The Role of Orthography and Visual Form on Word Recognition

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Abstract

It is mostly agreed that in order to identify a visually presented word, both the identity and the position of it's constitute letters must be encoded. However, currently most models of word recognition only start after the processes involved in letter encoding has been completed: the so called “visual word form” level. These models concentrate on the process involved in the encoding of the letter position, giving several different solutions to the encoding problem. The problem here is not necessarily that there are different solutions but that each solution is as good at modelling the current data as the next. Thus the solution to disambiguating between them may lie in a better understanding of the sublexical processes involved. Although this seems a logical step it is surprising that very little research has been carried out regarding these processes. The aim of this current PhD project is to address some of the issues involved with investigating sublexical processes, and to start a systematic investigation of several early perceptual processes that may modulate visual word recognition.

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Chapter 1

Orthographic Processing in Visual Word Recognition

Overview of the Problems with Current Research

There has in recent years been a resurgence of interest in the early orthographic processes involved in visual word recognition, such as letter encoding. This increased interest has produced several models with various competing models of letter encoding schemes (e.g. Davis, 1999, 2010; Gomez, Ratcliff, & Perea, 2008; Grainger & van Heuven, 2003, Grainger, Grainger, Farioli, Van Assche, &van Heuven, 2006, Grainger & Whitney, 2004, Norris, Kinoshita, & van Casteren, 2010; Whitney, 2001; Whitney & Cornelissen, 2008).One of the problems with testing these models is counterintuitive, as it is not their inability to account for the current experimental data but rather their success at doing so. This means that it is becoming increasingly difficult to differentiate between them on the basis of prevailing evidence. Therefore, new experimental paradigms are needed that can focus on areas that have been previously difficult to investigate and thus overlooked.

For example, there has been surprisingly little research focusing on developing an understanding of the processes involved in letter identification prior to visual word recognition. The neglect of these lower-level processes means that most models of word recognition start after letter identification has been completed, at the "visual word form" level (Finkbeiner & Coltheart, 2009). This means that processes involved in letter perception that may influence later word recognition processes are either left out of models, such as lateral inhibition at the abstract letter level (see Rey, Dufau, Massol, & Grainger, 2009), or are assumed to result from later processes.

One reason for this is that the task predominately used for investigating sublexical processes in visual word recognition is the masked-priming lexical decision task (for a review see Grainger, 2008). As the decision is whether the presented letter strings are words or not, lexical representations need to be activated (Forster & Davis, 1984). As a consequence, priming effects in this task are modulated by lexical and other higher order linguistic influences. This does not mean that perceptual and sublexical influences are not apparent in this task (Humphreys, Besner, & Quinlan, 1988), just that it is not possible to identify where the locus of these effects lie.

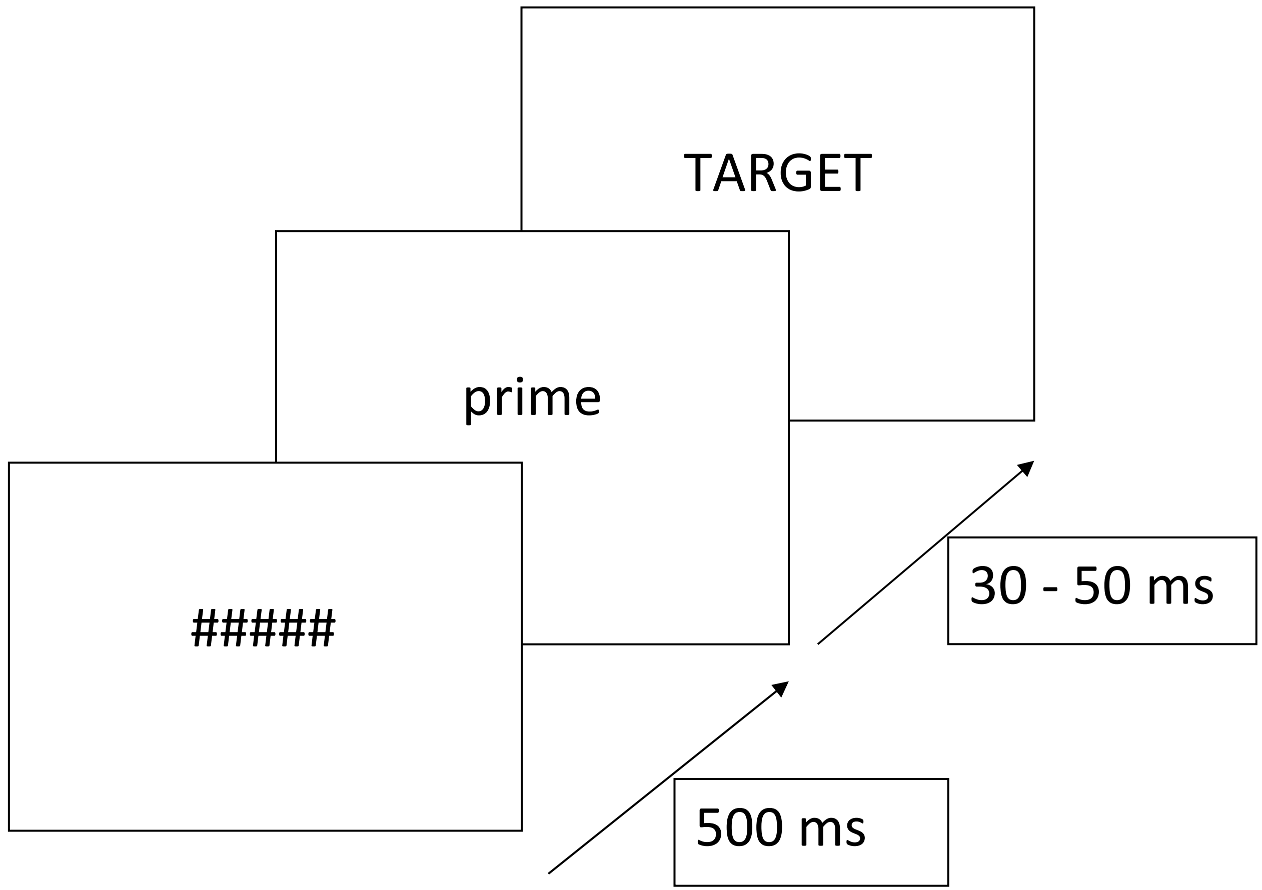
Recently, two variations on the masked-priming paradigm have been presented as task that overcome the influence of lexical and other higher order influences, the masked-priming same-different task (Norris & Kinoshita, 2008; Kinoshita & Norris, 2009) and the sandwich priming task (Lupker and Davis, 2009). The next section will describe the standard masked-priming lexical decision task along with these two recent variations.

Tasks used to Investigate Visual Word Recognition

Masked-Priming Lexical Decision Task

The procedure for the masked-priming lexical decision task (see Figure 1), based on the Forster & Davis (1984) paradigm, consists of three stages: First, a forward mask (e.g., a series of hash marks, #######) is presented for about 500 ms, Next the mask is replaced by a prime letter string and presented very briefly (up to 60 ms) in a lowercase font, finally, the target letter string presented in an uppercase font immediately after the prime string. The change in case between the prime and target is generally assumed to make the target act as a backwards mask. The participants' task is to decide whether the target letter string is a word or not. The priming effect in this task refers to the difference in response times (and/or error rate) for targets preceded by, for example, orthographic related primes compared to unrelated control primes. The mask and the brief nature of the prime's presentation means that the prime is virtually invisible, and therefore the processing of the prime is assumed to be unconscious.

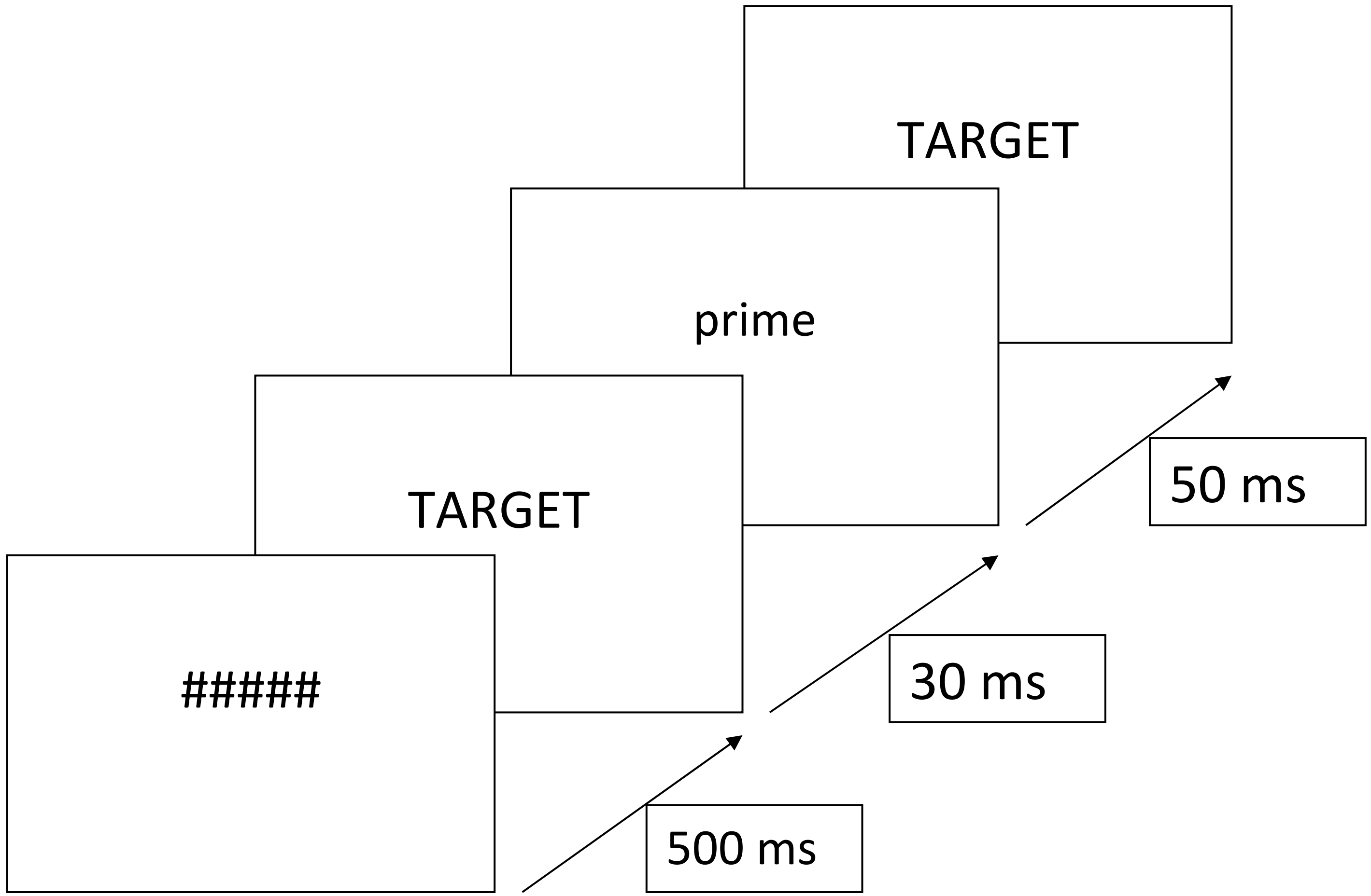
Figure 1. The sequence of presentation for the masked-priming same-different task.



Sandwich Priming Lexical Decision Task

The sandwich priming task first introduced by Lupker and Davis (2009) is similar to that of the standard masked-priming lexical decision task, except that there are two masked primes before the target string is presented in uppercase. The first masked prime is the target string presented for 33 ms in uppercase followed by the prime string presented again very briefly (< 60 ms) in lowercase (see Figure 2). Note that sometimes in the literature the first presentation of the target was also in lowercase, e.g., Lupker, Zhang, Perry & Davis, 2015) ..Like the prime itself, this brief presentation duration means that participants are not consciously aware of its presence

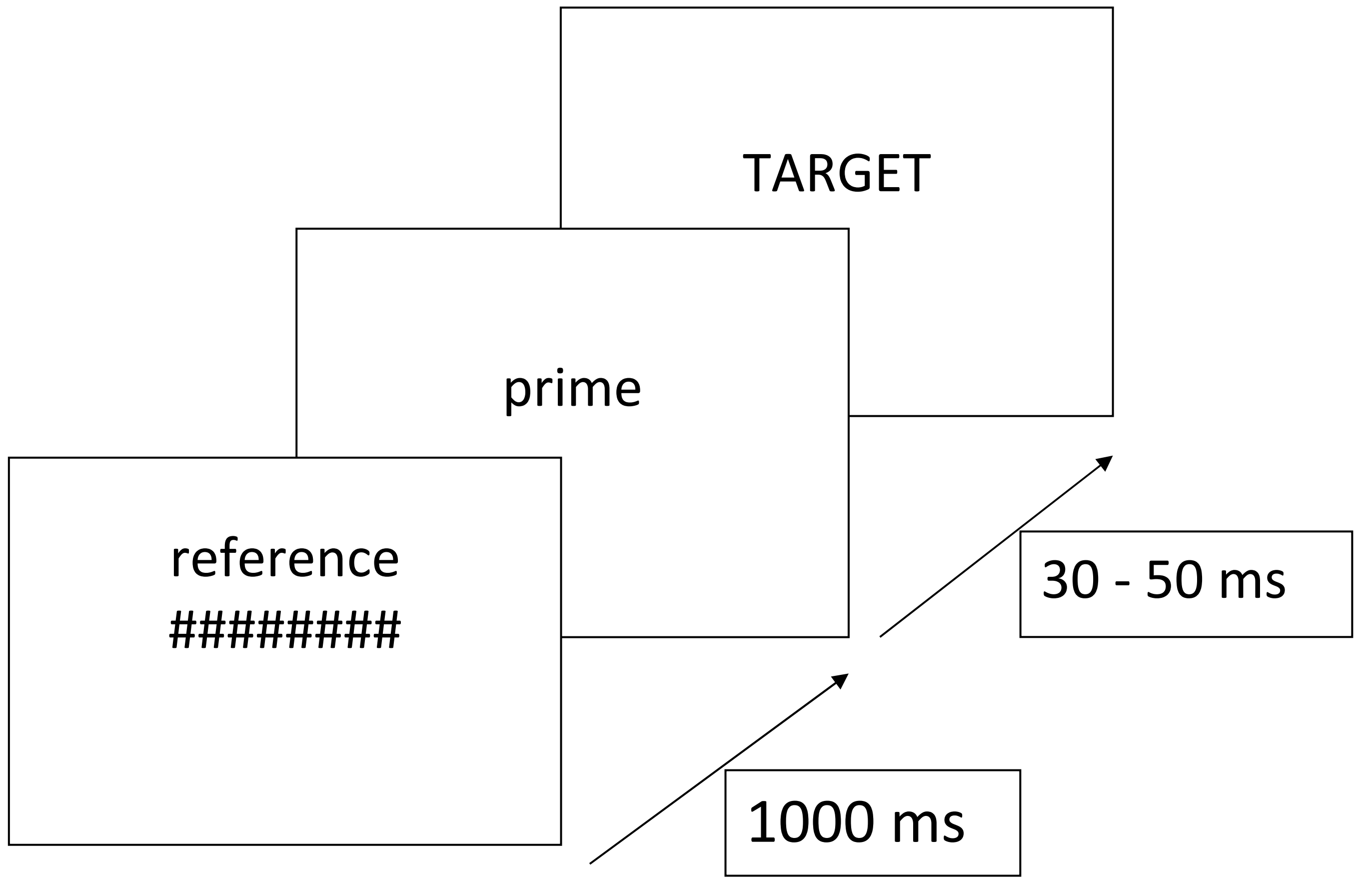
Figure 2. The sequential events for the sandwich priming task.



Masked-Priming Same-Different task

The masked-priming same-different task (Norris & Kinoshita, 2008; Kinoshita & Norris, 2009) differs from the masked-priming lexical decision task by the addition of a reference stimulus in lowercase presented above the forward mask, which is visible for one second before it disappears at the same time as the mask (see Figure 3). Just like the standard masked-priming task, the mask is then replaced by the prime followed by the target presented in uppercase. Importantly, the participant in this task has to decide whether the target is the same or different to the reference (ignoring the change in case). This means that the decision is not based on the lexical status of the target, as in the lexical decision task, but rather based on whether or not the reference is the same as the target.

Figure 3. The sequence of presentation for the masked-priming same-different task.



Models of Visual Word Recognition

There are a large number of models of reading and visual word recognition in the literature. These models can be classified into two main types: descriptive models (using boxes and arrows and/or written descriptive models) and computational models (algorithmic or mathematical, e.g., Interactive Activation model (IA) McClelland & Rumelhart, 1981; Rumelhart & McClelland,1982; Bayesian Reader, Norris, 2006). The difference between descriptive and computational models is that computational models are implemented in a computer program and therefore their effectiveness can be tested by simulating experimental data. However, computational models can be difficult to conceptualize, therefore architectures can be helpful (particularly for algorithmic models) in understanding the processes being simulated. A classic example of this is the dual-route cascade (DRC) model (Coltheart et al., 2001), although a computational model of reading aloud the processes it simulates are presented as a box and arrow model (see Figure 4). Similarly most connectionist models can also be represented as simple box and arrows models as well as with their underlying algorithms (e.g., IA model, see Figure 5).

Figure 4. The dual-route cascade (DRC) model as presented by Coltheart et al. (2001).

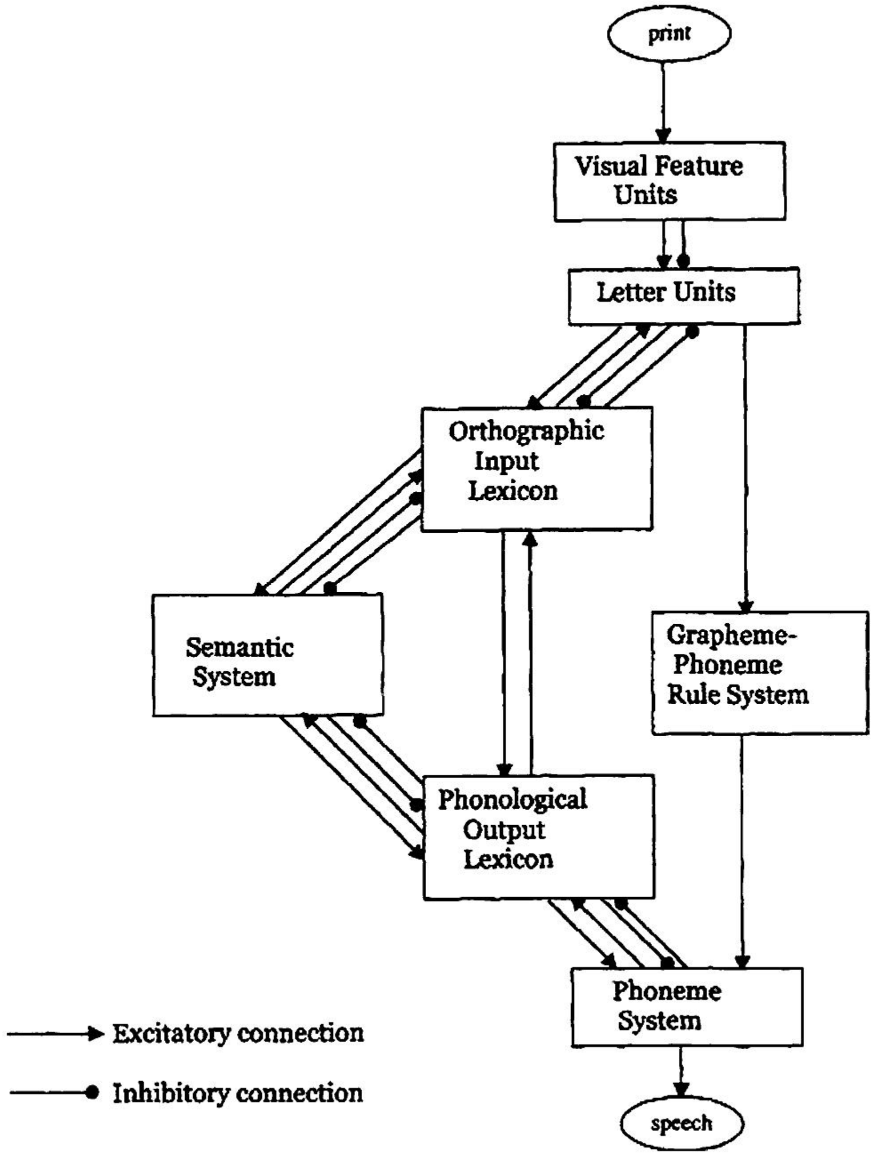
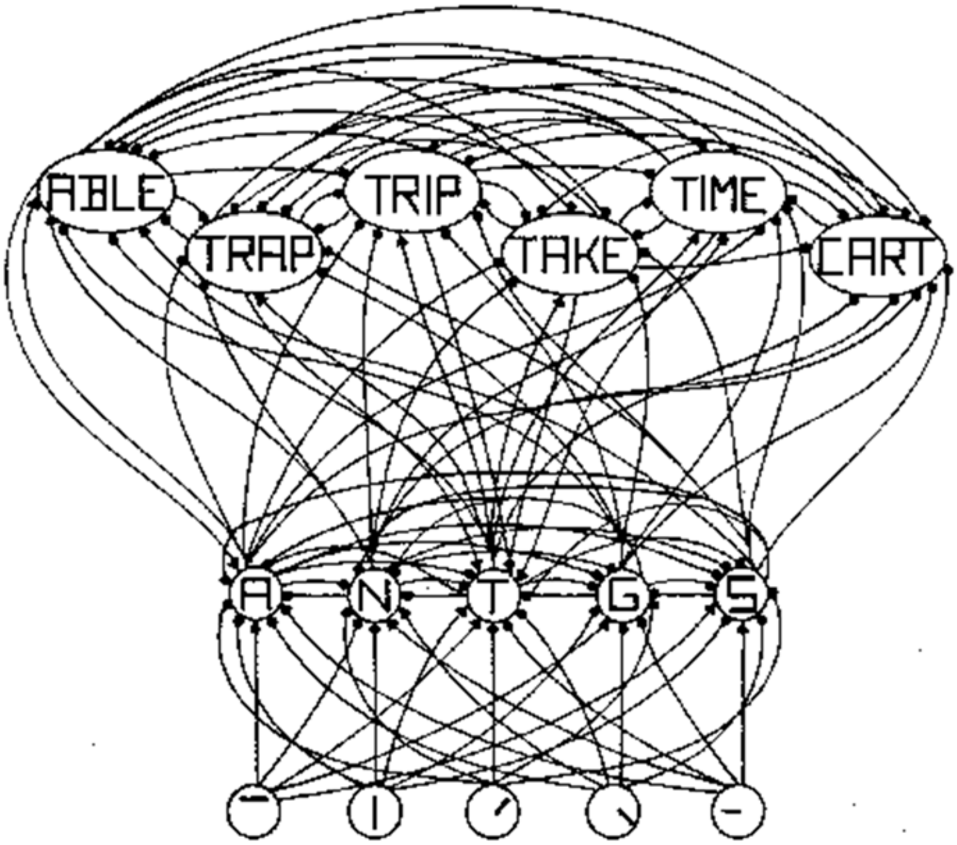


Figure 5. The Interactive Activation model as presented by McClelland &Rumelhart, (1981).



This ability of connectionist models to be represented at two levels reveals an important differences between algorithmic based and mathematical models, which is the level that which these models work. Connectionist models are network models and thus make predictions/assumptions as to the nature of representations and processes involved, i.e., the implementation of representations and processes involved. These models are said to be 'neurological inspired' or 'neurologically plausible' models, that is they are attempting to produce a model that represents how the brain implements a given cognitive function. Mathematical models work at an abstract level making no assumptions to the processes involved, rather focusing on the computations involved, i.e., the type of mathematical formula used. This difference is important to the understanding and evaluating different models as most mathematical models can incorporate different representation and/or processes suggested by connectionist (and other algorithmic) models without out changing the nature of the model itself (its mathematical formula). Thus, these models are not making predictions as to the representations or processes/mechanisms involved.

In the following sections different models of visual word recognition will be discussed and their letter coding systems. These will include three connectionist models (IA, McClelland &Rumelhart, 1981; Open-Bigram models, Grainger & van Heuven, 2003; and the Spatial Coding Model (SCM), Davis, 2012) and one mathematical model (Bayesian Reader, Norris, 2006; Kinoshita & Norris, 2008; 2009; 2010). These models will be discussed only in reference to the general principals and letter coding scheme.

Interactive Activation (IA) Model

The IA model (McClelland &Rumelhart, 1981; Rumelhart& McClelland, 1982) is based on connectionist theory in which processing of information is based on separate simple sub units that are interconnected into a network. The IA model of word recognition consists of three different representation levels; letter features, letters and words. These levels are interconnected by excitatory and inhibitory connections such that representations that are consistent (e.g. letter 'D' and the word 'DOOR') are connected by excitatory weighted connections and those that are inconsistent (e.g. letter 'P' and the word 'DOOR') are inhibitory weighted. There are also inhibitory connections between representations at the word level (lateral inhibition). Finally, top-down excitatory connections exist between word and the letter level, so that any words activated reinforce the activity of the letters that they contain. It is through the complex interactions between bottom-up and top-down excitation and inhibition, along with lateral inhibition, that node activation builds up over time.

In the IA framework the priming effect is caused by the pre-activation of the target word by the prime, which facilitates the processing of the target itself. For example, a nonword prime that is orthographically related to the target word will activate the target word, whereas a nonword that is orthographically different from the target word does not activate the target word. The size of the priming effect is determined by the amount of orthographic overlap between the prime and target. The priming effect is further modulated by inhibition that comes from the activation of other words that share orthographic information with the prime and target (i.e., shared neighbourhood effect, van Heuven, et al., 2001), which reduces the size of the facilitation effect. Importantly, priming effects are due to the activation of whole word lexical representations by the prime. This also accounts for the lack of orthographic priming effects for nonword targets in lexical decision task, as by their nature they have no stored lexical representation and therefore an orthographically related nonword prime cannot pre-activate the nonword target.

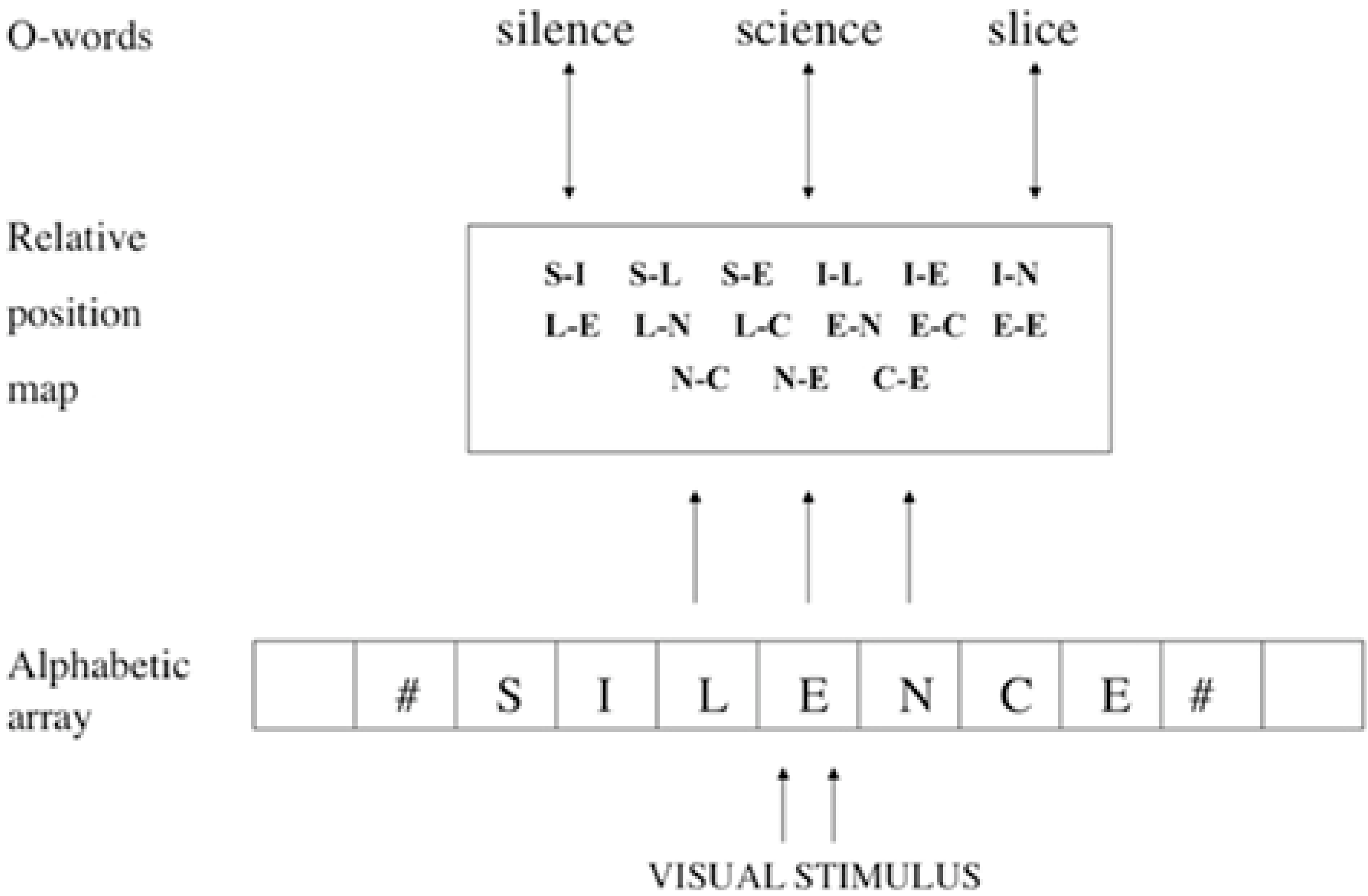
A similar explanation of priming in the lexical decision task was provided by Humphreys, Besner, & Quinlan (1988). However, they suggest that although masked-priming activates lexical representation it is not certain that this is the only source of the priming effect. They propose that any processes activated during visual word recognition could facilitate the recognition of the visual properties of the target. Thus, priming effects may not be due solely to lexical properties but also prelexical processes including letter perception. Furthermore, the effects of masked-priming may be observed with nonwords targets if the task is changed. The latter point is important with regards to the later discussion of the same-different task.

Although the general framework can provide an overall explanation for priming, the letter coding system used in McClelland & Rumelhart (1981) and Rumelhart & McClelland's (1982) original IA model uses a slot-based letter position encoding system. As discussed in the literature (e.g., Grainger, 2008) this letter position encoding system does not have the flexibility to account for relative-position priming effects such as transposed letter priming. This is because the identity of the letter is only relevant to word recognition if it is in the correct position.

Open-Bigram Model

The account for relative position priming and transposition priming effects, Grainger & van Heuven (2003) developed the open-bigram model, which uses open bigrams to encode relative position information of letters. The model consist of three layers: An alphabetic array with letter slots, a relative position map layer that contains open-bigrams, and an orthographic whole word layer that contains words. In the relative position map layer there are two different types of open-bigrams: contiguous open-bigrams, which consists of adjacent letters (e.g. FA, AI, IT, TH, for FAITH) and non-contiguous open-bigrams, which contain non-adjacent letters in the correct order but with intervening letters (e.g. FI, FT, TH, AT, AH, IH, TH). This means that unlike the original IA model (McClelland &Rumelhart, 1981;Rumelhart& McClelland's, 1982), the absolute position of the letters are no longer essential to the activation of a word, but rather their relative position to the other letters contained in the word. This in turn means that if a letter is presented in the incorrect position it identity is still relevant to the processing of the word. The open-bigrams in the relative position map are connected to whole word lexical representations through excitatory and inhibitatory connections (see Figure 6).Open-bigrams have also been used in other models, such as the overlap open-bigram model (Grainger et al., 2006) and the Serial model (Whitney &Cornelissen, 2005, 2008).

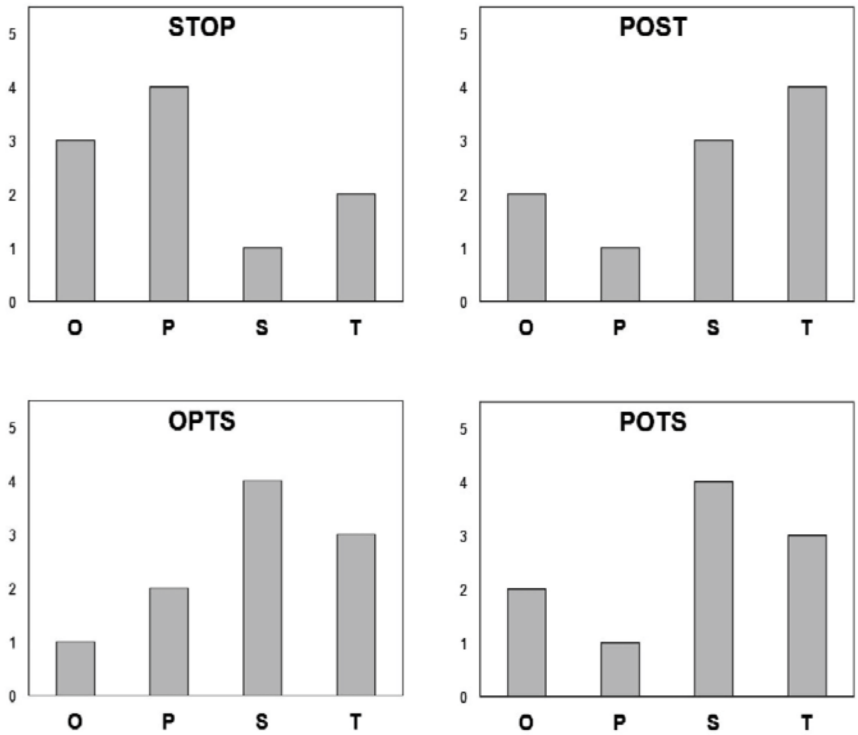
Figure 6. An example of bigram encoding taken from Grainger and van Heuven (2003)



Spatial Coding Model

A comprehensive explanation of the letter encoding system used in this models is beyond the scope of this thesis, due to the complexities of the algorithms used, thus for a full explanation see Davis (2010). Therefore, a simplified explanation will be given. As mentioned above the spatial-coding model uses the IA model as a framework. However, in the spatial-coding model each letter is treated as context and position independent abstract units. A string's constitute letter positions are encoding by assigning each letter a value based on its position. Thus, strings containing the same letters but in a different order will produce different patterns (see Figure 7). Therefore, word recognition is dependent on the similarity of the pattern from an input string to the stored representation. This has previously been estimated by calculating the difference in the values assigned to the individual constitute letters in two string.

Figure 7. Examples of how the Spatial-Coding model produces different patterns for different letter stings sharing the same constitute letters. The example is from Davis, (2010).



Bayesian Reader

A model of word recognition that is very different from the models discussed above is the Bayesian Reader (Norris, 2006). The main premise of the Bayesian Reader (Norris, 2006), and any other Bayesian models of cognitive function, is that we are an approximation of an ideal observer. The "ideal observer" or optimal interpretation comes from the suggestion that the visual system is close to optional. As the visual system constantly updates the incoming information, the optimal way to model this is to use Bayesian inference. As with all Bayesian models of the visual systems the objective of the ideal observer in the Bayesian Reader model is to calculate the probability of all possible the true state (all possible words) given the prior probabilities of the states and the evidence from the visual input.

The Bayesian Reader model is better understood in context to the standard masked-priming lexical decision task. In the lexical decision task the prime/target are compared to the whole lexicon and ’virtual nonwords’, this would represent the prior probabilities. The final decision is based on whether the target (evidence from the visual input) is closer to the words than to virtual nonwords. Furthermore, Kinoshita and Norris (2009) suggested that the target does not need to be identified as a particular word, only that it is closer to the representations of words than the virtual nonwords in order to complete the task.

There are two key characteristics of this model. First, the priors are dependent on the hypothesis upon which the decision is based, e.g., if the task was a perceptual identification task the priors would be word frequency (i.e.

the probability of the word given no evidence). Second, the prime is assumed to be mistaken for the target and therefore the priming effect is simply that the prime provides a "head start" in the processing of the target. Thus, the evidence provided by the prime is integrated with that of the target, which, in the case of the lexical decision task, is the lexical status of the target. If the prime and target are related then the evidence from the prime will increase the probability that the target is a word, thus producing a priming effect.

The explanation of the masked-priming effects in the lexical-decision task given by the Bayesian Read model (Norris, 2006) is not that different from that of the IA model (McClelland &Rumelhart, 1981; Rumelhart& McClelland, 1982). As Grainger & Jacobs, (1996) also suggested to successfully perform the task it may not be necessary for individual lexical representation to be identified. However, the Bayesian Reader models assumptions are task specific and the focus of this type of model is on how and/or what type the decision is and not the processes that are involved.

Letter position in the Bayesian Reader model is similar to that used in the Spatial-Coding model in that the uncertainty of the letter position is based on algorithm which estimates the difference in location between identical letters (see Norris, 2006). Thus, the identification of a letter-string is based on the similarity of the pattern of the letter-positions in the presented stimuli compared to stored lexical representation. However, as Norris (2006) states the Bayesian Reader model can utilize any current coding system including bigrams.

Lexical Effects in the Masked-Priming Same-Different Task

Orthographic priming effects for both words and nonwords in the masked-priming same-different task has been used as evidence that the task is not influenced by lexical or phonological information (Kinoshita & Norris, 2009). However, if this task is genuinely free of lexical influences, response times should be similar for reference-target pairs that are words or nonwords. However, results from all versions of the same-different task (unprimed or primed) have showed a consistent advantage for the processing of words (and familiar acronyms) over nonwords (e.g., Chambers& Forster, 1975; Marmurk, 1989; Kinoshita & Norris, 2009; Perea & Acha, 2009; Perea, Moret-Tatay, & Carreiras, 2011) – an effect that clearly needs to be explained.

Several different accounts have been put forward to explain the word advantage seen in unprimed versions of the same-different task. For example, Chambers and Foster (1975) accounted for the word advantage in a three level matching model in which matching can occur at the whole word (lexical), letter cluster, and/or letter level, depending on the nature of the stimuli presented. The model is based on their findings that along with an overall matching advantage for words over nonwords, further advantages occurred for high- over low-frequency words and legal over illegal nonwords. This, they argued, showed that words were matched at all three levels, with lexical access facilitating the frequency effect along with the overall word advantage. As legal nonwords have no stored lexical representations but contain legal letter clusters they can utilise both the letter cluster and letter levels, but illegal nonwords can only be matched at the letter level. This is consistent with models of word recognition that suggest the encoding of words follows a letter-bigram-word structure (e.g., Grainger & van Heuven, 2003, Grainger et al., 2006; Whitney, 2001).

Marmurek (1989) also suggested that lexical units that are only available for words are responsible for the word advantage observed in the unprimed version of the same-different task. In addition, he demonstrated that the word advantage is reduced when the reference and target are presented sequentially (as in the masked-priming version of the same-different task) compared to simultaneous presentations (as used by Chambers & Forster (1975) in the unprimed version of the task). Marmurek proposed that this decrease in the word advantage is due to the creation of new cognitive units for the nonword reference stimuli that are required to successfully complete the task (i.e. some form of temporary memory representation for nonwords is created).Furthermore, Marmurek suggested that the size of the word advantage is dependent on the probability of successfully establishing these memory representations for the nonword stimuli. The implication is that as the strength of the new nonword representation increases it reduces or eliminates the word advantage.

In contrast, Angiolillo-Bent and Rips (1982) argued against the hypothesis that words utilise lexical units in the same-different matching task. They investigated the effects of letter displacement in memory encoding by using familiar trigrams (abbreviations such as GDP) and unfamiliar trigrams (e.g., RVT). Participants were required to identify whether the first trigram consisted of the same letters, regardless of position, as a second trigram presented between 500 ms and 2,500 ms later. Despite finding an advantage for processing familiar compared to unfamiliar trigrams this did not interact with the effects of letter displacement or inter-stimulus-interval (ISI) duration. They argued that the lack of interaction indicates that the representations used in the matching process are the same for both familiar and unfamiliar items.

The masked-priming same-different task uses sequential presentation of the reference and target. Based on evidence from Marmurek (1989) and Angiolillo-Bent and Rips (1989) and their own studies, Kinoshita and Norris (2009) argued that in this version of the task the representations used for processing the reference would be the same for words and nonwords. Furthermore, they found no interaction between string type and prime type, in Experiment 4 of their study, illustrating that the pattern of priming is similar for words and nonwords. Thus, they posited that the matching process is based on abstract letter representations that are not affected by lexical and/or phonological representations. In this particular experiment (Experiment 4) Kinoshita and Norris manipulated relative letter position across 5 different prime types, (identity, e.g., faith – FAITH; transposed letters (TL), e.g., fiath – FAITH; two substituted letters (2L Sub), e.g., fouth – FAITH; scrambled, e.g., ifhat – FAITH; and unrelated, e.g., agent - FAITH). Despite finding no significant interaction between string and prime type, a significant advantage for the processing of words over nonwords was found. Kinoshita and Norris argued that the advantage for processing words over nonwords reflects differences in the ease of processing familiar items.

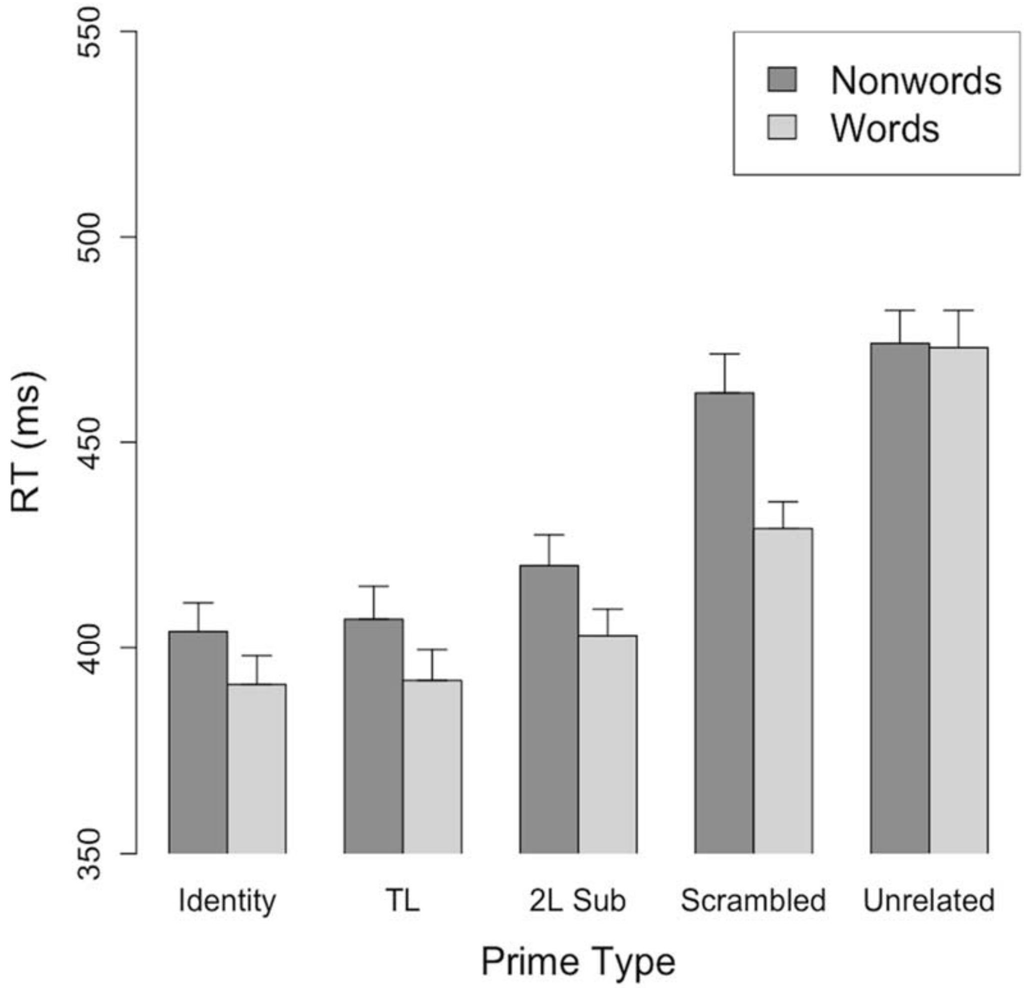
Kinoshita (1987) explained familiarity as a global measure that operates before or during the processes involved in encoding/ identifying individual letters. To date studies using the masked priming same-different task have suggested that the performance effects that arise within this task are based on representations occurring at or after the abstract letter level because the same pattern of priming is found for both words and nonwords (e.g., Norris & Kinoshita, 2008; Kinoshita & Norris, 2009; Kinoshita & Kaplan, 2008). This finding also rules out the possibility that low-level perceptual processes contribute to the word advantage in this task, as any perceptual effect would occur before the abstract letter level and therefore would apply to both words and nonwords. Importantly, in the masked priming version of the same-different task, factors that influence lexical access, such as frequency and neighbourhood density, have been shown not to modulate performance (Norris & Kinoshita, 2008; Kinoshita, Castle & Davis, 2009, respectively). Although this suggests that higher-level lexical information does not influence the processing of the prime and target, it does not preclude sublexical orthographic influences (e.g., bigrams).

