE	FIDDLE	un	yes	exp	rel	rvf
	COUGAR	BUGLE	un	yes	fill	unrel	lvf
	CHIMNEY	FUNNEL	un	yes	exp	rel	lvf
	TULIP	HEARTH	un	yes	fill	unrel	rvf
	PARSLEY	MAPLE	un	yes	exp	rel	lvf
	MAGNET	DILL	un	yes	fill	unrel	rvf
	DONKEY	PIG	un	yes	exp	rel	rvf
	ZIPPER	MULE	un	yes	fill	unrel	lvf
	OCEAN	BAY	un	yes	exp	rel	rvf
	SALAD	PUDDLE	un	yes	fill	unrel	lvf
	LICE	ROACH	un	yes	exp	rel	lvf
	BUCKET	CAT	un	yes	fill	unrel	rvf
	POET	CLERK	un	yes	exp	rel	lvf
	RAVEN	SCRIBE	un	yes	fill	unrel	rvf
	TENNIS	FRISBEE	un	yes	exp	rel	rvf
	RACCOON	RUGBY	un	yes	fill	unrel	lvf
	STEEPLE	ROOF	un	yes	exp	rel	rvf
	ATHLETE	DOME	un	yes	exp	unrel	lvf
	SQUID	SPIDER	un	yes	exp	rel	lvf
	THIMBLE	SALMON	un	yes	fill	unrel	rvf
	SOOT	GRIT	un	yes	exp	rel	lvf
	UMPIRE	GRIME	un	yes	exp	unrel	rvf
	TUSK	FANG	un	yes	exp	rel	rvf
	GULLY	SPIKE	un	yes	fill	unrel	lvf
	YOGURT	BUTTER	un	yes	exp	rel	rvf
	AUTO	CHEESE	un	yes	fill	unrel	lvf
	NAPKIN	BIB	un	yes	exp	rel	lvf
	VILLAGE	DIAPER	un	yes	fill	unrel	rvf
	TOMATO	APPLE	un	yes	exp	rel	lvf
	CRATER	LEMON	un	yes	fill	unrel	rvf
	GROVE	JUNGLE	un	yes	exp	rel	rvf
	VODKA	FOREST	un	yes	fill	unrel	lvf

Table 61 (continued)

RCF[j]							
	PETAL	YOLK	un	yes	fill	unrel	lvf
	CART	SOCK	un	yes	fill	unrel	rvf
	CLAMP	MUD	un	yes	fill	unrel	lvf
	RICE	GOLD	un	yes	fill	unrel	rvf
	SLEET	DIME	un	yes	fill	unrel	rvf
	COUNTER	STITCH	amb[k]	yes	fill	unrel	lvf
	SQUASH	JINGLE	amb	yes	fill	unrel	rvf
	VASE	TRACK	un	yes	fill	unrel	lvf
	CAPE	RADIO	amb	yes	fill	unrel	lvf
	BEGGAR	SUITOR	un	yes	fill	rel	lvf
	DRILL	WRENCH	amb	yes	fill	rel	rvf
	ACT	LAW	amb	yes	fill	rel	lvf
	FAULT	CANYON	amb	yes	fill	rel	rvf
	EAGLE	CROW	un	yes	fill	rel	rvf
	ROBIN	TURKEY	un	yes	fill	rel	lvf
	SOFA	DRESSER	un	yes	fill	rel	rvf
	CIGAR	PIPE	un	yes	fill	rel	lvf
	PONY	CHICKEN	un	yes	fill	rel	rvf
	COINS	PEM	un	no	fill	non	lvf
	NIGHT	BOOSH	un	no	fill	non	rvf
	WING	VIST	un	no	fill	non	lvf
	COPPER	SHEEM	amb	no	fill	non	rvf
	SEASON	DROIN	amb	no	fill	non	rvf
	SPRING	LENCH	amb	no	fill	non	lvf
	WHALE	LARCE	un	no	fill	non	rvf
	CRUMB	NOVET	un	no	fill	non	lvf
	NUMBER	SHANOW	un	no	fill	non	rvf
	CLUB	NELVE	amb	no	fill	non	lvf
	GARLIC	PILLAX	un	no	fill	non	rvf
	TEMPLE	CELK	amb	no	fill	non	lvf
	BOTTLE	VOAX	un	no	fill	non	rvf
	DRAPES	TEY	un	no	fill	non	rvf
	RADISH	SPOP	un	no	fill	non	lvf
	SWORD	YEAD	un	no	fill	non	rvf
	COACH	SLEAM	amb	no	fill	non	lvf
	TOMAHAWK	FOOP	un	no	fill	non	lvf