Recently, Kinoshita and Lagoutaris (2010) argued that orthotactic knowledge is used for encoding the reference in the masked priming same-different task. They proposed that the representation of the reference is held in visual short-term memory (similar to the "graphemic buffer" first proposed for spelling e.g., Caramazza, Miceli, 1990). Orthotactic knowledge is used to either reconstruct or reintegrate decaying memory traces and thus allowing orthographically legal, pronounceable, nonwords containing more than four letters to be successfully stored in visual short-term memory (which is presumed to have a capacity equal to or less than four). Kinoshita and Lagouyaris described this orthotactic knowledge as being at a higher level than that of abstract letter representations, however no further specification was given.

A second possibility is that different orthotactic information is used for encoding word and nonword reference stimuli. As discussed earlier, Chambers and Forster (1975) suggested that matching of the reference and target could occur at three different levels depending on the nature of the letter string, with words matching at the letter, letter cluster, and word level, and pronounceable nonwords matching at the letter and cluster levels. Thus, the word advantage could result from the utilisation of different sized units when encoding and supporting the representation of the reference stimuli, with words being encoded as a single unit supported by their lexical representations and nonwords being encoded as orthotactic chunks. These "chunks" could be phonologically-based graphemes or purely orthographically-based letter combinations, such as bigrams, which could be contiguous bigrams (e.g., BL in BLANK), noncontiguous open-bigrams (e.g., BA in BLANK), or larger units, such as rhymes (e.g., OUGH, IGHT).

Whatever the nature of orthotactic knowledge, it is important to note that the lack of interaction between prime type and string type in the studies of Angiolillo-Bent and Rips (1982) and Kinoshita and Norris (2009) indicates that lexical processes do not modulate performance in the masked priming same-different task. However, close inspection of the mean response times of Experiment 4 in Kinoshita and Norris suggests the possibility of an interaction between two of the five priming conditions (scrambled, e.g., ifhat - FAITH and unrelated, e.g., agent - FAITH). As illustrated in Figure 8, there appears to be no word advantage for unrelated primes and no scrambled priming effect for nonwords.

Figure 8. Mean response times, with standard error bars, for Experiment 4 of Kinoshita and Norris (2009).



The three critical priming conditions in Kinoshita and Norris (2009) are identity, scrambled, and unrelated. These priming conditions provide critical comparisons, as the only difference between identity and scrambled primes is the absence of correct positional information in the latter condition. Thus, identity primes share both letter identity and positional information with the target, whereas scrambled primes share only letter identity information with the target. The difference between scrambled and unrelated primes arises from access to letter identity information in the scrambled, but not in the unrelated prime condition. Thus, scrambled and identity primes can produce priming at different levels of processing: identity priming at the letter, letter cluster (e.g., grapheme, bigram) and lexical (word) level and scrambled priming at the letter level only. An interaction between these three primes and string type indicates that matching in the same-different task occurs at different levels, whereas no interaction rules out matching at multiple levels.

In the masked priming same-different task the reference stimulus is presented for one second – sufficient time for "one trial" learning which could support long-term priming (see Bowers, 2010 and Bowers & Kouider, 2003). This should enable successful encoding of the reference for immediate use in the matching process. Varying the presentation time of the reference stimulus should thus affect the extent of the advantage shown for words over nonwords in the masked priming same-different task.

An alternative explanation for the word advantage shown in the masked priming same-different task is that different processing strategies are used for word and nonword stimuli, based on the predictability of the target string type. In the standard task procedure, reference-target pairs consist of the same string type (either words or nonwords) even in the different condition, when the reference stimulus differs from the target (e.g., often – DRUMS). Thus, target string type is highly predictable from the reference stimulus within any one trial. If the reference stimulus is a word this may induce lexical strategies, whereas if the reference stimulus is a nonword, sublexical strategies may be employed. Several studies using repetition proportion (RP) priming have demonstrated that masked priming is susceptible to the use of strategies (e.g., Bodner & Masson, 2003; 2009; Bodner & Johnson, 2009). RP priming effects occur when the proportion of experimental primes appearing in the task, compared to control primes, are manipulated, with higher proportions of experimental primes generally resulting in larger priming effects (e.g., Bodner & Masson, 2003; 2009; Bodner & Johnson, 2009). These RP priming effects have been argued to demonstrate that the cognitive system automatically changes the level of influence the prime has on processing the target depending on the probability that the prime will be of use in the task (Bodner & Stanlinski, 2008). Although the proportion of primes are not different in the masked priming same-different task, the design involves blocks of target strings of the same type, therefore the target string type is highly predictable *between*-trials.

The Role of Shape in Visual Word Recognition

As discussed above, most contemporary models of visual word recognition are based on the notion that words are recognised via their constituent letters (e.g., Davis, 2010, Whitney, 2001; Grainger & van Heuven, 2003), so-called *analytical* models. Although the weight of current evidence suggests that the identification of a word's constituent letters is critical to word recognition, many studies also suggest that, at some level at least, the overall shape of a word plays a role in the recognition process (e.g., Allen, Wallace, & Weber, 1995; Perea& Rosa, 2002). However, the evidence for a word shape effect is inconsistent and the locus of this effect is unclear.

One reason why the evidence has been inconsistent may be due to the methods employed to investigate word shape effects. The majority of methods distort the overall shape by alternating case (e.g. AlTeRnAtInG, Besner, 1989), size (e.g., alternating, Perea & Rosa, 2002) or by degrading the visual appearance of the words (Perea, Comesana, Soares, & Moret-Tatay, 2012). However, these methods normally distort across dimensions relating to assumptions used by letter-level coding models, that the overall shape and the component features of letters play little or no role in the identification of the word (Adams, 1979; Besner& Johnston; 1989; McClelland & Rumelhart, 1981), and that the letter codes used in identification of the word are abstract in nature (Bowers, Vigliocco & Haan, 1998). However, the problem with methods such as size alternation is that they seem to be more appropriate for testing the nature of these abstract representations, i.e. whether these abstract representations are size- and case-invariant, rather than the role of the overall shape.

A further problem with methods that distort the overall shape of the words is that although the overall results, that distorting the stimuli causes an inhibitory effect, are consistent, whether these effects are additive or interactive are inconsistent. For example, in the lexical decision task both Kinoshita (1987) and Allen et al., (1995), demonstrated an inhibitory effect of case alternations. In the experiment of Kinoshita (1987) there was no interaction between case alternation and word type (word vs. nonwords) suggesting that the effect is additive. However, Allen et al. (1995) did find a significant interaction, thus suggesting the effect is interactive, and therefore inconsistent with purely analytical models. Furthermore, the extent of these effects also depends on other manipulations. For example, Perea& Rose (2002) demonstrated that size alternation effects are only apparent in low frequency words[1]. This suggestion of a frequency effect was also given by Kinoshita to explain the differences between her results and those of earlier studies by Besner (1983), and Besner and McCann (1987).

The apparent lack of shape effects with high frequency words has also been used to argue against the overall effect of shape under the assumption that if words were processed holistically then this would be most apparent in high frequency words (Perea & Rose, 2002). However, the lack of effects in high frequency words may be due to these words being so familiar that they have reached a ceiling effect.

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[1]Note, Perea& Rose (2002), suggested their finding are more in line with *resonance* models (e.g., Grossberg& Stone, 1986; Stone & Van Orden, 1993; 1994; Van Orden&Goldinger, 1994).

Outline of Chapters

Below I will outline the aims of each of the following chapters of this thesis.

Chapter 2

The aim of Chapter 2 was to investigate the locus of the word processing advantage that has consistently been observed in the masked-priming same-different task. The first experiment of this thesis tested whether it is possible to replicate the interaction seen in Kinoshita and Norris's (2009) Experiment 4. Next, the chapter tested two different explanations for the word advantage: the use of different processing strategies (Experiment 2) or the result of different strengths in the representations used by words and nonwords (Experiments 3 & 4).

Chapter 3

In Chapter 3 explored the nature of the representations used in the masked-priming same-different task, using a multi-modal version of the task, in which the reference was presented auditory. This tested the model presented in Chapter 2 that suggested that the word advantage is the result of different sized representations being used for words and nonwords.

Chapter 4

Chapter 4 investigated whether other higher order linguistic factors affected the masked-priming same-different task, namely, phonology in Experiment 7, and semantics in Experiment 8.

Chapter 5

The experiments presented in Chapter 5 compared the standard masked-priming lexical decision task, the masked-priming same-different task and the sandwich-priming lexical decision task in order to find out which of these tasks is more sensitivity to low level orthographic processing. The experiments investigated the positional overlap between the prime and target not only to compare the different task but also to provide new data to evaluate current models of visual word recognition.

Chapter 6

In the final experimental chapter the role of word shape was investigated. This was performed using a paradigm that unlike previous studies did not distort the appearance of the stimuli. Thus, this allowed the investigation of different factors that may be the locus of any effect, such as normal reading fixation point.

Chapter 7

Chapter 7 presents as summary of the findings presented in this thesis. Furthermore, some preliminary simulations are presented to investigate which of the models of visual word recognition can account for the data presented in Chapter 5. Furthermore, limitations of the present thesis as well as future directions are discussed.

Chapter 2

Visual Masked-Priming Same-Different Task

Introduction

The masked-priming same-different task has recently been presented as a task that is not affected by higher-level information, such as whole word lexical or phonological information (Norris & Kinoshita, 2008; Kinoshita & Norris, 2009). Thus it has been purported to be a task suitable for investigating the lower level processes involved in visual word recognition. However, studies using this task have consistently found a processing advantage for words (and familiar acronyms, e.g. ETA) over nonwords. This chapter presents a series of experiments that were designed to elucidate the underlying nature of the advantage for words over nonwords which is consistently reported in the masked-priming same-different task.

As discussed in Chapter 1, the priming conditions, Identity, Scrambled, and Unrelated provide critical comparisons, as the only difference between identity and scrambled primes is the absence of correct positional information in the latter condition. Thus, identity primes share both letter identity and positional information with the target, whereas scrambled primes share only letter identity information with the target. An interaction between these three primes and string type indicates that matching in the same-different task occurs at different levels, in line with Chambers and Forster's (1975) three 3 level matching model. Hence Experiment 1 tested the possibility of an interaction between String and three of the five priming conditions, Identity, Scrambled and, unrelated primes used in Experiment 4 of Kinoshita and Norris (2009).

Experiment 2 further explores this issue by investigating whether the processing advantage for words is the result of different processing strategies being used for words and nonwords, stimuli, based on the predictability of the target string type, by removing the blocking of trials by string type to reduce between-trials predictability, and also by mixing string type across reference-target pairs in the different condition to reduce predictability *within*-trials.

Finally, Experiments 3 and 4 tested the prediction that the word advantage results from a difference in the strength of representation of the reference stimulus. It is possible to modulate the strength of a nonword reference representation by changing the reference presentation time. Extending the duration of the reference stimulus should increase the strength of representation for nonwords, which should in turn reduce the size of the word advantage (Marmurek, 1989). Likewise, reducing the duration of the reference stimulus should reduce the strength of representation for nonwords, which in turn should increase the size of the word advantage. In Experiment 3 the reference duration used in Kinoshita and Norris (2009) and in the previous experiment was increased to 2 seconds. This should increase the strength of representation for nonwords, which should in turn reduce the size of the word advantage. In Experiment 4 the reference duration was reduced to 500 ms, this should reduce the strength of representation for nonwords, which in turn should increase the size of the word advantage.

Experiment 1: Replication of Kinoshita and Norris (2009)

Method

Participants

Twenty-four students from the University of Nottingham took part in this experiment. All were native English speakers with normal or corrected-to-normal vision.

Stimuli and design

Critical stimuli for the "same" trials were taken from Kinoshita and Norris (2009). These consisted of 78 five-letter words, 78 nonwords, and three groups of 78 primes (identity, scrambled and unrelated). The identity prime was the same as the target (e.g., faith-FAITH). The scrambled prime was a 31524 permutation for five-letter strings when denoted as 12345, ensuring none of the letters: 1) appeared in the same position, 2) were adjacent to the same letters that they were adjacent to in the original string (i.e. no transposition of adjacent letters), and 3) relative positioning was removed, for example, ifhat-FAITH. For the unrelated primes 26 five-letter words were used, 20 from the Kinoshita and Norris study and due to the reduction in the number of priming conditions increasing the number of trials per prime from 20 to 26 an additional six words were needed which were matched in characteristics to the original 20.

As the non-critical stimuli, those used for the "different" trials, from the Kinoshita and Norris (2009) study were not available, 156 five-letter filler words (78 used as target stimuli and 78 as reference stimuli) were selected using the same criteria as the original study. The words were matched in characteristics to the critical condition words and the three priming conditions were constructed using the same methods as for the critical target words. Each target word was paired with one reference word, for example, reference: anger, target: MONTH. To produce the 156 filler nonwords and their corresponding prime's one letter was changed in each filler word.

The design was identical to that used by Kinoshita and Norris (2009). It involved a counterbalanced blocked presentation of words and nonwords. Each of the four groups of target stimuli ("same" and "different" trials words and nonwords) were separated into three groups and assigned different prime conditions across three lists. This allowed each target item to be presented to each participant once only but in a different priming condition. Thus six lists were used and each list consisted of 156 target words (78 critical and 78 filler) and 156 target nonwords (78 critical and 78 filler), 78 identity, scrambled and unrelated primes; 26 of each for the four groups of target stimuli. Each participant was randomly assigned to one of the six lists.

Procedure

The procedure was identical to Kinoshita and Norris (2009). Each trial started with a forward pattern mask consisting of five hash marks (#####) presented in the centre of the screen and the reference stimulus in lower case directly above, which remained on the screen for 1000 ms. This was followed by the prime in lower case, which was presented for 37 ms, then the target stimulus was presented in upper case and remained on the screen until either a response was made or 2000 ms had passed. After each trial a blank screen was presented for 500 ms before the next trial started. DMDX (Forster & Forster, 2003) was used to present the stimuli and record the responses. All responses were made using an external button box connected to the computer. Each participant was tested separately. The stimuli were high contrast and presented in a *white* Courier New font (10 point) on a *black* background. The participants were instructed to attend to the letter string presented above the string of hash marks. When these disappeared a second letter string would replace the hash marks. The participants were then asked to decide as quickly and accurately as possible whether the new letter string presented in upper case was the same or different than the first letter string, ignoring the change in case, by pressing the right button if it was the same and the left button if it was different. The presence of a prime was not mentioned. Each participant completed 328 trials in total, comprising sixteen practice and 312 test trials. All trials within each block were presented in a randomized order. Response times were measured in milliseconds from the onset of the target stimulus.

Results

Analyses were run on both the mean correct response times (RT) and the percentage of errors (total 4.2%). Trials with latencies above 1400 ms and below 250 ms were excluded from the analyses (0.2% of the trials). The "same" and "different" trials were analysed separately using two-way repeated measures ANOVA with String Type (words or nonwords) and Prime Type (identity, scrambled or unrelated) using both by-participant (F_1) and by-item (F_2) analyses. Mean RTs to correct trials and error rates are presented in Table 1.

"Same" trials

For the response latencies the main effect of String Type was significant, $F_1(1, 23) = 12.60$, $p < .01$, $F_2(1, 155) = 41.06$, $p < .001$ with responses to words 25 ms faster than those to nonwords, indicating a processing advantage for words. The main effect of Prime Type was also significant, $F_1(2, 22) = 65.84$, $p < .001$, $F_2(2, 154) = 41.71$, $p < .001$. There was no interaction between String Type and Prime Type, all Fs < 1.Therefore Subsequent planned comparisons were run on Prime Type, with RTs collapsed across String Type. This revealed relative to the unrelated condition facilitation effects for the identity, $F_1(1, 23) = 152.15$, $p < .001$, $F_2(1,155) = 80.13$, $p < .001$, and scrambled conditions $F_1(1, 23) = 20.14$, $p < .001$, $F_2(1, 155) = 13.59$, $p < .001$.

Furthermore, the identity condition differed significantly from the scrambled condition, $F_1(1, 23) = 44.65$, $p < .001$, $F_2(1, 155) = 24.37$, $p < .001$. The mean RTs for the identity primes were 26 ms faster than the scrambled primes, which were 19 ms faster than unrelated primes.

No significant main effect of String Type was found in the error rates, all Fs < 1. There was a main effect of Prime Type, $F_1(2, 46) = 7.25$, $p < .01$, $F_2(1, 153) = 11.15$, $p < .001$. There was no interaction between the variables, all Fs < 1. Planned comparison carried out on the error rates collapsed across String Type showed, as for the RTs, significant priming effects for the identity and scrambled conditions, $F_1(1, 23) = 11.71$, $p < .01$, $F_2(1, 155) = 20.46$, $p < .001$, and $F_1(1, 23) = 6.52$, $p < .05$, $F_2(1, 155) = 7.65$, $p < .01$ respectively. There was no significant difference between the identity and scrambled condition $F_1 < 1$, $F_2(1, 155) = 3.69$, $p = .06$. Thus, identity and scrambled primes were responded to more accurately then unrelated primes (3.5% and 5% versus 7.7%)

"Different" trials

For the RTs there were no significant effects for String Type, $F_1(1, 23) = 1.05$, p = .32, $F_2(1, 155) = 2.98$, $p = .09$, Prime Type, or interaction, all Fs < 1. In the error rates no main effect for String Type was found, Fs < 1, but there was a significant main effect of Prime Type $F_1(2, 22) = 4.28$, $p = .02$, $F_2(2, 154) = 11.15$, $p < .001$. There was no interaction, Fs < 1. Collapsed across String Type error rates revealed significantly less errors for both the identity and the scrambled conditions relative to the unrelated condition, $F_1(1, 23) = 7.96$, $p < .01$, $F_2(1, 155) = 20.46$, $p < .001$, and $F_1(1, 23) = 4.73$, $p < .05$, $F_2(1, 155) = 7.65$, p < .01. There was no significant difference between the identity and scrambled prime conditions, Fs < 1.

Table 1 *Mean response times in milliseconds, percentage error rate, and standard error (SE) of the means of Experiment 1.*

String Type / Prime Type	Prime - Target Pair Examples	Response Times (SE)	% Error (SE)
"Same" Trials			
Words	(Reference: flair)		
Identity	flair - FLAIR	419 (14)	3.5 (0.7)
Scrambled	afrli - FLAIR	449 (16)	4.5 (0.9)
Unrelated	panel - FLAIR	465 (13)	7.5 (1.3)
Nonwords	(Reference: ditle)		
Identity	ditle - DITLE	447 (16)	3.4 (0.9)
Scrambled	tdeil - DITLE	469 (16)	5.4 (1.2)
Unrelated	glimb - DITLE	491 (14)	7.9 (1.2)

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"Different" Trials			
Words	(Reference: often)		
Identity	drums - DRUMS	483 (14)	3.8 (0.5)
Scrambled	udsrm - DRUMS	489 (13)	4.1 (0.8)
Unrelated	acted - DRUMS	489 (14)	5.1 (0.8)
Nonwords	(Reference: ampty)		
Identity	benor - BENOR	496 (18)	3.7 (0.7)
Scrambled	nbroe - BENOR	493 (16)	4.0 (0.7)
Unrelated	acide - BENOR	497 (15)	5.8 (0.8)

"Discussion

The results from Experiment 1 revealed that, for same responses, times to words were faster than those to nonwords. Furthermore, significant priming effects for both the identity and scrambled primes were found, with identity primes producing larger facilitation effects than the scrambled primes. Critically there was no interaction between string type and prime type, consistent with Kinoshita and Norris (2009). However, our results differ from those of Kinoshita and Norris in two key findings. First, we found clear numerical differences between the response times of the words and nonwords in the unrelated priming condition, and second the priming effect of the scrambled condition was similar in size for both words and nonwords (22 ms and 16 ms respectively as opposed to 44 ms and 12 ms in Kinoshita and Norris (2009) Experiment 4). As noted previously, it was the apparent lack of these two effects in Kinoshita and Norris' experiment that led us to suspect that an interaction might exist between string and prime type if only the three critical primes conditions employed here were used. However, we also found the word advantage did not interact with prime type. Nonetheless, the advantage shown for processing words over nonwords in this experiment, and other studies using the same-different task, still requires explanation.

Experiment 2: Strategic Effects

The aim of Experiment 2 was to see if the advantage for words over nonwords found in the masked-priming same-different task arises from different strategies being employed when processing word and nonword reference-target pairs. Thus, in this experiment blocking by stimulus type between trials was removed to reduce the predictability of the stimuli presented on consecutive trials and lessen the effectiveness of any strategy use in this task. In addition, to eliminate within-trial predictability of the target stimulus from the reference stimulus string type, reference-target pairs in the "different" trials were mixed so that the reference string type could no longer be used to predict the string type of the target.

Method

Participants

Twenty-four undergraduate and postgraduate students (18 females and 6 males with an average age of 21.1 years) from the University of Nottingham were recruited to this experiment. All were native English speakers with normal or corrected-to-normal vision. None of them had participated in any of the pervious Experiments.

Stimuli and design

Stimuli were the same as in Experiment 1. The design was also the same as in Experiment 1 except that for the 156 filler target items (i.e. those requiring a “different” response) half of the 78 target words were paired with nonword reference stimuli and vice versa for nonword targets (e.g., reference:

often – target: MUNDS). Blocking of word and nonword trials was also removed hence all trials were presented in a randomized order. Three stimulus lists were constructed which were presented to an equal number of participants.

Procedure

The procedure was the same as in Experiment 1.

Results

The analysis was performed on both the mean correct response times (RT) and the percentage of errors (5.1%). Trials with latencies above 1400 ms and below 250 ms were excluded from the analyses (0.1% of trials). The overall error rate was. Mean RTs and error rates are presented in Table 2. A two-way repeated measures ANOVA was performed on the "same" condition with String Type (word or nonword) and Prime Type (identity, scrambled or unrelated) as variables. For the "different" trials a three-way repeated measures ANOVA was preformed, with Sting Type (word or nonword), Reference-Target Pair (consistent or inconsistent) and Prime Type (identity, scrambled or unrelated). All analysis was run both by-participant (F_1) and by-item (F_2).

"Same" trials

Responses to nonwords were 25 ms slower than to words, $F_1(1, 23) = 44.07$, $p < .001$, $F_2(1, 155) = 25.67$, $p < .001$. A main effect of Prime Type was found, $F_1(2, 22) = 55.53$, $p < .001$, $F_2(2, 154) = 66.15$, $p < .001$ and there was no interaction between Prime Type and String Type, Fs < 1. Data were collapsed across String Type and planned comparisons were conducted for Prime Type. These revealed a facilitation effect for the identity and scrambled primes relative to the unrelated primes, $F_1(1, 155) = 103.35$, $p < .001$, $F_2(1, 23) = 151.30$, $p < .001$ and $F_1(1, 155) = 33.82$, $p < .001$, $F_2(1, 23) = 35.61$, $p < .001$ respectively. Furthermore, the identity primes differed significantly from the scrambled primes, $F_1(1, 155) = 11.475$, $p < .01$, $F_2(1, 23) = 24.26$, $p < .001$. Thus, identity primes were responded to faster (26 ms) than scrambled primes, which were faster (30 ms) than unrelated primes.

There was a significant main effect in the error rates of String Type, $F_1(1, 23) = 4.22$, $p = .05$, $F_2(1, 153) = 3.94$, $p < .05$, and Prime Type, $F_1(2, 46) = 6.32$, $p < .01$, $F_2(1, 153) = 9.56$, $p < .001$, but again, no interaction between these variables was observed, $F_1(2, 46) = 1.62$, $p = .21$, $F_2 < 1$. Planned comparisons revealed significantly less errors in the identity and scrambled prime conditions relative to the unrelated prime condition, $F_1(1, 23) = 7.36$, $p < .05$, $F_2(1, 155) = 16.53$, $p < .001$, and $F_1(1, 23) = 5.00$, $p < .05$, $F_2(1, 155) = 6.77$, $p < .01$, respectively. Error rates in the identity prime condition were significantly less than in the scrambled prime condition by-participant, $F_1(1, 23) = 5.11$, $p < .05$, and marginally by-item, $F_2(1, 155) = 3.14$, $p = .08$

"Different" trials

No significant effects were found in the RTs for String Type, $F_1(1, 23) = 1.49$, $p = .24$, $F_2 < 1$, Reference-Target Pair, $F_1(1, 23) = 1.93$, $p = .18$, $F_2(1, 155) = 1.07$, $p = .30$, and Prime Type, and no interaction, all Fs < 1.

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Table 2. *Mean response times in milliseconds, percentage error rate, and standard error (SE) of the means of Experiment 2.*

String Type Prime Type	Prime - Target Pair Examples	Response Times (SE)	% Error.(SE)
"Same" Trials			
Words	(Reference: flair)		
Identity	flair - FLAIR	401 (8)	3.2 (0.8)
Scrambled	afrli - FLAIR	427 (11)	6.6 (1.0)
Unrelated	panel - FLAIR	462 (9)	9.3 (1.8)
Nonwords	(Reference: ditle)		
Identity	ditle - DITLE	429 (8)	6.6 (0.8)
Scrambled	tdeil - DITLE	455 (11)	7.1 (1.2)
Unrelated	glimb - DITLE	479 (10)	11.7 (2.3)

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"Different" Trials			
Words	(Reference: often)		
Identity	drums - DRUMS	482 (19)	3.1 (0.6)
Scrambled	udsrm - DRUMS	485 (22)	4.4 (0.6)
Unrelated	acted - DRUMS	481 (19)	5.6 (1.5)
Nonwords	(Reference: ampty)		
Identity	benor - BENOR	482 (20)	3.6 (0.8)
Scrambled	nbroe - BENOR	486 (19)	3.8 (0.9)
Unrelated	acide - BENOR	493 (21)	5.6 (1.5)

The analyses of the error rates revealed no differences between word and nonword targets, Fs < 1, but a significant effect of Prime Type, $F_1(2, 22) = 5.78$, $p < .01$, $F_2(2, 154) = 9.85$, $p < .001$, and Reference-Target Pair, $F_1(1, 23) = 12.80$, $p < .01$, $F_2(1, 155) = 15.67$, $p < .001$ with a lower error rate for inconsistent than for consistent reference-target pairs. There were no interactions between String Type and Prime Type, Fs < 1, String Type and Reference-Target Pair, $F_1(2,154) = 2.15$, $p = 0.15$, $F_2(2,154) = 1.31$, $p = 0.25$, Prime Type and Reference-Target Pair, $F_1(2,154) = 1.93$, $p = 0.15$, $F_2 < 1$, and String Type, Prime Type and Reference-Target Pair, $F_1(2,154) = 1.27$, $p = 0.29$, $F_2 < 1$. Planned comparisons across the different prime conditions revealed that there were significantly less errors for both the identity and the scrambled prime conditions than the unrelated prime condition, $F_1(1, 23) = 8.10$, $p < .01$, $F_2(1, 155) = 15.87$, $p < .001$, and $F_1(1, 23) = 4.24$, $p = .05$, $F_2(1, 155) = 8.43$, $p < .01$, respectively. There was no significant difference between the identity and scrambled prime conditions, $F_1(1, 23) = 2.67$, $p = .12$, $F_2(1, 155) = 2.1$, $p = .15$.

Discussion

Results of Experiment 2 mirror those found in Experiments 1. Words were processed faster than nonwords and critically there was no interaction between string and prime type. These results suggest that the predictability of the target string type did not influence the pattern of priming effects found on the masked-priming same-different task. Thus, blocking trials by stimulus type, and pairing reference and target stimuli by string type, did not induce the use of different strategies for processing words and nonwords in this task.

Experiment 3 & 4: Effects of a Shorter and Longer Reference Presentation Duration

The aim of Experiments 3 and 4 was to test the prediction that the word advantage results from a difference in the strength of representation of the reference stimulus. It is possible to modulate the strength of a nonword reference representation by changing the reference presentation time. Extending the duration of the reference stimulus should increase the strength of representation for nonwords, which should in turn reduce the size of the word advantage (Marmurek, 1989). Likewise, reducing the duration of the reference stimulus should reduce the strength of representation for nonwords, which in turn should increase the size of the word advantage. Accordingly, in Experiment 3 the reference duration used in Kinoshita and Norris (2009) and in the previous experiments was increased to 2 seconds, and in Experiment 4 it was reduced to 500 ms.

Experiment 3: Effects of a Longer Reference Presentation

Method

Participants

In this experiment a total of forty-one undergraduate students from the School of English at the University of Nottingham took part in exchange for course credit. All were native English speakers with normal or corrected-to-normal vision.

Stimuli and design and procedure

The stimuli, design, and procedure for these two experiments were the same as those described in Experiment 1, except that this experiment both the reference and the forward mask were presented for 2000 ms.

Results

The correct response times (RT) and percentage of errors (3.3%) were analysed in the experiment. Trials with response latencies above 1400 ms and below 250 ms were excluded from the analyses (1.9% of all trials) to remove outliers. The "same and different" trials were analysed separately using a two-way ANOVA with String Type (word or nonword) and Prime Type as variables. The analysis was run using both by-participant and by-item. Mean RTs and error rates are presented in Table 3.

"Same" trials

Responses to nonwords were 29 ms slower than to words, $F_1(1, 40) = 7.6$, $p < .01$, $F_2(1, 155) = 40.61$, $p < .001$. A main effect of Prime Type was found, $F_1(2, 39) = 32.59$, $p < .001$, $F_2(2, 154) = 19.3$, $p < .001$ and there was no interaction between String Type and Prime Type, Fs < 1. Data were therefore collapsed across String Type and planned comparisons across Prime Type were conducted. These revealed a facilitation effect for the identity and scrambled primes relative to the unrelated prime condition, $F_1(1, 40) = 47.54$, $p < .001$, $F_2(1, 155) = 39.57$, $p < .001$ and $F_1(1, 40) = 7.12$, $p < .01$, $F_2(1, 155) = 4.81$, $p < .05$, respectively. Furthermore the identity prime condition differed significantly from the scrambled prime condition, $F_1(1,40) = 37.74$, $p < .001$, $F_2(1,155) = 14.75$, $p < .001$. Thus responses for identity primes were faster (28 ms) then those for scrambled primes, which were faster (14 ms) than unrelated primes.

There was a significant main effect in the error rate for String Type, $F_1(1, 40) = 8.39$, $p < .01$, $F_2(1, 155) = 9.41$, $p < .01$, with nonwords producing more errors than words (6.4% versus 4.7%). There was an effect of Prime Type by-participant, $F_1(2, 155) = 3.05$, $p = .05$, but not by-item, $F_2 < 1$. However, there was no interaction, Fs < 1

"Different" trials

For response times, the main effect of String Type by-participant approached significance, $F_1(1, 40) = 2.95$, $p = .09$, and a significant effect by-item was found, $F_2(1, 155) = 7.44$, $p < .01$. There were no main effect of Prime Type, $F_1(2,39) = 2.22$, $p = .23$, $F_2 < 1$ and a significant interaction by-participant, $F_1(2,39) = 3.83$, $p < .05$, but not by-item, $F_2(2,154) = 1.56$, $p = .21$.

The analysis of the error rates revealed a significant main effect of String Type, $F_1(1,40) = 4.09$, $p < .05$, $F_2(1,155) = 7.86$, $p <.01$, with more errors made to nonwords than words (5.7% versus 4.6%). There was no significant effect of Prime Type, or interaction, Fs <1.

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Table 3. *Mean response times in milliseconds, percentage error rate, and standard error (SE) of the means of Experiment 3.*

String Type Prime Type	Prime - Target Pair Examples	Response Times (SE)	% Error (SE)
"Same" Trials			
Words	(Reference: flair)		
Identity	flair – FLAIR	657 (18)	4.0 (0.8)
Scrambled	afrli – FLAIR	688 (18)	4.6 (0.6)
Unrelated	panel - FLAIR	704 (17)	5.5 (0.8)
Nonwords	(Reference: ditle)		
Identity	ditle – DITLE	690 (24)	5.5 (0.7)
Scrambled	tdeil – DITLE	717 (22)	6.7 (1.1)
Unrelated	glimb - DITLE	728 (23)	6.9 (0.9)

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"Different" Trials			
Words	(Reference: often)		
Identity	drums - DRUMS	732 (19)	4.7 (0.7)
Scrambled	udsrm - DRUMS	733 (18)	4.8 (0.6)
Unrelated	acted - DRUMS	741 (19)	4.5 (0.6)
Nonwords	(Reference: ampty)		
Identity	benor - BENOR	741 (22)	5.4 (0.8)
Scrambled	nbroe - BENOR	759 (23)	6.1 (1.0)
Unrelated	acide - BENOR	742 (22)	5.7 (0.7)

Experiment 4: Effects of a Shorter Reference Presentation

Method

Participants

In this experiment a total of thirty-three undergraduate students from the School of English participated in exchange for course credit. All were native English speakers with normal or corrected-to-normal vision.

Stimuli and design and procedure

The stimuli, design, and procedure for this experiment was the same as those described in Experiment 1, except that in this experiment both the reference and the forward mask were presented for 500 ms.

Results

All analysis were preformed on the correct response times (RT) and percentage of errors (3.5%). Trials with latencies above 1400 ms and below 250 ms were excluded from the analyses (0.4% of the trials). Two separate two-way ANOVAs were performed on the "same" and "different" trials, with String Type (word or nonword) and Prime Type (identity, scrambled or unrelated) as variables. The ANOVAs were performed using both by-participant (F_1) and by-item (F_2) analysis. Mean RTs and errors rates are presented in Table 4.

"Same" trials

For the responses latencies the main effect of String Type was significant, $F_1(1,32) = 9.56$, $p < .01$, $F_2(1,155) = 48.368$, $p < .001$, with responses to words 27 ms faster than those to nonwords. The main effect of Prime Type was also significant, $F_1(2,31) = 9.3$, $p < .001$, $F_2(2,154) = 25.84$, $p < .001$. There was no interaction between String and Prime Type, $F_1(2,31) = 1.81$, $p = .17$, $F_2(2,154) = 1.72$, $p = .18$, so RTs were collapsed across String Type. Subsequent planned comparisons across Prime Type revealed relative to the unrelated condition facilitation effects for both the identity and scrambled conditions, $F_1(1,32) = 11.23$, $p < .01$, $F_2(1,155)$, 55.98, $p < .001$, and $F_1(1,32) = 7.03$, $p < .05$, $F_2(1,155) = 8.24$, $p < .01$, respectively. Furthermore, the identity condition differed significantly from the scrambled condition, $F_1(1,32) = 6.81$, $p < .05$, $F_2(1,155) = 17.12$, $p < .001$. The mean RTs for identity primes were 13 ms faster than those for scrambled primes, which were 14 ms faster than unrelated primes. No significant main effect of String Type was found in the error rates, $F_1(1,32) = 1.56$, $p = .22$, $F_2(1,155) = 1.53$, $p =.21$. There was a main effect of Prime Type, $F_1(2,31) = 5.14$, $p < .01$, $F_2(2,154) = 4.32$, $p < .05$, but there was no interaction, $F_1(2,31) = 1.47$, $p = .24$, $F_2(2,154) = 1.74$, $p = .18$. Planned comparisons conducted on error rates collapsed across String Type showed unrelated primes differed significantly from identity primes, $F_1(1,32) = 5.53$, $p < .05$, $F_2(1,155) = 4.94$, $p < .05$, and scrambled primes by-participant, $F_1(1,32) = 7.72$, $p < .01$, but not by-item, $F_2 < 1$.

There was no difference between identity and scrambled primes, Fs < 1. Thus, identity and scrambled primes were responded to more accurately than unrelated primes (3.8% and 4% versus 6.6%).

"Different" trials

For the RTs the effect of String Type was not significant by-participant, $F_1(1,32) = 2.09$, $p = .16$, but significant by-item, $F_2(1,155) = 8.49$, $p < .01$. There was no significant main effect of Prime Type, $F_1(2,31) = 2.39$, $p = .10$, $F_2 < 1$, or interaction, Fs < 1. In the error rates no main effect of String Type was found, Fs < 1, but there was a significant main effect of Prime Type by-participant, $F_1(2,31) = 6.64$, $p < .01$, but not by-item, $F_2 <1$. The interaction between these factors was marginal by-participant, $F_1(2,31) = 2.7$, $p =.07$, and significant by-item, $F_2(2,154) = 3.38$, $p < .05$.

Table 4. *Mean response times in milliseconds, percentage error rate, and standard error (SE) of the means of Experiment 4.*

String Type / Prime Type	Prime - Target Pair Examples	Response Times (SE)	% Error (SE)
"Same" Trials			
Words	(Reference: flair)		
Identity	flair - FLAIR	581 (16)	3.7 (1)
Scrambled	afrli - FLAIR	590 (14)	4.0 (0.8)
Unrelated	panel - FLAIR	612 (14)	7.8 (1.4)
Nonwords	(Reference: ditle)		
Identity	ditle - DITLE	607 (17)	3.8 (0.7)
Scrambled	tdeil - DITLE	624 (14)	4.1 (0.8)
Unrelated	glimb - DITLE	631 (15)	5.4 (0.9)

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"Different" Trials			
Words	(Reference: often)		
Identity	drums - DRUMS	655 (17)	2.9 (0.6)
Scrambled	udsrm - DRUMS	657 (19)	3.1 (0.5)
Unrelated	acted - DRUMS	644 (20)	5.6 (0.7)
Nonwords	(Reference: ampty)		
Identity	benor - BENOR	664 (15)	4 (0.5)
Scrambled	nbroe - BENOR	667 (15)	3.6 (0.6)
Unrelated	acide - BENOR	661 (16)	4.4 (0.5)

General Discussion

This chapter investigated the origin of the lexicality effect shown consistently in the same-different task. The overall pattern of results in Experiments 1-4 showed a consistent processing advantage for words over nonwords (magnitude of the lexicality effects Exp 1: 25 ms, Exp 2: 24 ms, Exp 3: 29 ms, Exp 4: 27 ms). Critically, the pattern of masked-priming effects was the same for words and nonwords. Both the lexicality effects and patterns of priming found in Experiments 1-4 were independent of the duration of the reference stimuli and the predictability of the target string type (both between and within trials).

Although the results from Experiments 1-4 showed no significant interaction between string type and prime type further exploration of the effects of prime type on identity and scrambled priming for words and nonwords independently were conducted. Table 5 reports the effect sizes found for the different prime types across Experiments 1-4. As can be seen, no significant word advantage in the identity priming condition was shown across Experiments 1-4 confirming our earlier analyses. Likewise, no significant word advantage was found across the scrambled priming condition in Experiment 1-3 when the reference duration was relatively long (i.e. $\geq$ 1000 ms). However, in Experiment 4 with the short reference duration (500 ms) there was no significant scrambled priming effect for the nonwords whereas for the words there was a significant and moderate to large scrambled priming effect (Cohen's $d = .70$). In addition, the difference in magnitude of the scrambled priming effect across words and nonwords was significant ($p < .05$)

whereas for identity priming there was no word advantage $t(32) < 1$). Seemingly the duration of the reference stimulus influences the extent of scrambled priming for nonwords. This may be accounted for by lexical processing in that the short duration of the reference might be sufficient to activate its lexical representation (or similar to the reference, e.g. orthographic neighbours) which feedback to prelexical processes.

Whilst Kinoshita and Norris (2009) argued that the same representations are used in the matching process for words and nonwords this seems unlikely because there is a consistent word advantage, as shown clearly in Experiments 1-4. Rather, the results of our experiments suggest that the word advantage may arise from differences in the representations involved in matching the reference and target. As suggested by Chambers and Forster (1975) matching could occur at several levels depending on the type of string used, with nonwords matching at the sublexical level and words matching at both the sublexical and lexical level. This would fit in with a multiple level matching explanation (e.g., Chambers and Forster, 1974). As discussed in Chapter 1, in this model of the task both words and nonwords can utilize letter and letter clusters (e.g., bigrams), with only words utilizing whole word lexical representations. This would be in line with current models of visual word recognition that include bigrams for letter position encoding (e.g., Grainger & van Heuven, 2003; Whitney & Cornelissen, 2005; Grainger et al., 2006; Whitney & Cornelissen, 2008).

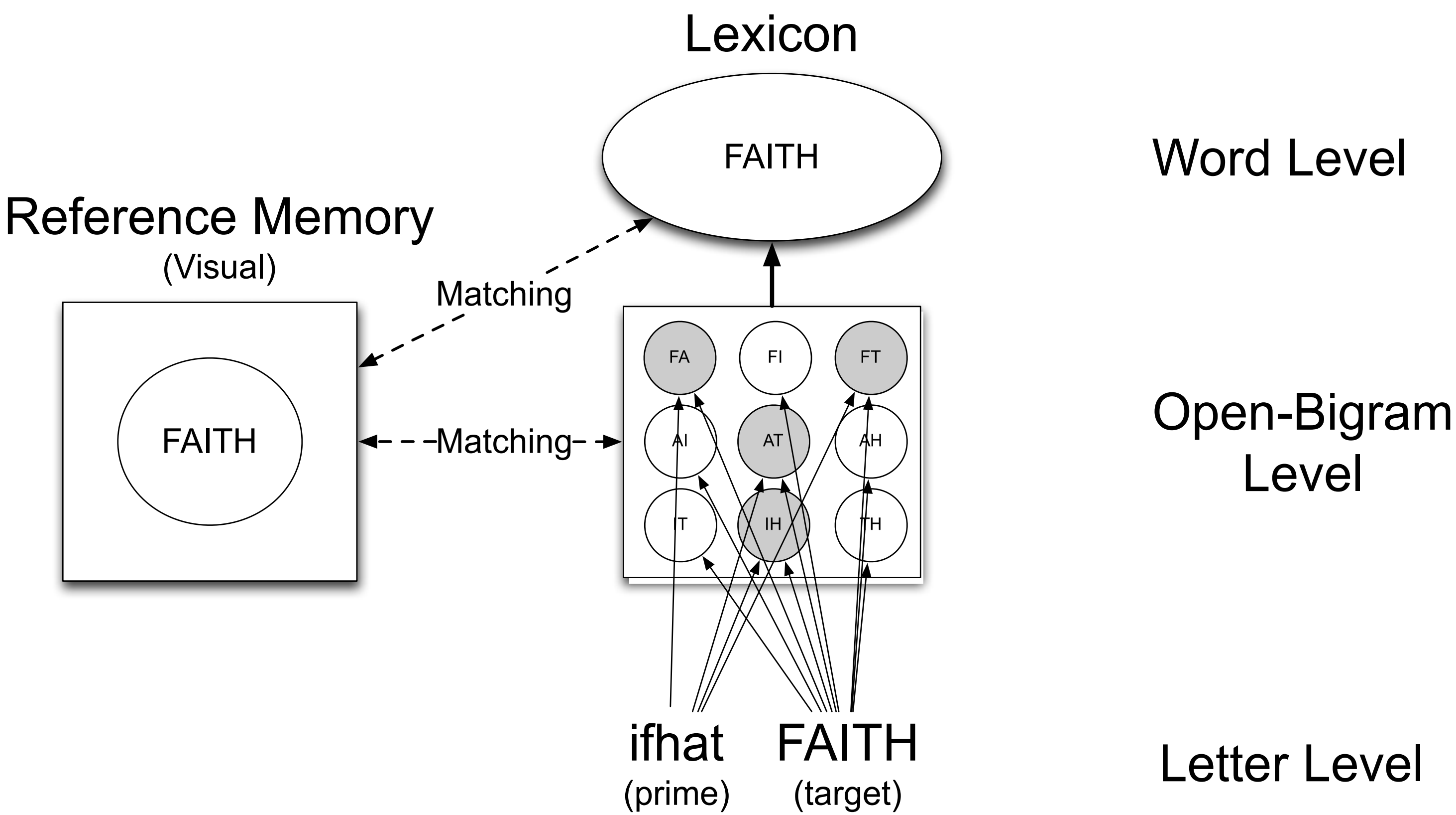
Table 5.*Significance, magnitude, and effect sizes (Cohen's d) of identity and scrambled priming (in milliseconds) for Experime*nts 1 - 4.

		Identity Priming			Scrambled Priming		
Experiment	Reference Duration	Words (*d*)	Nonwords (*d*)	Word Advantage	Words (*d*)	Nonwords (*d*)	Word Advantage
Experiment 1	1000 ms	46 ** (1.8)	45 ** (2.1)	$t < 1$	16 ** (0.58)	22 ** (0.84)	$t < 1$
Experiment 2	1000 ms	61** (1.94)	50 ** (1.35)	$t = 1.25, p = 0.22$	35 ** (1.23)	24 ** (0.69)	$t = 1.40, p = 0.17$
Experiment 3	2000 ms	47 ** (0.92)	36 ** (0.85)	$t = 1.15, p = 0.26$	17 * (0.4)	10 ns (0.26)	$t < 1$
Experiment 4	500 ms	31 ** (0.55)	23 * (0.47)	$t < 1$	23 ** (0.70)	6 ns (0.16)	$t = 2.26, p < 0.05$

Close examination of the scrambled primes used in the current experiments revealed that they shared four out of nine possible open-bigrams with the target, one contiguous and three non-contiguous. Thus, the scrambled primes not only matched the targets in terms of their letter identity but they also contained some relative positional information. Thus, it is possible that the effects of priming in the scrambled condition are due to the number of shared open-bigrams with the target.

Figure 9 illustrates a proposed model of the same-different task based on Chambers and Forster (1975) that involves open-bigrams as in the model of Grainger and van Heuven (2003), contiguous, with adjacent letters (e.g., FA, AI, IT, TH, for FAITH) and non-contiguous with non-adjacent letters in the correct order but with one or more intervening letters (e.g., FI, FT, FH, AT, AH, IH). When the reference is presented in the visual domain, nonword matching occurs at the open-bigram level, whereas matching for words occurs at either the open-bigram or word level. Thus, this model predicts both the word advantage and scrambled priming effects for both words and nonwords.

Figure 9. Model of the masked-priming same-different task. Gray-filled circles at the Open-Bigram Level indicate shared open-bigrams between prime and target.



Chapter 3

Auditory Referenced Masked-Priming Same-Different Task

Introduction

In Chapter 2 a model of the task, based on Grainger and van Heuven's (2003) open-bigram model of visual word recognition, was presented. This model proposes that both words and nonwords utilize the same prelexical bigram representations, but only word can utilize whole word lexical representations. It is the difference in the representations used that is proposed to be the locus of the processing advantage for words over nonwords seen across all variations of the same-difference task. The aim of Chapter 3 is to provide further evidence to support the suggestion that different representation are used for words and nonwords in the masked-priming same-different task and to explore further the nature of the representations used. To test this, Experiments 5-7 change the modality of the presentation of the reference stimulus from visual to auditory.

When the reference stimulus is presented in the auditory modality the matching process could occur at the phonological level through the target being converted into a phonological code. For words this could occur at the lexical or sublexical level but for nonwords this is only possible sublexically. When letter order is preserved, as in identity primes, conversion of the target to phonology is facilitated for both words and nonwords, but when letter order is disrupted, as in scrambled primes, conversion of the target to phonology is not facilitated at the sublexical level. However, scrambled primes could still potentially facilitate the processing of word targets at the lexical level through activation of shared sublexical orthographic representations (e.g., open-bigrams). In contrast, scrambled priming effects would not occur for nonword targets because they do not have lexical representations.

Experiment 5: Auditory Same-Different Task

Method

Participants

Twenty-four undergraduate and postgraduate students (19 females and 5 males with an average age of 23.1 years) from the University of Nottingham participated in this experiment. All were native English speakers with normal or corrected-to-normal vision and none had participated in the previous experiments.

Stimuli and design

Stimuli were the same as in Experiment 1. Reference stimuli were recorded using a female adult speaker with a non-specific English accent. Audio was recorded in an anechoic chamber, with a sampling rate of 44,100 Hz and edited using Amadeus Pro (www.hairersoft.com/AmadeusPro/). Each of the audio files was edited so that the total duration was 1 second (the same duration that the hash marks remained on the screen), and the offsets of the audio stimulus and hash marks were synchronous. The design used for this experiment was the same as Experiment 1.

Procedure

The procedure was the same as Experiment 1, except that the reference stimuli were presented in the auditory rather than visual domain.

Results

Trials with latencies above 1400 ms or below 250 ms were removed from the analyses, accounting for 0.3% of the total data. The analysis was then performed on both the correct response times (RT) and the percentage of errors (3.6% in total). The mean RTs and error rate are given in Table 6. The "same" and "different" trials were analysed separately using two-way repeated measures ANOVAs, with String Type (word or nonword) and Prime Type (identity, scrambled or unrelated) as variables. The analysis was perform both by-participant (F_1) and by-item (F_1).

"Same" trials

Analysis of RT latencies for the "same" trials showed a significant effect of String Type, $F_1(1, 23) = 27.74$, $p < .001$, $F_2(1, 155) = 36.15$, $p < .001$, with responses to nonwords 48 ms slower than to words. The effect of Prime Type was also significant, $F_1(2, 22) = 31.04$, $p < .001$, $F_2(2, 154) = 29.43$, $p < .001$. In contrast to our previous experiments, there was a significant interaction between String Type and Prime Type, $F_1(2, 22) = 3.25$, $p < .05$, $F_2(2, 154) = 3.08$, $p < .05$. As the pattern of priming differed across words and nonwords, a series of pair wise comparisons were conducted for words and nonwords separately to elucidate where the differences in priming occurred.

Words. Significant identity and scrambled priming effects were found relative to the unrelated prime condition, $F_1(1, 23) = 75.51$, $p < .001$, $F_2(1, 77)$

= 58.62, $p < .001$ and $F_1(1, 23) = 12.68$, $p < .01$, $F_2(1, 77) = 9.88$, $p < .01$, respectively. The identity prime condition also differed significantly from the scrambled prime condition, $F_1(1, 23) = 15.73$, $p < .001$, $F_2(1, 77) = 19.10$, $p < .001$. Thus, response times for identity primes were 38 ms faster than scrambled primes, which in turn were 30 ms faster than unrelated primes.

Nonwords. RTs for the identity prime condition differed significantly from both the scrambled prime and unrelated prime conditions, $F_1(1, 23) = 6.16$, $p < .05$, $F_2(1, 77) = 7.21$, $p < .01$ and $F_1(1, 23) = 7.71$, $p < .05$, $F_2(1, 77) = 13.35$, $p < .001$ respectively. Importantly, the scrambled prime condition did not differ significantly from the unrelated prime condition, *F*s < 1. Thus, nonword targets preceded by an identity prime were responded to 30 ms faster than both scrambled and unrelated primes.

Analysis of error rates in the "same" trials revealed a significant effect of String Type, $F_1(1, 23) = 44.02$, $p < .001$, $F_2(1, 153) = 4.54$, $p < .05$ and a marginal effect of Prime Type by-participant, $F_1(2, 46) = 2.93$, $p = .06$, and a significant effect of Prime Type by-item, $F_2(1, 153) = 4.57$, p < .01. There was no interaction between String Type and Prime Type, *F*s < 1. Pairwise comparisons for data collapsed across String Type revealed that identity primes differed from scrambled and unrelated primes, $F_1(1, 23) = 4.55$, $p < .05$, $F_2(1, 155) = 3.91$, $p < .05$ and $F_1(1, 23) = 4.14$, $p < .05$, $F_2(1, 155) = 8.11$, $p < .01$, respectively. There was no difference between scrambled and unrelated primes, *F*s < 1.

“Different” trials

The analyses of RTs in the "different" trials showed that the effect of String Type was not significant by-participant, $F_1(1, 23) = 1.80$, $p = .19$, but was significant by-item, $F_2(1, 155) = 5.85$, $p < .05$. There was no effect of Prime Type, $F_1(2, 22) = 2.56$, $p = .09$, $F_2(2, 154) = 1.48$, $p = .23$, and no interaction, Fs < 1.

Analysis of error rates revealed a similar pattern; a significant effect for String Type by-participant, $F_1(1, 23) = 28.37$, $p < .001$, but not by-item, $F_2(1, 154) = 2.44$, $p = .12$, no effect of Prime Type, $F_1(2, 22) = 1.72$, $p = .19$, $F_2(2, 154) = 2.33$, $p = .10$, and no interaction, $F_1(2, 46) = 1.13$, $p = .33$, $F_2 < 1$.

Table 6. *Mean response times in milliseconds, percentage error rate, and standard error (SE) of the means of Experiment 5.*

String Type Prime Type	Prime - Target Pair Examples	Response Times (SE)	% Error (SE)
"Same" Trials			
Words	(Reference: flair)		
Identity	flair - FLAIR	447 (14)	2.2 (0.9)
Scrambled	afrli - FLAIR	485 (15)	3.5 (0.9)
Unrelated	panel - FLAIR	515 (14)	4.8 (1.1)
Nonwords	(Reference: ditle)		
Identity	ditle - DITLE	509 (19)	7.1 (1.6)
Scrambled	tdeil - DITLE	539 (15)	7.1 (1.0)
Unrelated	glimb - DITLE	543 (15)	9.3 (1.0)

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"Different" Trials			
Words	(Reference: often)		
Identity	drums - DRUMS	530 (17)	2.5 (0.6)
Scrambled	udsrm - DRUMS	532 (19)	3.2 (0.6)
Unrelated	acted - DRUMS	541 (20)	3.5 (0.7)
Nonwords	(Reference: ampty)		
Identity	benor - BENOR	546 (15)	4.5 (0.8)
Scrambled	nbroe - BENOR	541 (15)	4.1 (0.5)
Unrelated	acide - BENOR	553 (16)	5.5 (0.5)

Discussion

Results from this experiment again revealed a lexicality effect. However, in contrast to Experiments 1-4 a significant interaction emerged between string type and prime type when reference stimuli were presented in the auditory domain, demonstrating a different pattern of priming across words and nonwords. Specifically, scrambled primes produced a facilitation effect for word targets but not for nonword targets. Thus, the lack of scrambled priming effects for nonwords differs from the results of Experiments 1-4, where scrambled priming effects were found consistently for both nonwords and words.

These results are consistent with the hypothesis that the matching process occurs at multiple levels for words but only at the sublexical level for nonwords (Chambers & Forster, 1975). One possibility is that when reference stimuli are presented in the auditory modality the target has to be converted to phonology to perform the same-different task. In this instance, scrambled primes facilitate processing of words at the lexical level through activation of shared orthographic representations such as open-bigrams. This does not occur for nonword targets, as they do not have lexical representations.

An alternative possibility is that auditory reference stimuli are converted to orthography and that matching occurs at the orthographic level. In this case, the interaction found between string type and prime type could have arisen from ambiguity in the spelling of the spoken nonword reference stimuli. Thus, ambiguity of spelling could impact on scrambled priming for nonwords as there could be multiple spellings. No ambiguity would arise for matching auditory word reference stimuli to visual word targets, as the target words used in the experiment had only one possible spelling.

To test this hypothesis a control experiment 6 was conducted without nonword stimuli, as it is virtually impossible to create nonwords with unambiguous spellings. Instead, to manipulate ambiguity of spelling across the word stimuli, the experiment included two types of reference word stimuli: heterographic homophones, i.e. words that are spelt differently but have the same pronunciation (e.g., THEIR and THERE) and non-homophonic control words.

Heterographic homophones provide an interesting way to test if ambiguity in spelling affects the pattern of priming, as heterographic homophone pairs generally consist of one spelling that is higher in frequency than the other (e.g., BOARD has a frequency of 64 versus BORED with a frequency of 20 per million). Several experimental paradigms have shown that this difference in written frequencies results in dominance for the higher frequency spelling (e.g., Gorfein & Weingartner, 2008). This effect of spelling dominancy is extremely robust and is not influenced by regency effects and spelling regularity (Sandra, 2010). Furthermore, when required to spell an auditory-presented heterographic homophone the spelling with the highest frequency is given in almost all cases (Gorfein & Weingartner, 2008).

Thus, when presented with auditory reference stimuli that are heterographic homophones we predict that the dominant, higher frequency, spelling will be more likely to be activated than the lower frequency spelling. As a consequence, responses should be faster to targets with dominant compared to non-dominant spellings. Furthermore, if the auditory reference stimulus is converted to an orthographic code a different pattern of priming would be expected for dominant compared to non-dominant spellings. Scrambled priming effects should be observed with dominant spellings of the homophones, whereas no scrambled priming is expected for non-dominant spellings (where the auditory reference will create spelling ambiguity). Alternatively, if the target is converted to phonology to match to the auditory-presented reference, the pattern of priming should be similar across dominant and non-dominant spellings. Thus, if the match occurs at the phonological level there should be no interaction between homophone dominance and prime type.

Experiment 6: Auditory Homophone Same-Different Task (Words Only)

Method

Participants

Twenty-four undergraduate and postgraduate students (16 females and 8 males, mean age 22.4 years) participated in this experiment. All were native English speakers with normal or normal-to-corrected vision.

Stimuli and design

Seventy-eight heterographic homophone word pairs (156 words) were selected from a list of 207 presented in Gorfein and Weingartner (2008). Homophone pairs were selected that matched in length (M = 4.7) but differed in spelling dominance as measured by word frequency (196 vs. 16 occurrences per million according to the SUBTLEX-US database, Brysbaert & New, 2009). Two lists of homophone pairs were created, matched for frequency, for "same" and "different" trials (all $t < 1$). A set of 156 control words (78 words for the "same" and "different" trials) were selected from the SUBTLEX-US to match in length and written frequency to each of the 156 homophones (all $t < 1$). A further set of 156 words was selected as reference stimuli for use in the "different" trials. The three priming conditions, identity, scrambled and unrelated, were created using the same method as described in Experiment 1. Homophones were fully counterbalanced across same-different trials and priming condition. Thus, in total six lists were created. Each participant was randomly assigned to one of the six lists. All auditory reference stimuli were recorded using the same method described in Experiment 5.

Procedure

The procedure for this experiment was the same as Experiment 5.

Results

Trials with latencies over 1400 ms or below 250 ms were removed from the analyses, accounting for 0.4% of the total data. The analysis was then performed on the correct response times (RT) and the percentage of errors (5.2% in total). Two-way repeated measures ANOVAs were conducted on the "same" and "different" trials separately. To investigate the effect of homophone dominancy and the pattern of priming the first ANOVAs used Homophone Dominancy (dominant vs. non-dominant) and Prime Type (identity, scrambled, vs. unrelated) as independent variables on the homophone trials only. To explore the general effect of homophones compared to control words in relation to priming condition the second

ANOVAs were conducted using all trials with Word Type (homophones vs. control words) and Prime Type (identify, scrambled, vs. unrelated).Mean RTs and error rates are presented in Table 7.

"Same" trials

The latency analysis revealed a significant effect of Homophone Dominancy, $F_1(1,23) = 45.30$, $p < .001$, $F_2(1,78) = 26.22$, $p < .001$, with responses to dominant homophone spellings 88 ms faster than non-dominant spellings. A main effect of Prime Type was found, $F_1(2,46) = 10.59$, $p < .001$, $F_2(1,78) = 14.43$, $p < .001$. Importantly, no significant interaction was obtained, $F_1(2,46) = 1.76$, $p =.18$, $F_2(1,155) = 2.78$, $p = .07$.

To investigate the main effect of Prime Type RTs were collapsed across Homophone Dominancy and planned comparisons were conducted. These revealed that identity and unrelated primes differed significantly, $F(1,23) = 8.64$, $p < .05$, $F_2(1,78) = 22.17$, $p < .001$. Scrambled primes were faster than unrelated primes but this difference just failed to reach significance (2-tailed), $F(1,23) = 4$, $p = .06$, $F_2(1,78) = 3.72$, $p = .06$. Identity primes also differed significantly from scrambled primes, $F(1,21) = 4.75$, $p < .05$, $F_2(1,78) = 10.52$, $p < .01$. Thus, identity primes were responded to faster (24 ms) than scrambled primes, and scrambled primes were faster (27 ms) than unrelated primes.

Error rates revealed a significant effect of Homophone Dominancy, $F_1(1,23) = 4.19$, $p = .05$, $F_2(1,77) = 9.14$, $p < .01$, with responses to dominant spellings 4.8% more accurate than non-dominant spellings. A significant effect of Prime Type was found by-participant, $F_1(2,46) = 3.60$, $p < .05$, but not by-item, $F_2(1,154) = 2.25$, $p = .11$. Importantly, no significant interaction was found, Fs < 1.

“Different” trials

Responses latencies and error rates revealed no significant main effects for Homophone Dominancy, Prime Type, and no interactions, all Fs < 1.

Homophones versus controls

"Same" trials

As expected the latency analysis revealed a significant main effect of Word Type, $F_1(1,23) = 40.96$, $p < .001$, $F_2(1,155) = 80.68$, $p < .001$, with responses to homophones (where there is spelling ambiguity) 60 ms slower than control words. Again a main effect of Prime Type was found, $F_1(2,46) = 19.85$, $p < .001$, $F_2(1,155) = 43.81$, $p < .001$, and the interaction was not significant, Fs < *1*.

To investigate the main effect of Prime Type RTs were collapsed across Word Type and planned comparisons were conducted. These revealed that both the identity and scrambled primes differed significantly from the unrelated primes, $F(1,23) = 27.56$, $p < .001$, $F_2(1,155) = 109.5$, $p < .001$, and $F(1,23) = 13.18$, $p < .01$, $F_2(1,155) = 10.85$, $p < .01$, respectively. Identity primes also differed significantly from scrambled primes, $F(1,21) = 12.35$, $p < .01$, $F_2(1,155) = 29.13$, $p < .001$. As before, identity primes were responded to faster (32 ms) than scrambled primes, and scrambled primes were faster (31 ms) than unrelated primes.

Table 7. *Mean response times in milliseconds, percentage errors, and standard error (SE) of the means of Experiment 6.*

Prime Type	Spelling Dominance	Prime - Target Pair Examples	Response Times (SE)		% Error (SE)	
			Homophones	Controls	Homophones	Controls
"Same" Trials						
		(Reference: birth / berth)				
Identity	High	birth - BIRTH	492 (23)	464 (17)	3.4 (1.7)	5.4 (2.4)
	Low	berth - BERTH	565 (30)	448 (14)	8.3 (2.3)	3.8 (1.6)
Scrambled	High	rbhit - BIRTH	511 (17)	496 (17)	3.9 (1.4)	5.2 (1.5)
	Low	rbhet - BERTH	597 (23)	494 (14)	7.7 (2.6)	0.6 (0.6)
Unrelated	High	calls - BIRTH	528 (16)	517 (17)	7.3 (2.2)	10.3 (1.8)
	Low	calls - BERTH	633 (21)	542 (15)	12.3 (2.6)	3.7 (1.6)

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"Different" Trials						
		(Reference: warn / worn)				
Identity	High	exit - EXIT	543 (22)	530 (21)	12.3 (2.6)	5.6 (1.7)
	Low	exit - EXIT	530 (18)	519 (19)	4.3 (2.0)	5.9 (1.9)
Scrambled	High	xtei - EXIT	552 (23)	524 (25)	11.8 (2.1)	4.3 (1.6)
	Low	xtei - EXIT	537 (21)	522 (16)	3.7 (1.6)	5.7 (2.5)
Unrelated	High	such - EXIT	542 (17)	533 (19)	11.4 (2.3)	5.8 (2.5)
	Low	such - EXIT	538 (21)	541 (18)	3.6 (1.6)	3.7 (1.3)

Error rates revealed a marginal effect of Word Type by-item, $F_1 < 1$, $F_2(1,77) = 3.48$, $p = .06$, and a significant main effect of Prime Type, $F_1(1,23) = 5.12$, $p < .01$, $F_2(1,77) = 4.99$, $p < .01$. No significant interaction was found, Fs < 1.

When collapsed across Word Type, identity primes were significant more accurate than unrelated primes (3.2%), $F_1(1,23) = 4.78$, $p < .05$, $F_2(1,77) = 4.44$, $p < .05$. Scrambled primes were significantly more accurate than unrelated primes (4.1%), $F_1(1,23) = 9.30$, $p < .05$, $F_2(1,77) = 12.96$, $p < .001$. The difference in error rates between identity and scrambled primes (.8%) was not significant, Fs < 1.

"Different" trials

Both responses latencies and error rates revealed no significant main effects for Word Type, (RTs: $F_1(1,23) = 3.67$, p = .07, $F_2 < 1$), Prime Type, and no interactions, all Fs < 1.

Discussion

This experiment was conducted to test the prediction that the lack of scrambled priming in nonwords observed in Experiment 5, when reference stimuli were presented in the auditory domain, arose through spelling ambiguity. Here, spelling ambiguity was manipulated explicitly through using heterographic homophones with dominant and non-dominant spellings.

As expected responses were faster to targets with dominant than non-dominant spellings. Importantly, no interaction was found between homophone dominancy and prime type. Thus, spelling dominancy did not modulate scrambled priming effects. This suggests that when the reference stimulus is presented in the auditory domain the target is converted to a phonological code and the match occurs at the phonological, rather than the orthographic, level. Furthermore, responses to homophones were slower than to control words and a similar pattern of priming was found.

General Discussion

The aim of Experiments 5-6 was to investigate whether different representations are used for words and nonwords in the masked-priming same-different task. The results from Experiment 5 revealed the same overall processing advantage for words over nonwords to those found in the experiments presented in Chapter 2. However, presenting the reference stimuli in the auditory, rather than the visual domain, produced a different pattern of priming. Critically an interaction was found between String Type and Prime type. In particular, a significant scrambled priming effect was observed *words only*. Furthermore, ambiguity in nonword spelling could not account for the scrambled priming effect because when the task was conducted with heterographic homophones (Experiment 6) the scrambled priming effect remained.

Together, the experiments reported in Chapter 2 and 3 provide compelling evidence that the advantage for processing words is due to the activation of whole word lexical representations (Chambers & Forster, 1975; Marmurek, 1989). This lexicality effect supports the theory that matching in the same-different task can occur at several different levels (Chambers & Foresters, 1975), with nonwords matching at the sublexical level and words at the lexical and sublexical levels.

A key result of the experiments reported in Chapter 3 is that scrambled priming effects occurred for words *only* when the reference stimuli were presented in the auditory domain (Experiment 5). Even when spelling ambiguity was manipulated across words by using heterographic homophones, scrambled priming effects were shown (Experiment 6). These results are consistent with the assumption that when the reference stimulus is presented in the auditory modality the matching process occurs at the phonological level, therefore the target has to be converted into a phonological code. For words this could occur at the lexical or sublexical level but for nonwords this is only possible sublexically. When letter order is preserved, as in identity primes, conversion of the target to phonology is facilitated for both words and nonwords, but when letter order is disrupted, as in scrambled primes, conversion of the target to phonology is not facilitated at the sublexical level. However, as suggested previously, scrambled primes could still potentially facilitate the processing of word targets at the lexical level through the activation of shared sublexical orthographic representation (e.g., open-bigrams) between the prime and target. For example, although scrambled primes do not contain contiguous positional information, they can still contain non-contiguous positional information (e.g., SOUTH scrambled becomes USHOT, in which the open-bigrams SO, SH, UH, and UT are preserved) and thus they can activate the lexical representations. In contrast, scrambled priming effects cannot occur for nonword targets because they do not have lexical representations.

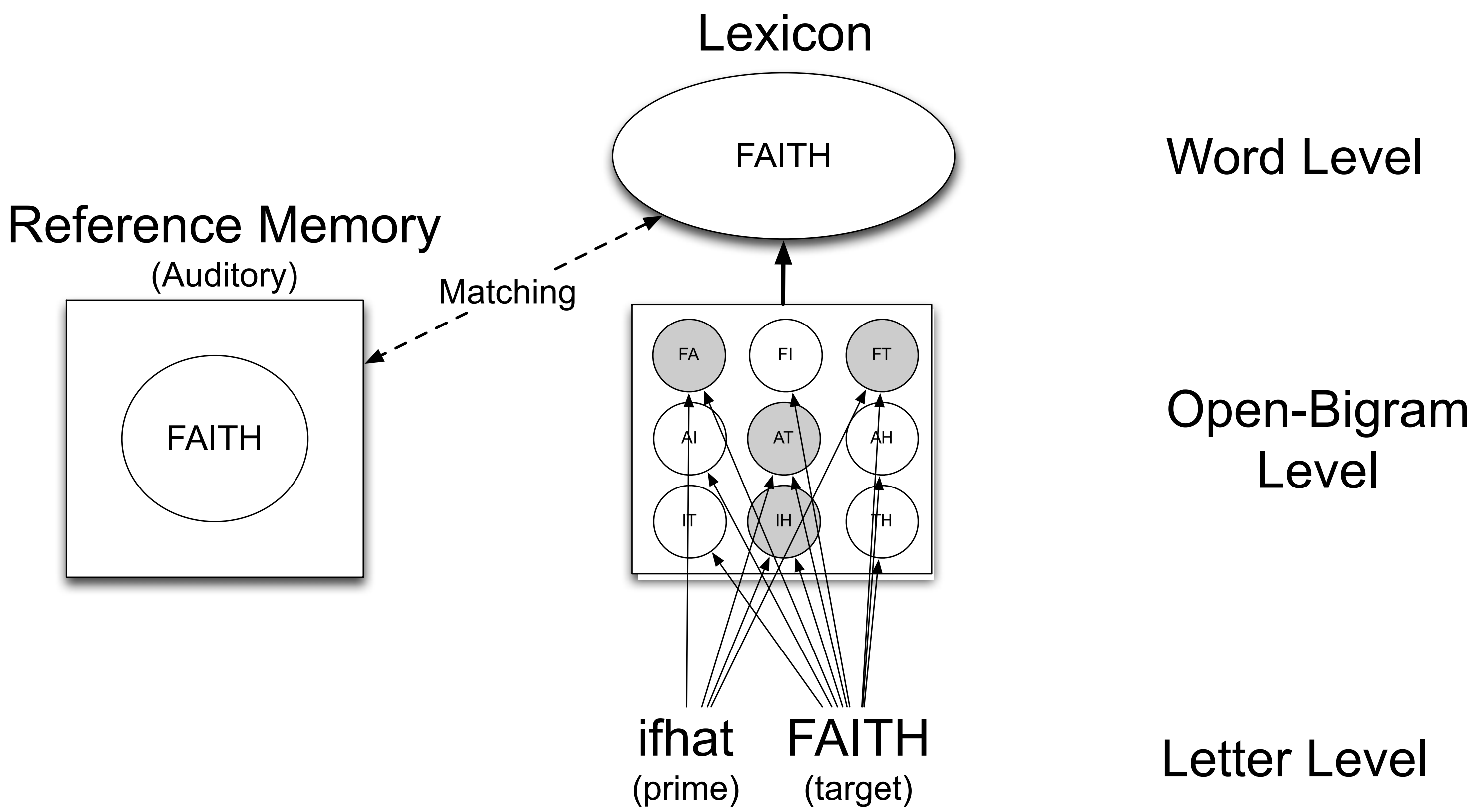
If scrambled primes contain just letter identity information, as argued by Kinoshita and Norris (2009), priming should occur for both words and nonwords. Importantly, the results of Experiment 5 revealed that scrambled priming effects occurred *only* for words, confirming that scrambled primes are able to activate lexical representations in the same-different task. This supports the hypothesis that lexical effects operate in the same-different task.

Figure 10 presents a comparison of the model presented in Chapter 2 when the reference stimuli are presented in both domains. This shows that the model is also compatible with the key finding of Experiment 5 where no scrambled priming for nonwords was found when the reference was presented in the auditory domain so matching cannot occur at the orthographic level. The matching process for nonwords must therefore occur through conversion of the visual target to phonology. This is supported by longer reaction times for Experiment 5 (523 ms) than Experiment 1 (473 ms).

Summary of Chapter 2 & 3

The results of the experiments reported in Chapters 2 & 3 demonstrate that the lexicality effect shown in the masked-priming same-different task arises from the activation of different sized representations for words and nonwords. Specifically, words activate lexical and sublexical representations, whereas nonwords only activate sublexical representations. Thus, these data provide evidence for lexical influences in the masked-priming same-different task and constrain the interpretation of priming effects found in previous studies using this task. Furthermore the pattern of findings reported in Chapters 2 & 3 suggest that lexical activation may well be an obligatory consequence of experimental tasks that involve the presentation of real word stimuli.

Figure 10. Model of the multi-modal version of the masked-priming same-different task. Gray-filled circles at the Open-Bigram Level indicate shared open-bigrams between prime and target.



Chapter 4

Investigation of Semantic and Phonological Influences in the Masked-Priming Same-Different Task

Introduction

Chapter 3reported an interesting interaction between string type and prime type in "same" trials when the reference was presented auditory (Experiment 5). As discussed in the previous chapter, a possible explanation for this interaction is the ambiguity in the spelling of the spoken nonword reference stimuli. This ambiguity would occur when matching happens at the orthographic level and an auditory reference needs to be converted into orthography. To investigate the impact of spelling ambiguity on the masked-priming same-different task with an auditory reference, Experiment 6 explicitly manipulated spelling ambiguity using dominant and non-dominant heterographic homophones (e.g., BIRTH and BERTH) and nonhomophonic control words. The results showed that spelling dominancy did not interact with prime type. This suggests that the matching process in Experiment 5 had occurred for the nonwords at the phonological level, and for words at the lexical level. Therefore, the standard visual version of the masked-priming same-different task seems to involve only orthographic processes. However, it is still unclear whether potentially other higher order linguistic processes (e.g., Semantics) can impact the pattern of priming in the visual masked-priming same-different task .The aim of Chapter 4 is to investigate the potential influence of phonology using heterographic homophones (Experiment 7) and semantic related word pairs (Experiment 8) on the visual masked-priming same-different task.

In Experiment 7 each word from the homophone pairs will appear as a target in both the "same" and the "different" condition, just as in Experiment 6. However, in the different condition, instead of homophone targets being paired with an unrelated word, the reference and targets will be homophone pairs (e.g. warn and worn). In the standard masked-priming lexical decision task, homophones cause an inhibitory effect, compared to nonhomophonic control words (e.g., Kerswell & Siakaluk, 2007). If there is an effect of phonology, when heterographic pairs are used as the reference and target it would be expected that there would be an effect of word type in both the "same" and "different" conditions, with slower reaction times compared to nonhomophone pairs. However, if the masked-priming same-different task only measures the processes involved in orthographic processing then the type of words used in the task should have no effect in the either the "same" or "different" condition. Therefore, there should be no effect of word type.

Conversely, according to Kinoshita and Norris (2008), as the decision is made purely on the orthographic difference between the reference and target, there should be no difference between heterographic homophones and control word pairs. Furthermore, the pattern of priming would be the same as in the previous experiments using the visual version of the task. Importantly, in the different condition there will be no priming effects due to the assumption that all the prime types (identity, scrambled and unrelated) provide equal evidence to the "different" decision. However, due to the nature of heterographic homophones, there is a large overlap in the number of shared letters within the pair. Therefore, this orthographic overlap may produce an overall inhibitory effect for homophone pairs. Furthermore, with identity primes this orthographic overlap would be expected to provide both evidence for the “same” and “difference” decision. Moreover, in many cases there will be more information for a “same” over a “different” decision. Under these assumptions identity primes may cause an inhibitory effect.

To test the effects of semantics in the masked-priming same-different task, Experiment 8 will use semantically related pairs in the "different" condition. If there are any effects of semantics in this task it is expected that there would be an overall difference in the reaction times between semantic and non-semantic pairs (e.g., groom - bride vs. river - steal). For example, if the presentation of the reference activates semantically related lexical representations then this may cause an inhibitory effect. However, it is difficult to predict the direction of the difference, because in the standard masked-priming task, there is a consistent priming effect of semantically related primes.

Experiment 7: Visual Same-Different task with homophones

Method

Participants

Twenty-four English students participated in this experiment in exchange for course credit. All were native English speakers, with normal or corrected-to-normal vision.

Stimuli and design

The stimuli and design were identical to those of Experiment 6 (Chapter 3).

Procedure

The procedure was the same as Experiment 1 (Chapter 2).

Results

Latencies less than 250 ms and greater than 1400 ms were removed from the analysis, accounting 0.3% of the total data. The analysis was then conducted on the reaction time data of correct responses and the percentage of errors (total 6.1%). The "Same" and "Different" trials were analysed separately. A two-way repeated ANOVA was conducted with Word Type (homophone vs. control word) and Prime Type (identity, scrambled, vs. unrelated) as independent variables. The mean RTs and error rates are presented in Table 8.

"Same" trials

For the response latencies there was a significant effect of Word Type, $F_1(1,47) = 15.86$, $p < .001$, $F_2(1,77) = 11.62$, $p < .001$, with slower responses to homophones than to control words (17 ms). There was also a significant effect of Prime Type, $F_1(2,46) = 106.57$, $p < .001$, $F_2(2,76) = 147.94$, $p < .001$, however, there was no interaction, Fs< 1. Planned comparisons were carried out on Prime Type collapsed across Word Type, with slower reaction times for unrelated primes compared to identity (88 ms),$F_1(1,47) = 177.65$, $p < .001$, $F_2(1,77) = 273.78$, $p < .001$, and scrambled primes (53 ms), $F_1(1,47) = 33.1$, $p <$

.001, $F_2(1,77) = 45.09$, $p < .001$, and scrambled compared to identity primes (35 ms), $F_1(1,47) = 92.2$, $p < .05$, $F_2(1,77) = 115.35$, $p < .001$. For the percentage of errors there was a significant effect of Prime Type, $F_1(2,46) = 14.8$, $p < .001$,$F_2(2,76) = 13.03$, $p < .001$, with more errors for Unrelated primes compared to both identity primes (4.8%), $F_1(1,47) = 26.9$, $p<.001$, $F_2(1,77) = 31.56$, $p < .001$, and the scrambled primes (2.5%),$F_1(1,47) = 7.41$, $p < .01$, $F_2(1,77) = 4.76$ $p < .05$, for scrambled compared to identity primes (2.3%), $F_1(1,47) = 8.28$, $p < .01$, $F_2(1,77) = 7.77$, $p < .01$.[report also effect of Word Type and the interaction between Word Type and Prime Type.]

"Different" trials

The analysis of the response time latencies revealed a significant effect of Word Type, $F_1(1,47) = 163.1$, $p < .001$,$F_2(1,76) = 208.21$, slower reaction times for homophones than for control words (75 ms)and Prime Type, $F_1(2,46) = 3.82$, $p < .05$, $F_2(2,76) = 4.43$, $p < .05$. There was no interaction, Fs< 1. Planed comparisons were carried out for Prime Type on the reaction time collapsed over Word Type, which revealed slower reaction times (16 ms) for identity compared to scrambled primes, $F_1(1,47) = 11.06$, $p < .05$, $F_2(1,77) = 7.87$, $p < .01$. There was no significant difference between unrelated and identity by participant, $F_1(1,47) = 2.21$, $p = .21$, but marginally significant by item, $F_2(1,77) = 3.77$,$p = .05$ or unrelated and scrambled primes, $F_1(1,47) = 1.59$, $p = .21$, $F_2(1,77) = 1.37$, $p = .24$.

Table 8. *Mean response times in milliseconds, percentage errors, and standard error (SE) of the means of Experiment 6.*

Prime Type	Spelling Dominance	Prime - Target Pair Examples	Response Times (SE) Homophones	Response Times (SE) Controls	% Error (SE) Homophones	% Error (SE) Controls
"Same" Trials						
		(Reference: birth / berth)				
Identity	High	birth - BIRTH	596 (15)	584 (12)	4.5 (3)	2.2 (2.1)
	Low	berth - BERTH	593 (12)	584 (13)	3.8 (2.8)	2.6 (2.3)
Scrambled	High	rbhit - BIRTH	643 (13)	633 (12)	4.8 (3.1)	5.1 (3.2)
	Low	rbhet - BERTH	668 (13)	632 (14)	9.4 (4.2)	3.2 (2.5)
Unrelated	High	calls - BIRTH	678 (14)	664 (13)	7.1 (3.7)	7.7 (3.8)
	Low	calls - BERTH	694 (13)	672 (12)	12.2 (4.7)	5.4 (3.3)

(continued on the next page)

<u>"Different" Trials</u>						
		(Reference: warn / worn)				
Identity	High	warn - WARN	710 (13)	648 (12)	13.8 (5)	2.5 (2.3)
	Low	worn - WORN	723 (13)	649(13)	12.8 (4.8)	3.9 (2.8)
Scrambled	High	awnr - WARN	733 (15)	659 (15)	14.7 (5.1)	4.2 (2.9)
	Low	ownr - WORN	740 (14)	658 (13)	9.9 (4.3)	2.2 (2.1)
Unrelated	High	such - WARN	731 (16)	653 (13)	11.6 (4.6)	2.3 (2.1)
	Low	such - WORN	730 (13)	649 (13)	10.2 (4.4)	2.6 (2.3)

For the Percentage of Errors there was a significant effect of Word Type, $F_1(1,47) = 81.62$, $p < .001$, $F_2(1,77) = 68.44$, $p < .05$, with more errors for homophones than for control words(9.2 %). There was also a significant effect of Prime Type, $F_1(2,46) = 3.28$, $p < .05$, $F_2(2,76)= 3.34$, $p < .05$. There was no interaction, Fs< 1. Planed comparisons were preformed for Prime Type collapsed across Word Type, with more errors for unrelated compared to identity primes (1.6 %), $F_1(1,47) = 6.27$, $p < .05$, $F_2(1,77) = 6.78$, $p < .01$. There was no significant difference between scrambled and both identity, $F_1(1,47) = 1.97$, $p = .17$, $F_2 (1,77) = 3.08$, $p = .08$, and unrelated primes, $F_1(1,47) = 1.35$, $p = .25$, $F_2 < 1$.

Discussion

The results of this experiment revealed overall slower responses to homophones than to control words in the "same" and "different" conditions. This suggests that there may be an effect of phonology in the task. Importantly, the pattern of priming in the "same" condition was the same as that seen in the previous experiments using the visual version of the task. However, interestingly in the different condition there was an inhibitory effect for identity primes compared to scrambled primes. This is contrary to the assumption of Kinoshita and Norris(2009) who suggested priming cannot occur in the different condition. This priming effect may be due to the orthographic overlap between the heterographic homophone pairs. This will be discussed further in the general discussion. The next experiment will explore the potential impact of semantics on the masked-priming same-different task

Experiment 10: Semantic Effects

Method

Participants

Twenty-four English students from the University of Nottingham took part in this experiment in exchange for course credit. All were native English speakers with normal or corrected-to-normal vision.

Stimuli and Design

The "critical" seventy-eight semantically related pairs were selected from those used in the Semantic Priming Project (Hutchison et. al., 2013). The semantic pairs were matched in length (M = 5.7 letters). Because of the limited number of semantic pairs it was not possible to select word pairs without overlapping letters. Therefore, only the words with the least number of overlapping letters were selected. Another set of 78 words was selected from SUBTLEX-US as semantically unrelated references. The semantically unrelated words were pairwise matched to the 78 "critical" semantic pairs on length frequency (M=60 based on SUBTLEX-US, Brysbaert& New, 2009, t< 1), and where possible shared the same letters as the original semantically related pair shared. The three priming conditions (identity, scrambled and unrelated) were constructed using the same method as in Experiment 1 (Chapter 2). A further set of 78 words was selected from SUBTLEX-US for the "same" trials. Words for the "Same" trials were matched on length and frequency (t<1)with the targets of the semantically related pairs in the "Different" trials. The semantically related and unrelated pairs were fully counterbalanced across the priming conditions. Thus, a total of six lists were created, with each participated being randomly assigned to one the lists.

Procedure

The procedure was identical to that of Experiment 1 (Chapter 1).

Results

The analysis was performed on both the reaction time data and the percentage of errors (total 3.4%). Response time latencies less than 250 ms and greater than 1400 ms were removed from the analysis of the reaction time data, accounting for only 0.3% of the total data. The mean RTs and error rate are presented in Table 9. In line with the previous experiments, "Same" and "Different" trials were analysed separately. A one-way ANOVA was performed on the "Same" trials with Prime Type (identity, scrambled or unrelated) as the independent variable. A two-way ANOVA was conducted on the "Different" trials with Semantic Relatedness (related vs. unrelated), and Prime Type (identity, scrambled, vs. unrelated). The analysis was performed both by-participant (F_1) and by-item (F_2).

Same" trials

For the response latencies there was a significant effect of Prime Type, $F_1(2,76) = 23.37$, $p < .001$, $F_1(2,76) = 23.65$, $p < .001$, with slower reaction times for unrelated primes compared to identity (49 ms),$F_1(1,77) = 30.05$, $p < .001$, $F_2(1,77) = 42.58$, $p < .001$, and scrambled primes (30 ms), $F_1(1,77) = 28.84$, $p < .001$, $F_2(1,77) = 21.9$, $p < .001$, and scrambled compared to identity primes (18 ms), $F_1(1,77) = 7.57$, $p < .05$, $F_2(1,77) = 6.21$, $p < .05$

The error analysis revealed no effect of Prime Type, *F*s<1.

"Different" trials

The response time analysis revealed no significant effects of Semantic Relatedness, *F*s< 1 or Prime Type, $F_1(2,22) = 2.44$, $p = .10$, $F_2(2,76) = 1.55$, $p = .22$, or an interaction, $F_1(2,76) = 2.07$, $p = .14$, $F_2 < 1$.

For the percentage of errors there was a marginally significant effect of Semantic Relatedness by participant, $F_1(1,23) = 3.25$, $p = .08$, and a significant effect by item, $F_2(1,77) = 5.35$, $p < .05$, with more errors for unrelated compared to related words (1.8%). There was no significant effect of Prime Type, *F*s<1, or an interaction, $F_1(2,22) = 2.07$, $p = .14$, $F_2(2,76) = 1.82$, $p = .17$.

Table 9. *Mean response times in milliseconds, percentage errors, and standard error (SE) of the means of Experiment 6.*

Prime Type	Response Times (SE)	% Errors (SE)
"Same" Trials		
Identity	478 (26)	4.2 (4.1)
Scrambled	496 (23)	3.4 (3.7)
Unrelated	527 (24)	5.3 (4.6)
"Different" Trials		
Semantically Related		
Identity	553 (27)	3.5 (3)
Scrambled	558 (30)	5.1 (2.3)
Unrelated	569 (31)	3.2 (3.4)
Control Words		
Identity	550 (28)	2.2 (0.6)
Scrambled	553 (29)	1.3 (0.5)
Unrelated	569 (31)	2.9 (0.7)

Discussion

The results showed the same pattern of priming for "Same" trials, as in previous experiments. As expected there was no effect of Semantic Relatedness, or an effect of Prime Type in different condition.

General Discussion

The aim of Chapter 4 was to investigate phonological and semantic effects in the visual version of the masked-priming same-different task. In Experiment 7 heterographic homophones were used to investigate the effect of phonology in the visual version of the masked-priming same-different task. The results showed an overall processing advantage for nonhomophone compared to homophone pairs in both the "same" and "different" condition (17ms and 75ms respectively). For the "same" condition the pattern of priming was that same previous experiments. Critically, unlike in all previous experiments, in the "different" condition a priming effect was found, with faster responses time for identity compared to the scrambled primes. The results from the semantic experiment where identical to those found using none semantically related word, with no effect of semantic priming in the "different" different condition.

The effect of homophones in both the "same" and "different" conditions, in Experiment 7, suggests that phonology may play some role in the visual version of the masked-priming same-different task. However, as there were no interaction between word and prime type suggests that this effect may be due to the activation of both versions of the homophone pair at the lexical level rather than match at the phonological level. This would further confirm the results from Chapters 2 and 3, that words and nonwords utilize different sized representations, lexical and sublexical respectively.