Table 61 (continued)

LCF[l]							
	HORN	POCKEN	un	no	fill	non	lvf
	VACUUM	TYRANK	un	no	fill	non	lvf
	SKY	BOTTON	un	no	fill	non	rvf
	HERD	DOUTH	un	no	fill	non	lvf
	WRIST	FUSH	un	no	fill	non	lvf
	RUIN	YARL	un	no	fill	non	rvf
	OPERA	HUS	un	no	fill	non	rvf
	HILL	FEX	un	no	fill	non	lvf
	STAIRS	BISS	un	no	fill	non	lvf
	SPOON	CLAFF	un	no	fill	non	rvf
	SILK	SLEDE	un	no	fill	non	rvf
	FINGER	JAGE	un	no	fill	non	rvf
	MOUNTAIN	CARCET	un	no	fill	non	lvf
	EDITOR	BOUP	un	no	fill	non	lvf
	ROSE	POLIME	un	no	fill	non	lvf
	WATER	TILGE	un	no	fill	non	lvf
	MAYOR	CHESH	un	no	fill	non	rvf
	SLIPPERS	BRY	un	no	fill	non	rvf
	STAGE	DAILOR	amb	no	fill	non	lvf
	TAP	LOUND	amb	no	fill	non	rvf
	WAVE	PRAN	amb	no	fill	non	rvf
	SPEAKER	PREASE	amb	no	fill	non	lvf
	POOL	PEWER	amb	no	fill	non	lvf
	NET	ARNER	amb	no	fill	non	rvf
	RESORT	MALOON	amb	no	fill	non	lvf
	RIGHT	CRIDIT	amb	no	fill	non	lvf
	PAGE	PLAB	amb	no	fill	non	lvf
	PARTY	BELM	amb	no	fill	non	rvf
	GRADE	HABOT	amb	no	fill	non	rvf
	FENCE	SNAIM	amb	no	fill	non	lvf
	MEAL	SPORL	amb	no	fill	non	rvf
	CRANK	OBJECH	amb	no	fill	non	rvf
	COURT	JEAL	amb	no	fill	non	lvf
	DROP	ZUR	amb	no	fill	non	rvf
	BAND	SMILL	amb	no	fill	non	rvf
	WATCH	LAFE	amb	no	fill	non	rvf

[a] Experimental vs. Filler Item
[b] Experimental items, Unambiguous Filler items
[c] Unambiguous
[d] Experimental
[e] Related
[f] Left visual field
[g] Filler
[h] Unrelated
[i] Right visual field
[j] Repetition Control Filler items
[k] Ambiguous
[l] Lexicality Control Filler items

Table 62 List A & B: Counterbalancing (number of items)

List & Stimulus Type	Related		Unrelated		Nonword		Sum
	lvf-RH[a]	rvf-LH[b]	lvf-RH	rvf-LH	lvf-RH	rvf-LH	
List A							
EXP/UNF[c]	10	9	9	10			38
RCF[d]	4	5	5	4	10	8	36
LCF[e]					17	19	36
Sum	14	14	14	14	27	27	
List B							
EXP/UNF	10	9	9	10			38
RCF	4	5	5	4	9	9	36
LCF					18	18	36
Sum	14	14	14	14	27	27	

[a] Left visual field – Right Hemisphere
[b] Right visual field – Left Hemisphere
[c] Experimental items, Unambiguous Filler items
[d] Repetition Control Filler items
[e] Lexicality Control Filler items

Table 63 SLD List (Word list for single lexical decision task)