The key result of Experiment 7 is the significant priming effect found in the "different" condition. As discussed in this and the previous chapters, according to Kinoshita and Norris (2009) there should be no priming in the "different" condition as all primes provide evidence for a different decision. However, unlike the stimuli used in their experiment and those reported in the previous chapters, heterographic homophones share a large amount of orthographic information, with many pairs only differing by one letter. Furthermore, there was no interaction between word type and prime type, thus, this priming effect is most like the result of the number of shared letters rather that any phonological influence. Unfortunately, the variance in the number letters shared between word pairs is small and is confounded by word length with most variances occurring in 7 and 8 letter words. As these constituted only a limited number of the total stimuli it was not possible to run a reliable analysis. It would be suggested that a further set of experiments would be needed to confirm this hypothesis ideally using nonwords so that it would be possible to systematically change the number and position of the shared letters.

The results from this and Chapters 2 and 3, provides further evidence that the masked-priming same-different task does provide a better measure of lower level orthographic processes than the standard version of the task. However, the task is not as suggested a pure measure (Kinoshita and Norris, 2009) but is affected by higher-level information, such as lexical status and to a lesser degree phonology. However, as the task produce similar levels of priming for words and nonword, these effects can be negated by using nonwords which proved the opportunity to manipulate the orthographic without the constraints required when using real words.

Recently, Lupker & Davis (2009) have also presented a task that is more sensitive to sublexical processes than the standard masked-priming lexical decisions, the sandwich-priming lexical decision task. In Chapter 5 the masked-priming same-difference tasks and sandwich-priming lexical decision task are compared, along with standard masked-priming lexical-decision task.

Chapter 5

Impact of task and priming technique on lexical competition

Introduction

The masked-priming lexical decision task has become the dominant task for the investigation of the representations and processes underpinning orthographic word recognition (for review see Grainger, 2008). However, as discussed in Chapter 1, the problem with the masked-priming lexical decision task is that to perform the task successfully multiple whole word lexical representations are activated. This is regardless of whether the lexical decision is based on the activation level of a single representation (e.g., Coltheart et al., 2001; Forster & Davis, 1984) or some measure of global activation (e.g., Grainger & Jacobs, 1996; Norris, 2006). The decision process in the masked-priming task is affected by competition between whole word orthographically representations similar to the target word and their associated lexical properties, such as frequency and neighbourhood density (e.g., Brysbaert & New, 2009; van Heuven, et al., 2001 respectively). Thus, it is possible that these higher-level lexical processes may mask more subtle lower level orthographic processes. Recently two different tasks have been presented that overcome this problem, the masked-priming same-different task (Norris & Kinoshita, 2008; Kinoshita & Norris, 2009) and the sandwich-priming lexical decision task (Lupker& Davis, 2009), making them more sensitive to lower level processes.

As discussed in the previous chapters, in the masked-priming same-different task the reference stimulus is clearly displayed for 1 second above the forward mask. The reference then disappears and the mask is replaced by the prime, followed by the target. The presentation of the reference stimuli reduces the possible candidates for matching with the target to one. Furthermore, the participant is no longer required to make a lexical decision but instead decide whether the reference and target stimuli are the same or different. The difference in the nature of the decision process produces consistent and robust priming effects for nonwords, which do not generally occur in the lexical decision task. These differences between the same-different and lexical decision task reduces the competition between whole word representations for words and allowing temporary representations to be created for nonwords. Thus, the same-different task does not require a lexical decision therefore reducing the impact of orthographic neighbours and the influence of their associated lexical properties such as frequency.

The sandwich-priming lexical decision task (Lupker& Davis, 2009) has also been presented as a task that overcomes competition between competing lexical representations . As with the masked-priming same-different task, the sandwich-priming paradigm aims to reduce the number of possible activated representations. This is achieved by the introduction of a reference stimulus (identical to the target) in uppercase, which is presented for 33 ms between the forward mask and the prime in the standard masked-priming lexical decision task. Lupker and Davis (2009) argued that the duration of the reference presentation is long enough to ‘boost’ the activation level of the target's representation above that of other orthographically similar representations, thus reduce their influence on the processing of the target.

The evidence for an increase in the sensitivity of both the masked-priming same-different task and the sandwich-priming lexical decision task to lower level orthographic processes, compared to the standard masked-priming lexical decision task, comes from the use of "extreme" primes. These are primes that share very little orthographic overlap with the target. Lupker and Davis (2009), using the sandwich priming task, demonstrated priming effects for both transposed all (T-All) primes (e.g., avacitno – VACATION) and 3 letter substitution primes (3SL) (e.g., coshure – CAPTURE), effects that do not occur using the standard masked-priming paradigm (e.g., Guerrera & Forster, 2008; Schoonbaert & Grainger, 2004 respectively). Because the primes used in both these conditions share a reduced amount of information with the target (T-All - no absolute positional information, 3 SL – 57 % of their letters in common for 8 letter words) indicates that this task is indeed more sensitive to low level orthographic processing than the standard masked-priming paradigm.

Similarly, as demonstrated in the preceding chapters and Experiment 4 of Kinoshita and Norris's (2009) study, scrambled priming (ifhat – FAITH) effects were shown for both words and nonwords, using the masked-priming same-different task. These primes, like the T-All primes used by Lupker and Davis (2009), are designed to eliminate the absolute positional overlap between the prime and target. However, as discussed in Chapter 2, models that use bigrams to encode relative positional information (e.g. Grainger & van Heuven, 2003; Grainger et al., 2006; Whitney &Cornelissen, 2005, 2008) would predict some overlap between the prime and the target. Based on the Grainger and Van Heuven (2003) model the scrambled primes used by Kinoshita and Norris share 4 out of the 9 possible open bigrams with the target, (e.g., the scrambled prime ifhat for the target FAITH shares the open-bigrams FA, FT, AT and IH). This is in contrast to the T-All letter primes used by Lupker and Davis, which share 13 out of the 18 possible bigrams with the target (e.g., the T-All prime avacitno for the target VACATION shares the open bigrams VA, VC, VA, AC, AA, CT, CI, AT, AI, TO, TN, IO and IN). Furthermore, as the match scores in Table 10 demonstrate, most of the other current models of word recognition would also predict a similar degree of overlap between the prime types and the targets.

The difference between the types of primes used in the Kinoshita and Norris (2009), and Lupker and Davis (2009) studies make it difficult to compare the two tasks based on the current evidence. Thus, the aim of Chapter 5 is to directly compare the masked-priming same-different task and sandwich-priming lexical decision task using identical priming conditions. As scrambled primes share less positional information with the target than T-All primes, these primes provide a better test of the sensitivity of these tasks. Furthermore, by using six letter words instead of the five letter words, as used in the original Kinoshita and Norris (2009) experiment and the preceding chapters, the amount of positional overlap between the prime and target can be varied. Following the rules for producing scrambled primes as set out by Kinoshita and Norris (2009) (see, methods of Experiment 1 for full description) only two different permutations can be produced for five letter words (i.e., 24153 or 31524; were a five letter word is denoted as 12345).

These two permutations produce the same number of shared bigrams (4 in total; 1 contiguous and 3 noncontiguous). Six letter words can be scrambled in 25 different combinations (see Table 11) producing primes that share 3 to 7 bigrams with the target. The type of bigram can also be manipulated so that the prime-target overlap consists of either all contiguous or non-contiguous bigrams. Experiments 9-11 will test the sensitivity to low level orthographic processing in all three tasks: the standard masked-priming lexical decision task (Experiment 9), the masked-priming same-different task (Experiment 10) and the sandwich-priming lexical decision task (Experiment 11). Previous studies using extreme primes have failed to find a priming effect in the standard masked-priming lexical decision task (e.g., e.g., Guerrera& Forster, 2008; Schoonbaert& Grainger, 2004), therefore, no prime effect is expected with scrambled primes as these prime share less positional information with the target than the prime types previously used. The masked-priming same-different task has already demonstrated sensitive to scrambled primes (see Kinoshita & Norris, 2009; Kelly et al, 2013), therefore it is expected that scrambled priming would occur. Furthermore, it is expected that the pattern of priming will be the same for both words and nonwords. If the sandwich-priming lexical decision task is as sensitive as the same-different task then a similar pattern of priming would be expected for word targets. However, because the sandwich-priming lexical decision task relies on a lexical decision it is expected that there would be a different pattern of priming for words and nonword, i.e., no priming in the nonword condition. However, if the addition of the reference has a similar effect as the reference in the masked-priming same-different task then a similar pattern of priming would be expected for words and nonwords using sandwich-priming.

Table 10. *Match Scores* * *for Six Letter Scrambled Primes used in Experiments 9-11,for the Spatial Coding Model, Davis (2012), Binary Open Bigram Model, Granger & van Heuven (2003), Overlap Open Bigram Model, , and SERIOL Model, Whitney (2006).*

	Prime - Target Pair	Model Type			
Prime Type	Examples	Spatial Coding Model	Binary Open Bigram	Overlap Open Bigram	SERIOL
3 Shared	eioclp – POLICE	0.26	0.25	0.27	0.21
4 Contiguous	Ipcoel – POLICE	0.31	0.33	0.38	0.29
4 Non-Contiguous	oipelc – POLICE	0.36	0.33	0.33	0.29
7 Shared	lpieoc – POLICE	0.38	0.59	0.3	0.5

*Match scores produced using the Match Calculator, Davis (2003).

Table 11: *All possible scrambled permutation for a six letter word when denoted as 123456, with bigram type, position and number shared with the word. Scrambling was preformed following the rule as stated in Kinoshita and Norris (2009); ensuring none of the letters: 1) appeared in the same position, 2) were adjacent to the same letters that they were adjacent to in the original string (i.e. no transposition of adjacent letters), and 3) relative positioning was removed**.

	Bigram Type												Number of Shared Bigrams with Word	
Scrambled combinations	Contiguous Bigrams					Non-contiguous Bigrams							Contiguous	Non-contiguous
123456	12	23	34	45	56	13	14	24	25	35	36	46	n/a	n/a
614253	61	14	42	25	53	64	62	12	15	45	43	23	3	2
631524	63	31	15	52	24	61	65	35	32	12	14	54	1	3
635142	63	35	51	14	42	65	61	31	34	54	52	12	2	2
641352	64	41	13	35	52	61	63	43	45	15	12	32	2	2
642513	64	42	25	51	13	62	65	45	41	21	23	53	2	2

(continued on the next page)

514263	51	14	42	26	63	54	52	12	16	46	43	23	2	2
531642	53	31	16	64	42	51	56	36	34	14	12	62	3	2
531624	53	31	16	62	24	51	56	36	32	12	14	64	2	3
415362	41	15	53	36	62	45	43	13	16	56	52	32	2	2
415263	41	15	52	26	63	45	42	12	16	56	53	23	4	0
461524	46	61	15	52	24	41	45	65	62	12	14	54	2	3
462531	46	62	25	53	31	42	45	65	63	23	21	51	2	2
314625	31	14	46	62	25	34	36	16	12	42	45	65	3	4
315624	31	15	56	62	24	35	36	16	12	52	54	64	2	3
315642	31	15	56	64	42	35	36	16	14	54	52	62	1	3
315264	31	15	52	26	64	35	32	12	16	56	54	24	2	2
351642	35	51	16	64	42	31	36	56	54	14	12	62	2	3

(continued on the next page)

361524	36	61	15	52	24	31	35	65	62	12	14	54	1	4
241635	24	41	16	63	35	21	26	46	43	13	15	65	0	4
246135	24	46	61	13	35	26	21	41	43	63	65	15	0	4
246315	24	46	63	31	15	26	23	43	41	61	65	35	1	3
251624	25	51	16	62	24	21	26	56	52	12	14	64	2	3
251642	25	51	16	64	42	21	26	56	54	14	12	62	2	2
264135	26	64	41	13	35	24	21	61	63	43	45	15	1	3

* Note, relative position as defined by Kinoshita and Norris (2009).

Experiment 9: Standard Masked-Priming Lexical Decision Task

Method

Participants

Thirty undergraduate psychology students participated in exchange for course credit. All were native English speakers with normal or corrected-to-normal vision.

Stimuli and design

The experiment consisted of 160 six-letter words, with five groups of 160 primes (three shared bigrams – 3S, four contiguous bigrams – 4C, four non-contiguous bigram – 4N, and seven shared bigrams – 7S, all letter different - ALD). The words were selected from the SUBTLEX-US database (Brysbaert& New, 2009) with a mean frequency of 75 per million. Only words that contained different letters were used to exclude the possibility letter overlap between the prime and target after scrambling. All primes were scrambled versions of the target words with the exception of the ALD primes which were scrambled versions of six-letter words selected for each target to differ in all their constitute letters. The type of bigram (contiguous or noncontiguous) refers to the type of bigram as it appears in the target word. The four different scrambled permutations were created using the method described in Experiment 1. The following permutations, where six-letter words are denoted as 123456, were used: 642531 for the 3S (two contiguous and one non-contiguous), 415263 for the 4C, 241635 for the 4NC, and 314625 for the 7S (three contiguous and four non-contiguous). These four permutations were randomly assigned to one of the ALD primes to produce 20 scrambled ALD primes for each permutation. For the sake of the lexical decision task one letter was changed in each of the target word stimuli to produce 160 nonwords and their corresponding primes.

The two groups of target stimuli (words and nonwords) were separated into five groups and assigned different priming condition across five lists. This allows each target item to be presented only once to each participant but in a different priming condition. Therefore five lists were used each containing 160 target words and 160 target nonwords, 80 three shared, four contiguous, four non-contiguous, seven shared and ALD primes: 20 of each for the two groups of target stimuli. Each participant was randomly assigned to one of the lists.

Procedure

The procedure used was the same as Lupker and Davis (2009). At the start of each trial a forward mask consisting of six hash marks (######) was presented for 500 ms, followed by the prime in lowercase for 47 ms. The target was then presented in upper case for 3 s or until the participant responded. The stimuli were presented and all responses were recorded using DMDX (Forster & Forster, 2003). Responses were made using an external button box connected to the computer. All participants were tested separately. The stimuli were high contrast presented in white on a black background in Courier New font (10 points). Participants were told that a set of hash marks would appear in the centre of the screen, which would be replaced by a letter string. They were asked to respond as quickly and accurately as possible to the letter string by pressing the right button if the string was a real English word and the left button if it was not a real English word. The presence of the prime was not mentioned. Each participant completed 336 trials in total, comprising sixteen practice and 320 test trials. All trials were presented in a randomized order. Response times were measured in milliseconds from the onset of the target stimulus.

Results

Analysis was carried out on both the mean correct times (RT) and the percentage of errors (total 4.8%). All trials with latencies above 1400 ms or below 250 ms were excluded from the analysis (0.5% of the total trials). The experimental trials were analysed using a two-way repeated measures ANOVA with String Type (Word or Nonword) and Prime Type (3S, 4C, 4NC, 7S or ALD) using both by-participant (F_1) and by-item (F_2) analyses. The mean RT for the correct trials and the percentage of errors are presented in Table 12

The reaction time analysis revealed a significant effect of String Type, $F_1(4,21) = 99.69$, $p < .001$, $F_2(1,319) = 195.6$, $p < .001$, with faster reaction times for Words (66 ms) than Nonwords. There was no significant effect of Prime Type, $F < 1$, or an interaction $F_1(1,24) = 2.32$, $p = .081$, $F_2(1,319) = 1.99$, $p = .09$.

For the percentage of errors, there was a significant effect of String Type, $F_1(4,21) = 8.23$, $p < .01$, $F_2(1,319) = 6.58$, $p < .05$, with fewer errors (3%) for Words than Nonwords. There was no significant effect of Prime Type or an interaction, both Fs < 1.

Discussion

The results of this experimented revealed a significant processing advantage for words over nonwords (66 ms). However, there was no effect of Prime Type, or interaction between Prime Type and String Type. This finding is in line with studies using extreme primes (e.g., Guerrera& Forster, 2008; Schoonbaert& Grainger, 2004) who did not find any priming effects in the masked-priming lexical decision task. The next experiment will explore whether priming effects can be obtained using the same-different task.

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Table 12: *Experiment 9: the Masked-priming Lexical Decision Task: Mean Response Times in Milliseconds, the Percentage Error Rates, and the standard error of the mean (SE).*

String Type Prime Type	Prime - Target Pair Examples	Response Times (SE)	% Error (SE)
Words			
3 Shared	eioclp – POLICE	551 (1.4)	7.8 (0.5)
4 CS	Ipcoel – POLICE	542 (1.4)	6.6 (0.4)
4 NCS	oipelc – POLICE	557 (1.5)	5.3 (0.4)
7 Shared	lpieoc – POLICE	556 (1.7)	7.1 (0.4)
ALD	dubrsa – POLICE	556 (1.6)	7.8 (0.5)
Nonwords			
3 Shared	dkoect - TOCKED	618 (1.8)	10.6 (0.6)
4 CS	kteodc - TOCKED	624 (1.9)	9.1 (0.5)
4 NCS	oktdce - TOCKED	620 (1.8)	9.7 (0.6)
7 Shared	ctkdoe - TOCKED	612 (1.7)	8.9 (0.5)
ALD	gvhsit - TOCKED	616 (1.7)	9(0.5)

Experiment 10: Masked-Priming Same-Different Task

Method

Participants

Twenty students took part in this Experiment. All were native English speakers with normal or corrected-to-normal vision.

Stimulus and design

For this experiment the 160 target words and 160 target nonwords and their corresponding primes from Experiment 9 were split equally into four groups, with 80 words and 80 nonwords used as the critical stimuli (those requiring the "same" response).

The remaining 80 words and 80 nonwords were used for the non-critical target stimuli (those requiring the "different" response). A further 80 words were selected from the SUBLEX-US database (Brysbaert & New, 2009) to act as the reference stimuli. The words were matched with the previously selected targets words in terms of length and frequency. Each target word was paired with one reference word, which were selected so their shared none of the same letters with the target, and no more than one letter with the all letter different (ALD) prime[2]. The 80 reference nonwords were created using the same method as described in Experiment 1.

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[2]This was due to the difficulty in finding enough words that differed in their constitute letters across three words, while matching for all other characteristics.

The design was a counterbalanced blocked presentation of words and nonwords. The four groups of target stimuli (the critical "same" condition words and nonwords, and the filler "different" condition words and nonwords) were separated into five groups and assigned different priming condition across five lists. This allows each target item to be presented only once to each participant but in a different priming condition. Therefore, 10 lists were used each containing 160 target words (80 critical and 80 filler) and 160 target nonwords (80 critical and 80 filler), 80 three shared, four contiguous, four non-contiguous, seven shared and ALD primes: 20 of each for the four groups of target stimuli. Each participant was randomly assigned to one of the 10 lists.

Procedure

The procedure was the same as that used in Experiment 1.

Results

The analysis was carried out on both the mean correct times (RT) and the percentage of errors (total 4.1%). All trials with latencies above 1400 ms or below 250 ms were excluded from the analysis (0.6% of the total trials). The "same" and "different" trials were analysed separately using a two-way repeated measures ANOVA with String Type (words or nonwords) and Prime Type (3S, 4C, 4NC, 7S or ALD) using both by-participant (F_1) and by-item (F_2) analyses. The mean RT for correct trials and the percentage of errors are presented in Table 13.

Same condition

For the response latencies a significant main effect of String Type was found, $F_1(1,19) = 5.55$, $p < .05$, $F_2(1,159) = 22.44$, $p < .001$, with responses to words 20 ms faster than for nonwords. The main effect of Prime Type was also significant, $F_1(4,16) = 6.55$, $p < .001$, $F_2(4,156) = 4.31$, $p < .01$. There was no interaction between String Type and Prime Type, Fs< 1, thus RTs were collapsed across String Type. Planned comparisons revealed significant facilitation effects for the 3C, 4C, 4NC, 7S primes compared to the ALD prime, $F_1(1,19) = 14.44$, $p < .01$, $F_2(1,159) = 10.37$, $p < .01$, $F_1(1,19) = 8.54$, $p < .01$, $F_2(1,159) = 7.61$, $p < .01$, $F_1(1,19) = 13.48$, $p < .01$, $F_2(1,159) = 10.37$, $p < .01$, $F_1(1,19) = 23.52$, $p < .001$, $F_2(1,159) = 14.24$, $p < .001$, respectively. All other comparisons were not significant, Fs< 1.

For the percentage of errors, there was no significant effect for String Type, Fs< 1. The main effect of Prime Type was significant by subject, $F_1(4,16) = 2.97$, $p < .05$, but not by item, $F_2(4,156) = 2.15$, $p = .07$. There was no interaction, $F_1(1,19) = 1.05$, $p = .39$, $F_2 < 1$.

Different condition

For the RTs there were no effects of String Type, $F_1 < 1$, $F_2(1,159) = 1.5$, $p = .22$, Prime Type, Fs< 1, or interaction, Fs< 1. The analysis of the percentage of errors also showed no effects for String type, $F < 1$, Prime Type $F_1(4,16) = 1.7$, $p = .16$, $F_2(4,156) = 1.7$, $p = .16$, or interaction, Fs< 1.

Discussion

The results showed again the expected processing advantage for words over nonwords. In contrast to Experiment 9, a significant effect of prime type was found but no interaction between prime type and string type, demonstrating that the pattern of priming is identical for both words and nonwords. Significant priming effects were found relative to the ALD prime, for 4C, 4NC and 7S primes. This pattern of priming is consistent with the results reported in Chapters 2, 3 & 4.

Table 13. *Experiment 10 the masked-priming same-different task: mean response times in milliseconds, the percentage error rates, and the standard error of the mean (se).*

String Type Prime Type	Prime - Target Pair Examples	Response Times (SE)	% Error (SE)
"Same" Trials			
Words	(Reference: police)		
3 Shared	eioclp – POLICE	470 (11)	8.4 (1.4)
4 Contiguous Shared	Ipcoel – POLICE	469 (13)	5.3 (1.5)
4 Non-contiguous Shared	oipelc – POLICE	463 (13)	4.1 (1.4)
7 Shared	lpieoc – POLICE	466 (12)	4.1 (1.3)
ALD	dubrsa – POLICE	493 (16)	8.1 (1)
Nonwords	(Reference: tocked)		
3 Shared	dkoect - TOCKED	496 (19)	6.3 (1.2)
4 Contiguous Shared	kteodc - TOCKED	490 (15)	5 (0.9)
4 Non-contiguous Shared	oktdce - TOCKED	492 (17)	6.9 (1.4)
7 Shared	ctkdoe - TOCKED	482 (16)	5 (0.7)
ALD	gvhsit - TOCKED	512 (20)	7.5 (1.5)

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"Different" Trials			
Words	(Reference: around)		
3 Shared	ypilms - SIMPLY	508 (14)	5.2 (0.8)
4 Contiguous Shared	psliym – SIMPLY	507 (17)	4.1 (0.8)
4 Non-contiguous Shared	ipsyml – SIMPLY	504 (16)	3.3 (0.8)
7 Shared	mspyil - SIMPLY	494 (15)	3.8 (1.2)
ALD	rhoetb – SIMPLY	514 (13)	5.8 (0.8)
Nonwords	(Reference: maughs)		
3 Shared	nkeocl - LECKON	518 (18)	5.3 (1)
4 Contiguous Shared	kloenc – LECKON	507 (17)	4.2 (0.8)
4 Non- contiguous Shared	eklnco – LECKON	516 (19)	5.3 (0.9)
7 Shared	clkneo - LECKON	511 (16)	3.9 (0.7)
ALD	blasut - LECKON	510 (15)	5.5 (1)

Experiment 11: Sandwich Priming

Method

Participants

Twenty-five undergraduate students from the University of Nottingham were recruited to this experiment. All were native English speakers with normal or corrected-to-normal vision.

Stimuli and design

The stimuli and design of this experiment was identical to that of Experiment 9

Procedure

The procedure was identical to Experiment 9 with the exception of the target being presented in uppercase for 35ms between the forward mask and the prime.

Results

Analysis was carried out on both the mean correct response times (RT) and the percentage of errors (total 5.6 %). All trials with latencies above 1400 ms or below 250 ms were excluded from the analysis (1.5 % of the total trials). The analysis was carried out using a two-way repeated measures ANOVA with String Type (words or nonwords) and Prime Type (3S, 4SC, 4SNC, 7S or ALD) using both by-participant (F_1) and by-item (F_2) analysis.

The mean RT for correct trials and the percentage of errors are presented in Table 14.

For the latencies a significant main effect of String Type was found, $F_1(1,24) = 72.31$, $p < .001$, $F_2(1,319) = 184.61$, $p < .001$, with responses to words 77 ms faster than to nonwords. Prime Type was also significant, $F_1(4,21) = 5.1$, $p < .01$, $F_2(1,319) = 4.14$, $p < .01$. There was no interaction between String Type and Prime Type, Fs< 1.

Planned comparisons carried out on the RTs collapsed across String Type revealed significant facilitation compared to ALD prime for 4C, 4NC, 7S primes, $F_1(1,24) = 9.75$, $p < .01$, $F_2(1,319) = 4.77$, $p < .05$, $F_1(1,24) = 6.02$ $p < .05$, $F_2(1,319) = 5.91$, $p < .05$, and $\mathrm{F}_1(1,24) = 23.14$, $p < .001$, $F_2(1,319) = 13.62$, $p < .001$, respectively. There was no significant difference between ALD and 3S primes by subjects, $F_1(1,24) = 3.03$, $p < .1$, but was significant by item, $F_2(1,319) = 6.16$, $p < .05$.

Response to 7S primes were also significantly faster than those to 3S, $F_1(1,24) = 8.95$, $p < .01$, $F_2(1,319) = 3.77$, $p < .05$, and 4C primes, by subject $F_1(1,24) = 5.56$, $p < .05$ and marginally by item, $F_2(1,319) = 3.01$, $p = .08$. There was no difference between 7S primes and 4NC primes, $F_1(1,24) = 2.6$, $p = .12$, $F_2(1,319) = 2.23$, p .14 , with all other comparisons not significant, Fs$<$ 1.

Analysis of the error rate showed a significant effect of String Type, $F_1(1,24) = 6.32$, $p < .05$, $F_2(1,319) = 6.47$, $p<.05$, with nonwords producing 2.7 % more errors than words. There was no effect of Prime Type or interaction, all Fs< 1.

Table 14: *Experiment 11 the Sandwich Priming Task: Mean Response Times in Milliseconds, the Percentage Error Rates, and the standard error of the mean (SE).*

String Type Prime Type	Prime - Target Pair Examples	Response Times (SE)	% Error (SE)
Words			
3 Shared	eioclp – POLICE	694 (19)	4.5 (0.8)
4 CS	Ipcoel – POLICE	692 (22)	5.5 (1.1)
4 NCS	oipelc – POLICE	690 (21)	5.4 (1)
7 Shared	lpieoc – POLICE	682 (19)	5.8 (1)
ALD	dubrsa – POLICE	704 (22)	6.1 (1.5)
Nonwords			
3 Shared	dkoect - TOCKED	771 (26)	7.4 (1.7)
4 CS	kteodc - TOCKED	764 (24)	8.1 (1.5)
4 NCS	oktdce - TOCKED	767 (24)	7.6 (1.7)
7 Shared	ctkdoe - TOCKED	763 (22)	8.3 (1.8)
ALD	gvhsit - TOCKED	780 (23)	8.6 (2.3)

Discussion

Just as in the other experiments a processing advantage for words over nonwords was found. Importantly, similar to the masked-priming same-different task, there were significant priming effects, for 4C, 4NC and 7S primes, compared to the ALD prime. Interestingly, the response times to 7S primes were significantly faster than those to 3S. This pattern is in the same direction as degree of overlap of the positional information between the prime and target. Somewhat surprisingly, there was not the expected interaction between prime type and string type normally seen in the standard masked prime lexical decision task, indicating that the pattern of priming is similar for both words and nonwords.

General Discussion

The present experiments used four different six-letter scrambled primes that varied in the amount of positional information that they shared with the target (either 3, 4 contiguous, 4 noncontiguous, 7 bigrams), to test the sensitivity of the masked-priming same-different and sandwich priming tasks. As expected from the results of previous studies, there was only a processing advantage for words over nonwords (66 ms), with no scrambled priming effects when using the standard masked-priming lexical decision task (Experiment 9). An advantage for processing words over nonwords (20 ms) was also found when using the same-different task (Experiment 10). Critically, this task revealed significant priming across all four priming condition compared to the control ALD prime. However, the degree of positional overlap between the primes and the targets did not modulate the size of the priming effect. As expected for the same-different task, the priming effects did not interact with string type. Also with the sandwich-priming paradigm (Experiment 11), an advantage was found for processing words over nonwords (77 ms). However, the pattern of priming was different than that of the same-different task, with significant priming effects for 4C, 4NC, 7S primes, but no priming effect 3S primes, compared to the ALD primes. In addition, 7S primes produced a significant priming effect compared to the 3S. Interestingly, unlike normally observed in a masked-priming lexical decision paradigm there was no interaction between the prime type and string type.

The patterns of results for the same-different and sandwich priming experiments demonstrate that both of these tasks are more sensitive to orthographic processes than the commonly used standard masked-priming paradigms. However, the difference in the pattern of priming between the two tasks suggests that the priming effects may be produced/influenced by differences in the levels of processing. The results of the present chapter suggest that sandwich priming is more sensitive than the masked-priming same-different task to the degree of positional overlap between the prime and target. The sandwich priming experiment produced significantly larger priming effects for the 7S primes compared to the 3S primes and no significant priming effect for the 3S compared to the control ALD primes. These differences and the general pattern of results are consistent with the level of positional overlap between the prime and the target.. Obviously the nature of the decision required by both these tasks must play a significant role in these differences.

The difference in the decision required means that the degree to which these tasks represent all the processes involved in orthographic word recognition also differs. In the same-different task, the decision is based on the similarity of reference and target (i.e., same or different). As the decision is no longer lexical, it does not require the target to activate a whole word representation, thus the decision is not based on the level of activation of these representations. Instead the reference produces representations for the target to match against. Using the model presented in Chapter 2 (see Figure 9), the representations are temporarily stored in some form of short term memory. Depending on the lexical status of the reference, the number of representations may vary and/or the type of representations used to encode and support the temporary representations. Although the type of representation and the level at which the matching occurs may differ depending upon the nature of the reference-target pair (Kelly et al., 2013), the task itself does not depend on the identification of the target as either a word or a nonword. Thus, the task should eliminate inhibition from other similar whole word representations. This in turn means that the lexical properties normally associated with a specific whole word representation are no longer evident. As Kinoshita and Norris (2009) point out, the presentation of the reference for 1 second produces a temporary lexicon of one. Therefore, it is possible that the task is only tapping into the very early orthographic processes that are general processes involved in the processing of all visual information rather than those specific to word recognition (see Dunabeitia, Kinoshita, Carreiras& Norris, 2010 for similar conclusion).

Conversely, in the sandwich priming task the decision is the same as in the standard lexical decision task. Therefore, to successfully perform the task the target needs to be identified as either a word or nonword. Thus, the decision in the sandwich priming task is still reliant on the activation and identification of specific whole word representation or the summation of activation of representations at the lexical level. Lupker and Davis (2009) argued that the addition of the briefly presented reference stimulus between the forward mask and the prime 'boosts' the activation level of the target above that of its orthographically similar competitors, reducing the effect of inhibition. However, the decision is still based on the activation level of whole word lexical representations, whether this is the result of the activation of a specific representation or the summation of activation of representations at the lexical level. Thus, as seen in Figure 11, this 'boost' does not eliminate competition but rather reduces the effects of competition. Therefore, the task necessitates the use of all processes involved in visual word recognition. This means that the properties associated with whole word lexical representations may still play a role in this task, without masking lower level influences.

The role of the prime also changes in the sandwich-priming paradigm, compared to both the masked-priming same-different task and the standard masked-priming lexical decision task. In the sandwich priming task the prime no longer provides an advantage in the processing of the target through the activation of shared representation. Instead the prime effects the level of activation of the orthographic target representation at the time the target is presented. The more information shared, the greater the level of activation. Thus, identity primes increasing the level of activation and primes sharing only some information slowing the rate of decay. This slowing in the rate of decay would be mediated by the degree of overlap in the shared information between the prime and target. Therefore, unlike priming in the lexical decision task, the prime would not necessarily activate whole word representations that share information with the prime only, or provide information for a "different" decision in the case of the same-different task. This will be discussed further in Chapter 7.

In conclusion, the results from the present experiments demonstrated that both the same-different and sandwich priming tasks are more sensitive to extreme positional primes. However, because the sandwich task revealed priming effects that are consistent with the degree of orthographic overlap between the prime and target, it suggests that this task may provide a better investigatory tool for visual word processing.

Figure 11. Showing the difference in the activation patterns between effect for *VACATION* and *AVIATION* given two different prime types (i.e., *avacitno–VACATION* and *etorcism– ACATION*), in the a) standard masked-priming lexical decision task and b) sandwich priming task

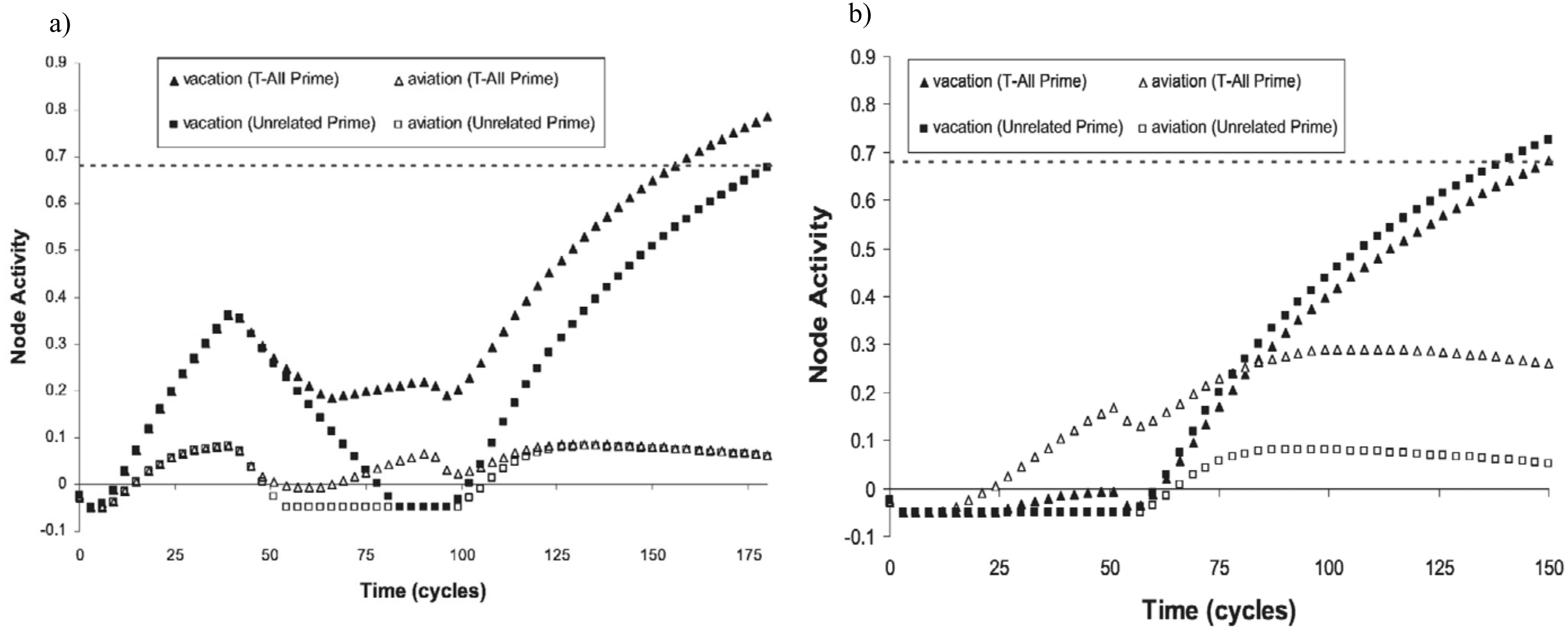


Figure taken from Lupker and Davis (2009)

Chapter 6

Revisiting word shape effects: The influence of ascender letters in visual word recognition.

Introduction

It is apparent from the evidence presented in Chapter 1 that the role of word shape in visual word recognition is far from clear. Furthermore, this ambiguity may be partly due to the methods previously used which distort the shape of the stimuli by alternating the case (e.g. AlTeRnAtInG, Besner, 1989), the size (e.g., alternating, Perea& Rosa, 2002)of individual letters, or distorting the overall shape (Perea, Comesana, Soares, &Moret-Tatay, 2012). In this chapter we use a different method for investigating the role of shape which does not visually distort the stimuli in any way, making it a more ecologically valid technique. This is achieved simply using the lexical decision task to compare five-letter words and nonwords, each containing only one ascender or descender in one of the five possible positions (e.g., ‘frame’, ‘charm’, ‘eaten’, ‘scale’ or ‘ranch’),to control words and nonwords containing no ascenders or descenders (e.g., ‘manor’). Although presenting undistorted words has been used before, this has either been as comparisons for size and case alternation (e.g., Allen, Wallace & Weber, 1995; Perea& Rosa, 2002) or the investigation of function words (Besner, 1989). This present method also has a further advantage of allowing analysis of other factors that may be responsible for the shape effects, such as letter frequency, shape uniqueness and letter position information, through measures of both bigram uniqueness and frequency.

Due to the inconsistency of previous results and the differences in the types of stimuli employed there are no prediction regarding the direction of effects for the current study was made.

Experiment 12: Effects of Ascenders in the Lexical Decision Task

Method

Participants

Twenty-four participants all undergraduates or postgraduates participated in the experiment. All were native English speakers with normal or corrected-to-normal vision. Participants with dyslexia were excluded from taking part.

Stimuli and design

240 five-letter low frequency (mean 6.8 per million) words were selected from the SUBTLEX-US database (Brysbaert& New, 2009), 40 words for each of the ascender positions (P1, P2, P3, P4, P5) and the control no ascender condition. For the words with an ascender all other letters contained in the word were non-ascender/descender letters, (e.g., ‘frame’, ‘charm’, ‘eaten’, ‘scale’ or ‘ranch’). The no ascender condition contained only non-ascender/descender letters (e.g., manor). 240 orthographically legal five-letter nonwords were constructed, 40 for each of the ascender position conditions

and a no ascender condition, by changing one letter from the word stimuli while keeping the type of letter constant (e.g. eater – nater).

Each of the 12 groups of stimuli (words ascender positions P1, P2, P3, P4, P5, and no ascender, and the nonwords ascender positions P1, P2, P3, P4, P5, and no ascender) were separated into two groups and assigned a different case (upper or lower) across two lists. This allowed each item to be presented to each participant only once but in a different case. Thus each of the two lists consisted of 240 words (120 in lowercase and 120 in uppercase) and 240 nonwords (120 in lowercase and 120 in uppercase), 100 with ascenders at P1, P2, P3, P4, P5 and none; 20 for each of the five groups. Each participant was randomly assigned to one of the two lists.

Procedure

For each trial a letter string was presented in the centre of the screen and remained on the screen until a response was made or 2000 ms had passed. After each trial a blank screen was presented for 500 ms before the next trial started. All stimuli were presented and the responses recorded using DMDX (Forster & Forster, 2003). The stimuli were high contrast and presented in a white Courier New font (10 points) on a black background. The participants were asked to decide as quickly and as accurately as possible whether the letter string was a word or a nonword. Each participant completed 495 trials in total, comprising of 15 practice trials and 480 test trials. All trials were presented in a randomized order, with responses times measured in milliseconds from the onset of the target stimuli.

Results

The analysis was run on the correct response times (RTs) only. The total percentage of errors was 8%. Trial latencies below 250 ms and non responses (i.e., those equal to 2000ms) were excluded from the analysis (less than 1% of the trials). The mean response times and percentage of errors are presented in Table 15.

The data were analysed using two linear mixed-effect models. The first model analysed only trials with ascender words to test the effect of ascender position, with the second model using only non-ascender data as a control. For both models the following factors were used: String Type (words vs. nonwords), Case (lower vs. uppercase), Log Word Frequency and the Log Bigram Frequency (bigrams based on the Grainger & van Heuven, 2003, model). For the first model an extra factor was added: Position of Ascender (P1, P2, P3, P4, and P5). All frequencies are based on the SUBTLEX-US database (Brysbaert& New, 2009), bigram frequency were as token frequencies. Table 16 shows the results of backwards modelling for the ascender and non-ascender Models. All planed comparison t-tests were Bonferroni corrected for multiple comparisons.

The result for the ascenders revealed a significant main effect of String Type, $F(1,23) = 266.36$, $p< .001$, with faster responses for words (96ms) compared to nonwords. There also a significant effect of Case, $F(1,23) = 49.46$, $p< .001$, with lowercase strings 26 ms faster than uppercase stings. Ascender Position was also significant, $F(4,20) = 3.51$, $p< .01$, with faster responses for ascender at P4 compared to P1 (31 ms), $t(1,78) = 3.26$, $p< .05$, P2 (27 ms), $t(1,78) = 3.18$, $p< .05$. There were further significant effects for

String Frequency, $F(1,23) = 59.66$, $p < .001$, non-contiguous Bigram with letters at P1 and P4, $F(1,23) = 4.51$, $p < .05$. There was a significant interaction between String Type and Case, $F(1,23) = 10.52$, $p < .01$. This revealed that lowercase words were responded to 32 ms faster than uppercase words, $t(1,118) = 7.26$, $p < .05$, and that lowercase nonwords were also responded to faster than uppercase nonwords by 11 ms, $t(1,118) = 2.68$, $p < .05$. There were faster responses for lowercase words than nonwords (36 ms), $t(1,118) = 15.81$, $p < .05$, there were also faster responses to uppercase words than nonwords (85 ms), $t(1,118) = 12.6$, $p < .05$.

For the control non-ascender data the results show only effects for String Type, $F(1,23) = 266.36$, $p < .001$, with faster responses to words by 90 ms, than nonwords.

Table 15. *Mean response times, percentage of errors and standard error (SE) of the means for word and nonword ascenders in both lower- and uppercase for Experiment 12.*

			Case							
	Target Examples		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Ascender Position	Word	Nonword	Word		Nonword		Word		Nonword	
1	trace	teace	718 (41)	745 (48)	828 (45)	857 (49)	5 (5)	7 (5)	11 (7)	9 (6)
			731 (44)		842 (47)		6 (5)		10 (6)	
2	alien	elien	701 (34)	745 (45)	831 (42)	854 (49)	6 (5)	7 (5)	10 (6)	10 (6)
			723 (39)		843 (46)		7 (5)		10 (6)	
3	eaten	saten	707 (39)	744 (44)	810 (45)	810 (43)	11 (7)	15 (7)	7 (5)	5 (5)
			725 (42)		810 (44)		13 (7)		6 (5)	
4	socks	vocks	696 (38)	734 (45)	787 (40)	804 (47)	5 (5)	8 (6)	8 (6)	7 (5)
			715 (41)		795 (43)		7 (5)		8 (6)	
5	ranch	rench	708 (37)	741 (43)	810 (44)	811 (43)	8 (6)	9 (6)	9 (6)	8 (6)
			725 (40)		811 (43)		8 (6)		9 (6)	
Non-Ascender	curse	vurse	710 (39)	724 (41)	808 (46)	806 (46)	11 (7)	12 (7)	11 (7)	10 (6)
			717 (40)		807 (46)		11 (7)		10 (6)	

Table 16. *Results of the Mixed-Effect Model for RT of Ascenders and Non-Ascenders only Experiment 12.*

	Sum Sq.	Mean Sq.	*F* Value	*p* <
<u>Ascenders</u>				
String Type	10.29	10.29	266.36	.001
Case	1.91	1.91	49.46	.001
Ascender Position	0.54	0.14	3.51	.01
String Frequency	2.31	2.31	59.66	.001
NC-Bigram P1-P4	0.17	0.17	4.51	.05
String Type*Case	0.41	0.41	10.52	.01
<u>Non-Ascenders</u>				
String Type	1.69	1.69	42.8	.001

Discussion

The results from Experiment 12 revealed, for the ascender model, faster response times for words compared to nonwords, lowercase compared to uppercase strings and a significant effect of String Frequency. Importantly, there was a significant effect of Ascender Position, with a processing advantage for strings with an ascender at position four compared to ascenders at all other positions. Furthermore, there was a significant effect for the non-contiguous bigram containing letters at position one and four. An interaction was also found between String Type and Case, and this was driven by the difference in reaction times between lowercase and uppercase words and nonwords (107 ms and 14 ms, respectively). Critically, for control letter strings with no ascenders there was only a significant effect of String Type, with words responded to faster than nonwords, with no positional letter advantages or effects of bigrams.

Although the results demonstrate that there is a processing advantage for words containing an ascender, the locus of this effect is still unclear. One possibility is that the effect is not due to shape *per se* but is specific to ascenders. Therefore the experiment will be repeated except using descenders instead of ascenders. If the effects found in the first experiment are due to the shape of a letter string, a similar effect would be predicted for letter strings containing only descenders.

Experiment 13: Effects of Descenders in the Lexical Decision Task

Method

Participants

Twenty-four participants all undergraduates or postgraduates participated in the experiment. All were native English speakers with normal or corrected-to-normal vision. Participants with dyslexia were excluded from taking part.

Stimuli and design

The 240 five-letter words and 240 five-letter nonwords were selected using the same method as Experiment 12, except that the letter strings, where appropriate, contained descenders rather than ascenders. The design was identical to Experiment 12

Procedure

The procedure was identical to that of Experiment 12

Results

The analysis was run on the correct response times (RTs) only. Trial latencies below 250 ms and non responses (trial with response times equal to 2000 ms were excluded from the analysis (less than 1 % of the trials). The mean response times and percentage of errors are shown in Table 17. The data was analysed using the two linear mixed-effect models that were analogous to those used for Experiment 12. All planed comparison t-tests were Bonferroni corrected for multiple comparisons.

Table 18 shows the results of backwards modelling for the Strings containing descenders. This revealed significant effects of String Type, $F(1,23) = 152.93$, $p< .001$, with faster response latencies for words (97ms) than nonwords. There was a significant effect of Descender Position, $F(4,20) = 2.48$, $p< .05$, with faster response latencies for descenders at P3 compared to P5 (35 ms) $t(78) = 2.77$, $p< .05$. String Frequency was also significant, $F(1,23) = 65.19$, $p< .001$, along with Bigram Frequency for non-contiguous bigrams containing letters at P2 and P4,$F(1,23) = 4.83$, $p< 05$, and P2 and P5, $F(1,23) = 4.65$, $p< .05$. There was a significant interaction between String Type and Case, $F(1,23) = 6.65$, $p< .05$, with faster responses for lowercase words than nonwords (83 ms), $t(1,78) = 9.23$, $p< .05$, and uppercase words compared to nonwords (110 ms), $t(1,78) = 11.9$, $p< .05$.

For the control non-descender data the results in Table 18 show a significant effect for String Type $F(1,23) = 98.66$, $p< .001$. There were also significant effects for contiguous bigrams containing letters at positions P1 and P2, and P3 and P4, $F(1,23) = 4.14$, $p< .05$, $F(1,23) = 7.98$, $p< .01$, respectively.

Table 17. *Mean response times, percentage of errors and standard error (SE) of the means for word and nonword descender in both lower- and uppercase for Experiment 13.*

			Case							
	Target Example		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Descender Position	Word	Nonword	Word		Nonword		Word		Nonword	
1	pizza	pezza	785 (44)	754 (41)	859 (37)	908 (51)	5.3 (4.5)	5.7 (4.6)	8.8 (5.7)	5.4 (4.5)
			769 (42)		883 (44)		5.5 (4.6)		7.1 (5.1)	
2	agree	igree	777 (47)	781 (50)	842 (40)	873 (48)	9.2 (5.8)	7.9 (5.4)	8.3 (5.5)	9.1 (5.8)
			779 (48)		858 (44)		8.5 (5.6)		8.7 (5.6)	
3	sugar	vugar	752 (41)	737 (40)	843 (43)	856 (46)	3.5 (3.7)	5.2 (4.5)	5.8 (4.7)	5.8 (4.7)
			745 (41)		850 (45)		4.4 (4.1)		5.8 (4.7)	
4	range	ronge	787 (49)	800 (51)	871 (47)	873 (46)	4.8 (4.3)	8.4 (5.6)	5.8 (4.7)	4.2 (4)
			794 (50)		873 (46)		6.6 (4.9)		5 (4.4)	
5	among	omong	758 (47)	731 (41)	865 (46)	843 (42)	2.9 (2.2)	3.2 (2.6)	7.1 (5.2)	8 (5.4)
			745 (44)		854 (44)		3.1 (2.4)		7.6 (5.3)	
6	scare	smare	736 (37)	728 (35)	875 (45)	859 (44)	3.1 (2.5)	2.9 (2.1)	7.1 (5.1)	6.7 (5)
			732 (36)		867 (45)		3 (2.3)		6.9 (5.1)	

Table 18. *Results of the Mixed-Effect Model for RT of Descenders and Non-Descenders only Experiment 13.*

	Sum Sq.	Mean Sq.	*F* Value	*p* <
Descenders				
String Type	5.8842	5.8842	152.9344	.001
Descender Position	0.3815	0.0954	2.4786	.05
String Frequency	2.508	2.508	65.1853	.001
NC-Bigram P2-P4	0.1859	0.1859	4.8329	.05
NC-Bigram P2-P5	0.1791	0.1791	4.6546	.05
String Type * Case	0.2559	0.2559	6.6519	.01
Non-descenders				
String Type	3.421	3.421	98.6627	.001
C-Bigram P1-P2	0.1435	0.1435	4.1383	.05
C-Bigram P3-P4	0.2768	0.2768	7.982	.01

Discussion

The results for letter strings containing descenders were similar to those found in Experiment 13, in that there were faster reaction times for words compared to nonwords, and a significant effect of String Frequency. Critically, there was a significant effect of Descender Position, with faster responses to letter strings containing a descender at position three compared to positions five. Further, there were significant effects for the non-contiguous bigrams containing letters at positions two and four, and two and five. For the control non-descenders, there were faster responses for words compared to nonwords. Unlike the non-ascenders, there were also significant effects for contiguous bigrams containing letters at positions, one and two, and three and four.

These results demonstrate that the pattern of findings seen in Experiment 12 are not specific to ascenders and thus are likely mediated by the overall shape of the letter stings. However, in both the previous experiments the position of the significant ascender and descender is located within the normal reading fixation point for five letter words, between the third and fourth letters, thus these letters may be more salient. Further the effect found in the non-descender control words for one of the two bigrams, containing both letters in positions three and four, suggest that the fixation point (where visual acuity is greatest) may play a role in the ascender/descender effects reported.

Therefore, to test this prediction, in Experiments12 and 13 the target letter string will be presented either above or below a central fixation point. To remove the effects of making a saccade to the normal fixation position in reading, the targets were only presented for 250 ms. If the results of the previous two experiments are limited to the presence of ascenders and descenders at the fixation position then it would be predicted that this advantage would disappear when targets are presented more eccentrically in the visual field with respect to the fovea.

Experiment 14: Effects of Presenting Words Contain Ascenders Above or Below Fixation

Method

Participants

A further twenty-four undergraduate students at the University of Nottingham participated in this experiment. All were native English speakers with normal or corrected-to-normal vision. None had taken part in the previous experiment.

Stimuli and design

The stimuli and design were the same as Experiment 12.

Procedure

The procedure was the same as Experiment 12except that the target appeared either above or below the central fixation point, remaining on the screen for 250 ms.

Results

Trials with latencies above below 250 ms and non responses (response times equal to 2000 ms were excluded from the analysis (lessthan1% of trials). The overall error rate was 13.3%. The correct responses were analysed using the same two linear mixed-effect models as Experiment 13. The mean response times and percentage of errors are presented in Table 19.The models were applied to the above and below fixation presentation data separately. Table 20 & 21 shows the results of backwards modelling for the ascender and non-ascender presented above the fixation point, with the below fixation point presentation models. All planed comparison t-tests were Bonferroni corrected for multiple comparisons.

Above

The analysis of the response latencies for ascenders presented above the fixation point revealed a significant effect of Sting Type, $F(1,23) = 107.39$, $p < .001$, with faster reaction times for words (67 ms) compared to nonwords. There was also a significant main effect of String Frequency, $F(1,23) = 17.31$, $p < .001$, and an interaction between String Type and Ascender position, $F(1,23) = 3.29$, $p < .05$, this shows a different pattern for words and nonwords. For words there were faster response latencies for ascenders at P4 compared to P3 (44 ms), $t(1,78) = 2.53$, $p < .05$. For the nonwords, faster response latencies were found for ascenders at P3 compared to P1 (44 ms), $t(1,78) = 2.79$, $p < .05$.

The model of non-ascenders showed only a significant effect of String Type, $F(1,23) = 27$, $p < .001$, with response latencies 52 ms faster for words than nonwords.

Table 19. *Mean response times, percentage of errors and standard error (SE) of the means for word and nonword ascender, in lower- and uppercase, above and below the fixation point for Experiment 14.*

Ascender Position	Target Examples: Word	Target Examples: Nonword	Case: Word Lower	Case: Word Upper	Case: Nonword Lower	Case: Nonword Upper	Case: Word Lower	Case: Word Upper	Case: Nonword Lower	Case: Nonword Upper
Above Fixation Point										
1	trace	teace	671 (37)	693 (49)	782 (50)	771 (39)	13.3 (6.8)	12 (6.5)	17.3 (7.6)	10.3 (6.1)
			682 (43)		777 (46)		12.7 (6.7)		13.8 (6.8)	
2	alien	elien	690 (44)	717 (41)	785 (45)	749 (34)	13.3 (6.8)	14.7 (7.1)	13 (6.7)	21 (8.2)
			703 (42)		767 (39)		14 (6.9)		17.2 (7.5)	
3	eaten	saten	703 (49)	707 (44)	733 (39)	732 (40)	17.7 (7.6)	20 (8)	10.7 (6.2)	9.3 (5.8)
			705 (47)		733 (39)		18.8 (7.8)		10 (6)	
4	socks	vocks	646 (32)	677 (36)	748 (43)	756 (42)	11.3 (6.4)	17.7 (7.6)	12 (6.5)	10 (6)
			662 (34)		752 (43)		14.5 (7)		11 (6.3)	
5	ranch	rench	695 (40)	682 (38)	767 (46)	724 (39)	15 (7.2)	17.7 (7.6)	16 (7.3)	11 (6.3)
			688 (39)		746 (43)		16.3 (7.4)		13.5 (6.8)	
Non-Ascender	curse	vurse	686 (40)	674 (38)	743 (39)	719 (37)	17.3 (7.6)	14 (7)	7.3 (5.2)	12 (6.5)
			680 (39)		731 (38)		15.7 (7.3)		9.7 (5.9)	

(continued on the next page)

Below Fixation Point										
1	trace	teace	668 (33)	670 (34)	806 (49)	759 (38)	13.3 (6.8)	12 (6.5)	17.3 (7.6)	10.3 (6.1)
			669 (34)		782 (44)		12.7 (6.7)		13.8 (6.8)	
2	alien	elien	661 (35)	693 (37)	802 (49)	779 (49)	13.3 (6.8)	14.7 (7.1)	13 (6.7)	21 (8.2)
			677 (36)		790 (49)		14 (6.9)		17.2 (7.5)	
3	eaten	saten	661 (29)	698 (42)	755 (45)	737 (38)	17.7 (7.6)	20 (8)	10.7 (6.2)	9.3 (5.8)
			679 (35)		746 (41)		18.8 (7.8)		10 (6)	
4	socks	vocks	669 (36)	687 (39)	790 (45)	730 (41)	11.3 (6.4)	17.7 (7.6)	12 (6.5)	10 (6)
			678 (37)		760 (43)		14.5 (7)		11 (6.3)	
5	ranch	rench	697 (42)	681 (33)	789 (47)	745 (41)	15 (7.2)	17.7 (7.6)	16 (7.3)	11 (6.3)
			689 (37)		767 (44)		16.3 (7.4)		13.5 (6.8)	
Non-Ascender	curse	vurse	705 (45)	678 (45)	751 (43)	725 (40)	14.7 (7.1)	16 (7.4)	14 (7.5)	11.3 (5.8)
			692 (45)		738 (42)		15.3 (7.2)		12.7 (6.7)	

Table 20. *Results of the Mixed-Effect Model for RT of Ascenders and Non-Ascenders presented above the fixation point, for E*xperiment14.

	Sum Sq.	Mean Sq.	*F* Value	*p* <
Ascenders				
String Type	4.06	4.06	107.39	.05
String Frequency	0.65	0.65	17.31	.001
String Type*Ascender Position	0.5	0.12	3.29	.05
Non-Ascenders				
String Type	0.96	0.96	27	.001

Below

The results for ascenders presented below the fixation point revealed significant effects of String Type, $F(1,24) = 190.13$, $p < .001$, with RT for words faster (81 ms) than nonwords. There was also a significant effect of Case, $F(1,24) = 4.42$, $p < .05$, with faster responses to uppercase strings (22 ms) than lowercase letter strings. There were further significant effects for String Frequency, $F(1,23) = 13.02$, $p < .001$, and the non-contiguous Bigram containing letters at P2 and P4, $F(1,23) = 5.92$, $p < .05$. Significant interactions were also found for String Type and Case, $F(1,23) = 17.1$, $p < .001$, for Words there no significant difference between upper and lower case, $t(1.23) = 1.43$, $p=.15$ but a significant difference for nonwords, $t(1,23) = 4.44$, $p < .05$, with responses to 19 ms faster for upper- compared to lowercase nonwords. Responses for words were faster than nonwords for both upper- (44 ms) and lowercase (71 ms), $t(1,23) = 7.69$, $p < .05$, $t(1,23) = 13.14$, $p < .05$, respectively.

For the non-ascenders, there was a significant main effect of String Type, $F(1,23) = 19.07$, $p < .001$, with words responded to 46 ms faster than nonwords. There was also a main effect of Case, $F(1,23) = 5.52$, $p < .05$, with responses to uppercase strings 27 ms faster than to lowercase. There was a further significant effect of the non-contiguous Bigram containing letters at P3 and P5, $F(1,23) = 9.06$, $p < .01$.

Table 21. *Results of the Mixed-Effect Model for RT of Ascenders and Non-Ascenders presented below the fixation point, for E*xperiment14.

	Sum Sq.	Mean Sq.	*F* Value	*p* <
Ascenders				
String Type	7.07	7.07	190.13	.001
Case	0.16	0.16	4.42	.05
String Frequency	0.48	0.48	13.02	.001
NC-Bigram P2-P4	0.22	0.22	5.92	.05
String Type*Case	0.64	0.64	17.1	.001
Non-Ascenders				
String Type	0.79	0.79	19.07	.001
Case	0.23	0.23	5.52	.05
NC-Bigram P3-P5	0.38	0.38	9.06	.01

Discussion

The results from Experiment 14, showed the same effects for String Type and Frequency as Experiments 12 and 13, for strings contain ascenders presented above and below the fixation point. Although there was no significant effect for Ascender Position for letter strings presented above the fixation point, there was an interaction with String Type. This revealed a different pattern for words and nonwords, with faster responses for words containing an ascender at position four compare to position three. For nonwords there were faster times for position three and position one. Again, for the control non-ascender there was only a significant effect of String Type. However, for letter strings presented below the fixation point, there was no effect of Ascender Position, but there was a significant effect of the bigram containing ascenders at positions two and four. There was a significant effect of Case with, unusually, faster response times for uppercase letter stings, though there was also an interaction between String Type and Case. This revealed that for words there was no difference between uppercase and lowercase letters, but faster responses for uppercase nonwords, thus driving both the interaction and the main effect of Case. The results for the non-ascenders showed that there was a significant effect of String Type, with word responses faster than nonwords. Case was also significant, but again uppercase letter strings were responded to fastest. Interestingly, there was also a significant effect for the bigram containing letters at positions three and five.

The overall results are mixed, with the presentation above the fixation point suggesting that that the effects found Experiments 12 and 13 were not due to the normal reading fixation position for five-letter words. However, in the below presentation condition there was an effect of a non-contiguous bigram contain a letter at position three.

Experiment 15: Effects of Presenting Words Contain Descenders Above or Below Fixation

Method

Stimuli and design

The stimuli and design was identical to that of Experiment 13

Procedure

The procedure was the same as that of Experiment 14

Results

The analysis was run on the correct response times (RTs) only. The total errors rate was 14%. Trial latencies below 250 ms and non responses (trials with response times equal to 2000 ms were excluded from the analysis (< .001 % of the trials). The mean response time and percentage of errors are presented in Table 22. The same analysis was performed as Experiment 14. Table 23 & 24 shows the results of backwards modelling for the descenders and non-descenders presented above the fixation point with the below models. All planed comparison t-tests were Bonferroni corrected for multiple comparisons.

Above

There results of the backwards modelling for strings containing descenders presented above the fixation are shown in Table 23. The results show a significant effect of String Type, $F(1,23) = 126.45$, $p < .001$, with faster reaction times for words (84 ms) compared to nonwords. There was also a significant effect of String Frequency, $F(1,23) = 28.54$, $p < .001$.

For non-descender strings the results are also shown in Table 23. These show a similar pattern of results with a significant effect of String Type, $F(1,23) = 17.33$, $p < .001$, with faster response latencies for words (71 ms) than nonwords, and String Frequency, $F(1,23) = 4.78$, $p < .05$. However, there was also a significant effect of Bigram Frequency of the non-contiguous bigram containing letters at P1 and P3, $F(1,23) = 5.65$, $p < .05$.

Below

Table 24 shows the results of backwards modelling for the descender data presented below the fixation point. This revealed significant effects of String Type, $F(1,23) = 93.05$, $p < .001$, with responses faster to words by 83 ms than nonwords. There was also a significant effect of String Frequency.

For the non-descenders there was only a significant effect of String Type, $F(123) = 26.63$, $p < .001$.

Table 22. *Mean response times, percentage of errors and standard error (SE) of the means for word and nonword descender, in lower- and uppercase, above and below the fixation point for Experiment 15.*

Ascender Position	Target Examples		Case							
	Word	Nonword	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
			Word		Nonword		Word		Nonword	
Above Fixation Point										
1	trace	teace	645 (26)	666 (41)	741 (31)	774 (45)	11.1 (6.3)	7.7 (5.4)	23.3 (8.5)	14.2 (7)
			656 (33)		758 (38)		9.4 (5.8)		18.8 (7.7)	
2	alien	elien	652 (36)	673 (31)	741 (36)	721 (28)	10.8 (6.2)	19.2 (7.9)	16.7 (9.1)	9.1 (5.9)
			663 (34)		731 (32)		15 (7.1)		12.9 (6.6)	
3	eaten	saten	662 (44)	654 (32)	742 (42)	717 (31)	13.5 (6.9)	15.1 (7.3)	10 (6)	7.5 (5.3)
			658 (38)		730 (36)		14.3 (7.1)		8.8 (5.7)	
4	socks	vocks	662 (32)	697 (34)	761 (36)	763 (40)	9.9 (6)	17.1 (7.6)	19.2 (7.9)	12.5 (6.6)
			679 (33)		762 (38)		13.5 (6.8)		15.8 (7.3)	
5	ranch	rench	637 (23)	640 (28)	727 (32)	750 (42)	11.7 (6.5)	13.5 (6.9)	9.4 (6.2)	7.3 (5.9)
			639 (25)		739 (37)		12.6 (6.7)		8.4 (6)	
Non-Ascender	curse	vurse	683 (38)	651 (25)	749 (31)	726 (41)	13.5 (6.9)	12.7 (6.7)	12 (6.5)	12.8 (6.7)
			667 (32)		737 (36)		13.1 (6.8)		12.4 (6.6)	

(continued on the next page)

<u>Below Fixation Point</u>										
			647 (28)	670 (32)	757 (38)	755 (39)	12.6 (6.7)	18 (7.7)	25.8 (8.8)	14.2 (7)
1	trace	teace	658 (30)		756 (39)		15.3 (7.2)		20 (7.9)	
			695 (37)	687 (32)	760 (35)	754 (36)	18.3 (7.8)	24.2 (8.6)	12.9 (6.7)	14.4 (7)
2	alien	elien	691 (34)		757 (35)		21.3 (8.2)		13.6 (6.9)	
			667 (36)	684 (38)	735 (35)	760 (41)	15.4 (7.2)	13.7 (6.9)	6.7 (5)	13.3 (6.8)
3	eaten	saten	676 (37)		748 (38)		14.5 (7.1)		10 (5.9)	
			691 (41)	715 (41)	753 (39)	736 (32)	20.5 (8.1)	19.7 (8)	19.2 (7.9)	12.5 (6.6)
4	socks	vocks	703 (41)		744 (35)		20.1 (8)		15.8 (73)	
			640 (28)	655 (29)	737 (35)	761 (35)	12.8 (6.7)	16.2 (7.4)	9.5 (5.9)	7.9 (5.4)
5	ranch	rench	648 (28)		749 (35)		14.5 (7.1)		8.7 (5.7)	
			647 (24)	646 (31)	724 (35)	744 (32)	14 (7)	11.4 (6.4)	14.6 (7.1)	15.4 (7.3)
Non-Ascender	curse	vurse	646 (27)		734 (34)		12.7 (6.7)		15 (7.2)	

Table 23. *Results of the Mixed-Effect Model for RT of Descenders and Non-Descenders presented above the fixation point, for* Experiment 15.

	Sum Sq.	Mean Sq.	*F* Value	$p <$
Descenders				
String Type	4.83	4.84	126.45	.001
String Frequency	1.09	1.09	28.54	.001
Non-Descenders				
String Type	0.6	0.6	17.33	.001
String Frequency	0.17	0.17	4.78	.05
NC-Bigram P1-P3	0.2	0.2	5.65	.05

Table 24. *Results of the Mixed-Effect Model for RT of Descenders and Non-Descenders presented above the fixation point, for* Experiment 15.

	Sum Sq.	Mean Sq.	*F* Value	$p <$
Descenders				
String Type	3.57	3.5701	93.05	.001
String Frequency	0.97	0.97	25.32	.001
Non-Descenders				
String Type	0.78	0.78	26.63	.001

Discussion

The results for Experiment 15 showed a different pattern of results than those of Experiments12, 13 and 14. Unlike the previous experiment there were only significant effects for String Type and String Frequency for both letter strings presented above and below the fixation point. For the control non-descenders there was also a significant effect of String Type. However, for the presented above fixation condition there was also a significant effect of String Frequency and non-contiguous Bigram containing letters at positions one and three. These results will be discussed in relation to the previous experiments in the general discussion.

General Discussion

The current experiments sought to test the role of word shape in the processing of visual words, using undistorted stimuli. In Experiment 12, there was an interaction between String Type and Case which was due to faster responses for lowercase words compared to nonwords. Critically, there was a processing advantage for letter strings containing an ascender in position four. There was also an effect of the non-contiguous Bigram containing letters at positions one and four. However, for the control non-ascender words there was only an effect of String Type. Experiment 13, used descenders instead of ascenders, to test whether the results from Experiment 12 were specific to ascenders. The results showed a similar pattern of results with faster response times for strings containing a descender at position three compared to positions five. Again the non-descenders showed a significant effect of String

Type. However, there were also significant effects of contiguous Bigrams containing letters in positions two and four, and two and five.

Experiments 14 and 15, tested the role of the normal reading fixation location in the ascender-descender effect. In experiment 14, using ascenders, when the strings were presented above the fixation point there was an interaction between String Type and Ascender Position. This showed a different pattern for words and nonwords. For the words there was a processing advantage for ascenders at position four compared to three. For the nonwords the processing advantage occurred for ascenders in position three compared to one. The control non-ascenders only showed an effect of string type. In the below fixation point condition there was no effect of ascender position, however, there was an effect for the non-contiguous Bigram containing letters at positions two and four. There was also an interaction between String Type and Case, which was driven by faster responses for uppercase nonwords compared to lowercase, with no difference between Case for words. For the control condition there was processing advantage for words over nonwords, and uppercase over lowercase strings. Importantly, there was an effect for the non-contiguous Bigram containing letters at positions three and five.

The results for Experiment 15 revealed that for descenders there were only significant effects for String Type and String Frequency, in both the above and below fixation point presentation conditions. For the non-descenders there was an effect for String Type in both conditions. However, in the above fixation point presentation condition there was an effect for the non-contiguous Bigram with letters in positions one and three.

Overall the results presented here suggest that there is some processing advantage for words containing ascenders and/or descenders. However, the results from all experiments show, that this effect only occurs at certain letter positions. Thus suggesting that the normal reading fixation point is in part responsible for the effects of ascenders and descenders. Furthermore, when an effect of bigram occurs, they include letters at the same positions. Critically, these are the bigrams found for several of the control conditions. This suggests that the effect is in part due to the location of those letters relative to the fixation point.

Although, the fixation point does play a role in this effect, the main locus of the effect is the presence of ascenders/descenders at these positions. There are at least two possible explanations for this effect: it is the result of the letters' lexical properties or their visual characteristics. In terms of the former possibility it is important to note that the average letter frequency for five letter non-ascenders/descenders is almost twice that of the ascenders/descenders letters (1340 vs. 756), suggesting that lexical properties do not underlie any processing advantage for ascenders and descenders. Furthermore, as already discussed this effect is modulated by the normal reading fixation point. Together this strongly suggests that the processing advantage is due to the visual properties of ascender/descenders.

The effect of descenders in these experiments is particularly interesting as they are contradictory to the results of Perea, Comesaña, Soares and Moret-Tatay (2012). In their experiment they used mutilated words, where either the upper or lower half of the word was removed, as repetition primes. The results from four experiments revealed significant priming effects only for primes maintaining the upper portion of the word. This, Perea et al. argued, demonstrated that there is a special role for upper portions of words. They go further to suggest that word shape does not play a role in visual word recognition. However, the results from Experiment 13 suggest that the inclusion of a descender at either position three or four also causes a facilitory effect. Therefore, if there were more words with ascenders at position three and four, than words with descenders at the same positions, the special role for upper portions of words may be due to the nature of the words included in the study. Nevertheless, Perea et al.'s results would fit with an explanation based on the salience of information in the upper proportions of the word, due to the position of fixation.

Although the present results are not in complete agreement with those of Perea, Comesaña, Soares and Moret-Tatay (2012), they do support a similar conclusion in that rapid visual word recognition is unlikely to be driven completely by a shape-based sensitive mechanism. Nonetheless, it does suggest that the facilitory effects found are the result of visual properties, rather than any lexical properties, in that performance is determined in part by both the orthographic nature of ascenders and descenders together with the normal reading fixation point. However, a new set of experiments are needed to investigate this further. Nonetheless the present experiments are important in that they have clearly demonstrated that it is possible to investigate the role of shape in visual word recognition without distorting the stimuli in a non-ecological manner.

Chapter7

General Discussion

Kinoshita and Norris (2009) claimed that the masked-priming same-different task is not influenced by higher level processes such as lexical, phonological or semantic processes. Furthermore, they claimed that the representations that are used in matching process for words and nonwords (sublexical representations) are the same. Thus, they argued that this task is in particular suitable for investigating lower level processes. However, as has been demonstrated across all experiments presented in the previous chapters of this thesis, and the experiments of Kinoshita and Norris (2008; 2009) there is a consistent processing advantage for word over nonwords. This suggested that the difference in the lexical status of words and nonwords is an important factor in the task. Furthermore, results from studies using the unmasked version of the task (e.g., Chambers and Forster, 1974) suggested that different sized units are used in the matching process, words using lexical and sublexical representations and nonwords only sublexical. Chapters 2 and 3 systematically tested these assumptions, using both the standard visual version and a multi modal version of the task.

Experiment 1 (Chapter 2) used the standard visual version of the task to investigate the possibility of an interaction between three of the five priming conditions originally used in Experiment 4 of the Kinoshita and Norris's (2009) study (identity, scrambled and ALD). As disused in Chapters, 1, 2 & 3 these priming conditions are critical as the only orthographic difference between scrambled and identity primes is the absence of correct positional information for scrambled primes. Furthermore, both Kinoshita and Norris (209), and Angiolillo-Bent and Rips (1982) suggested that a lack of an interaction between string type and prime type in the masked and unmasked version of the same-different task demonstrated that the matching process involves the same representations for words and nonwords. Conversely, an interaction between prime type and string type, would suggest that the matching process in the same-different task utilizes different representations for words and nonwords with this difference being the source of the word advantage. This would be in line with the suggestion of Chambers and Forster (1975) who proposed a three level matching model of the same-different task. Although the results from Experiment 1 showed the same pattern of priming as Kinoshita and Norris, there was still a clear processing advantage for words over nonwords. However, this result does not necessarily support or rule out either explanation for the processes involved in the task.

Experiment 2 (Chapter 2) investigated therefore whether the word advantage in the same-different task is the result of strategic processing. Bodner and Masson (2003) and Bodner and Johnson (2009) have demonstrated that, in the standard masked-priming lexical decision task, different cognitive processing can be induced for primes based on the probability of a prime being used in the task. Although there were no differences in the proportion of the primes being used in the masked-priming same-different task, the blocking of the targets string types means that string type is highly predictable between trials. Furthermore, this blocking also means that reference target string type was also highly predictable within trials. Therefore, different processing strategies may have been employed for words than for nonwords, causing the word advantage. However, Experiment 2 (Chapter 2) revealed that removing both the overall blocking and mixing the reference target pair's string types had no effect on the overall pattern of result with both the processing advantage and pattern of priming remaining. Thus, this indicates that there is no difference in processing strategies between words and nonwords in the masked-priming same-different task. Nevertheless, the question remains why there is word advantage. Furthermore, the results do not rule out an explanation based on different size unit being utilized for words and nonword in the matching process.

An alternative account, put forward by Marmurek (1989), is that the word advantage is due to the nature of the representations. However, rather than different size units being used in the matching process the advantage is due to the strength of the representation. Because nonwords require the creation of a new cognitive representation (i.e. some form of temporary memory representation), the word advantage is dependent on the success of creating the nonword representation. Therefore, the word advantage should be modulated by the exposure period to the reference string, longer reference presentation producing stronger nonword representations reducing the word advantage. Experiments 3 and 4 (Chapter 2) explored this hypothesis by reducing and increasing the reference presentation latencies, respectively. Again, the results from both experiments revealed the same pattern of results as the previous experiments. Critically, the size of the word advantage was similar not only across Experiments 3 and 4 (29 ms vs. 27 ms) but also to that of Experiment 1 (25 ms).

The overall results from Chapter 2, ruled out that the locus of the word advantage was due to strategic effects or the strength of the representations used in the matching process. This suggests that the advantage may be due to the differences in the size of the representation, as suggested by Chambers and Forster (1975). As discussed in Chapter 2, although scrambled primes share no absolute positional information with either the reference or target, they still share a degree of relative information. This overlap was demonstrated using the open bigram model of Grainger and van Heuven (2003), which showed that scrambled primes shared four out of a possible nine bigrams with the target (one contiguous and three non-contiguous bigrams). Based the overlap between scrambled primes and targets a model was proposed in Chapter 2 for the masked-priming same-different task based on Chambers and Forster (1975) multiple level matching, using the open-bigrams model of Grainger and van Heuven (2003). The model is presented in Figure 9 Chapter 2. For the visual version of the task matching occurs in the model at the open bigram level only, with words able to match at both the open-bigram and the lexical level. Thus, this model is able to account for the both the scrambled priming effects for both words and nonwords, and the overall word advantage.

Although, the overall results presented in Chapter 2, suggest the use of different representation for words and nonwords, the lack of an interaction between String and Prime Type does pose a problem. Therefore, Experiments 5 and 6 (Chapter 3) used a multi-modal version of the masked-priming same-difference task, in which the reference was presented in the auditory domain with both the prime and target still presented visually. Experiment 5, used the same set of stimuli as in the Chapter 2. The results revealed again a processing advantage for words over nonwords. Crucially, there was an interaction between string and prime type, with the same pattern previously seen for words, but no scrambled priming in the nonword condition. This demonstrated that matching occurred at the phonological level with the target being encoded into a phonological code. Furthermore, the results of Experiment 5 showed that scrambled priming was preserved only for words at the lexical level through the activation of shared orthographic representations. This would not be possible for nonwords because they have no lexical representations.

However, the lack of scrambled priming for nonwords could also be the results of the ambiguity in the spelling of the auditory presented nonwords. To investigate this possibility, Experiment 6 used heterographic homophones, because it was difficult to create unambiguous nonwords. The results of Experiment 6 revealed the same pattern of priming found in previous experiments with a significant priming effect for scrambled primes. This is critical, as it confirms that when the reference is presented in the auditory domain matching occurs at the phonological level, therefore the target has to be converted into a phonological code. Furthermore, the findings indicate that the scrambled priming effect for word is the result of the activation of the word's lexical representation through share orthographic representation between the primes and targets. As Figure 10 shows the results of the experiments presented in Chapter 3 are consistent with the model presented in Chapter 2 (see Figure 9).

Overall, the results from Chapters 2 and 3 suggest that the use of words in the masked-priming same-different activates lexical representations. Thus, the claim of Kinoshita and Norris (2009) that that task is free of lexical influences is not supported by the data from Chapters 2 and 3. Furthermore, the locus of the word advantage is due to different representations being utilized by words and nonwords in the matching process. Specifically, words utilize both lexical and sublexical representations, whereas nonwords only utilizing sublexical representations.

The aim of Chapter 4 was to further explore higher level linguistic influences in the visual only version of the masked-priming same-different task. Experiment 7 tested the effects of phonology, using the same heterographic homophones as used in Experiment 4. There results showed that there was an overall effect of homophone, with slower responses for homophonic words, in both the "same" and "different" conditions, suggesting that phonology may play a role in the task. However, the pattern of results may also be the result of the activation of both lexical versions of the homophone, leading to competition between the representations. Nevertheless, this may be due to the activation of the joint phonological representation.

The critical result of Experiment 7 was the significant priming effect in the "different" condition, this finding is different from those in previous studies

(Norris & Kinoshita, 2008; Kinoshita & Norris, 2009; Kelly et al., 2013) and those present in Chapters 2 and 3. However, a possible explanation for this unexpected finding is that there is a large degree of orthographic overlap between the heterographic homophone pairs, with most differing by only one or two letters (e.g., warn and worn). Although, the number of letters shared varies, it is confounded with the length of the word pairs. The highest variance in the shared letters of the homophone pairs occur in words that are seven and eight letters long. However, it should be noted that this orthographic overlap is unlike to be responsible for the overall homophone effect because the nonhomophonic control pairs were matched in the number of shared letters in the "different" condition. Furthermore, there was no interaction between string type and priming condition in either the "same" or "different condition. Thus, the influence of phonology cannot be ruled out. Future experiments could further investigate this by systematically vary the degree of orthographic overlap.

Experiment 8 investigated the influence of semantics in the masked-priming same-different task by presenting semantically related words pairs in the "different" condition. The results revealed the same pattern of priming as those in Chapter 2, thus indicating that semantic processes did not impact the pattern of priming. These findings are in contrast to studies that found semantic effects in the masked-priming same-different task using non-cognate translation primes (Lupker, Perea and Nakayama, 2015). However, this influence of semantics in their study was only robust for cross-script primes (Japanese - English), but not for same-script primes (Spanish - English). Lupker, Perea and Nakayama suggested that the difference in the priming effects for same- and different-script non-cognates may be due the larger translations effects generally found in the lexical decision task for different-script bilinguals. An alternative explanation is that although non-cognates are words with the same meaning spelt differently in each language, many words do share some degree of orthographic overlap in the same-script pairs (e.g., barco - BOAT). This overlap may modulate the semantic effects. Nevertheless, Lupker, Perea and Nakayama overall conclusion, that their results demonstrate that the priming effect in the masked-priming same-different task is not solely the result of the orthographic overlap are consistent with the findings reported in Chapters 2, 3 and 4.

The experimented reported in Chapters 2, 3 and 4concentrated solely on the masked-priming same-different task. Chapter 5 focussed on comparing three masked-priming tasks that have been used to investigate orthographic processing: the masked-priming lexical decision task (Experiment 9), the sandwich priming task (Experiment 10), and the masked-priming same-different task (Experiment 11). Lupker and Davis (2009) suggested that the masked-priming sandwich priming task is more sensitive to the orthographic processes than the standard masked-priming task. The experiments in Chapter 5 focussed on scrambled primes, as they share no absolute position information, and the amount of shared relative positional information with the target words. Unlike the previous experiments six letter words were use, because only with six letter words it was possible to manipulate the degree of shared relative positional information (either 3, 4 contiguous, 4 non-contiguous, 7 bigrams& ALD). Although the degree of overlap was based on Match Scores between primes and targets calculated using the open-bigram model (Grainger and van Heuven, 2003), other current models of letters encoding predict a similar level of overlap (see Table 10 in Chapter 5). Experiment 9 involved the standard lexical decision task and the results revealed no priming effects for any of the scrambled prime conditions. This is in line with previous studies that have used primes that share a small amount of an orthographic overlap (e.g., all letter transposition primes, Guerrera& Forster, 2008; 3 letter substitution primes, Schoonbaert& Grainger, 2004).

As predicted, there was a significant priming effect for all scrambled primes in the masked-priming same-different task (Experiment 10). However, there was no difference in the size of the priming effect across the different scrambled priming conditions. This result goes against the predictions made by most current models. The masked-priming sandwich task (Experiment 11) also revealed significant priming effects. However, unlike the same-different task, there were significant differences in the size of the priming effects in line with the degree of orthographic overlap, with a significant priming effect for seven shared bigram primes compared to both the ALD and 3 shared bigram primes and no priming effect between three shared and ALD primes. These results revealed a pattern of priming effects that is consistent with the predictions of most models in the literature.

Although Match Scores are good predictors of the size of the priming effect, Lupker and Davis (2009) noted that they are not perfect. A problem with Match Scores is that for some models (e.g., bigram based models) the scores are only based on the similarity between the prime and target but not the difference, thus excluding the possibility of inhibition from these differences. For example, in Lupker, Zhang, Perry and Davis (2015) suggested that for superset primes (e.g., wjudge or judgew - JUDGE) Grainger and van Heuven's (2003) bigram model would produce a score of 1, because the prime contains all the same bigrams as the target. However, superset primes also produce bigrams not contained in the target, i.e., superset prime *wjudge* would produce the bigrams *wj*, *wu*, and *wd*, which are not contained in the target. Thus, the prime-target pair only shares nine out of the possible twelve bigrams (75% or a score of .75). This is a significant problem for Match Scores as models based on a connectionist IA framework generally include both bottom-up and lateral inhibition at the lexical level. This is particularly relevant for both the masked-priming same-different and sandwich priming task as the relationship is no longer a simple prime-target relationship but a reference/target-prime-target relationship. A solution to this is to average the Match scores produced by the comparisons of the overlap between the target/reference-prime and prime-target. This does not only change the predictions made for bigram based models, but also the spatial-coding model (Davis, 2010).

Rather than relying on Match Scores it would be better to use computational models and run simulations with the stimulus material. The next section presents some primary computer simulations with three models of visual word recognition to investigate which of these models is able to simulate the pattern of priming reported in Chapter 5.

Simulation Studies

Simulations were conducted using four implemented models of visual word recognition: the Bayesian Reader (Norris, 2009), the Spatial-Coding model (Davis, 2010), the Binary Open-Bigram model (using the Interactive Activation Network Constructor (IANC) version 2.73, van Heuven, 2015), the Letters in Time and Retinotopic Space (LTRS) (Adelman, 2011). There were several reasons for choosing these three models. Firstly, they are four of the most current models of letter encoding. Secondly, the Bayesian Reader and Spatial Coding models have been used to model the underlying processes of the masked-priming same-different and sandwich task, respectively. Furthermore, they are currently, the only models that have simulated their related tasks. Although, the LTRS model can only model the lexical decision task the model itself uses a similar method of encoding letter-position information to the Spatial Coding model but is not its underlying architecture is not based on the IA model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). Finally, the Binary Open-Bigram model was used because it represents the alternative model of the masked-priming same-different task presented in Chapters 2 and 3. Importantly, the Binary Open-Bigram model is also the only model that can currently simulate the three masked-priming tasks used in Chapter 5.

Although the simulations were carried out on the all stimuli used in Chapter 5, the two four shared bigram conditions (non-contiguous and contiguous) were treated as a single condition, because there was no difference in the size of the priming effect between these conditions in the experimental data (see Chapter 5). The parameters used for each model are presented in Tables 25 - 31.

Table 25. *Parameter for the Open-Bigram model, used for the simulation of the results of Experiment 9, the standard masked priming lexical decision task.*

Parameter	Value	Description
MaxActivation	1	Maximum node activation
MinActivation	-0.2	Minimum node activation
Excitation Feedback	0.3	Word to letter total excitation feedback
MaxInhibition	-0.015	Letter to word inhibition (for each letter) or open-bigram to word inhibition
ActivationRate	0.1	Set temporal resolution
ActivationThreshold	0.68	Response threshold (lexicon)
pField	0	Field the target string is presented
tField	30	Field the prime string is presented
excitation	0.07	Sets the excitation value
maxCycles	600	Max number of cycles the simulation runs

Table 26. *Parameter for the Open-Bigram model, used for the simulation of the results of Experiment 9, the masked-priming same different task.*

Parameter	Value	Description
MaxActivation	1	Maximum node activation
MinActivation	-0.2	Minimum node activation
Excitation Feedback	0.3	Word to letter total excitation feedback
MaxInhibition	-0.015	Letter to word inhibition (for each letter) or open-bigram to word inhibition
ActivationRate	0.1	Set temporal resolution
ActivationThreshold	0.8	Response threshold (lexicon)
ActivationThreshold	0.68	Response threshold (short-term memory)
pField	0	Field the target string is presented
tField	30	Field the prime string is presented
excitation	0.07	Sets the excitation value
maxCycles	600	Max number of cycles the simulation runs

Table 27. *Parameter for the Open-Bigram model, used for the simulation of the results of Experiment 11, the sandwich priming task.*

Parameter	Value	Description
MaxActivation	1	Maximum node activation
MinActivation	-0.2	Minimum node activation
Excitation Feedback	0.3	Word to letter total excitation feedback
MaxInhibition	-0.015	Letter to word inhibition (for each letter) or open-bigram to word inhibition
ActivationRate	0.1	Set temporal resolution
ActivationThreshold	0.68	Response threshold (lexicon)
pField	30	Field the target string is presented
tField	80	Field the prime string is presented
excitation	0.07	Sets the excitation value
maxCycles	600	Max number of cycles the simulation runs

Table 28. *Parameters* [*] *for the Spatial Coding Model simulations of both the masked prime lexical decision and sandwich priming tasks, Experiments 9 & 11, respectively.*

Parameter	Value	Description
Σ	1.25	Position uncertainty by length letter position uncertainty function
κ_{σ}	0.24	Position uncertainty by length function
FreqScale .	0.46	Scaling of word frequency in resting activities
FreqBias	1.8	Resting activity input to activity equation
min_l	-0.2	Minimum word node activity
min_w	-0.2	Minimum letter node activity
$decay_k$	0.35	Match-dependent decay
$decay_w$	1	Word activity decay
α_{FL}	0.28	Feature-letter excitation
γ_{FL}	6	Feature-letter inhibition
α_{LW}	0.4	Letter-word excitation
cp	2.5	Net word input
γ_{LW} .	0	Letter-word inhibition
γ_{WW} .	0.4	Word–word inhibition
α_{WW}	0.4	Word-word excitation
w_{mf}	0.35	Masking field weight
γ_{len}	0.06	Length mismatch
α_{WL}	0	Word–letter feedback
dt	0.05	Step size: Temporal scaling
Fgain	0.05	parameter for scaling word frequency in resting activities
μ	0.68	local activity threshold for word identification

[*]Note these are the same parameters used in Davis (2010) except $decay_k$ which was decreased from 0.4 to 0.35 as used in Lupker and Davis (2009) sandwich priming simulations.