Words			Nonwords		
Stimulus Type	Target	Visual Field	Stimulus Type		
EXP[a]			LCF[b]		
	RAFT	lvf[c]		MINEN	rvf[d]
	HONEY	rvf		LYSTEM	lvf
	BEACON	rvf		ANCH	lvf
	LAMP	rvf		GLIVE	rvf
	GUITAR	lvf		DEVAY	rvf
	DRUM	lvf		DRIG	rvf
	STOVE	lvf		FLUG	lvf
	SUGAR	rvf		SQUORE	rvf
	BISON	rvf		PARELT	rvf
	DOG	rvf		MOOST	lvf
	RIVER	lvf		MOTHEN	lvf
	POND	lvf		TETLE	lvf
	MOTH	lvf		PLINE	lvf
	MAGGOT	lvf		HABIS	rvf
	READER	rvf		DAILOR	lvf
	DANCER	rvf		LOUND	rvf
	HOCKEY	rvf		PRAN	rvf
	LID	lvf		PREASE	lvf
	SNAKE	lvf		PEWER	lvf
	CINDER	rvf		ARNER	rvf
	ANTLER	rvf		MALOON	lvf
	BACON	lvf		CRIDIT	lvf
	CREAM	lvf		PLAB	lvf
	APRON	lvf		BELM	lvf
	MANGO	rvf		HABOT	rvf
	FIELD	lvf		SNAIM	lvf
	CAR	lvf		OBJECH	rvf
	SODA	lvf		JEAL	lvf
	SUN	rvf		ZUR	rvf
	BLAZE	lvf		SMILL	rvf
	FIDDLE	rvf		LAFE	rvf
	FUNNEL	lvf		PILLAX	lvf
	MAPLE	lvf		SCRELL	lvf
	PIG	rvf		SNORP	rvf
	BAY	rvf		FOOP	lvf
	ROACH	lvf		YEAD	rvf
	CLERK	lvf		OIN	lvf
	FRISBEE	rvf		TEY	rvf
	ROOF	rvf		SPOP	rvf
	DOME	lvf		MAIDER	rvf
	SPIDER	lvf		BLOOG	rvf
	GRIT	lvf		VOAX	rvf
	GRIME	rvf		NELVE	lvf

Table 63 (continued)

	FANG	rvf		MUB	rvf
	BUTTER	rvf		RINCH	rvf
	BIB	lvf		SLEAM	lvf
	APPLE	lvf		CELK	lvf
	JUNGLE	rvf		ENBOW	lvf
RCF[e]			RCF		
	BEANS	lvf		RADGE	rvf
	PISTOL	rvf		VIST	lvf
	SPEAR	lvf		PEM	lvf
	PILLOW	rvf		GEALM	rvf
	BEETS	rvf		ROLIE	rvf
	STICK	lvf		SHANOW	rvf
	LEADER	lvf		LODIE	lvf
	HOUSE	rvf		NOVET	lvf
	SUITOR	lvf		LARCE	rvf
	TURKEY	lvf		TORM	lvf
	CHICKEN	rvf		GOAM	rvf
	DRESSER	rvf		SHEEM	rvf
	CROW	rvf		DROIN	lvf
	WRENCH	rvf		GLAY	rvf
	CANYON	rvf		DUT	rvf
	LAW	lvf		LENCH	lvf
FC[f]					
	1	cen[g]			
	2	cen			
	3	cen			
	4	cen			
	5	cen			
	6	cen			
	7	cen			
	8	cen			
	9	cen			
	1	cen			
	2	cen			
	3	cen			
	4	cen			
	5	cen			
	6	cen			
	7	cen			
	8	cen			
	2	cen			

[a] Experimental vs. Filler Item
[b] Lexicality Control Filler items
[c] Left visual field
[d] Right visual field
[3] Repetition Control Filler items
[f] Fixation Control item
[g] central

C.2 **EXPERIMENT 2**

Table 64 Lists 1 – 4 (Experimental items for Experiment 2)

Lists	Prime	Target	Relatedness	Visual Field	Meaning[a]
List 1					
	IRON	STROLL	unrel[b]	lvf[c]	2nd
	MISS	FUMBLE	rel[d]	rvf[e]	2nd
	MARBLE	GLAND	unrel	rvf	1st
	SEAL	PLUG	rel	lvf	2nd
	SHED	BARN	rel	rvf	1st
	LITTER	DUKE	unrel	lvf	2nd
	FILE	STRETCH	unrel	rvf	1st
	BARK	CRUST	rel	rvf	2nd
	CLOG	IMPEDE	rel	rvf	1st
	MOLD	MOSS	rel	lvf	1st
	CRAFT	SQUAT	unrel	rvf	1st
	DART	CORNEA	unrel	rvf	2nd
	FAN	PATRON	rel	lvf	2nd
	BRIDGE	SPADES	rel	lvf	2nd
	CALF	ANKLE	rel	rvf	2nd
	MOLE	BAG	unrel	lvf	1st
	PEN	CORRAL	rel	lvf	2nd
	MATCH	MILL	unrel	rvf	2nd
	LAND	PEACH	unrel	lvf	1st
	FALL	TEAM	unrel	lvf	1st
	STAPLE	PIN	rel	lvf	1st
	STORY	SAGA	rel	rvf	1st
	LETTER	WEAKEN	unrel	rvf	2nd
	TOAST	MUFFIN	rel	lvf	1st
	SWALLOW	RECORD	unrel	lvf	2nd
List 2					
	MARCH	JULY	rel	rvf	1st
	PLANE	GIRL	unrel	rvf	1st
	ORGAN	TUBA	rel	rvf	2nd
	TOLL	SHARK	unrel	rvf	1st
	BLUFF	OOZE	unrel	lvf	2nd
	COUNT	TALLY	rel	lvf	1st
	STRAIN	RINSE	rel	lvf	2nd
	POT	GROWL	unrel	rvf	1st
	PANEL	SANDAL	unrel	lvf	2nd
	TRIP	SCULPT	unrel	rvf	2nd

Table 64 (continued)

	PERCH	TROUT	rel	lvf	2nd
	PUPIL	NOVICE	rel	lvf	1st
	CASE	BLOWER	unrel	lvf	1st
	HAIL	LINK	unrel	lvf	1st
	PARK	LAMB	unrel	rvf	1st
	HAMPER	HOBBLE	rel	rvf	2nd
	LACE	CRAYON	unrel	lvf	1st
	PLANT	SHRUB	rel	lvf	1st
	PRUNE	TRIM	rel	lvf	2nd
	STAFF	WAND	rel	rvf	2nd
	PALM	GOODS	unrel	rvf	2nd
	BLADE	LEVEL	unrel	rvf	2nd
	TIRE	HOOP	rel	rvf	1st
	SOIL	PRAISE	unrel	lvf	2nd
	LOG	TIMBER	rel	rvf	1st
List 3					
	MARCH	STROLL	rel	lvf	2nd
	PLANE	FUMBLE	unrel	rvf	2nd
	ORGAN	GLAND	rel	rvf	1st
	TOLL	PLUG	unrel	lvf	2nd
	BLUFF	BARN	unrel	rvf	1st
	COUNT	DUKE	rel	lvf	2nd
	STRAIN	STRETCH	rel	rvf	1st
	POT	CRUST	unrel	rvf	2nd
	PANEL	IMPEDE	unrel	rvf	1st
	TRIP	MOSS	unrel	lvf	1st
	PERCH	SQUAT	rel	rvf	1st
	PUPIL	CORNEA	rel	rvf	2nd
	CASE	PATRON	unrel	lvf	2nd
	HAIL	SPADES	unrel	lvf	2nd
	PARK	ANKLE	unrel	rvf	2nd
	HAMPER	BAG	rel	lvf	1st
	LACE	CORRAL	unrel	lvf	2nd
	PLANT	MILL	rel	rvf	2nd
	PRUNE	PEACH	rel	lvf	1st
	STAFF	TEAM	rel	lvf	1st
	PALM	PIN	unrel	lvf	1st
	BLADE	SAGA	unrel	rvf	1st
	TIRE	WEAKEN	rel	rvf	2nd
	SOIL	MUFFIN	unrel	lvf	1st
	LOG	RECORD	rel	lvf	2nd
List 4					
	IRON	JULY	unrel	rvf	1st
	MISS	GIRL	rel	rvf	1st
	MARBLE	TUBA	unrel	rvf	2nd

Table 64 (continued)

SEAL	SHARK	rel	rvf	1st
SHED	OOZE	rel	lvf	2nd
LITTER	TALLY	unrel	lvf	1st
FILE	RINSE	unrel	lvf	2nd
BARK	GROWL	rel	rvf	1st
CLOG	SANDAL	rel	lvf	2nd
MOLD	SCULPT	rel	rvf	2nd
CRAFT	TROUT	unrel	lvf	2nd
DART	NOVICE	unrel	lvf	1st
FAN	BLOWER	rel	lvf	1st
BRIDGE	LINK	rel	lvf	1st
CALF	LAMB	rel	rvf	1st
MOLE	HOBBLE	unrel	rvf	2nd
PEN	CRAYON	rel	lvf	1st
MATCH	SHRUB	unrel	lvf	1st
LAND	TRIM	unrel	lvf	2nd
FALL	WAND	unrel	rvf	2nd
STAPLE	GOODS	rel	rvf	2nd
STORY	LEVEL	rel	rvf	2nd
LETTER	HOOP	unrel	rvf	1st
TOAST	PRAISE	rel	lvf	2nd
SWALLOW	TIMBER	unrel	rvf	1st

[a] Meaning of ambiguous prime: 1st vs. 2nd
[b] Unrelated
[c] Left visual field
[d] Related
[e] Right visual field