Table 29. *The parameters and thresholds used for the Bayesian Reader model to model the Experiment 9, the standard masked priming lexical decision task.*

Parameter	Value	Description
InitialSD	10	The standard deviation of the sampling noise added to each element of the input vector
PositionSD	5	Standard deviation of the sampling noise added to the position code associated with each letter slot
Average	50	Average results over 50 iterations
MaxSteps	1500	Number of steps before stopping Stop after 1500 steps
MinSteps	5	Number of steps before starting
UseLetterFrequency	off	Use letter frequencies
SetWordPriors	on	Update word priors at end of prime
SetLetterPriors	off	Update letter priors at end of prime
SetProbePrior	off	Update probe/reference priors at end of prime
VirtualNonWordFrequency	0	Use virtual nonwords
UseBackgroundNonWords	off	Use background words
PrimeSteps	30	Prime presentation latency (in steps)
P_a_WordThreshold	0.95	The yes probability threshold
	0.05	The NO probability threshold
	10	The minimum number of steps before a response can be made

Table 30. *The parameters and thresholds used for the Bayesian Reader model to model the Experiment 10, the masked-priming same-different task.*

Parameter	Value	Description
InitialSD	10	The standard deviation of the sampling noise added to each element of the input vector
PositionSD	5	Standard deviation of the sampling noise added to the position code associated with each letter slot
Average	50	Average results over 50 iterations
MaxSteps	1500	Number of steps before stopping Stop after 1500 steps
MinSteps	5	Number of steps before starting
UseLetterFrequency	off	Use letter frequencies
SetWordPriors	on	Update word priors at end of prime
SetLetterPriors	off	Update letter priors at end of prime
SetProbePrior	on	Update probe/reference priors at end of prime
ProbeFrequency	1	Frequency given to the probe/references
VirtualNonWordFrequency	0	Use virtual nonwords
UseBackgroundNonWords	off	Use background words
PrimeSteps	30	Prime presentation latency (in steps)
ProbeRatioThreshold	0.95	The same response probability threshold
	0.05	The different response probability threshold
	10	The minimum number of steps before a response can be made

Table 31. *Parameters[*] for the Letters In Time And Retinotopic Space model, used to model Experiment 9, the standard lexical decision task.**

Parameter	Value	Description
Α	21.298 ms	Onset mean
Σ	12.262 ms	Onset SD
Ω	31.086 ms	Offset of the prime
Β	0.198 MHz	Processing Rate
Η	0.362 (Ratio: time−1/time−1)	Initial position: Identity Ratio
Λ	3.53 (Ratio: time−1/time−1)	Position: Identity Ratio

[*] Note these are the parameter values fitted to data summarized by Davis (2010) this was because these parameters allow for different string lengths.

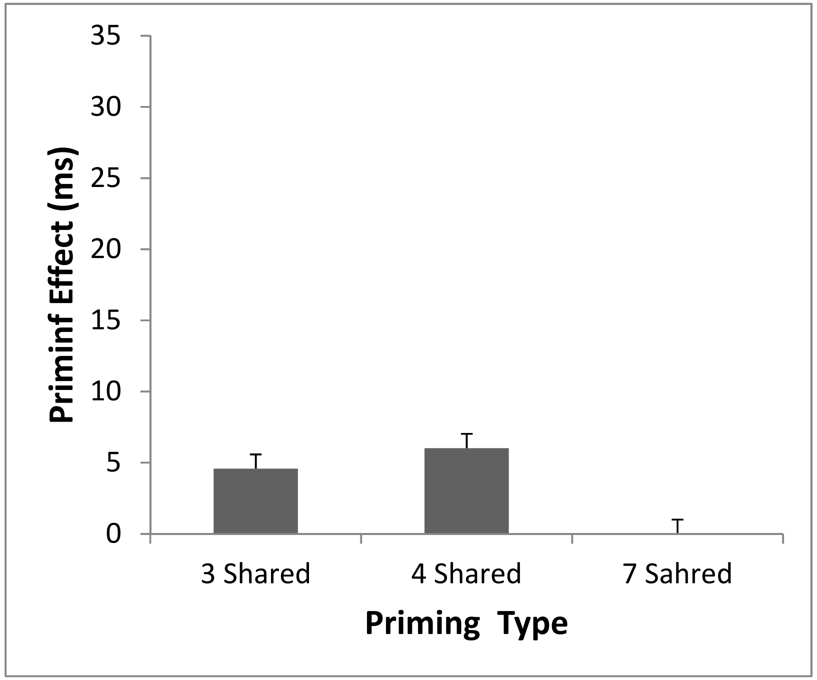
Simulation Study 1: Masked-priming lexical decision task

No priming effects were observed in the standard masked-priming lexical decision task (Experiment 9). However, the simulations shown in Figure 12, indicate that the Open Bigram produced significant priming effects for the 7 shared priming condition and smaller priming effects for the both the 4 shared and 3 shared conditions. This is in line with the predictions of the Match Scores (see Table10). However, this is not what the behavioural data showed, because no significant priming effects were found in Experiment 9 (See Figure11). Both the Bayesian Reader and LTRS models also produced priming effects although, these were smaller than those of the Open-Bigram model. However, again these effects were also linear effect with larger priming effects for the 7 shared compared to 4 shared and 3 shared conditions. Conversely, the behavioural results showed no priming for the 7 shared but small priming effects for both the 3 and 4 shared conditions. In contrast, the Spatial Coding model showed no priming across all condition the simulations are more consistent with the results of Experiment 9.

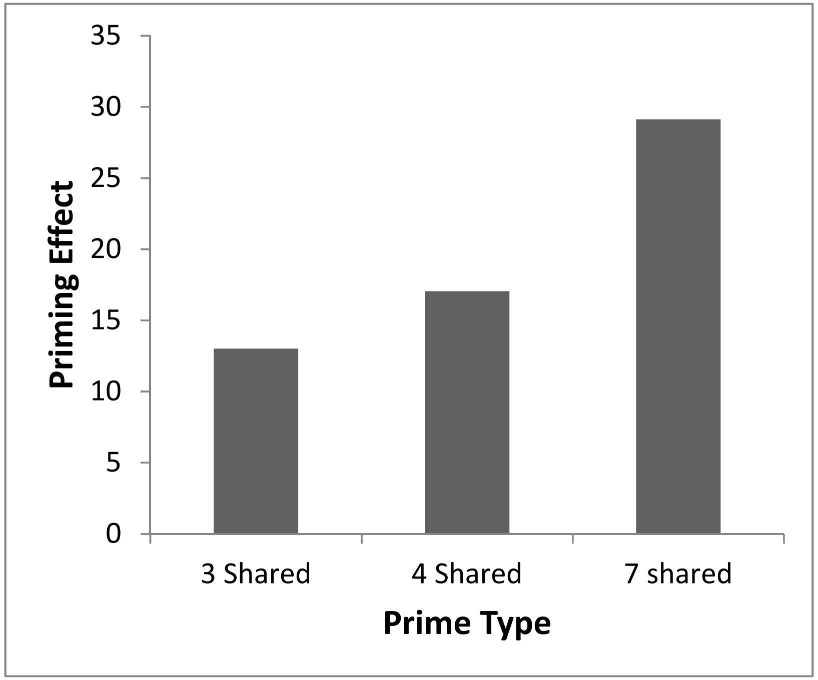
The large priming effects found in the Open-Bigram model can be reduced by increasing the level of excitation between consistent nodes. In the current version of the Open-Bigram model the excitation parameter is set at 0.07, by increasing this value to 0.2 the size of the priming effects are reduced.

Figure 12. Shows the comparison of the results of a) Experiment 9 using the standard masked-priming lexical-decision task and the simulation of the b) Open-Bigram model, c) Spatial-Coding model, d) Bayesian Reader model and e) Letters In Time And Retinotopic Space model.

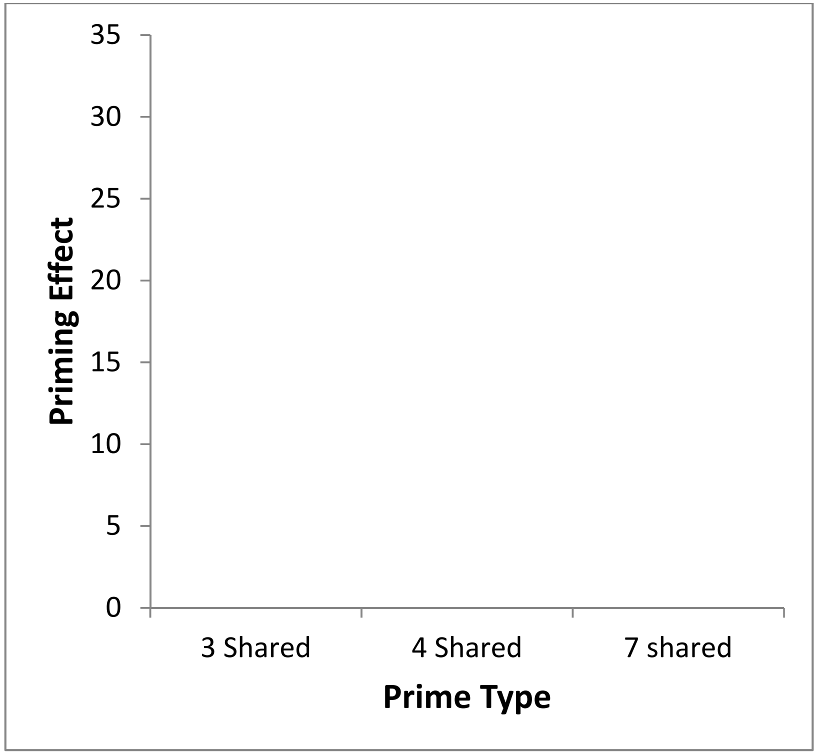
a)

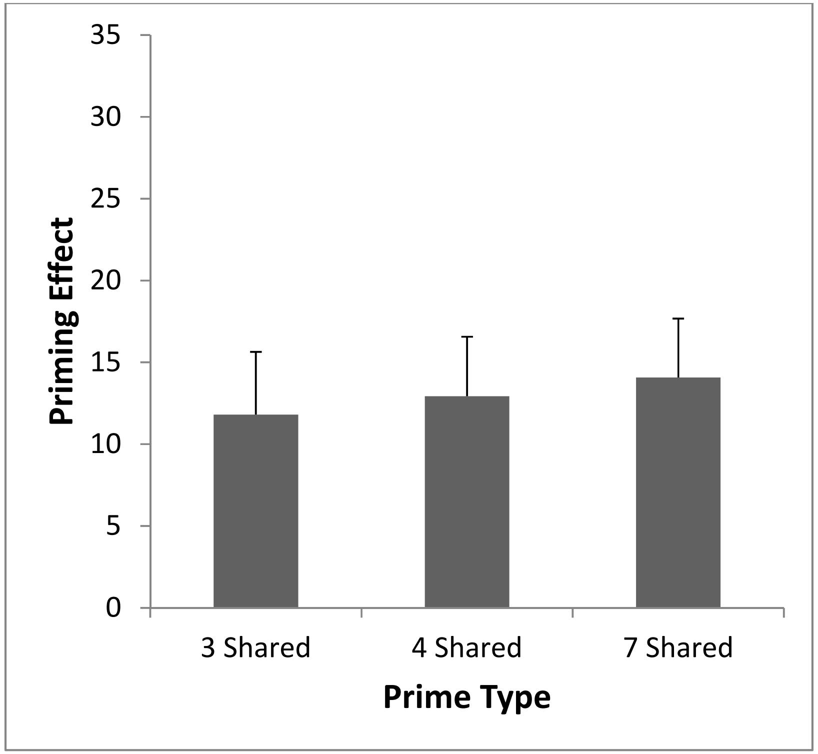


b)

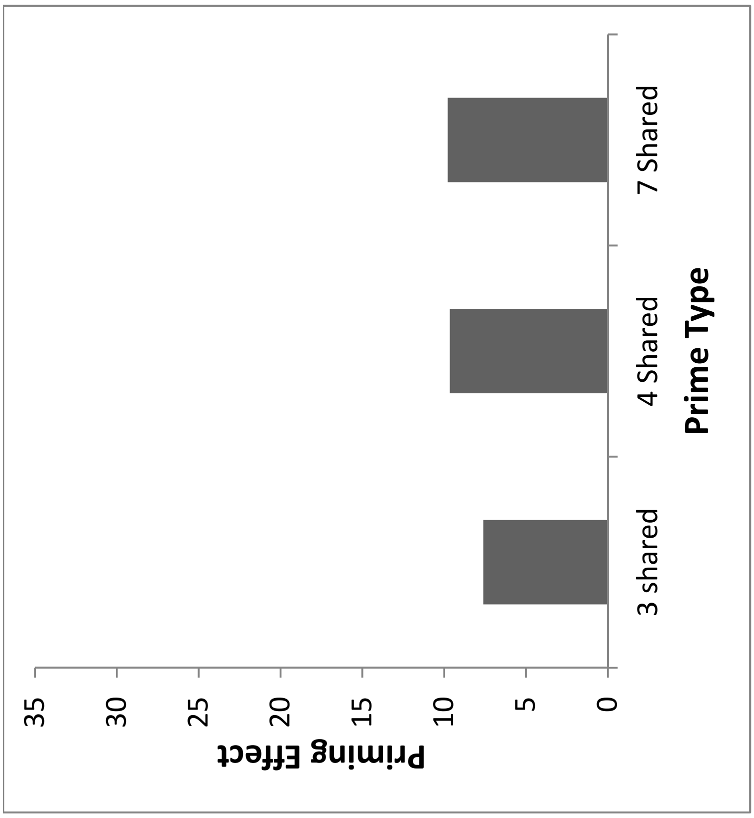


C)..d)


35
30
25
20
15
10
5
0
Priming Effect
3 Shared
4 Shared
7 shared
Prime Type


35
30
25
20
15
10
5
0
Priming Effect
3 Shared
4 Shared
7 Shared
Prime Type

e)


Priming Effect
35
30
25
20
15
10
5
0
3 shared
4 Shared
7 Shared
Prime Type

Simulation Study 2: Masked-priming Same-Different task

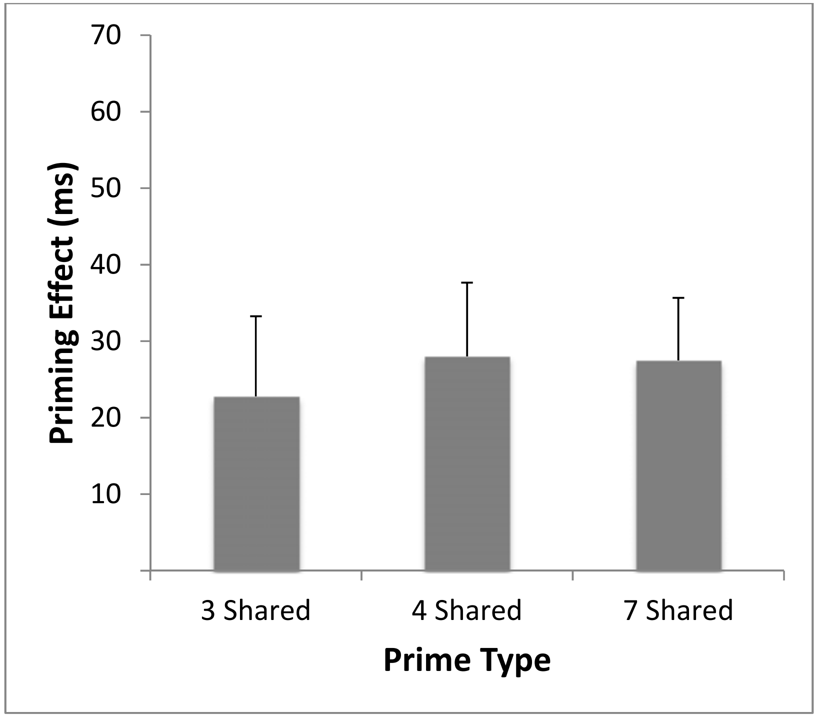
The second simulation study investigated whether the models could simulate the results of the masked-priming same-different task (Experiment 10). Both the Bayesian Reader and Open-Bigram models showed a priming effects for all prime types (see Figure 13), consistent the data from Experiment 10. The simulations with the Open-Bigram model revealed a linear priming effect with a larger priming effect for seven shared bigram compared four bigrams, and, although smaller, for four compared to three shared bigrams. These results are consistent with the predictions of Match Scores (see Table 10).

The simulations with the Bayesian Reader Model showed the same linear effects as the Open-Bigram model except the priming effects were much larger twice those of the behavioural data. The different in the overall size of the priming effects can be reduced by changing the ProbeRatioThreshold parameter. By reducing the "same" response probability threshold from 0.95 to 0.99 the overall size of the priming effects are also reduced without affecting the overall pattern of priming.

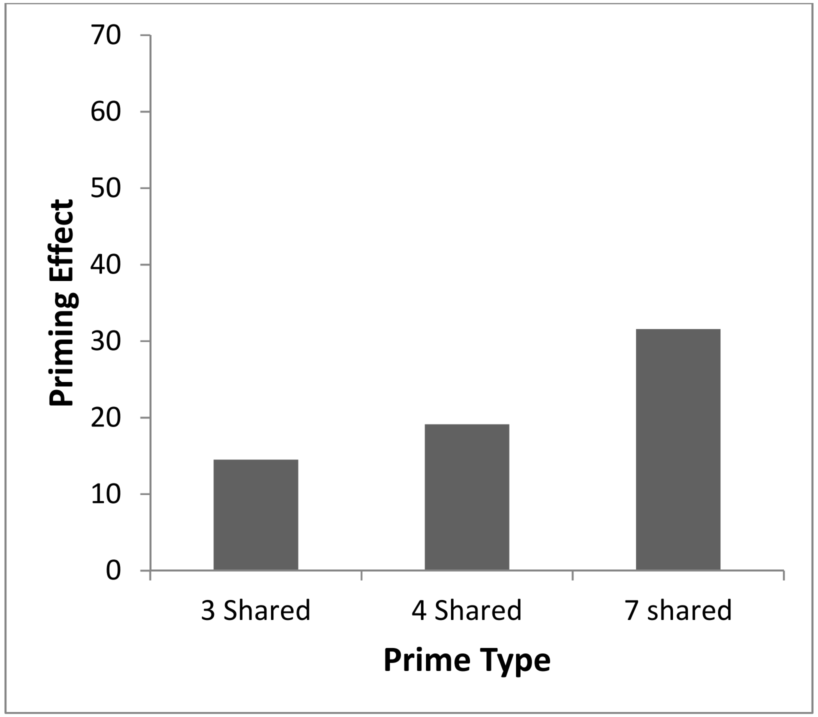
Although the priming effects for both the Open-Bigram and Bayesian Reader model is linear, contrary to the pattern from the behavioural data, this may not be the result of differences in the encoding of the letter position. An experiment not reported in this thesis, using the exact same stimuli as Experiment 10, did reveal a linear priming effect (see figure 14) The only difference between this experiment and previous experiments was that the references, primes and targets were all presented in lowercase. This change in the case and the corresponding results suggest that pattern of priming seen in Experiment 10 may in part be due to the change in case between the reference/prime and the target, thus a lower level visual effect occurring at the letter level (letter identification). As discussed in the introduction, almost all current models of word recognition (including the models simulated here) start after letter identification occurs. This means that they assume that the process for identifying letters has minimal or no effect on the overall priming effect. Several studies have investigated the effects of cross case visually similar (e.g., c/C, x/X) and dissimilar letters (e.g. a/A, b/B) in both the masked-priming lexical decision and masked-priming same-different task (Bowers, Vigliocco, and Haan, 1998; Kinoshita and Kaplin, 2008, respectively). Although they have demonstrated that cross case dissimilar letters do produce priming effects, the overall size of the priming effects are significantly larger for similar than dissimilar letter. Further, Kinoshita and Kaplin's (2008) study, using the masked-priming same-different task, only investigated the priming of individual letters and not words containing dissimilar letters. Importantly, neither the Bowers Viglocco, and Haan or the Kinoshita and Kaplin studies investigated the effect of cross case dissimilar letters in reference to letter position encoding. The aims of both studies were to investigate the nature of the representations used in letter encoding, and in the Bowers, Viglocco and Haan if the nature of the task modulated the overall effect of cross case dissimilar letters. Therefore, a more thorough systematic investigation into the effects of cross case dissimilar letters is needed.

Figure 13. Shows the comparison of the results of a) the masked-priming same-different (Experiment 10) task and the simulation of the b) Open-Bigram model, and c) Bayesian Reader model

a)



b)



c)

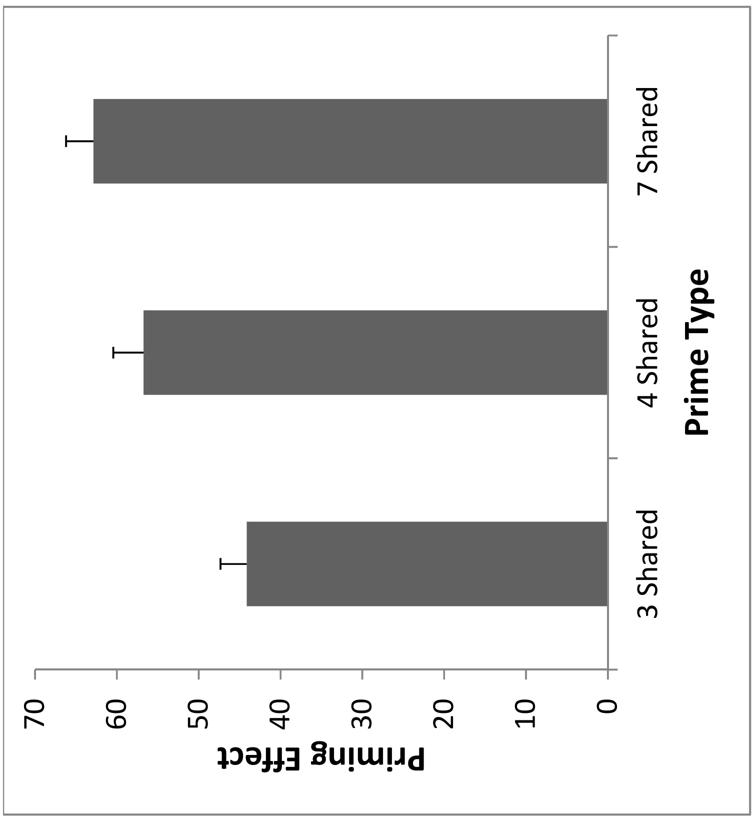
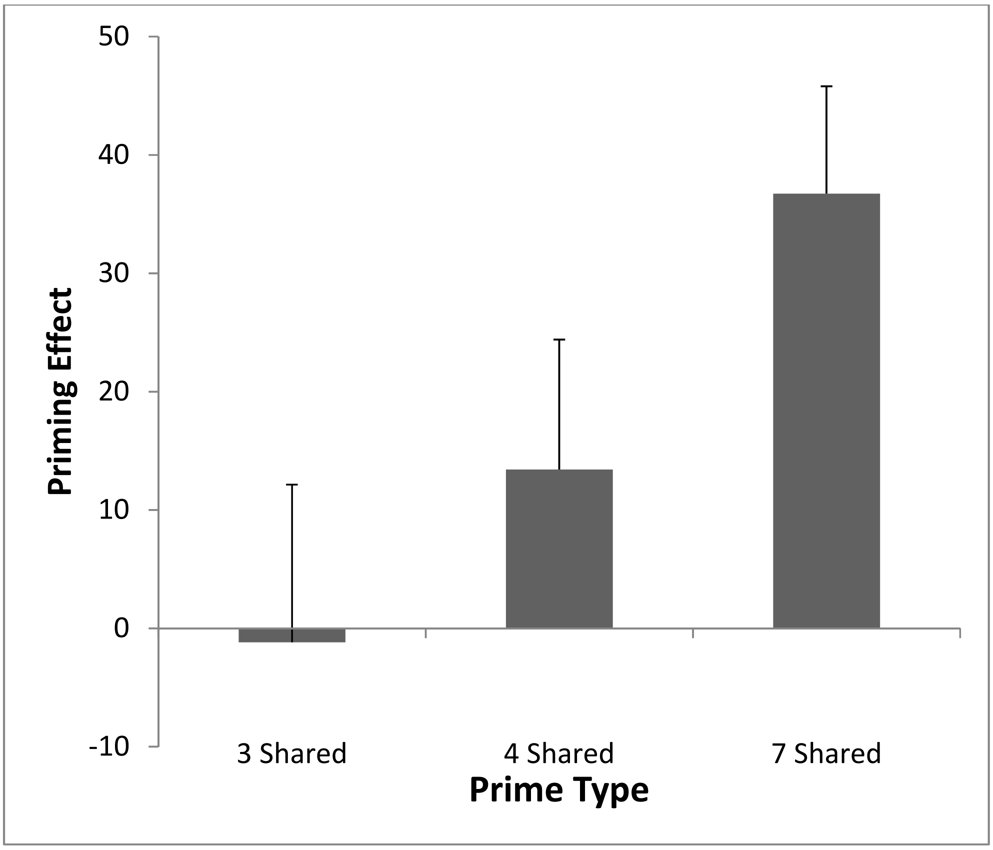

Priming Effect
70
60
50
40
30
20
10
0
3 Shared
4 Shared
7 Shared
Prime Type

Figure 14. Graph showing the priming effects for the masked-priming same-different task using the stimuli from Experiment 10 when the references, primes, and targets are all presented in lowercase.



Simulation Study 3: Masked-priming Sandwich Task

The final simulation study evaluated the ability of the models to simulate the pattern of results obtained in masked-priming sandwich task (Experiment 11). However, this time simulations were only conducted with the Open-bigram and the Spatial-Coding models as currently neither the LTRS or Bayesian Reader model is not currently able to simulate this task

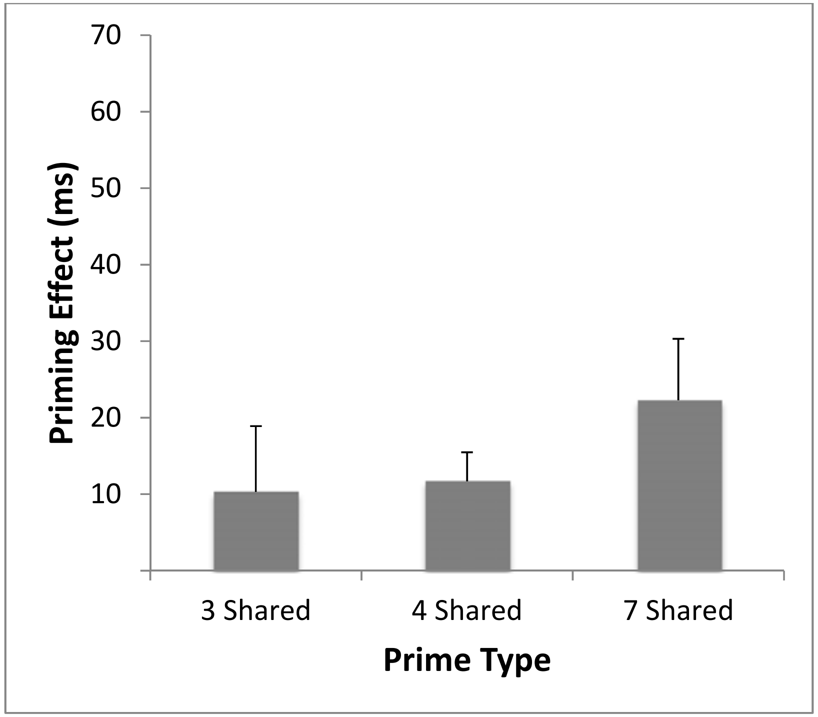
The simulations results of the Open-Bigram model revealed the same pattern of priming as obtained with the masked-priming same-different task (Simulation Study 2), larger priming effects for seven shared compared to four shared, and four compared to three shared (see Figure 15). This is in line with the linear pattern of priming obtained in Experiment 11. In contrast, the Spatial-Coding model produced negligible priming effects across all conditions. This is an unexpected finding, because the explanation of the processes involved in the task, given by Lupker and Davis (2009) were based on the Spatial-Coding model. However, by changing the DecayCutOff ($decay_k$) parameter priming effects may be produced.

The DecayCutOff is the match depended control for the exponential node decay. In the standard IA, nodes decay at an exponential rate towards the resting value regardless how well they match the input stimulus. However, in the SCM there is no decay for word nodes that match the input stimulus well. This means that activation level of word nodes that's match value ≥ than the DecayCutOff value will no longer be effect by exponential decay but only by the level of matching and mismatching between the input stimuli and the word nodes. If the match value is reduced by any mismatch between the input and the word nodes so that its overall value falls below the DecayCutOff value exponential decay is reintroduced.

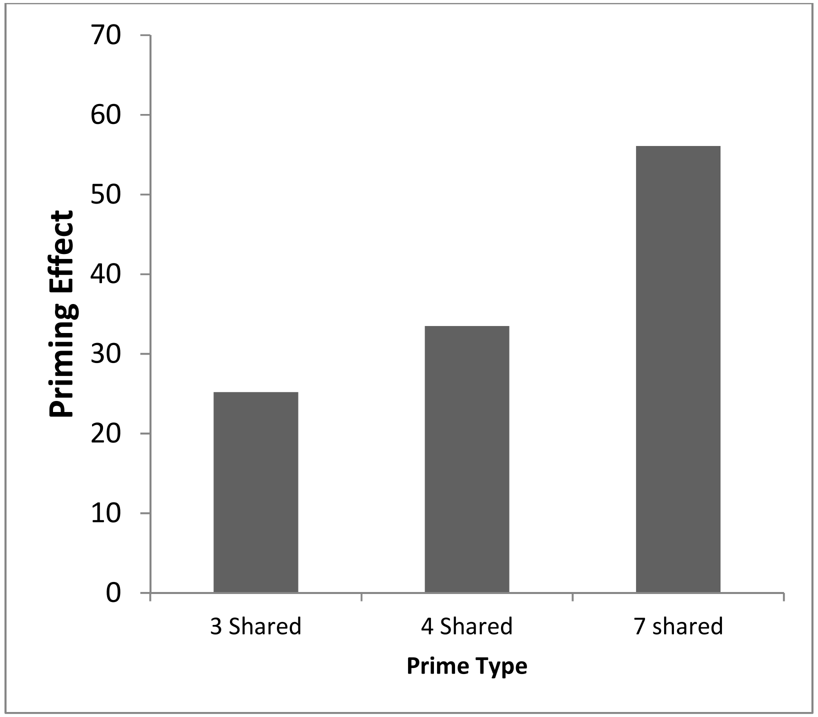
As discussed in the introduction, the nature of the sandwich priming task, specifically the brief presentation of the target before the prime, gives the target word node a boost. If this boost produces a match value that is greater than the DecayCutOff, then the target node is not only given a head start in regards to its activation level but also removes the effects of exponential decay. Further, the degree of match and mismatch match between the stimulus and the word node becomes the primary factor for the level of the nodes activation. Therefore, the greater the overlap between the prime and target means a smaller effect of inhibition, and a slower decline in the activation level of the node, thus producing a larger priming effect. To test this, the DecayCutOff was systematically reduced in 0.25 steps from the original 0.35 to 0. As shown in Figure 16, priming starts to appear when the DecayCutOff is set to 0.3, with a similar pattern of priming as the Open-Bigram simulations between 0.3 and 0.2, also increasing the size of the priming effect as the DecayCutOff is reduced. Importantly, changing the DecayCutOff did not affect the level of priming for the masked-priming lexical decision task simulation. However, further simulation are needed to test whether this reduction in the DecayCutOff effects previous simulation carried out by Davis (2010).

Figure 15. Shows the comparison of the results of a) sandwich priming (Experiment 11) task and the simulation of the b) Open-Bigram model, and c) Spatial-Coding model

a)



b)



c)

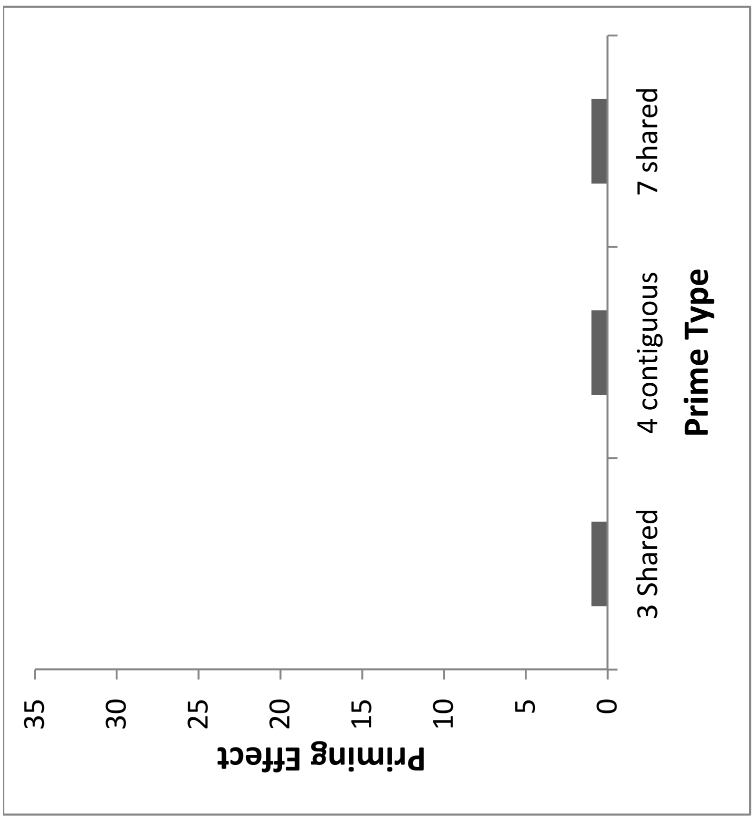
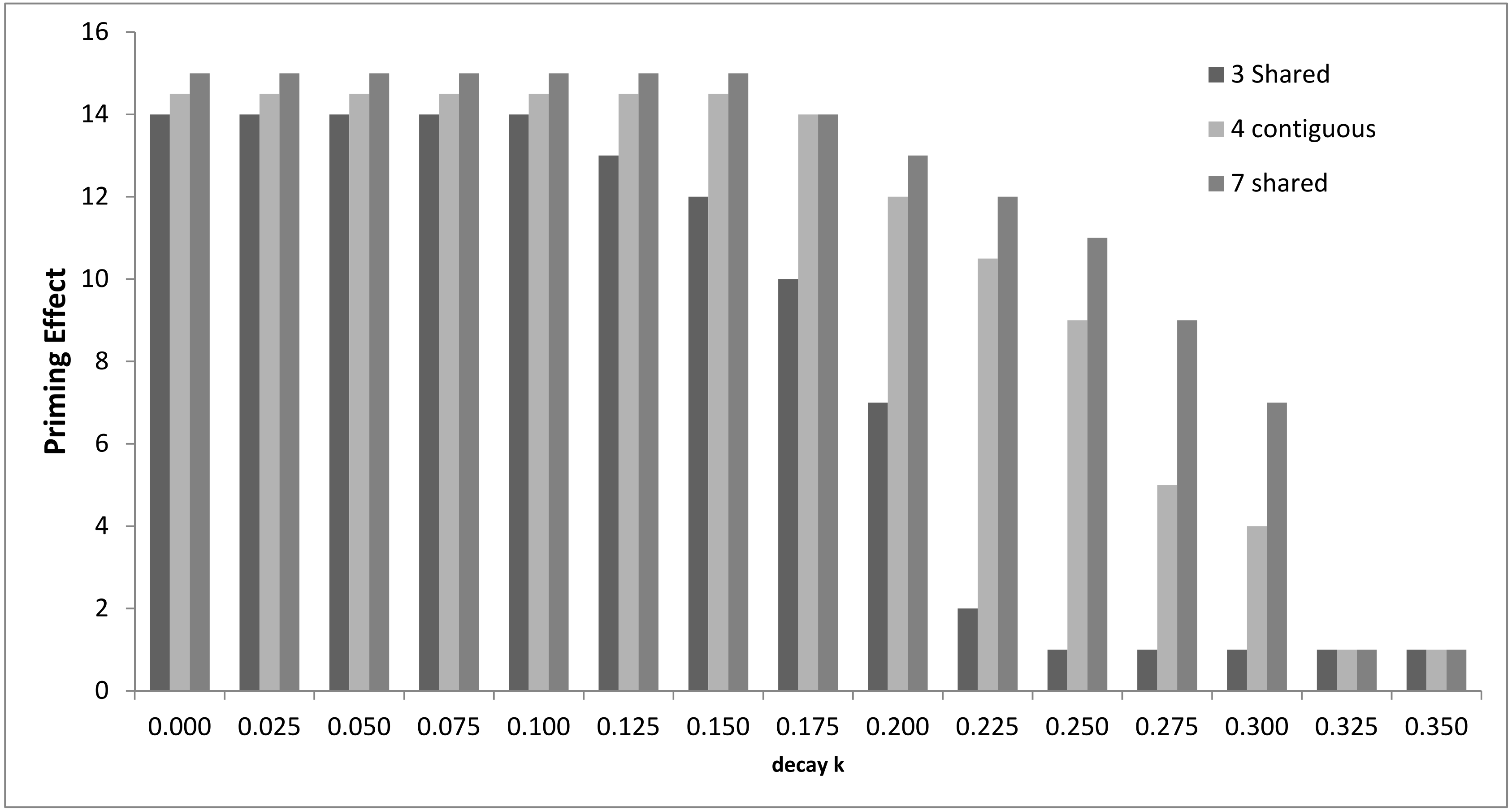

Priming Effect
35
30
25
20
15
10
5
0
3 Shared
4 contiguous
7 shared
Prime Type

Figure 16. Priming effects for the spatial coding model when the $decay_k$ parameter is systematically reduced.



Simulation Studies: Summary and Conclusions

Overall, the results of the simulation studies reveal that, in their current implementations, none of the models were successful at modelling the results from Experiments 9 - 11. For the masked-priming lexical decision task (Experiment 9), which tested all four models, only the SCM (Davis, 2010) produced results similar to the behavioural data with minimal or no priming effects. The Open-Bigram (van Heuven, 2015), Bayesian Reader (2009) and LTRS (Alderman, 2011) models produce larger priming effects, with a linear pattern not seen in the behavioural data. Furthermore, the Open-Bigram model produce significant priming effects for the 7 shared bigram condition.

The simulations of the masked-priming same-different task, using the Open-Bigram and Bayesian Reader model, produced the priming effects however, the pattern of priming was different to that of the behavioural data from Experiment 10. However, as discussed above, this may be the result lower-level visual processes connected to the identification of letters. Currently, most models of visual word recognition ignore the processes involved in letter identification and start after letter identification has occurred, or assume that there is no processing difference for cross case dissimilar letters. The influence of low-level visual processes may also provide an explanation for the pattern of priming produced by the Open-Bigram, Bayesian Reader, and LTRS models in the lexical decision task.

Finally, when the sandwich priming task was simulated using the SCM and Open-Bigram model only, the Open-Bigram model produced priming effects constant with the behavioural data. Furthermore, the pattern of priming was also constant with the behavioural data. The SCM produce minimal priming across all condition. This is a surprising result considering that the SCM has previously been used both to simulate and explain the processes involved in the sandwich priming task (Lupker and Davis, 2009).

Although none of the models in their current implementation were able to account for the behavioural data, by simply adjusting the parameters of each model it was possible to produce a better fit to the behavioural data. However, these adjustments were either to the underlying architecture of the models (i.e., changes to the DecayCutOff in the SCM and the excitation in the Open-Bigram model) or the decision threshold (i.e., the probability threshold for the same decision in the Bayesian Reader model) and not the method used for encoding letter position. Thus, the adjustment does not provide evidence for or against any particular letter positional coding system. Nevertheless, the use of implemented models to simulate experimental data does provide a critical tool in the investigation of visual word recognition by providing a framework to test theoretical assumption.

Impact of word shape on orthographic processing

The experiments for Chapters 2 - 5 have concentrated on letter encoding, however, other non-lexical orthographic processes may also affect the processing of words. In particular, Chapter 6 investigated the role of word shape. As discussed in Chapter 6, previous experiments investigating word shape showed contradictory results because of the use of distorted stimuli by alternating the case (e.g. AlTeRnAtInG, Besner, 1989), the size of individual letters (e.g., alternating, Perea& Rosa, 2002), or distorting the overall shape (Perea, Comesana, Soares, &Moret-Tatay, 2012). To overcome this problem the lexical decision task was used in Chapter 5 to compare five-letter words and nonwords, each containing only one ascender or descender in one of the five possible positions (e.g., 'frame', 'charm', 'eaten', 'scale' or 'ranch'),to control words and nonwords containing no ascenders or descenders (e.g., 'manor').

The results from Experiment 12, using ascenders only, revealed a significant processing advantage of ascenders position four and an effect for bigrams containing letters at position one and four. There was no difference in the effects of ascenders for words and nonwords. In the control non-ascender condition there were no effects based on letter position. It is important to note that for the control condition it was the lack of bigram which were used to test for simple effects due to the position of a letter. Experiment 13 was similar to experiment 12 except that descenders were used. This experiment was conducted to test the theory that the effects found in Experiment 12 may be specific to ascenders and not an effect of shape. Interestingly, the results also showed a facilitatory effect for descenders at letter position three compared to descenders at five, again for words and nonwords. Further, there were significant effects for bigrams containing letters at positions two and four, and two and five. However, in the control condition there was an effect for Bigrams containing letters in positions one and two, and three and four. This suggests that the effect of ascender-descender position may be the result of the normal reading fixation point for five letter words, which falls between letter positions three and four, thus making the ascender-descender more salient.

Experiments 14 and 15 tested the role of the normal reading fixation point by presenting ascender-descenders, respectively, above and below the normal fixation point. The results from Experiment 14 revealed that for ascenders presented above the fixation point words there was a processing advantage for ascenders at position four compared to three. For the nonwords the processing advantage occurred for ascenders in position three compared to one. Similar to Experiment 12, there were no effects for the control non-ascenders. When the ascenders were presented below the fixation point, there was only an effect for bigrams containing letters at positions two and four. However, for the non-ascenders there was an effect of bigrams with letters at positions three and five. Conversely, in Experiment 15, the only effect found was in the non-descender above fixation point condition, for bigram with letters in positions one and three.

The results presented in Chapter 6 indicate that the effects of ascender-descenders are in part due to the normal reading fixation point, because the majority of the effects were found for letters at positions thee and four. However, the results still suggest that the effects are due to the orthographic nature of the ascender-descender and not any lexical properties. As discussed in Chapter 6, the frequency of ascender-descenders is nearly half that of non-ascender-descender letters. Nevertheless, the results of Chapter 6 are not consistent with a completely shape-based theory. Although more experiments are needed to investigate the role of shape on visual word processing further, the present experiments have demonstrated that it is possible to investigate the role of shape without distorting the stimuli.

Conclusions

The experiments presented in Chapters 2 - 4 have systematically investigated the processes and nature of the representations used in the masked-priming same-different task. The overall results indicate that, in contrast to the suggestion of Kinoshita and Norris (2009), the task is not a pure measure of orthographic processes. The masked-priming same-different task can be affected by processes at other levels, e.g., lexical, or phonology. This along with the similarity of the results of this task with the masked-priming sandwich task suggest that it may not be able to produce a task that could be completely free from influences from other levels (e.g., phonology, lexical)when using real word stimuli. Nevertheless, the experimental data produced by both the masked-priming same-different and the sandwich task has proved to be problematic for current models of letter encoding. However, with simple adjustments to the underlying parameters these models can produce a better fit. Although, these adjustments do not help to disambiguate the differences in letter position coding between the competing models. Additionally, Chapter 6 presented a method of investigating word-shape without the need to distort the visual appearance of stimuli. Thus, to conclude, this thesis has demonstrated that models of visual word recognition are currently unable to explain all the processes involved in visual word recognition. Specifically, effects that occur during the processing of letter identities.

References

Adams, M.J. (1979). Models of word recognition. *Cognitive Psychology*, 11, 133-176.

Adelman, J., Johnson, R., McCormick, S., McKague, M., Kinoshita, S., Bowers, J., Perry, J., Lupker, S., Forster, K., Cortese, M., Scaltritti, M., Aschenbrenner, A., Coane, J., White, L., Yap, M., Davis, C., Kim, J., & Davis, C., (2014). A behavioural database for masked form priming. *Behaviour Research Methods, 46*, 1052–1067.

Adelman, J. (2011). Letters in Time and Retinotopic Space. *Psychological Review, 118*, 570-582.

Allen, P., Wallace, B., & Weber, T., (1995), Influence of case type, word frequency and exposure duration on visual word recognition. *Journal of experimental psychology. Human perception and performance, 21*(4), 914-34.

Angiolillo-Bent, J. S., & Rips, L. J. (1982). Order information in multiple-element comparison. *Journal of experimental psychology. Human perception and performance, 8*(3), 392-406.

Besner, D., (1989). On the role of outline shape and word-specific visual pattern in the identification of function words: None. *The Quarterly Journal of Experimental Psychology, 23*(5) 91-105.

Besner, D., & Johnston, J. C. (1989). Reading and the mental lexicon: On the uptake of visual information. In W. Marslen-Wilson (Ed.), *Lexical representations and processes,* 291-316. Cambridge, MA: MIT Press.

Besner, D., McCann, R., (1987) Word frequency and pattern distortion in visual word identification and production: An examination of four classes of models. In M. Coltheart, (Ed)*Attention and performance 12: The psychology of reading.* 201-219. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Besner, D. (1983). Basic decoding components in reading: Two dissociable feature extraction processes. *Canadian Journal of Psychology*, *37*, 429-438.