Table 65 Lists 1 – 4 Counterbalancing: Meaning/Relatedness (number of items)

List	1st Meaning		2nd Meaning	
	related	unrelated	related	unrelated
1	6	6	7	6
2	6	7	6	6
3	6	6	6	7
4	7	6	6	6

Table 66 List 1 – 4 Conterbalancing: Meaning/Visual Field (number of items)

List	1st Meaning		2nd Meaning	
	lvf-RH[a]	rvf-LH[b]	lvf-RH	rvf-LH
1	6	6	7	6
2	6	7	6	6
3	6	6	7	6
4	6	7	6	6

[a] Left visual field – Right Hemisphere
[b] Right visual field – Left Hemisphere

Table 67 List 1 – 4 Counterbalancing: Relatedness/Visual Field (number of items)

List	Related		Unrelated	
	lvf-RH[a]	rvf-LH[b]	lvf-RH	rvf-LH
1	7	6	6	6
2	6	6	6	7
3	6	6	7	6
4	6	7	6	6

[a] Left visual field – Right Hemisphere
[b] Right visual field – Left Hemisphere

Table 68 Lists C & D (Word/nonword fillers, 2nd testing session)

	Prime	Target	Response	Relatedness	Visual Field
List C					
	EAR	FOOT	yes	rel[a]	rvf[b]
	HOE	SPADE	yes	rel	lvf[c]
	LAWYER	NURSE	yes	rel	rvf
	FOX	HORSE	yes	rel	lvf
	TABLE	BED	yes	rel	rvf
	SHOE	GLOVE	yes	rel	lvf
	COTTON	SILK	yes	rel	rvf
	FLEA	ANT	yes	rel	lvf
	BANANA	PEACH	yes	rel	rvf
	TULIP	DAISY	yes	rel	rvf
	STREET	PATH	yes	rel	lvf
	BIRCH	ELM	yes	rel	lvf
	JELLY	BELL	yes	unrel[d]	rvf
	NAVY	CIDER	yes	unrel	lvf
	FAUCET	CYCLE	yes	unrel	rvf
	STORK	CAMERA	yes	unrel	lvf
	MITTENS	CUP	yes	unrel	rvf
	AXE	FRIDGE	yes	unrel	lvf
	CORNER	CAKE	yes	unrel	rvf
	HOE	RIBBON	yes	unrel	lvf
	DRAPES	INK	yes	unrel	rvf
	BOTTLE	SPINACH	yes	unrel	lvf
	BARBER	NYLONS	yes	unrel	rvf
	CEREAL	KNOB	yes	unrel	lvf
	HORN	POCKEN	no	non[e]	rvf
	VACUUM	TYRANK	no	non	lvf
	SKY	BOTTON	no	non	rvf
	HERD	DOUTH	no	non	lvf
	STAIRS	BISS	no	non	rvf
	GULF	CLAFF	no	non	lvf
	PAPER	SLEDE	no	non	rvf
	FINGER	JAGE	no	non	lvf
	DENMARK	CHESH	no	non	rvf
	SLIPPERS	BRY	no	non	lvf
	COINS	KILE	no	non	rvf
	SLEET	ZOVE	no	non	lvf
	WHALE	STIRE	no	non	rvf
	RICE	SKELL	no	non	lvf
	WIRE	BLICK	no	non	rvf
	CIRCUS	FORG	no	non	lvf
	CITY	WINDAW	no	non	rvf

Table 68 (continued)

	OZARKS	BARREG	no	non	lvf
	FEAST	PLURAG	no	non	rvf
	PRIDE	NICKET	no	non	lvf
	CREEK	PLARL	no	non	rvf
	BUS	GLIVE	no	non	lvf
	TRIBE	DEVAY	no	non	rvf
	DEAN	DRIG	no	non	lvf
List D					
	ARM	NOSE	yes	rel	rvf
	PANTS	HAT	yes	rel	lvf
	DESK	STOOL	yes	rel	rvf
	MIRROR	PUDDLE	yes	rel	lvf
	STEM	PETAL	yes	rel	rvf
	CARROT	CORN	yes	rel	lvf
	FLOOR	WALL	yes	rel	rvf
	VELVET	LINEN	yes	rel	lvf
	BEGGAR	TRADER	yes	rel	lvf
	HAIR	FUR	yes	rel	rvf
	STEEL	BRASS	yes	rel	rvf
	ROOF	DOOR	yes	rel	lvf
	BLENDER	ORCHID	yes	unrel	rvf
	MAT	SONG	yes	unrel	lvf
	SAUCER	SHIRT	yes	unrel	rvf
	POTATO	JET	yes	unrel	lvf
	DAGGER	ART	yes	unrel	rvf
	KING	TROUT	yes	unrel	lvf
	QUARTZ	SOFA	yes	unrel	rvf
	ROBIN	POWER	yes	unrel	lvf
	PUPPET	VAN	yes	unrel	rvf
	MYTH	LIME	yes	unrel	lvf
	MAYOR	DRAGON	yes	unrel	rvf
	SPOON	HERMIT	yes	unrel	lvf
	WRIST	FUSH	no	non	rvf
	RUIN	YARL	no	non	lvf
	OPERA	HUS	no	non	rvf
	HILL	FEX	no	non	lvf
	MOUNTAIN	CARCET	no	non	rvf
	EDITOR	BOUP	no	non	lvf
	ROSE	POLIME	no	non	rvf
	WATER	TILGE	no	non	lvf
	CLAMP	YOUP	no	non	rvf
	NUMBER	PON	no	non	lvf
	TERN	TUGER	no	non	rvf
	CRUMB	OLOUR	no	non	lvf
	SAW	GASK	no	non	rvf

Table 68 (continued)

	FELT	FOURET	no	non	lvf
	CRANBERRY	LIZALD	no	non	rvf
	OSTRICH	LUNCE	no	non	lvf
	HOME	MINEN	no	non	rvf
	SHELVES	LYSTEM	no	non	lvf
	TENT	ANCH	no	non	rvf
	SELLER	BOBLE	no	non	lvf
	CORE	FLUG	no	non	rvf
	SAP	SQUORE	no	non	lvf
	ORANGE	PARELT	no	non	rvf
	STORE	MOOST	no	non	lvf

[a] Related
[b] Right visual field
[c] Left visual field
[d] Unrelated
[e] Nonword

C.3 FIXATION CONTROL ITEMS

Table 69 Lists X, Y (Session 1), Lists x, y (Session 2)

	Prime	Target		Prime	Target
List X			List Y		
	VESSEL	1		MIST	1
	CARD	2		SCALP	2
	RACE	3		GAS	3
	SAP	4		PUNDIT	4
	MYTH	5		ENERGY	5
	RATE	6		GARDEN	6
	CLINIC	7		BAKER	7
	PUPPET	8		ZOO	8
	RADIO	9		STATION	9
	GINGER	1		DOLL	1
	TUB	2		GLOBE	2
	OWL	3		WHALE	3
	SKUNK	4		COOKIE	4
	BIKE	5		CHILD	5
	DANISH	6		CHAIR	6
	CUSTOMS	7		FACE	7
	CHURCH	8		STAR	8
	CORN	9		SLIDE	9
	FIG	1		FLOAT	3
	BARBER	4		RELISH	5
	PICKLE	3		SENSE	8
	MUSKET	7		NOTE	9
	GUIDE	8		GARBAGE	2
	CEILING	2		PAPER	4
List x			List y		
	GALLON	1		TENOR	1
	SCALP	2		COW	2
	HINGE	3		RACE	3
	PUNDIT	4		STROLLER	4
	LEMONADE	5		FAIRY	5
	GARDEN	6		SCOOTER	6
	BAKER	7		CLINIC	7
	CLOVES	8		PUPPET	8
	STATION	9		RADIO	9
	DOLL	1		GINGER	1

Table 69 (continued)