Bodner, G., Johnson, J., (2009). Repetition proportion affects masked priming in nonspeeded tasks. *Psychonomic bulletin and review, 16*(3), 497-502.

Bodner, G., Masson M., (2003). Beyond spreading activation: an influence of relatedness proportion on masked semantic priming. *Psychonomic Bulletin And Review, 10*(3), 645-52.

Bodner, G.E. & Stalinski, S.M. (2008) Masked repetition priming and proportion effects under cognitive load. *Canadian Journal of Experimental Psychology, 62*, 127-131.

Bowers, J.S. (2010). Does masked and unmasked priming reflect Bayesian inference as implemented in the Bayesian Reader? *European Journal of Cognitive Psychology, 22*, 779-797.

Bowers JS, Kouider S (2003) Developing theories of priming with an eye on function. In: J.S. Bowers & C. Marsolek. *Rethinking Implicit Memory*. Oxford: Oxford University Press.

Bowers, S., Vigliocco, G., & Haan ,M. (1998). Orthographic, phonological, and articulatory contributions to masked letter and word priming.

Journal of Experimental Psychology: Human Perception and Performance, *24*(6), 1705-1719.

Brysbaert, M., & New B., (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behaviour Research Method, 41*(4), 977-990.

Chambers, S., M., & Forster, K.I. (1975). Evidence for lexical access in a simultaneous matching. *Journal of Memory and Cognition, 3*(5), 549-559.

Caramazza, A. & Miceli, G. (1990). The structure of graphemic representations. *Cognition, 37*, 243-297.

Coltheart M., Rastle K., Perry C., Langdon R., & Ziegler J., (2001). DRC: A Dual Route Cascaded Model of Visual Word Recognition and Reading Aloud. *Psychological Review, 108*(1), 204-256.

Davis, C. (2003). Factors underlying masked priming effects in competitive network models of visual word recognition. In S. Kinoshita & S. J. Lupker (Eds.) *Masked Priming: The State of the Art.* Philadelphia: Psychology Press.

Davis, C., (2010) The spatial coding model of visual word identification. *Psychological review, 113*(2), 713-58.

Davis, C. (2010). The Spatial Coding Model Simulator. http://www.bristol.ac.uk/expsych/research/processes/clc/resources/scm/

Davis, C. (2012)The spatial coding model of visual word identification. *Psychological review, 117* (3), 713-58

Dunabeitia, J., Kinoshita, S., Carreiras, M., & Norris, D., (2010) Is morpho-orthographic decomposition purely orthographic? Evidence from masked priming in the same-different task. *Journal of Language and Cognitive Processes,* 26,509-529

Finkbeiner, M. & Coltheart, M. (2008). Letter recognition: From perception to representation. *Cognitive Neuropsychology, 26* (1), 1–6.

Forster, K. I., & Forster, J. C., (2003) DMDX: A Windows display program with millisecond accuracy. *Behaviour Research Methods, Instruments, and Computers,* (1), 116-124

Forster, K., & Davis, C., (1984) Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10* (4), 680-698.

Gomez P., Ratcliff R., &Perea M.(2008). The overlap model: a model of letter position coding. *Psychological Review*, *115*(3), 577-600.

Gorfein, D. S., & Weingartner, K. M., (2008) On the norming of homophones. *Journal of Behaviour Research Methods,* 2, 522-530

Grainger J., Whitney C., (2004). Does the huamn mnid raed wrods as a wlohe? *Trends Cognitive Science.8*(2), 58-9.

Grainger J., Grainger, J., Farioli, F., van Assche E., & van Heuven W., (2006) Letter position information and printed word perception: the relative-position priming constraint. *Journal of experimental psychology. Human perception and performance, 32*(4), 865-84

Grainger J., (2008) Cracking the orthographic code: An introduction. *Journal of Language and Cognitive Processes, 23*(1), 1-35

Grainger, J. & van Heuven, W., (2003) Modelling Letter Position coding in printed word perception. In P. Bonin (Ed.) *Mental Lexicon. Some words to talk about words.* New York: Nova Science Publishers.

Grainger, J., & Jacobs, A., (1996), Norris, D., (2006) Orthographic Processing in Visual Word Recognition: A Multiple Read-Out Model. *Journal of The American Psychological Association 1966,* 3*,* 518-565

Guerrera C, Forster K., (2008) Masked form priming with extreme transposition. *Language and Cognitive Processes,* 23, 117–142.

Humphreys, G., Besner, D., & Quinlan, P., (1988). Event perception and the word repetition effect. *Journal of Experimental Psychology*, 117, 51-67.

Hutchison, K. Balota, D. Neely, J. Cortese, M. Cohen-Shikora, E. Tse, C. Yap, M. Bengson, J. Niemeyer, D., & Buchanan, E. (2013) The semantic priming project. *Journal of Behaviour Research Methods 45*(4), 1099–1114

Kelly, A. N., van Heuven W. J. B., Pitchford N. J. &Ledgeway T. (2013). Is the masked priming same-different task a pure measure of prelexical processing? *PLoS ONE*, *8*

Kerswell, L. Siakaluk, P. Pexman, P. Sears, C., & Owen, W. (2007) Homophone effects in visual word recognition depend on homophone type and task demands. *Canadian journal of experimental psychology61*(4), 322-7

Kinoshita, S. (1987). Case alternation effect: Two types of word recognition? *Quarterly Journal of Experimental Psychology*, 39A, 701-720.

Kinoshita, S., Castles, A., & Davis, C. (2009). The role of neighbourhood density in transposed letter priming. *Language and Cognitive Processes, 24*, 506-526.

Kinoshita, S. & Kaplan L (2008) Priming of abstract letter identities in the letter match task. *Quarterly Journal of Experimental Psychology, 61*, 1873-1885.

Kinoshita, S. & Lagoutaris, S. (2010). Priming by NUMB3R5 Does Not Involve Top-Down Feedback. *Journal of Experimental Psychology: Learning, Memory and Cognition, 36*, 1422-1440. Kinoshita, S. & Norris, D. (2008) Perception as evidence accumulation and Bayesian inference: insights from masked priming. *Journal of Experimental Psychology. General*, *137*(3), 434–455

Kinoshita, S. & Norris, D. (2009) Transposed-letter priming of prelexical orthographic representations. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *35*(1), 1–18.

Lupker, S. & Davis, C., (2009) Sandwich priming: a method for overcoming the limitations of masked priming by reducing lexical competitor effects. *Journal of experimental psychology. Learning, memory, and cognition, 35*(3), 618-39

Lupker, S. J., Zhang, Y. J., Perry, J. R., & Davis, C. J. (2015).

Superset versus substitution-letter priming: An evaluation of open-bigram models. *Journal of Experimental Psychology. Human Perception and Performance, 41*(1), 138–151

Lupker, S., Perea, M., & Nakayama, M. (2015). Non-cognate translation priming effects in the same–different task, evidence for the impact of "higher level" information. *Journal of Language, Cognition and Neuroscience, 30*(7) 781-795.

Marmurek, H. H. C., (1989) Familiarity effects and word unitization in visual comparison tasks. *Journal of Memory and cognition,* (4), 483-9.

McClelland, J. L. & Rumelhart, D. E. (1981). An interactive-activation model of context effects in letter perception: IA. An account of basic findings. *Psychological Review*, 88, 375-407.

Norris, D., (2006) The Bayesian Reader: Explaining Word Recognition as an Optimal Bayesian Decision Process. *Psychological Review, 113* (2), 327-357.

Norris, D. (2009). Bayesian Reader Code. https://www.mrc-cbu.cam.ac.uk/people/dennis.norris/personal/BayesianReader

Perea, M. & Rosa, E., (2002). Does "whole-word shape" play a role in visual word recognition? *Perception and psychophysics, 64* (5), 785-94.

Perea, M., Comesana, M., Soares, A., & Moret-Tatay C., (2012) On the role of the upper part of words in lexical access: Evidence with masked priming. *Quarterly Journal of Experimental Psychology*, 65(5), 911-925.

Rey S., Dufau, S., Massol, S., Grainger, J. (2009).Testing computational models of letter perception with item-level event-related potentials. Cognitive Neuropsychology 26(1), 7-22

Rumelhart, D. E. & McClelland, J. L. (1982). An interactive activation model of context effects in letter perception: Part 2. The context enhancement effect and some tests and extensions of the model. *Psychological Review, 89,* 60-94

Sandra, D. (2010) Homophone Dominance at the Whole-word and Sub-word Levels: Spelling Errors Suggest Full-form Storage of Regularly Inflected Verb Forms. *Language and speech, 53*, 405-444

Schoonbaert, S., & Grainger, J., (2004) Letter position coding in printed word perception: Effects of repeated and transposed letters. *Journal of Language and Cognitive Processes, 19* (3), 333-367.

Whitney, C., & Cornelissen, P., (2005) Letter-position encoding and dyslexia. *Journal of Research in Reading 28* (3), 274-301

Whitney, C., & Cornelissen, P., (2008) SERIOL Reading. *Journal of Language and Cognitive 23* (1), 143-164

Whitney, C.,(2006). An alternative model of sentence parsing explains complexity phenomena more comprehensively, without problems of localist encoding. *Behavioural and Brain Sciences*, *29*(1), 87-88.

Van Heuven, W. J. B., Dijkstra, T., Grainger, J. &Schriefers, H. (2001). Shared neighbourhood effects in masked orthographic priming. *Psychonomic Bulletin and Review,* 8, 96-101.

Van Heuven, W.J.B. (2015). Interactive Activation Network Constructor (IANC) version 2.73.

Appendix A: Stimuli for Chapter 2.

Table 32. *Word references, targets and associated primes used in the "same" condition for the masked-priming same-different task Experiments 1-4, Chapters 2. These stimuli were the same as those used in Experiment 4 of Kinoshita and Norris (2009), with the exception of six which were added for counterbalancing purposes.*

	Prime Type		
Reference/Target	Identity	Scrambled	All Letter Different
FAITH	faith	ifhat	agent
FALSE	false	lfeas	agent
IDEAL	ideal	eilda	agent
DIRTY	dirty	rdyit	alert
BRIEF	brief	ibfre	alert
GIANT	giant	agtin	alert
CHEAP	cheap	ecpha	blunt
QUEST	quest	eqtus	blunt
SIEVE	sieve	eseiv	blunt
FANCY	fancy	nfyac	climb
EDGES	edges	gesde	climb
SIXTH	sixth	xshit	climb
OWNER	owner	norwe	crazy
ANGLE	angle	gaenl	crazy
WHEAT	wheat	ewtha	crazy
SIXTY	sixty	xsyit	crude
ALOUD	aloud	oadlu	crude
SOLVE	solve	lseov	crude
HARSH	harsh	rhhas	drift
ALIEN	alien	ianle	drift
JUICE	juice	ijeuc	drift
CHAIN	chain	acnhi	elite
GRIEF	grief	igfre	elite

(continued on next page)

MIDST	midst	dmtis	enemy
FAULT	fault	uftal	elite
RIDGE	ridge	dreig	enemy
CHOIR	choir	ocrhi	enemy
ANGEL	angel	galne	focus
ANKLE	ankle	kaenl	focus
NYLON	nylon	lnnyo	focus
PULSE	pulse	lpeus	frame
NOISY	noisy	inyos	frame
SPOIL	spoil	oslpi	frame
IMPLY	imply	piyml	graph
NOBLE	noble	bneol	graph
DISCO	disco	sdoic	graph
AISLE	aisle	saeil	grasp
THIEF	thief	itfhe	grasp
ONION	onion	ionno	grasp
MAIZE	maize	imeaz	knock
MERCY	mercy	rmyec	knock
RISKY	risky	sryik	knock
FIERY	fiery	efyir	magic
PEARL	pearl	apler	magic
GLEAM	gleam	egmla	magic
OUNCE	ounce	noeuc	media
RAINY	rainy	iryan	media
VAULT	vault	uvtal	media
DEALT	dealt	adtel	moist
RANCH	ranch	nrhac	moist
BERTH	berth	rbhet	moist
QUOTA	quota	oqaut	panel
GIPSY	gipsy	pgyis	panel
FLAIR	flair	afrli	panel
JUICY	juicy	ijyuc	panic

(continued on the next page)

ONSET	onset	sotne	panic
SHRUG	shrug	rsghu	panic
NYMPH	nymph	mnhyp	phase
IDIOM	idiom	iimdo	phase
LIMBO	limbo	mloib	phase
SNAIL	snail	aslni	relax
MOURN	mourn	umnor	relax
SUEDE	suede	eseud	relax
OPIUM	opium	iompu	smart
METRO	metro	tmoer	smart
EXPEL	expel	pelxe	smart
NIECE	niece	eneic	smoky
DEPTH	depth	pdhet	smoky
QUART	quart	aqtur	smoky
IDIOT	idiot	iitdo	super
TITLE	title	tteil	super
THROB	throb	rtbho	super
ENVOY	envoy	veyno	thumb
FARCE	farce	rfeac	thumb
SPRIG	sprig	rsgpi	thumb
SAUCE	sauce	useac	tiger
NOTCH	notch	tnhoc	tiger
REACT	react	artec	tiger

Table 33. *Nonword references, targets, and associated primes used in the "same" condition of the masked-priming same-different task Experiments 1-4. These stimuli were the same as those used in Experiment 4 of Kinoshita and Norris (2009), with the exception of six which were added for counterbalancing purposes.*

	Prime Type		
Reference/Target	Identity	Scrambled	All Letter Different
QUITA	quita	iqaut	banel
MIPSY	mipsy	pmyis	banel
COLVE	colve	lceov	banel
FUICY	fuicy	ifyuc	banic
OLIEN	olien	ionle	banic
FUEDE	fuede	efeud	banic
MUICE	muice	imeuc	crift
GARSH	garsh	rghas	crift
MYLON	mylon	lmnyo	crift
EDIUM	edium	iemdu	delax
NOURN	nourn	unnor	delax
SMAIL	smail	aslmi	delax
DRIEF	drief	idfre	docus
NIDST	nidst	dntis	docus
ENKLE	enkle	keenl	docus
AWNER	awner	narwe	drazy
INGLE	ingle	gienl	drazy
PHEAT	pheat	eptha	drazy
BAULT	bault	ubtal	figer
NAUCE	nauce	uneac	figer
BEACT	beact	abtec	figer
GHEAP	gheap	egpha	flunt
QUIST	quist	iqtus	flunt
FIEVE	fieve	efeiv	flunt
ENION	enion	ienno	frasp
OISLE	oisle	soeil	frasp

(continued on the next page)

PHIEF	phief	ipfhe	frasp
SAULT	sault	ustal	glimb
DITLE	ditle	tdeil	glimb
DOTCH	dotch	tdhoc	glimb
NAIZE	naize	ineaz	gnock
BEARL	bearl	abler	gnock
BULSE	bulse	lbeus	gnock
SOBLE	soble	bseol	grath
FISCO	fisco	sfoic	grath
OMPLY	omply	poyml	grath
YALSE	yalse	lyeas	igent
SLAIR	slair	asrli	igent
ELOUD	eloud	oedlu	igent
ODGES	odges	gosde	inemy
NERCY	nercy	rnyec	inemy
LIDGE	lidge	dleig	inemy
DISKY	disky	sdyik	luper
GOISY	goisy	igyos	luper
PHROB	phrob	rpbho	luper
DANCH	danch	ndhac	moast
SRIEF	srief	isfre	moast
VERTH	verth	rvhet	moast
PHOIR	phoir	oprhi	nagic
CLEAM	cleam	ecmla	nagic
BIERY	biery	ebyir	nagic
AUNCE	aunce	naeuc	nedia
MIECE	miece	emeic	nedia
CHRUG	chrug	rcghu	nedia
VIANT	viant	avtin	olert
VIRTY	virty	rvyit	olert
SYMPH	symph	mshyp	olert
NIXTH	nixth	xnhit	olite

(continued on the next page)

GANCY	gancy	ngyac	olite
SHAIN	shain	asnhi	olite
ANSET	anset	satne	phumb
STRIG	strig	rsgti	phumb
JARCE	jarce	rjeac	phumb
EPIUM	epium	iempu	sgart
NETRO	netro	tnoer	sgart
IXPEL	ixpel	pilxe	sgart
LAINY	lainy	ilyan	same
ONGEL	ongel	golne	same
EDIOT	ediot	ietdo	same
ODEAL	odeal	eolda	srude
JIXTY	jixty	xjyit	srude
KEALT	kealt	aktel	srude
BAITH	baith	ibhat	stoky
QUERT	quert	eqtur	stoky
TEPTH	tepth	pthet	stoky
RIMBO	rimbo	mroib	thase
ONVOY	onvoy	voyno	thase
SCOIL	scoil	oslci	thase

Table 34. *Word references, targets and associated primes used for the "different" condition in the masked-priming same-different task Experiments 1-4.*

		Prime Type		
Reference	Target	Identity	Scrambled	All Letter Different
often	DRUMS	drums	udsrm	acted
early	FROST	frost	oftrs	acted
games	PUBIC	pubic	bpcui	acted
river	HOTLY	hotly	thyol	arise
truth	MELON	melon	lmneo	arise
money	PILOT	pilot	lptio	arise
empty	FUNDS	funds	nfsud	aside
black	SENOR	senor	nsroe	aside
quite	THORN	thorn	otnhr	aside
third	APTLY	aptly	taypl	bulbs
plant	DRIVE	drive	iderv	bulbs
wrong	DRYER	dryer	ydrre	bulbs
could	BEING	being	ibgen	coral
major	STRIP	strip	rspti	coral
known	TAXIS	taxis	xtsai	coral
beach	LOWLY	lowly	wlyol	exits
wants	ROGUE	rogue	greou	exits
lives	TONGA	tonga	ntaog	exits
sharp	GLOBE	globe	ogelb	franc
royal	INEPT	inept	eitnp	franc
woman	LIBEL	libel	bllie	franc
angry	CRISP	crisp	icprs	froth
light	MONKS	monks	nmsok	froth
lunch	REALM	realm	armel	froth
given	CLEFT	cleft	ecflt	gaudy
until	FOYER	foyer	yfroe	gaudy
piece	WORST	worst	rwtos	gaudy

(continued on the next page)

great	HINDU	hindu	nhuid	germs
world	SAXON	saxon	xsnao	germs
found	VALID	valid	lvdai	germs
sorry	DIETS	diets	edsit	gravy
radio	FLUTE	flute	ufelt	gravy
other	LUCID	lucid	cldui	gravy
under	ARGUS	argus	gasru	inert
tired	BOGUS	bogus	gbsou	inert
final	PONDS	ponds	npsod	inert
girls	ENJOY	enjoy	jeyno	isles
human	PATIO	patio	tpoai	isles
price	SONAR	sonar	nsroa	isles
sugar	CHIEF	chief	icfhe	learn
paper	SWIFT	swift	istwf	learn
shape	TWIGS	twigs	itswg	learn
shown	CAMEL	camel	mclae	lofty
court	NAIVE	naive	ineav	lofty
quick	SHAWL	shawl	aslhw	lofty
thick	DEBUT	debut	bdteu	rhyme
table	LOTUS	lotus	tlsou	rhyme
value	STERN	stern	esntr	rhyme
party	CHANT	chant	acthn	roger
birds	LATIN	latin	tlnai	roger
heard	STUDY	study	usytd	roger
horse	BLOKE	bloke	obelk	skirt
image	LEMON	lemon	mlneo	skirt
ready	PONCE	ponce	npeoc	skirt
death	BURST	burst	rbtus	swarm
uncle	GLINT	glint	igtln	swarm
legal	OUTER	outer	torue	swarm
kitty	DECOR	decor	cdreo	timid
flesh	KNELT	knelt	rektnl	timid

(continued on the next page)

child	WEARY	weary	awyer	timid
today	ACRES	acres	rasce	total
worse	SIREN	siren	rsnie	total
space	URINE	urine	iuern	total
doubt	ITEMS	items	eastm	urged
music	LEAFY	leafy	alyef	urged
small	NECKS	necks	cnsek	urged
power	GAILY	gaily	igyal	utter
chair	GRIMY	grimy	igyrm	utter
facts	SLIMY	slimy	isylm	utter
while	IRONY	irony	oiyrn	veils
style	SUDAN	sudan	dsnua	veils
large	TREND	trend	etdrn	veils
brown	DANCE	dance	ndeac	whims
round	EATEN	eaten	tenae	whims
years	UNDER	under	durne	whims
might	LAPEL	lapel	pllae	windy
seven	TENOR	tenor	ntreo	windy
lying	THUGS	thugs	utshg	windy

Table 35. *Nonword references, targets and associated primes used in the "different" condition of the masked-priming same-different task Experiments 1-4.*

		Prime Type		
Reference	Target	Identity	Scrambled	All Letter Different
feach	MUNDS	munds	nmsud	acide
ampty	BENOR	benor	nbroe	acide
peath	CHORN	chorn	ocnhr	acide
nirds	PLEFT	pleft	epflt	caudy
shild	DOYER	doyer	ydroe	caudy
fiven	DORST	dorst	rdtos	caudy
mourt	EPTLY	eptly	taypl	culbs
dight	PAMEL	pamel	mplae	culbs
bould	PRYER	pryer	yprre	culbs
engry	PLOBE	plobe	opelb	dranc
woubt	ANEPT	anept	eatnp	dranc
gound	GIBEL	gibel	bglie	dranc
barly	FLOKE	floke	ofelk	ekirt
litty	KEMON	kemon	mkneo	ekirt
veard	HONCE	honce	nheoc	ekirt
creat	VOTLY	votly	tvyol	epits
wacts	BOWLY	bowly	wbyol	epits
kirls	RONGA	ronga	nraog	epits
dlack	CRIEF	crief	icfre	foral
funch	SHRIP	shrip	rsphi	foral
prown	SAXIS	saxis	xssai	foral
kaown	HIETS	hiets	ehsit	fravy
thair	BLUTE	blute	ubelt	fravy
omage	JUCID	jucid	cjdui	fravy
plesh	KINDU	kindu	nkuid	gearn
luman	TWIFT	twift	ittwf	gearn
dajor	THIGS	thigs	itshg	gearn

(continued on the next page)

hinal	BRUMS	brums	ubsrm	icted
phown	DRIMY	drimy	idyrm	icted
jarge	DUBIC	dubic	bdcui	icted
pight	UNJOY	unjoy	juyno	itles
susic	MONAR	monar	nmroa	itles
vears	SPUDY	spudy	usypd	itles
weven	NAILY	naily	inyal	itter
inder	ARONY	arony	oayrn	itter
aften	WONDS	wonds	nwsod	itter
megel	SHANT	shant	asthn	joger
laper	HATIN	hatin	thnai	joger
pying	MEARY	meary	amyer	joger
biver	SATIO	satio	tsoai	kerms
ither	FAXON	faxon	xfnao	kerms
luick	BALID	balid	lbdai	kerms
vower	FEING	feing	ifgen	mofty
boney	TRISP	trisp	itprs	mofty
tound	MAIVE	maive	imeav	mofty
buite	ERGUS	ergus	gesru	onert
narty	MOGUS	mogus	gmsou	onert
borse	THAWL	thawl	atlhw	onert
jadio	UTEMS	utems	eustm	orged
charp	KIELT	kielt	ektil	orged
thape	LECKS	lecks	clsek	orged
cives	HELON	helon	lhneo	orise
peady	AUTER	auter	tarue	orise
crong	PEALM	pealm	apmel	orise
hiece	CROST	crost	octrs	phyme
crice	NOTUS	notus	tnsou	phyme
gired	FONKS	fonks	nfsok	phyme
homan	ATRES	atres	raste	potal
noday	VIREN	viren	rvnie	potal

(continued on the next page)

skall	ORINE	orine	ioern	potal
doyal	HANCE	hance	nheac	proth
dants	CRIVE	crive	icerv	proth
shace	CLIMY	climy	icylm	proth
encle	LURST	lurst	rltus	sharm
nable	PLINT	plint	iptln	sharm
shyle	GILOT	gilot	lgtio	sharm
gorld	NEBUT	nebut	bnteu	thims
forry	VATEN	vaten	tvnae	thims
clant	ANDER	ander	darne	thims
nalue	WECOR	wecor	cwreo	fimid
rorse	GEAFY	geafy	agyef	fimid
mugar	SHERN	shern	esnhr	fimid
droth	GAPEL	gapel	pglae	vindy
phick	RENOR	renor	nrreo	vindy
bames	CHUNG	chung	ucshg	vindy
chird	BOGUE	bogue	gbeou	weils
entil	HUDAN	hudan	dhnua	weils
thile	PREND	prend	epdrn	weils

Appendix B: Stimuli used in Chapter 3

The stimuli for Experiment 5 were identitical to those used in Chapter 2

Table 36. *Homophone references, targets, and associated primes used in the "same" condition of Experiment 6.*

Reference/ Target	Frequency	Word Length	Prime Type: Identity	Prime Type: Scrambled	Prime Type: All Letter Different
BALL	High	4	ball	albl	once
BAWL	Low	4	bawl	albw	
BEAR	High	4	bear	erba	wish
BARE	Low	4	bare	aebr	
BOARD	High	5	board	abdor	light
BORED	Low	5	bored	rbdoe	
CAPITAL	High	7	capital	aiacplt	refused
CAPITOL	Low	7	capitol	aiocplt	
DAYS	High	4	days	asdy	hurt
DAZE	Low	4	daze	aedz	
FAINT	High	5	faint	iftan	works
FEINT	Low	5	feint	iften	
FATE	High	4	fate	aeft	body
FETE	Low	4	fete	eeft	
GATE	High	4	gate	aegt	book
GAIT	Low	4	gait	atgi	
HERE	High	4	here	eehr	boys
HEAR	Low	4	hear	erha	
MADE	High	4	made	aemd	town
MAID	Low	4	maid	admi	
PAIR	High	4	pair	arpi	soon
PARE	Low	4	pare	aepr	

(continued on the next page)

PIER	High	4	pier	irpe	lost
PEER	Low	4	peer	erpe	
POLE	High	4	pole	oepl	shut
POLL	Low	4	poll	olpl	
PRAY	High	4	pray	rypa	both
PREY	Low	4	prey	rype	
REAL	High	4	real	elra	most
REEL	Low	4	reel	elre	
SORE	High	4	sore	oesr	high
SOAR	Low	4	soar	orsa	
SURF	High	4	surf	ufsr	play
SERF	Low	4	serf	efsr	
VERSUS	High	6	versus	esvsru	taking
VERSES	Low	6	verses	esvsre	
HALL	High	4	hall	alhl	sing
HAUL	Low	4	haul	alhu	
BAIL	High	4	bail	albi	hour
BALE	Low	4	bale	aebl	
BEACH	High	5	beach	abhec	front
BEECH	Low	5	beech	ebhec	
BIRTH	High	5	birth	rbhit	calls
BERTH	Low	5	berth	rbhet	
BREAK	High	5	break	ebkra	music
BRAKE	Low	5	brake	aberk	
CHANCE	High	6	chance	hnceac	bloody
CHANTS	Low	6	chants	hncsat	
EXERCISE	High	8	exercise	xreeiecs	adjutant
EXORCISE	Low	8	exorcise	xreeiocs	
FAIR	High	4	fair	arfi	pull
FARE	Low	4	fare	aefr	
FEET	High	4	feet	etfe	pick
FEAT	Low	4	feat	etfa	

(continued on the next page)

HAIR	High	4	hair	arhi	cool
HARE	Low	4	hare	eehr	
LOOT	High	4	loot	otlo	meny
LUTE	Low	4	lute	uelt	
NAVAL	High	5	naval	vnlaa	yours
NAVEL	Low	5	navel	vnlae	
PEEL	High	4	peel	elpe	door
PEAL	Low	4	peal	elpa	
PLANE	High	5	plane	apeln	hours
PLAIN	Low	5	plain	apnli	
POOR	High	4	poor	orpo	head
POUR	Low	4	pour	orpu	
PRINCE	High	6	prince	rnpeic	formal
PRINTS	Low	6	prints	rnpsit	
SIGN	High	4	sign	insg	hard
SINE	Low	4	sine	iesn	
STARE	High	5	stare	asetr	lucky
STAIR	Low	5	stair	asrti	
SYMBOL	High	6	symbol	ybslmo	friend
CYMBAL	Low	6	cymbal	ybclma	
HAIL	High	4	hail	alhi	jury
HALE	Low	4	hale	aehl	
HEAL	High	4	heal	elha	rock
HEEL	Low	4	heel	elhe	

Table 37. *Non-homophone references, targets and associated primes used in the "same" condition, Experiment 6.*

Reference/ Target	Frequenc y	Word Length	Prime Type: Identity	Scrambled	All Letter Different
WAKE	High	4	wake	aewk	sort
HILT	Low	4	hilt	ithl	safe
LEGS	High	4	legs	eslg	junk
CANE	Low	4	cane	aecn	busy
NORTH	High	5	north	rnhot	lives
PRINT	Low	5	print	iptrn	class
COMMENT	High	7	comment	omncmte	highway
VIOLATE	Low	7	violate	iltvoea	unhappy
KIDS	High	4	kids	iskd	hang
WEBS	Low	4	webs	eswb	lion
STUNT	High	5	stunt	usttn	clear
ODOUR	Low	5	odour	oordu	times
TEAR	High	4	tear	erta	kiss
GYRO	Low	4	gyro	yogr	case
SOFT	High	4	soft	otsf	able
HYPO	Low	4	hypo	yohp	side
THEY	High	4	they	hyte	plan
STAY	Low	4	stay	tysa	line
GIRL	High	4	girl	ilgr	send
ROPE	Low	4	rope	oerp	glad
PAGE	High	4	page	aepg	boss
SNOG	Low	4	snog	ngso	hate
COAL	High	4	coal	olca	gets
USER	Low	4	user	srue	fact
PUMP	High	4	pump	uppm	gave
RUST	Low	4	rust	utrs	game
UNIT	High	4	unit	ntui	hope

(continued on the next page)

GRID	Low	4	grid	rdgi	eyes
ROOM	High	4	room	omro	each
COPE	Low	4	cope	oecp	half
HOST	High	4	host	oths	deal
SPAT	Low	4	spat	ptsa	fire
TECH	High	4	tech	ehtc	lady
ASHY	Low	4	ashy	syah	gone
CANDLE	High	6	candle	adcenl	though
PONDER	Low	6	ponder	odprne	attack
COPY	High	4	copy	oycp	late
FOLK	Low	4	folk	okfl	star
MASS	High	4	mass	asms	open
OATS	Low	4	oats	asot	knew
WORST	High	5	worst	rwtos	dance
INERT	Low	5	inert	eitnr	shoes
JOINT	High	5	joint	ijton	asked
TAINT	Low	5	taint	ittan	close
STORY	High	5	story	osytr	alive
SHADE	Low	5	shade	asehd	quick
FORGET	High	6	forget	ogftre	public
QUIRKY	Low	6	quirky	urqyik	please
SPECIFIC	High	8	specific	pccsfeii	barnyard
LIFESPAN	Low	8	lifespan	ienlpfsa	cookbook
SONG	High	4	song	ogsn	idea
SCAM	Low	4	scam	cmsa	five
STEP	High	4	step	tpse	fall
PLOY	Low	4	ploy	lypo	free
LUCK	High	4	luck	uklc	rest
VASE	Low	4	vase	aevs	drop
LUMP	High	4	lump	uplm	goes
KERB	Low	4	kerb	ebkr	till
MEDIC	High	5	medic	dmcei	shall

(continued on the next page)

VINYL	Low	5	vinyl	nvliy	water
MOCK	High	4	mock	okmc	read
YELP	Low	4	yelp	epyl	food
MONTH	High	5	month	nmhot	speak
UNION	Low	5	union	iunno	death
COLD	High	4	cold	odcl	true
RICE	Low	4	rice	ierc	also
NATURE	High	6	nature	aunetr	simply
TRAUMA	Low	6	trauma	rutaam	people
RIDE	High	4	ride	ierd	walk
FENS	Low	4	fens	esfn	part
SKIRT	High	5	skirt	istkr	ahead
WINCH	Low	5	winch	nwhic	party
MORGUE	High	6	morgue	ogmeru	anyway
ADVERT	Low	6	advert	deatvr	finish
DULL	High	4	Dull	uldl	fish
ICON	Low	4	Icon	cnio	huge
DISH	High	4	Dish	ihds	buck
MELT	Low	4	Melt	etml	card

Table 38. *Homophone references, non-homophone targets, associated primes and string length used in the "different" condition of Experiment 6.*

Reference	Frequency	Word Len	Target	Prime Type: Identity	Prime Type: Scrambled	Prime Type: All Letter Different
blue	High	4	FROM	from	rmfo	past
blew	Low	4				
sell	High	4	WANT	want	atwn	dumb
cell	Low	4				
course	High	6	LIVING	living	iilgvn	pretty
coarse	Low	6				
dear	High	4	JUST	just	utjs	blow
deer	Low	4				
freeze	High	6	SHOULD	should	husdol	making
frieze	Low	6				
jeans	High	5	WORRY	worry	rwyor	stick
genes	Low	5				
grown	High	5	STUFF	stuff	usftf	movie
groan	Low	5				
loan	High	4	MUST	must	utms	rich
lone	Low	4				
mall	High	4	THEN	then	hnte	grow
maul	Low	4				
minor	High	5	HAPPY	happy	phyap	trust
miner	Low	5				
pale	High	4	GUYS	guys	usgy	born
pail	Low	4				
piece	High	5	WRONG	wrong	owgrn	buddy
peace	Low	5				
road	High	4	MISS	miss	isms	ugly
rode	Low	4				
sale	High	4	TOOK	took	okto	drug
sail	Low	4				

(continued on the next page)

shoot	High	5	BRING	bring	ibgrn	saved
chute	Low	5				
steal	High	5	DRINK	drink	idkrn	touch
steel	Low	5				
tail	High	4	MUCH	much	uhmc	bond
tale	Low	4				
tied	High	4	LOOK	look	oklo	army
tide	Low	4				
week	High	4	GOOD	good	odgo	ship
weak	Low	4				
warn	High	4	EXIT	exit	xtei	such
worn	Low	4				
bore	High	4	WITH	with	ihwt	jump
boar	Low	4				
serial	High	6	NOBODY	nobody	oonybd	flight
cereal	Low	6				
creek	High	5	MIGHT	might	gmtih	floor
creak	Low	5				
foul	High	4	BABY	baby	aybb	kept
fowl	Low	4				
gamble	High	6	STUPID	stupid	tpsdui	coffee
gambol	Low	6				
great	High	5	FOUND	found	ufdon	smell
grate	Low	5				
lesson	High	6	AFRAID	afraid	faadri	bought
lessen	Low	6				
main	High	4	WORK	work	okwr	push
mane	Low	4				
meet	High	4	ONLY	only	nyol	kick
meat	Low	4				
pain	High	4	TOLD	told	odtl	sucks
pane	Low	4				
patients	High	8	WOODWORK	woodwork	odkwoowr	visually
patience	Low	8				

(continued on the next page)

right	High	5	FUNNY	funny	nfyun	black
write	Low	5				
roll	High	4	MANY	many	aymn	such
role	Low	4				
sense	High	5	WORLD	world	rwdol	heavy
cents	Low	5				
soul	High	4	BACK	back	akbc	trip
sole	Low	4				
sweet	High	5	CRAZY	crazy	acyrz	blind
suite	Low	5				
thrown	High	6	FAMILY	family	aifyml	excuse
throne	Low	6				
waste	High	5	YOUNG	young	uygon	crime
waist	Low	5				
current	High	7	FOOLISH	foolish	olsfohi	wrapped
currant	Low	7				

Table 39. *Non-homophone references, targets, associated primes and string length used in the "different" condition of Experiment 6.*

Reference	Frequency	Word Len	Target	Prime Type: Identity	Prime Type: Scrambled	Prime Type: All Letter Different
dude	High	4	WILL	will	ilwl	pass
harm	Low	4	LIKE	like	ielk	cost
ring	High	4	MAKE	make	aemk	fool
bomb	Low	4	VERY	very	eyvr	land
enough	High	6	ALWAYS	always	laaswy	picked
parcel	Low	6	THINGS	things	hntsig	cowboy
shot	High	4	CALL	call	alcl	burn
stab	Low	4	GIVE	give	iegv	lock
safety	High	6	GIVING	giving	iiggvn	looked
glints	Low	6	BEFORE	before	eobefr	campus
siren	High	5	WATCH	watch	twhac	group
turbo	Low	5	PLACE	place	apelc	using
mercy	High	5	WANTS	wants	nwsat	proud
chime	Low	5	START	start	asttr	enjoy
soda	High	4	FINE	fine	iefn	bull
text	Low	4	KILL	kill	ilkl	shop
iron	High	4	FEEL	feel	elfe	camp
arid	Low	4	LEFT	left	etlf	moon
hatch	High	5	UNDER	under	durne	books
gloss	Low	5	READY	ready	aryed	knock
tuna	High	4	HOOD	hood	odho	bood
swig	Low	4	HELP	help	ephl	fort
human	High	5	SLEEP	sleep	esple	radio
share	Low	5	UNTIL	until	tulni	moved
bill	High	4	MEAN	mean	enma	hook
lean	Low	4	STOP	stop	tpso	firm
hire	High	4	AWAY	away	wyaa	gold
flow	Low	4	TAKE	take	aetk	bird
child	High	5	KNOWS	knows	oksnw	paper
decoy	Low	5	FIGHT	fight	gftih	swear

(continued on the next page)

price	High	5	TODAY	today	dtyoa	bunch
slave	Low	5	TRUTH	truth	uthrt	lying
trap	High	4	SOME	some	oesm	wind
link	Low	4	HOME	home	oehm	fast
drag	High	4	WHEN	when	hnwe	list
fist	Low	4	NEED	need	edne	calm
word	High	4	TIME	time	ietm	bank
rush	Low	4	COME	come	oecm	band
soup	High	4	THIN	thin	hnti	face
leak	Low	4	BUZZ	buzz	uzbz	city
soil	High	4	THEM	them	hmte	dark
skid	Low	4	WELL	well	elwl	boat
defeat	High	6	MOVING	moving	oimgvn	church
wealth	Low	6	SOUNDS	sounds	onssud	bigger
cough	High	5	AFTER	after	tarfe	dying
bloat	Low	5	GUESS	guess	egsus	third
flip	High	4	NAME	name	aenm	duty
mesh	Low	4	KIND	kind	idkn	pool
ritual	High	6	SECOND	second	eosdcn	eighth
earing	Low	6	FOLLOW	follow	olfwlo	system
first	High	5	HAVEN	haven	vhnae	judge
optic	Low	5	LEAVE	leave	aleev	hurry
energy	High	6	SCHOOL	school	coslho	affair
nimble	Low	6	DOCTOR	doctor	otdrco	laughs
form	High	4	HELL	hell	elhl	nuts
balm	Low	4	DOES	does	osde	tiny
wife	High	4	LONG	long	ogln	arms
pack	Low	4	EVER	ever	vree	fill
club	High	4	THAN	than	hnta	joke
achy	Low	4	EVEN	even	vnee	slow
schedule	High	8	BRINGING	bringing	rngbiign	playbook
valuable	Low	8	TOMORROW	tomorrow	oowtrmro	psychics
about	High	5	WHILE	while	iwehl	drunk
small	Low	5	HONEY	honey	nhyoe	visit
upon	High	4	SAME	same	aesm	high
seek	Low	4	HOLD	hold	odhl	bang
dream	High	5	POINT	point	ipton	awful
panic	Low	5	HOUSE	house	uheos	madam
mess	High	4	TALK	talk	aktl	join

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mint	Low	4	LOVE	love	oelv	cars
sound	High	5	THEIR	their	etrhi	clock
shout	Low	5	BEING	being	ibgen	marry
threat	High	6	COMING	coming	oicgmn	pulled
colour	Low	6	THANKS	thanks	hntsak	needed
magic	High	5	EVERY	every	eeyvr	ought
motto	Low	5	YEARS	years	ayser	lunch
comfort	High	7	SLIPPED	slipped	lpesidp	arguing
leaflet	Low	7	KICKING	kicking	iknkcgi	propose

Appendix C: Stimuli for Chapter 4

Table 40. *References, targets, associated primes and string length used for the "same" condition for the masked-priming same-different task, Experiment 7.*

Reference/ Target	Word Length	Prime Type		
		Identity	Scrambled	All Letter Different
OBTAIN	6	obtain	nabito	brunch
MINUS	5	minus	nmsiu	arrow
GUARD	5	guard	agdur	bunch
TRUST	5	trust	uttrs	along
FLOWER	6	flower	rwleof	stands
RANKS	5	ranks	nrsak	poppy
SOLVE	5	solve	lseov	trail
AMOUNT	6	amount	tumnoa	direct
GIVES	5	gives	vgsie	round
IDEAS	5	ideas	eisda	spoke
NORMAL	6	normal	lmoarn	killer
RACING	6	racing	giancr	hooker
YOUNG	5	young	uygon	makes
YARDS	5	yards	rysad	noble
KEEPS	5	keeps	eksep	cream
FRIEND	6	friend	dernif	school
IDIOT	5	idiot	iitdo	space
SEEMS	5	seems	essem	order
ERROR	5	error	rerro	scale
CHANNELS	8	channels	nscaehnl	sidewalk
EPISODES	8	episodes	oseidpse	colonial
APPLIED	7	applied	pidpale	ketchup
DOCKS	5	docks	cdsok	arena
FLESH	5	flesh	efhls	armed
DRANK	5	drank	adkrn	diner
SQUAD	5	squad	usdqa	cents

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SMALL	5	small	aslml	quiet
TROOP	5	troop	otpro	spine
UNCLE	5	uncle	cuenl	senes
READING	7	reading	eigardn	contact
DANCER	6	dancer	rcaend	struck
PASTA	5	pasta	spaat	froze
RADIO	5	radio	droai	drunk
PARKING	7	parking	aigrpkn	towards
BROKE	5	broke	oberk	floor
EDITION	7	edition	dinieto	humming
BLAST	5	blast	abtls	opens
STABLE	5	stable	asltb	works
CHIEF	5	chief	icfhe	store
AVOID	5	avoid	oadvi	penny
APART	5	apart	aatpr	teeth
SILLY	5	silly	lsyil	pants
PAPER	5	paper	pprae	eight
BABY	4	baby	aybb	left
PIGEON	6	pigeon	neiogp	wander
UNIFORM	7	uniform	nomiufr	percent
TAILOR	6	tailor	rlaoit	groove
CRASH	5	crash	achrs	below
BREATH	7	breath	rtebah	destroy
COMBAT	6	combat	tboamc	oxygen
RELAX	5	relax	lrxea	seven
HOMICIDE	8	homicide	cehmioid	answered
NAMES	5	names	mnsae	bucks
MAGIC	5	magic	gmcai	fresh
FAMILY	6	family	yialmf	afraid
SHOULD	6	should	duhlos	before
WRIST	5	wrist	iwtrs	rumor
BISCUITS	8	biscuits	usbsiict	frontier

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POWERFUL	8	powerful	rlpwfoeu	language
NATION	6	nation	niaotn	butter
WATER	5	water	twrae	hands
LOVELY	6	lovely	yeolvl	return
GROWTH	6	growth	hwrtog	creeps
SCARY	5	scary	asycr	rooms
BASED	5	based	sbdae	joint
NYMPH	5	nymph	mnhyp	colds
LESSON	6	lesson	nseosl	female
BOUGHT	6	bought	tgohub	master
HISTORY	7	history	ioyshtr	forgive
SLEPT	5	slept	estlp	truly
GODSEND	7	godsend	oeddgsn	commute
DIARY	5	diary	adyir	rolls
MUSEUM	6	museum	meuusm	supply
LICENSE	7	license	inecles	stomach
DOUBLED	7	doubled	oldudbe	legends
EXHIBIT	7	exhibit	xbtheii	peanuts
FUNERAL	7	funeral	urlnfea	picking
LEARN	5	learn	alner	touch

Table 41. *Semantically related and unrelated references, targets and associated primes for the "different" condition of the same-different task Experiment.*