GLOBE	2	TUB	2
FAT	3	OWL	3
COOKIE	4	SKUNK	4
PICKLE	3	FIG	1

C.4 MAIN PRACTICE LISTS

Table 70 Practice Lists A and B

Practice List A			Practice List B		
Prime	Target	Visual Field	Prime	Target	Visual Field
SAP	SIGNAR	rvf	SAP	PROOF	rvf
SALT	4	center	SALT	6	center
EVIDENCE	PROOF	lvf	EVIDENCE	SIGNAR	rvf
TEMPER	GEESE	rvf	TEMPER	3	center
REED	9	center	REED	GEESE	lvf
UMBRELLA	CABIN	rvf	JAZZ	MUSIC	rvf
TAPE	2	center	TAPE	2	center
VISITOR	5	center	VISITOR	EWE	lvf
REBEL	EWE	lvf	REBEL	7	lvf
TALENT	SPUCE	rvf	TALENT	SPUCE	rvf
STILE	TAY	rvf	STILE	FRANCH	rvf
FROG	7	center	FROG	7	center
SILENCE	FEVER	rvf	SILENCE	4	center
DOLLAR	TEIN	lvf	CASSETTE	TEIN	lvf
SHAWL	GLOVE	lvf	ILLNESS	FEVER	rvf
VETO	FRANCH	rvf	VETO	TAY	rvf
STUDENT	FROST	rvf	CHESTNUT	KNEE	rvf
LESSON	6	center	LESSON	9	center
PALACE	TROCK	lvf	PALACE	TROCK	lvf
SUCCESS	TRIUMPH	rvf	SUCCESS	TRIUMPH	rvf
PLAZA	ELF	lvf	CANAD	ELF	lvf
PRAIRIE	HERRIT	lvf	PRAIRIE	HERRIT	lvf
BRASIL	1	center	BRASIL	1	center
RUMOUR	GINT	rvf	RUMOUR	GINT	rvf
OLIVE	GRAPE	lvf	OLIVE	GRAPE	lvf
VERSE	BUKE	rvf	VERSE	FAMILY	rvf
QUAIL	MIME	lvf	QUAIL	MIME	lvf
SEQUEL	FAMILY	lvf	SEQUEL	BUKE	lvf
GULF	3	center	CIDER	3	center
ROAR	SONG	lvf	ROAR	GRALL	rvf
STANZA	CHORUS	rvf	STANZA	SONG	rvf
MORASS	MILLION	lvf	MORASS	MILLION	lvf
NOSE	GRALL	lvf	SAUCER	BUDGIE	lvf
SCULL	SOUTS	rvf	SCULL	SOUTS	rvf
SCISSORS	SCATCH	lvf	SCISSORS	SCATCH	lvf
SPASM	FLAVOUR	rvf	SPASM	HULMET	rvf

Table 70 (continued)

WINTER	SITCH	rvf	WINTER	SITCH	rvf
TEST	HULMET	lvf	TEST	FLAVOUR	lvf
SHIELD	6	center	MASON	9	center
NURSE	DINER	lvf	NURSE	JOCKET	lvf
TEACHER	JOCKET	rvf	FILM	DINER	rvf
CATHEDRAL	8	center	CATHEDRAL	8	center
RIBBON	MUB	lvf	RIBBON	MUB	lvf
PEST	SIFE	lvf	PEST	SIFE	lvf
SLICE	PART	rvf	SLICE	PART	rvf
RECTOR	FRINS	lvf	RECTOR	FRINS	lvf
WOOD	2	center	TEACHER	2	center
GIANT	3	center	GIANT	3	center
MACKEREL	SARDINE	rvf	MACKEREL	COLNER	rvf
STANDARD	COLNER	rvf	STANDARD	TITHE	rvf

APPENDIX D

D.1 INSTRUCTIONS AND PRACTICE

D.1.1 Session 1

<u>Screen 1</u>

Thank you for helping with the experiment.

Please read the following instructions carefully.

Please ask questions whenever any part of the instructions is unclear to you.

-press YES-

<u>Screen 2</u>

On most trials, you will see two words on the screen, one following the other. The first word prepares you for the second word.

It is the SECOND word to which you will respond. This word will either be a real word (e.g., face) or a nonsense word (e.g., powne). Your job is to decide whether the second word is a real word or not.

-Press YES-

Screen 3

When the second word is a real word, press the "yes"-button on the response box. When the second word is a nonsense word, press the "no"-button on the response box.

Practice your response with the next examples (for this practice, only single words will appear)

-Press YES-

Practice List 1

CLOUDS
MESIC
SECARD
PICTURE
TILE
PLIMB

Screen 4

On each trial, the first word is presented in the center of the screen. The first word prepares you for the second one.

The second word is presented at the SIDE of the screen. Make your respone only to the second word.

Both words are presented quite quickly. Try it in the next few examples.

-press YES-

Practice List 2

Prime	Target	Visual Field
SMILE	FACE	lvf
OBJECT	POWNE	rvf
FUMES	KID	rvf
SIDE	SECARD	lvf

Screen 5

Each trial starts with a cross in the middle of the screen. You see this cross throughout the trial, from before the first word is presented until the presentation of the second word.

It is ABSOLUTELY ESSENTIAL that you look at the cross all the time when it is present. You need to look at it from the time it comes on until it disappears. Do not take away your gaze at any time in between.

You will need to blink with your eyes during this task. Try to blink only when the screen is empty, and avoid blinking when you look at the cross.

Practice looking at the cross in the next examples.

-Press YES-

Practice List 2a

Prime	Target	Visual Field
SMILE	FACE	rvf
OBJECT	POWNE	rvf
FUMES	KID	lvf
SIDE	SECARD	lvf

Screen 6

In some of the trials you will not see the second word at the side of the screen. Instead, a very small number will appear at the middle of the screen.

On these trials, your task is to say out loud the number you see in the center of the screen. You will only be able to do so if you actually look right at the cross, therefore these trials test if you maintain your gaze on the cross.

Practice a few of these number trials.

-Press YES-

Practice List 3

Prime	Target
AWARD	5
THORAX	2
GROUNDHOG	9
AWNING	8

Screen 7

Ok, now practice with both types of trials combined. On the next 10 trials there will be either a word/nonword trial, or a number trial.

On each trial, look at the first word, which prepares you for the second one. Respond to the second word, or the number.

Press the correct button for the word/nonword trials, and say the numbers for the number trials.

Always make sure that you look on the fixation cross throughout the trial.

Respond as quickly and accurately as you can.

-Press YES-

Practice List 4

Prime	Target	Visual Field
CLOUDS	SECARD	lvf
AWARD	POWNE	rvf
MUSIC	NOTE	rvf
CAMERA	5	center
SAILOR	BOAT	rvf
MARGARINE	TAXI	lvf
TIDE	CURRY	lvf
AUNT	3	center
MICROPHONE	SHALK	rvf
METHOD	MESIC	lvf
JAZZ	STIRPUL	rvf

Screen 8

Now there will be a longer practice block with 50 trials. Concentrate on pressing the buttons as quickly as you can, while maintaining accuracy.

Again, make sure to always look at the cross throughout the trial

-Press YES-

Practice Lists A and B (see Appendix C.4)

For main practice, Practice Block A was presented. If the main practice was repeated, practice Block B was presented with the following screen preceding it.

Screen 9 (optional)

This is another block with 50 trials. Concentrate on pressing the buttons as quickly as you can, while maintaining accuracy.

Again, make sure to always look at the cross throughout the trial

D.1.2 Instructions before Block 1, Session 1

Now to the real thing.

There are two blocks of 186 stimuli. Each block is twice interrupted by a short break. Use it to stretch, relax, and to close/blink your eyes.

This is the first block.

Remember:

Respond as FAST as as ACCURATE as you can.

Always look on the cross when it is on the screen.

-Press YES-

D.1.3 Instructions before Block 2, Session 1

Remember:

Respond as FAST as as ACCURATE as you can.

Always look on the cross when it is on the screen.

-Press YES-

D.2 **SESSION 2**

6.1.1. Practice

Screen 1

As you remember, this experiment consists of two types of trials, word/nonword trials and number trials.

Each trial begins with the first word, which prepares you for the second one at the side of the screen. Your task is to decide whether the second word is a word or not, by pressing the "yes"/"no" buttons.

On the number trials, a small number appears instead of the second word. Your task is to say the number out loud.

Practice your responses again on the next 10 trials. Concentrate especially on looking at the cross throughout the trial.

Respond as quickly and accurately as you can.

-Press YES-

Practice List 4 (Appendix D.1)

Screen 2

Now there will be a longer practice block with 50 trials. Concentrate on pressing the buttons as quickly as you can, while maintaining accuracy.

Again, make sure to always look at the cross throughout the trial

-Press YES-

Practice List B (Appendix C.4)

6.1.2. Instructions before Block 1 and 2, Session 2

Remember:

Respond as FAST as as ACCURATE as you can.

Always look on the cross when it is on the screen.

-Press YES-

6.1.3. Instructions before Block SLD

Screen 1

In this last block, your task is still the same: press the "yes"/"no" buttons to indicate whether the word at the side of the screen is a word or not, or say the number aloud.

However, the first word will not appear any more. Instead, you will see the word at the side of the screen (or the number in the middle) immediately after the initial cross is presented.

Still make sure that you ALWAYS look at the cross in the middle of the screen.

Respond as fast as you can, while being as accurate as you can.

Next will be 15 example stimuli.

Practice List 5

Target	Visual Field
SECARD	lvf
POWNE	rvf
NOTE	rvf
5	center
BOAT	rvf
TAXI	lvf
CURRY	lvf
3	center
SHALK	rvf
MESIC	lvf
STIRPUL	rvf
GREASE	lvf
4	center
OREN	lvf
LEEK	rvf
RIDDLE	lvf

Screen 2

This last block has 144 stimuli.

Again, concentrate on speed, accuracy, and always keep your gaze on the black cross in the middle

-Press YES-

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