TARGET	Semantic Relationship: Related Reference	Semantic Relationship: Unrelated Reference	Word Len	Prime Type: Identity	Prime Type: Scrambled	Prime Type: All Letter Different
THIRST	quench	bumper	6	thirst	trhsit	payoff
DITCH	gully	sunny	5	ditch	tdhic	probe
SMILE	frown	brown	5	smile	iseml	patch
CLEAR	vivid	bring	5	clear	ecrla	ought
JUNGLE	safari	vision	6	jungle	egulnj	hollow
FLIRT	tease	semen	5	flirt	iftlr	hound
CABIN	lodge	motel	5	cabin	bcnai	brush
POISON	deadly	wallet	6	poison	nsooip	circus
SMOKE	cigar	limit	5	smoke	osemk	rusty
NAKED	strip	split	5	naked	kndae	older
CHURCH	temple	fellow	6	church	hrhcuc	giving
ROCKET	launch	magnum	6	rocket	tkoecr	fights
POINT	sharp	stuff	5	point	ipton	never
GUILT	shame	beats	5	guilt	igtul	moron
TIGHT	loose	level	5	tight	gttih	study
EXCUSE	pardon	always	6	excuse	euxsce	trying
DIRTY	clean	peace	5	dirty	rdyit	books
BLACK	white	shoot	5	black	abklc	hurry
FAINT	swoon	flush	5	faint	iftan	types
SQUIRREL	chipmunk	tourest	8	squirrel	rlsurqie	tactical
THIRSTY	parched	realise	7	thirsty	hsyitrt	fooling
PUDDING	custard	sunrise	7	pudding	uigdpdn	bathtub
LAYER	ozone	exits	5	layer	ylrae	fudge
SNAKE	cobra	mixed	5	snake	asenk	photo
AWARD	merit	twist	5	award	aadwr	lobby
CLIFF	ledge	value	5	cliff	icflf	stops
PIECE	chunk	human	5	piece	epeic	words
WHEAT	grain	disco	5	wheat	ewtha	fuzzy
WRITE	essay	music	5	write	iwert	known
NERVOUS	anxiety	forward	7	nervous	eosrnvu	holding

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GLOVES	boxing	tracks	6	gloves	svleog	filthy
ONION	liver	jerks	5	onion	ionno	batch
ANGEL	saint	folks	5	angel	galne	third
SUCCESS	failure	growing	7	success	uescscs	watched
WEIRD	freak	class	5	weird	iwder	mouth
BIOLOGY	science	tricked	7	biology	ioyoblg	pumping
POKER	cards	sides	5	poker	kproe	fully
TABLE	chair	stick	5	table	bteal	count
JUDGE	court	brain	5	judge	djeug	enjoy
BRIDE	groom	plant	5	bride	iberd	sucks
KNIFE	blade	coach	5	knife	ikenf	empty
BEACH	coast	clock	5	beach	abhec	angry
EARTH	world	worst	5	earth	rehat	lucky
CARE	love	show	4	care	aecr	next
HUNGER	famine	tomato	6	hunger	rguenh	spends
HEALTHY	fitness	kissing	7	healthy	etyahlh	proceed
ORGASM	climax	skiing	6	orgasm	marsgo	bundle
BREAD	stale	style	5	bread	ebdra	punch
FLOWERS	bouquet	justice	7	flowers	lesofwr	dancing
TENNIS	racket	remote	6	tennis	sneint	deeply
HOTEL	suite	quick	5	hotel	thloe	agent
VALUABLE	precious	customer	8	valuable	aevlbaul	identify
STEAL	thief	river	5	steal	eslta	often
TASTE	smell	enemy	5	taste	steat	price
SECOND	minute	either	6	second	doencs	really
THANKS	please	freind	6	thanks	snhkat	course
STIFF	rigid	drown	5	stiff	isftf	album
IMMATURE	childish	knockout	8	immature	teimumar	sweeping
CRIMINAL	fugitive	students	8	criminal	ilcinrma	possibly
REFUSE	denial	digging	6	refuse	euesfr	complex
FUNNY	clown	bitch	5	funny	nfyun	asked
MIDDLE	center	attack	6	middle	edildm	hoping
KIDNAP	abduct	galaxy	6	kidnap	pniadk	shares
SWORD	saber	hates	5	sword	osdwr	pills
JUICE	prune	awake	5	juice	ijeuc	moves

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GRAPH	chart	excel	5	graph	aghrp	binds
SQUARE	circle	monkey	6	square	eaqrus	engine
SUMMER	spring	within	6	summer	rmuems	across
STATION	service	perfect	7	station	tinasto	quickly
NOISE	sound	proof	5	Noise	ineos	toast
ENLARGE	magnify	joyride	7	enlarge	nreleag	tantrum
SWAMP	marsh	nutty	5	swamp	aspwm	genie
HUNTER	bounty	smooth	6	hunter	rtuenh	firing
SOCIETY	culture	deliver	7	society	oeycsit	meaning
CLIMATE	weather	suffers	7	climate	laeicmt	annoyed
HALLWAY	passage	aspirin	7	hallway	awylhla	drowned
FREEDOM	liberty	divorce	7	freedom	dfeorem	warning
DREAM	sleep	lives	5	Dream	edmra	throw

Table 42. *Heterographic homophone word targets with the reference used for the "different" condition, associated primes and string length, for the masked-priming same-different task, Experiment 8.*

Different Reference	TARGET	Word Len	Prime Type: identity	scrambled	unrelated
bale	BAIL	4	bail	albi	hour
bail	BALE	4	bale	aebl	hour
bawl	BALL	4	ball	albl	once
ball	BAWL	4	bawl	albw	once
beech	BEACH	5	beach	abhec	front
beach	BEECH	5	beech	ebhec	front
birth	BERTH	5	berth	rbhet	calls
berth	BIRTH	5	birth	rbhit	calls
break	BRAKE	5	brake	aberk	music
brake	BREAK	5	break	ebkra	music
chants	CHANCE	6	chance	hnceac	bloody
chance	CHANTS	6	chants	hncsat	bloody
current	CURRANT	7	currant	urncrta	wrapped
currant	CURRENT	7	current	urncrte	wrapped
exorcise	EXERCISE	8	exercise	xreeiecs	adjutant
exercise	EXORCISE	8	exorcise	xreeiocs	adjutant
fare	FAIR	4	fair	arfi	pull
fair	FARE	4	fare	aefr	pull
feet	FEAT	4	feat	etfa	pick
feat	FEET	4	feet	etfe	pick
hare	HAIR	4	hair	arhi	cool
hair	HARE	4	hare	aehr	eehr
lute	LOOT	4	loot	otlo	meny
loot	LUTE	4	lute	uelt	many
navel	NAVAL	5	naval	vnlaa	yours
naval	NAVEL	5	navel	vnlae	yours
peel	PEAL	4	peal	elpa	door
peal	PEEL	4	peel	elpe	door

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plane	PLAIN	5	plain	apnli	hours
plain	PLANE	5	plane	apeln	hours
pour	POOR	4	poor	orpo	head
poor	POUR	4	pour	orpu	head
prints	PRINCE	6	prince	rnpeic	formal
prince	PRINTS	6	prints	rnpsit	formal
sine	SIGN	4	sign	insg	hard
sign	SINE	4	sine	iesn	hard
stare	STAIR	5	stair	asrti	lucky
stair	STARE	5	stare	asetr	lucky
symbol	CYMBAL	6	cymbal	ybclma	friend
cymbal	SYMBOL	6	symbol	ybslmo	friend
worn	WARN	4	warn	anwr	such
warn	WORN	4	worn	onwr	such
bore	BOAR	4	boar	orba	jump
boar	BORE	4	bore	oebr	jump
serial	CEREAL	6	cereal	eeclra	flight
cereal	SERIAL	6	serial	eislra	flight
creek	CREAK	5	creak	eckra	floor
creak	CREEK	5	creek	eckre	gmtih
fowl	FOUL	4	foul	olfu	baby
foul	FOWL	4	fowl	olfw	kept
gambol	GAMBLE	6	gamble	abgeml	coffee
gamble	GAMBOL	6	gambol	abglmo	coffee
great	GRATE	5	grate	agert	smell
grate	GREAT	5	great	egtra	smell
hale	HAIL	4	hail	alhi	jury
hail	HALE	4	hale	aehl	jury
heel	HEAL	4	heal	elha	rock
heal	HEEL	4	heel	elhe	rock
lesson	LESSEN	6	lessen	eslnse	bought
lessen	LESSON	6	lesson	eslnso	bought
mane	MAIN	4	main	anmi	push
main	MANE	4	mane	aemn	push

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meet	MEAT	4	meat	etma	kick
meat	MEET	4	meet	etme	kick
pane	PAIN	4	pain	anpi	sucks
pain	PANE	4	pane	aepn	sucks
patients	PATIENCE	8	patience	aiepntec	visually
patience	PATIENTS	8	patients	aispntet	visually
write	RIGHT	5	right	grtih	black
right	WRITE	5	write	iwert	black
roll	ROLE	4	role	oerl	cats
role	ROLL	4	roll	olrl	cats
sense	CENTS	5	cents	ncset	heavy
cents	SENSE	5	sense	nsees	heavy
soul	SOLE	4	sole	oesl	trip
sole	SOUL	4	soul	olsu	trip
sweet	SUITE	5	suite	iseut	blind
suite	SWEET	5	sweet	estwe	blind
thrown	THRONE	6	throne	hotern	excuse
throne	THROWN	6	thrown	hotnrw	excuse
waste	WAIST	5	waist	iwtas	crime
waist	WASTE	5	waste	sweat	crime
bear	BARE	4	bare	aebr	wish
bare	BEAR	4	bear	erba	wish
bored	BOARD	5	board	abdor	light
board	BORED	5	bored	rbdoe	light
capitol	CAPITAL	7	capital	aiacplt	refused
capital	CAPITOL	7	capitol	aiocplt	refused
daze	DAYS	4	days	asdy	hurt
days	DAZE	4	daze	aedz	hurt
feint	FAINT	5	faint	iftan	works
faint	FEINT	5	feint	iften	works
fete	FATE	4	fate	aeft	body
fate	FETE	4	fete	eeft	body
gate	GAIT	4	gait	atgi	book
gait	GATE	4	gate	aegt	book

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here	HEAR	4	hear	erha	boys
hear	HERE	4	here	eehr	boys
maid	MADE	4	made	aemd	camp
made	MAID	4	maid	admi	town
pare	PAIR	4	pair	arpi	soon
pair	PARE	4	pare	aepr	soon
pier	PEER	4	peer	erpe	lost
peer	PIER	4	pier	irpe	lost
poll	POLE	4	pole	oepl	shut
pole	POLL	4	poll	olpl	shut
prey	PRAY	4	pray	rypa	both
pray	PREY	4	prey	rype	both
reel	REAL	4	real	elra	most
real	REEL	4	reel	elre	most
sore	SOAR	4	soar	orsa	high
soar	SORE	4	sore	oesr	high
surf	SERF	4	serf	efsr	play
serf	SURF	4	surf	ufsr	play
versus	VERSES	6	verses	esvsre	taking
verses	VERSUS	6	versus	esvsru	taking
blue	BLEW	4	blew	lwbe	past
blew	BLUE	4	blue	lebu	past
sell	CELL	4	cell	elcl	dumb
cell	SELL	4	sell	elsl	want
course	COARSE	6	coarse	orceas	pretty
coarse	COURSE	6	course	orceus	pretty
deer	DEAR	4	dear	erda	blow
dear	DEER	4	deer	erde	blow
frieze	FREEZE	6	freeze	refeez	making
freeze	FRIEZE	6	frieze	refeiz	making
jeans	GENES	5	genes	ngsee	stick
genes	JEANS	5	jeans	ajsen	stick
grown	GROAN	5	groan	ognra	movie
groan	GROWN	5	grown	ognrw	movie
haul	HALL	4	hall	alhl	sing

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hall	HAUL	4	haul	alhu	sing
lone	LOAN	4	loan	onla	rich
loan	LONE	4	lone	oeln	rich
maul	MALL	4	mall	alml	grow
mall	MAUL	4	maul	almu	grow
minor	MINER	5	miner	nmrie	trust
miner	MINOR	5	minor	nmrio	trust
pale	PAIL	4	pail	alpi	born
pail	PALE	4	pale	aepl	born
piece	PEACE	5	peace	apeec	buddy
peace	PIECE	5	piece	epeic	buddy
rode	ROAD	4	road	odra	ugly
road	RODE	4	rode	oerd	ugly
sale	SAIL	4	sail	alsi	drug
sail	SALE	4	sale	aesl	drug
shoot	CHUTE	5	chute	uceht	saved
chute	SHOOT	5	shoot	ostho	saved
steel	STEAL	5	steal	eslta	touch
steal	STEEL	5	steel	eslte	touch
tale	TAIL	4	tail	alti	bond
tail	TALE	4	tale	aetl	bond
tied	TIDE	4	tide	ietd	army
tide	TIED	4	tied	idte	army
week	WEAK	4	weak	ekwa	ship
weak	WEEK	4	week	ekwe	ship

Table 43. *Non-homophone word targets with the reference used for the "different" condition and associated primes for the masked-priming same-different task, Experiment 8.*

Different Reference	Target	Word Len	Prime Type		
			Identity	Scrambled	Unrelated
worst	INERT	5	inert	eitnr	shoes
inert	WORST	5	worst	rwtos	dance
taint	JOINT	5	joint	ijton	asked
joint	TAINT	5	taint	ittan	close
story	SHADE	5	shade	asehd	quick
shade	STORY	5	story	osytr	alive
quirky	FORGET	6	forget	ogftre	public
forget	QUIRKY	6	quirky	urqyik	please
leaflet	COMFORT	7	comfort	ofrcmto	arguing
comfort	LEAFLET	7	leaflet	efelatl	propose
specific	LIFESPAN	8	lifespan	ienlpfsa	cookbook
lifespan	SPECIFIC	8	specific	pccsfeii	barnyard
song	SCAM	4	scam	cmsa	five
scam	SONG	4	song	ogsn	idea
step	PLOY	4	ploy	lypo	free
ploy	STEP	4	step	tpse	fall
vase	LUCK	4	luck	uklc	rest
luck	VASE	4	vase	aevs	drop
lump	KERB	4	kerb	ebkr	till
kerb	LUMP	4	lump	uplm	goes
vinyl	MEDIC	5	medic	dmcei	shall
medic	VINYL	5	vinyl	nvliy	water
yelp	MOCK	4	mock	okmc	read
mock	YELP	4	yelp	epyl	food
union	MONTH	5	month	nmhot	speak
month	UNION	5	union	iunno	death
rice	COLD	4	cold	odcl	true
cold	RICE	4	rice	ierc	also
trauma	NATURE	6	nature	aunetr	simply

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nature	TRAUMA	6	trauma	rutaam	people
ride	FENS	4	fens	esfn	part
fens	RIDE	4	ride	ierd	walk
winch	SKIRT	5	skirt	istkr	ahead
skirt	WINCH	5	winch	nwhic	party
morgue	ADVERT	6	advert	deatvr	finish
advert	MORGUE	6	morgue	ogmeru	anyway
soup	LEAK	4	leak	ekla	city
leak	SOUP	4	soup	opsu	face
soil	SKID	4	skid	kdsi	boat
skid	SOIL	4	soil	olsi	dark
wealth	DEFEAT	6	defeat	eedtfa	church
defeat	WEALTH	6	wealth	elwhat	bigger
cough	BLOAT	5	bloat	obtla	third
bloat	COUGH	5	cough	uchog	dying
mesh	FLIP	4	flip	lpfi	duty
flip	MESH	4	mesh	ehms	pool
ritual	EARING	6	earing	aiegrn	system
earing	RITUAL	6	ritual	iurlta	second
optic	FIRST	5	first	rftis	judge
first	OPTIC	5	optic	tocpi	hurry
icon	DULL	4	dull	uldl	fish
dull	ICON	4	icon	cnio	huge
melt	DISH	4	dish	ihds	buck
dish	MELT	4	melt	etml	card
nimble	ENERGY	6	energy	nreyeg	affair
energy	NIMBLE	6	nimble	ibneml	laughs
form	BALM	4	Balm	ambl	tiny
balm	FORM	4	Form	omfr	nuts
wife	PACK	4	Pack	akpc	fill
pack	WIFE	4	Wife	iewf	arms
club	ACHY	4	Achy	cyah	slow
achy	CLUB	4	Club	lbcu	joke
valuable	SCHEDULE	8	schedule	ceesuhdl	playbook
schedule	VALUABLE	8	valuable	auevblal	psychics

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small	ABOUT	5	About	oatbu	drunk
about	SMALL	5	Small	aslml	visit
upon	SEEK	4	Seek	ekse	bang
seek	UPON	4	Upon	pnuo	salt
panic	DREAM	5	Dream	edmra	awful
dream	PANIC	5	Panic	npcai	madam
mint	MESS	4	Mess	esms	join
mess	MINT	4	Mint	itmn	cars
sound	SHOUT	5	Shout	osthu	marry
shout	SOUND	5	Sound	usdon	clock
threat	COLOUR	6	colour	oocrlu	needed
colour	THREAT	6	Threat	hettra	pulled
motto	MAGIC	5	magic	gmcai	ought
magic	MOTTO	5	motto	tmoot	lunch
oats	MASS	4	mass	asms	open
mass	OATS	4	oats	asot	knew
wake	HILT	4	hilt	ithl	safe
hilt	WAKE	4	wake	aewk	sort
legs	CANE	4	cane	aecn	busy
cane	LEGS	4	legs	eslg	junk
print	NORTH	5	north	rnhot	lives
north	PRINT	5	print	iptrn	class
violate	COMMENT	7	comment	omncmte	highway
comment	VIOLATE	7	violate	iltvoea	unhappy
webs	KIDS	4	kids	iskd	hang
kids	WEBS	4	webs	eswb	lion
stunt	ODOUR	5	odour	oordu	times
odour	STUNT	5	stunt	usttn	clear
tear	GYRO	4	gyro	yogr	case
gyro	TEAR	4	tear	erta	kiss
soft	HYPO	4	hypo	yohp	side
hypo	SOFT	4	soft	otsf	able
they	STAY	4	stay	tysa	line
stay	THEY	4	they	hyte	plan
rope	GIRL	4	girl	ilgr	send

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girl	ROPE	4	rope	oerp	glad
song	PAGE	4	page	aepg	boss
page	SNOG	4	snog	ngso	hate
user	COAL	4	coal	olca	gets
coal	USER	4	user	srue	fact
rust	PUMP	4	pump	uppm	gave
pump	RUST	4	rust	utrs	game
unit	GRID	4	grid	rdgi	eyes
grid	UNIT	4	unit	ntui	hope
room	COPE	4	cope	oecp	half
cope	ROOM	4	room	omro	each
spat	HOST	4	host	oths	deal
host	SPAT	4	spat	ptsa	fire
tech	ASHY	4	ashy	syah	gone
ashy	TECH	4	tech	ehtc	lady
ponder	CANDLE	6	candle	adcenl	though
candle	PONDER	6	ponder	odprne	attack
harm	DUDE	4	dude	uedd	pass
dude	HARM	4	harm	amhr	cost
ring	BOMB	4	bomb	obbm	land
bomb	RING	4	ring	igrn	fool
parcel	ENOUGH	6	enough	nuehog	picked
enough	PARCEL	6	parcel	acplre	cowboy
stab	SHOT	4	shot	htso	burn
shot	STAB	4	stab	tbsa	lock
safety	GLINTS	6	glints	lngsit	campus
glints	SAFETY	6	safety	aesyft	looked
turbo	SIREN	5	siren	rsnie	group
siren	TURBO	5	turbo	rtoub	using
mercy	CHIME	5	chime	icehm	enjoy
chime	MERCY	5	mercy	rmyec	proud
folk	COPY	4	copy	oycp	late
copy	FOLK	4	folk	okfl	star
text	SODA	4	soda	oasd	bull
soda	TEXT	4	text	ettx	shop

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iron	ARID	4	arid	rdai	moon
arid	IRON	4	iron	rnio	camp
hatch	GLOSS	5	gloss	ogsls	knock
gloss	HATCH	5	hatch	thhac	books
tuna	SWIG	4	swig	wgsi	fort
swig	TUNA	4	tuna	uatn	bond
share	HUMAN	5	human	mhnua	radio
human	SHARE	5	share	asehr	moved
lean	BILL	4	bill	ilbl	hook
bill	LEAN	4	lean	enla	firm
hire	FLOW	4	flow	lwfo	bird
flow	HIRE	4	hire	iehr	gold
decoy	CHILD	5	child	icdhl	paper
child	DECOY	5	decoy	cdyeo	swear
slave	PRICE	5	price	iperc	bunch
price	SLAVE	5	slave	aselv	lying
trap	LINK	4	link	ikln	fast
link	TRAP	4	trap	rpta	wind
fist	DRAG	4	drag	rgda	list
drag	FIST	4	fist	itfs	calm
word	RUSH	4	rush	uhrs	band
rush	WORD	4	word	odwr	bank

Appendix D: Stimuli used in Chapter 5

The stimuli presented in Apperndix D are also the stimuli used for the simulations in Chapter 7.

Table 44. *Word targets and associated primes used for both the masked-priming lexical decision and sandwich-priming task, Experiments 9 and 11 respectively.*

	Prime Type (Number Of Shared Bigrams)				
Target	3 Shared	4 Contiguous Shared	4 Non-Contiguous Shared	7 Shared	All Letter Different
POLICE	eioclp	ipcoel	oipelc	lpieoc	dubrsa
PLENTY	ynltep	nptlye	lnpyet	epnylt	saudbr
POCKET	tkoecp	kpeotc	okptce	cpktoe	dubrsa
TWENTY	ynwtet	nttwye	wntyet	etnywt	uarbds
CRYING	girnyc	icnrgy	ricgyn	ycigrn	tkaesb
COLUMN	nuomlc	ucmonl	oucnlm	lcunom	sbktae
WORLDS	slodrw	lwdosr	olwsrd	rwlsod	tkaesb
FORMAL	lmoarf	mfaolr	omflra	rfmloa	kbeats
SOCIAL	lioacs	isaolc	oislca	csiloa	tguedb
SAILOR	rlaois	lsoari	alsrio	islrao	dbgtue
SHRINK	kihnrs	isnhkr	hiskrn	rsikhn	tguedb
SHRIMP	pihmrs	ismhpr	hisprm	rsiphm	gbeutd
COMING	gionmc	icnogm	oicgmn	mcigon	rluetb
MOVING	gionvm	imnogv	oimgvn	vmigon	tblrue
WISDOM	mdiosw	dwoims	idwmso	swdmio	rluetb
PSYCHO	ocshyp	cphsoy	scpoyh	ypcosh	lbeurt
FRIEND	dernif	efnrdi	refdin	ifedrn	tgahuc
REMIND	dienmr	irnedm	eirdmn	mriden	ucgtah
BODIES	yreatb	rbaeyt	erbyta	tbryea	tgahuc
SPIDER	rdpeis	dsepri	pdsrie	isdrpe	gchatu
TAKING	giankt	itnagk	aitgkn	ktigan	seorvc
GUILTY	ylutig	lgtuyi	ulgyit	iglyut	vcesor
LAYING	gianyl	ilnagy	ailgyn	yligan	seorvc
KINDLY	ydilnk	dkliyn	idkynl	nkdyil	ecrosv

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MINUTE	euitnm	umtien	iument	nmueit	daorwc
SINGLE	egilns	gslien	igsenl	nsgeil	wcador
ITSELF	fetlsi	eiltfs	teifsl	sieftl	daorwc
GENIUS	sieung	iguesn	eigsnu	ngiseu	acrodw
ASKING	gisnka	iansgk	siagkn	kaigsn	yuetpd
SIGNAL	lniags	nsailg	inslga	gsnlia	pduyet
BORING	sioedb	ibeosd	oibsde	dbisoe	yuetpd
GROANS	sarnog	agnrso	ragson	ogasrn	udteyp
CREDIT	tdriec	dcirte	rdctei	ecdtri	saunmh
BRIDGE	harteb	abtrhe	rabhet	ebahrt	mhasun
PERIOD	dieorp	ipoedr	eipdro	rpideo	saunmh
EDITOR	rtdoie	teodri	dterio	ietrdo	ahnusm
SHOULD	duhlos	uslhdo	husdol	osudhl	tamcpi
SHOWED	dwheos	wsehdo	hwsdoe	oswdhe	piatmc
BURNED	dnuerb	nbeudr	unbdre	rbndue	tamcpi
BURDEN	snrgib	nbgrsi	rnbsig	ibnsrg	aicmtp
THINKS	snhkit	ntkhsi	hntsik	itnshk	rdoeul
SWITCH	htwcis	tscwhi	wtshic	isthwc	uldroe
MIGHTY	yhitgm	hmtiyg	ihmygt	gmhyit	rdoeul
FIGHTS	shitgf	hftisg	ihfsgt	gfhsit	dleoru
SAYING	gianys	isnagy	aisgyn	ysigan	rdoewp
NIGHTS	shitgn	hntisg	ihnsgt	gnhsit	wpdroe
SAVING	gianvs	isnagv	aisgvn	vsigan	rdoewp
FACING	giancf	ifnagc	aifgcn	cfigan	dpeorw
JACKET	tkaecj	kjeatc	akjtce	cjktae	hiusnp
TRAVEL	lvreat	vterla	rvtlae	atvlre	npihus
BARELY	yealrb	eblayr	aebyrl	rbeyal	hiusnp
BACKED	dkaecb	kbeadc	akbdce	cbkdae	ipsuhn
DOUBLE	ebolud	bdloeu	obdeul	udbeol	shitgr
LOCKED	dkoecl	kleodc	okldce	clkdoe	grhsit
PLACED	dcleap	cpelda	lcpdae	apcdle	shitgr
BOUNCE	tgohub	gbhotu	ogbtuh	ubgtoh	hrtisg

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MAKING	giankm	imnagk	aimgkn	kmigan	dvoels
BACKUP	pkaucb	kbuapc	akbpcu	cbkpau	lsvdoe
ACTING	gicnta	iancgt	ciagtn	taigcn	dvoels
BUYING	giunyb	ibnugy	uibgyn	ybigun	vseodl
HUNGRY	ygurnh	ghruyn	ughynr	nhgyur	seolwt
DURING	giunrd	idnugr	uidgrn	rdigun	wtesol
BRANDY	sirnab	ibnrsa	ribsan	abisrn	seolwt
RACING	giancr	irnagc	airgcn	crigan	etlosw
PLAYED	dyleap	ypelda	lypdae	apydle	scrkut
WEAPON	npeoaw	pwoena	epwnao	awpneo	utcsrk
BELONG	goenlb	obnegl	eobgln	lbogen	scrkut
BEHALF	faelhb	ablefh	eabfhl	hbafel	ctkrsu
EXCUSE	euxsce	uesxec	xueecs	ceuexs	girnyt
FAMOUS	soaumf	ofuasm	aofsmu	mfosau	ytigrn
SEXUAL	lueaxs	usaelx	euslxa	xsulea	girnyt
SHAVED	dvheas	vsehda	hvsdae	asvdhe	itnrgy
JUNIOR	riuonj	ijourn	uijrno	njiruo	dhaesw
PUBLIC	cluibp	lpiucb	ulpcbi	bplcui	swhdae
COUNTY	ynotuc	nctoyu	oncyut	ucnyot	dhaesw
INFORM	monrfi	oirnmf	noimfr	fiomnr	hweads
CHARGE	erhgac	rcghea	hrceag	acrehg	snoduw
CARPET	tpaerc	pceatr	apctre	rcptae	uwnsod
ACTIVE	eicvta	iavcet	ciaetv	taiecv	snoduw
NICELY	yeilcn	enliyc	ienycl	cneyil	nwdosu
FINGER	rgienf	gfeirn	igfrne	nfgrie	sldtua
HIGHER	rhiegh	hheirg	ihhrge	ghhrie	ualsdt
RECKON	nkeocr	kroenc	ekrnco	crkneo	sldtua
HOCKEY	ykoech	kheoyc	okhyce	chkyoe	latdsu
SIMPLY	ypilms	psliym	ipsyml	mspyil	rhoetb
VISUAL	luiasv	uvails	iuvlsa	svulia	tbhroe
CAMPUS	spaumc	pcuasm	apcsmu	mcpsau	rhoetb
CANYON	nyaonc	ycoann	aycnno	ncynao	hbeort
HAVING	gianvh	ihnagv	aihgvn	vhigan	tkuecb

PARDON	ndaorp	dpoanr	adpnro	rpdnao	cbktue

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LOSING	gionsl	ilnogs	oilgsn	sligon	tkuecb
FLYING	gilnyf	ifnlgy	lifgyn	yfigln	kbeutc
ENOUGH	hungoe	uegnho	nuehog	oeuhng	silmac
FORGET	tgoerf	gfeotr	ogftre	rfgtoe	acislm
WONDER	rdoenw	dweorn	odwrne	nwdroe	silmac
TONGUE	snhkit	ntkhsi	hntsik	itnshk	icmlsa
FATHER	rhaetf	hfeart	ahfrte	tfhrae	suldoc
BREATH	ynrdab	nbdrya	rnbyad	abnyrd	ocusld
PERMIT	tmeirp	mpietr	emptri	rpmtei	suldoc
HEIGHT	tgehih	ghheti	eghtih	ihgteh	ucdlso
FIGURE	euirgf	ufrieg	iufegr	gfueir	tboamc
SURELY	yeulrs	esluyr	uesyrl	rseyul	mcbtoa
FIELDS	slidef	lfdise	ilfsed	eflsid	tboamc
INJURY	yunrji	uirnyj	nuiyjr	jiuynr	bcaotm
FILTHY	ytihlf	tfhiyl	itfylh	lftyih	eposrc
KNIGHT	tgnhik	gkhnti	ngktih	ikgtnh	rcpeos
MAGNUM	mnaugm	nmuamg	anmmgu	gmnmau	eposrc
UNFAIR	ranifu	auinrf	naurfi	fuarni	pcsoer
METHOD	dheotm	hmoedt	ehmdto	tmhdeo	gianyp
HUSTLE	etulsh	thlues	uthesl	shteul	ypigan
SHOWER	rwheos	wsehro	hwsroe	oswrhe	gianyp
COURSE	erosuc	rcsoeu	orceus	ucreos	ipnagy
SECOND	doencs	osnedc	eosdcn	csoden	yialmf
PERSON	nseorp	spoenr	espnro	rpsneo	mfiyal
POWERS	seorwp	eprosw	oepswr	wpesor	yialmf
SOURCE	erocus	rscoeu	orseuc	usreoc	iflaym
REASON	nseoar	sroena	esrnao	arsneo	tglhif
SCARED	drceas	rsecda	crsdae	asrdce	ifgtlh
SQUARE	eaqrus	asrqeu	qaseur	usaeqr	tglhif
SPREAD	depars	esapdr	pesdra	rsedpa	gfhlti
PLAGUE	egluap	gpulea	lgpeau	apgelu	dboirf

VALUES	suaelv	uveasl	auvsle	lvusae	rfbdoi

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PLACES	scleap	cpelsa	lcpsae	apcsle	dboirf
PLANET	tnleap	npelta	lnptae	apntle	bfiodr
STRONG	gotnrs	osntgr	tosgrn	rsogtn	ebulmh
SPRING	gipnrs	isnpgr	pisgrn	rsigpn	mhbeul
STRING	gitnrs	isntgr	tisgrn	rsigtn	ebulmh
WAKING	luiasv	uvails	iuvlsa	svulia	bhluem
BOXING	enocub	nbcoeu	onbeuc	ubneoc	ryreap
MONTHS	stohnm	tmhosn	otmsnh	nmtsoh	apyrre
COUSIN	nsoiuc	scionu	oscnui	ucsnoi	ryreap
INSULT	tunlsi	uilnts	nuitsl	siutnl	yperra
NOTICE	eioctn	incoet	oinetc	tnieoc	ywuabs
LONGER	rgoenl	gleorn	oglrne	nlgroe	bswyua
THRONE	eohnrt	otnher	hotern	rtoehn	ywuabs
NICKED	dkiecn	kneidc	ikndce	cnkdie	wsauyb
NUMBER	rbuemn	bneurm	ubnrme	mnbrue	tglhis
COMEDY	yeodmc	ecdoym	oecymd	mceyod	isgtlh
WARDEN	ndaerw	dweanr	adwnre	rwdnae	tglhis
PROVEN	nvreop	vperno	rvpnoe	opvnre	gshlti
NORMAL	lmoarn	mnaolr	omnlra	rnmloa	dkuecs
BRIGHT	edrgib	dbgrei	rdbeig	ibderg	cskdue
PROFIT	tfriop	fpirto	rfptoi	opftri	dkuecs
FAIRLY	yralif	rflayi	arfyil	ifryal	kseudc
STUPID	dptius	psitdu	tpsdui	uspdti	rkaelw
BOUGHT	gionrb	ibnogr	oibgrn	rbigon	lwkrae
POINTS	snotip	nptosi	onpsit	ipnsot	rkaelw
POUNDS	snodup	npdosu	onpsud	upnsod	kwearl
LIGHTS	shitgl	hltisg	ihlsgt	glhsit	dnaerw
POLICY	yioclp	ipcoyl	oipylc	lpiyoc	rwndae
FOUGHT	tgohuf	gfhotu	ogftuh	ufgtoh	dnaerw
GROUPS	surpog	ugprso	rugsop	ogusrp	nweadr
MYSELF	feylsm	emlyfs	yemfsl	smefyl	dairzw

HONEST	teosnh	ehsotn	oehtns	nhetos	zwadir
PHONES	snheop	npehso	hnpsoe	opnshe	dairzw
COUPLE	spoeuc	pceosu	opcsue	ucpsoe	awridz
PICKED	dkiecp	kpeidc	ikpdce	cpkdie	ytohrw
DECIDE	eiedcd	iddeec	eidecd	cdieed	rwtyoh
LICKED	dkieck	kkeidc	ikkdce	ckkdie	ytohrw
PENCIL	lceinp	cpieln	ecplni	npclei	twhoyr

Table 45. *Nonword targets and associated primes used for both the masked-priming lexical decision and sandwich-priming task, Experiments 9 and 11 respectively, Chapter 5.*

	Prime Type (Number Of Shared Bigrams)				
Target	3 Shared	4 Contiguous Shared	4 Non-Contiguous Shared	7 Shared	All Letter Different
FOLICE	eioclf	ifcoel	oifelc	lfieoc	dumrsa
CLENTY	ynltec	nctlye	lncyet	ecnylt	saudmr
BOCKET	tkoecb	kbeotc	okbtce	cbktoe	muadsr
SWENTY	ynwtes	nstwye	wnsyet	esnywt	uarmds
BRYING	girnyb	ibnrgy	ribgyn	ybigrn	tkaesp
DOLUMN	nuomld	udmonl	oudnlm	ldunom	spktae
VORLDS	slodrv	lvdosr	olvsrd	rvlsod	akptse
GORMAL	lmoarg	mgaolr	omglra	rgmloa	kpeats
POCIAL	lioacp	ipaolc	oiplca	cpiloa	tguedm
CAILOR	rlaoic	lcoari	alcrio	iclrao	dmgtue
THRINK	kihnrt	itnhkr	hitkrn	rtikhn	ugmtde
CHRIMP	pihmrc	icmhpr	hicprm	rciphm	gmeutd
JOMING	gionmj	ijnogm	oijgmn	mjigon	rluetf
BOVING	gionvb	ibnogv	oibgvn	vbigon	tflrue
HISDOM	mdiosh	dhoims	idhmso	shdmio	ulfrte
PLYCHO	oclhyp	cphloy	lcpoyh	ypcolh	lfeurt
CRIEND	dernic	ecnrdi	recdin	icedrn	tgahuw
SEMIND	dienms	isnedm	eisdmn	msiden	uwgtah
JODIES	sioedj	ijeosd	oijsde	djisoe	agwtuh
SHIDER	rdheis	dsehri	hdsrie	isdrhe	gwhatu
PAKING	giankp	ipnagk	aipgkn	kpigan	seorvj
HUILTY	ylutih	lhtuyi	ulhyit	ihlyut	vjesor
MAYING	gianym	imnagy	aimgyn	ymigan	oejsvr
WINDLY	ydilnw	dwliyn	idwynl	nwdyil	ejrosv
SINUTE	euitns	ustien	iusent	nsueit	daorwp
LINGLE	egilnl	gllien	iglenl	nlgeil	wpador

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ATSELF	fetlsa	ealtfs	teafsl	saeftl	oapdwr
KENIUS	sieunk	ikuesn	eiksnu	nkiseu	aprodw
ANKING	ginnka	ianngk	niagkn	kaignn	yuetpb
MIGNAL	lniagm	nmailg	inmlga	gmnlia	pbuyet
JORING	gionrj	ijnogr	oijgrn	rjigon	eubypt
CROANS	sarnoc	acnrso	racson	ocasrn	ubteyp
PREDIT	tdriep	dpirte	rdptei	epdtri	saunml
CRIDGE	edrgic	dcgrei	rdceig	icderg	mlasun
WERIOD	dieorw	iwoedr	eiwdro	rwideo	ualsmn
ADITOR	rtdoia	taodri	dtario	iatrdo	alnusm
THOULD	duhlot	utlhdo	hutdol	otudhl	tafcpi
PHOWED	dwheop	wpehdo	hwpdoe	opwdhe	piatfc
WURNED	dnuerw	nweudr	unwdre	rwndue	faitpc
CURDEN	nduerc	dceunr	udcnre	rcdnue	aicftp
SHINKS	snhkis	nskhsi	hnssik	isnshk	rdoeuf
SPITCH	htpcis	tscphi	ptshic	isthpc	ufdroe
WIGHTY	yhitgw	hwtiyg	ihwygt	gwhyit	odfrue
KIGHTS	shitgk	hktisg	ihksgt	gkhsit	dfeoru
CAYING	gianyc	icnagy	aicgyn	ycigan	rdoewl
PIGHTS	shitgp	hptisg	ihpsgt	gphsit	wldroe
GAVING	gianvg	ignagv	aiggvn	vgigan	odlrwe
HACING	gianch	ihnagc	aihgcn	chigan	dleorw
WACKET	tkaecw	kweatc	akwtce	cwktae	hiusnb
CARVEL	lvreac	vcerla	rvclae	acvlre	npihus
PARELY	yealrp	eplayr	aepyrl	rpeyal	uibhns
DACKED	dkaecf	kfeadc	akfdce	cfkdae	ibsuhn
FOUBLE	eboluf	bfloeu	obfeul	ufbeol	shitgv
TOCKED	dkoect	kteodc	oktdce	ctkdoe	gvhsit
BLACED	dcleab	cbelda	lcbdae	abcdle	ihvsgt
LOUNCE	enocul	nlcoeu	onleuc	ulneoc	hvtisg
GAKING	giankg	ignagk	aiggkn	kgigan	dvoelp
HACKUP	pkauch	khuapc	akhpcu	chkpau	lpvdoe

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ASTING	gisnta	iansgt	siagtn	taigsn	ovpdle
CUYING	giunyc	icnugy	uicgyn	ycigun	vpeodl
MUNGRY	ygurnm	gmruyn	ugmynr	nmgyur	seolwn
BURING	giunrb	ibnugr	uibgrn	rbigun	wnesol
SRANDY	ynrdas	nsdrya	rnsyad	asnyrd	oenswl
GACING	giancg	ignagc	aiggcn	cgigan	enlosw
BLAYED	dyleab	ybelda	lybdae	abydle	scrkus
MEAPON	npeoam	pmoena	epmnao	ampneo	uscsrk
HELONG	goenlh	ohnegl	eohgln	lhogen	rcssuk
VEHALF	faelhv	avlefh	eavfhl	hvafel	cskrsu
AXCUSE	euxsca	uasxec	xuaecs	cauexs	girnyb
LAMOUS	soauml	oluasm	aolsmu	mlosau	ybigrn
FEXUAL	lueaxf	ufaelx	euflxa	xfulea	ribgyn
CHAVED	dvheac	vcehda	hvcdae	acvdhe	ibnrgy
LUNIOR	riuonl	ilourn	uilrno	nliruo	dhaesk
HUBLIC	cluibh	lhiucb	ulhcbi	bhlcui	skhdae
MOUNTY	ynotum	nmtoyu	onmyut	umnyot	ahkdse
ANFORM	monrfa	oarnmf	noamfr	faomnr	hkeads
THARGE	erhgat	rtghea	hrteag	atrehg	snodul
MARPET	tpaerm	pmeatr	apmtre	rmptae	ulnsod
OCTIVE	eicvto	iovcet	cioetv	toiecv	snoduw
PICELY	yeilcp	epliyc	iepycl	cpeyil	nldosu
KINGER	rgienk	gkeirn	igkrne	nkgrie	slbtua
VIGHER	rhiegv	hveirg	ihvrge	gvhrie	ualsbt
LECKON	nkeocl	kloenc	eklnco	clkneo	blasut
MOCKEY	ykoecm	kmeoyc	okmyce	cmkyoe	latbsu
CIMPLY	ypilmc	pcliym	ipcyml	mcpyil	rhoetd
MISUAL	luiasm	umails	iumlsa	smulia	tdhroe
HAMPUS	spaumh	phuasm	aphsmu	mhpsau	ohdrte
PANYON	nyaonp	ypoann	aypnno	npynao	hdeort
KAVING	gianvk	iknagv	aikgvn	vkigan	tkuecl
FARDON	ndaorf	dfoanr	adfnro	rfdnao	clktue

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GOSING	gionsg	ignogs	oiggsn	sgigon	ukltce
FUYING	giunyf	ifnugy	uifgyn	yfigun	kleutc
EDOUGH	hudgoe	uegdho	duehog	oeuhdg	silmaf
KORGET	tgoerk	gkeotr	ogktre	rkgtoe	afislm
MONDER	rdoenm	dmeorn	odmrne	nmdroe	lifsam
DONGUE	egound	gduoen	ogdenu	ndgeou	ifmlsa
CATHER	rhaetc	hceart	ahcrte	tchrae	suldog
PREATH	hartep	aptrhe	raphet	epahrt	ogusld
BERMIT	tmeirb	mbietr	embtri	rbmtei	lugsod
JEIGHT	tgehij	gjheti	egjtih	ijgteh	ugdlso
WIGURE	euirgw	uwrieg	iuwegr	gwueir	tboamn
HURELY	yeulrh	ehluyr	uehyrl	rheyul	mnbtoa
CIELDS	slidec	lcdise	ilcsed	eclsid	obntma
ENJURY	yunrje	uernyj	nueyjr	jeuynr	bnaotm
JAMILY	yialmj	ijlaym	aijyml	mjiyal	eposrw
KEIGHT	tgehik	gkheti	egktih	ikgteh	rwpeos
FAGNUM	mnaugf	nfuamg	anfmgu	gfnmau	opwers
ANFAIR	ranifa	aainrf	naarfi	faarni	pwsoer
WETHOD	dheotw	hwoedt	ehwdto	twhdeo	gianyc
FUSTLE	etulsf	tflues	utfesl	sfteul	ycigan
THOWER	rwheot	wtehro	hwtroe	otwrhe	aicgyn
POURSE	erosup	rpsoeu	orpeus	upreos	icnagy
HECOND	doench	ohnedc	eohdcn	choden	yialmt
BERSON	nseorb	sboenr	esbnro	rbsneo	mtiyal
KOWERS	seorwk	ekrosw	oekswr	wkesor	aityml
FOURCE	erocuf	rfcoeu	orfeuc	ufreoc	itlaym
LEASON	nseoal	sloena	eslnao	alsneo	tglhic
SLARED	drleas	rselda	lrsdae	asrdle	icgtlh
SHUARE	eahrus	asrheu	haseur	usaehr	lgctih
SHREAD	dehars	esahdr	hesdra	rsedha	gchlti
CLAGUE	egluac	gculea	lgceau	acgelu	dboirt
PALUES	suaelp	upeasl	aupsle	lpusae	rtbdoi

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SLACES	scleas	cselsa	lcssae	ascsle	obtdri
CLANET	tnleac	ncelta	lnctae	acntle	bfiodr
SHRONG	gohnrs	osnhgr	hosgrn	rsoghn	ebulmc
SHRING	gihnrs	isnhgr	hisgrn	rsighn	mcbeul
STOING	gitnos	isntgo	tisgon	osigtn	ubceml
ZAKING	giankz	iznagk	aizgkn	kzigan	bcluem
LOXING	gionxl	ilnogx	oilgxn	xligon	ryreas
LONTHS	stohnl	tlhosn	otlsnh	nltsoh	asyrre
POUSIN	nsoiup	spionu	ospnui	upsnoi	rysrae
ONSULT	tunlso	uolnts	nuotsl	soutnl	yserra
GOTICE	eioctg	igcoet	oigetc	tgieoc	ywuabp
HONGER	rgoenh	gheorn	oghrne	nhgroe	bpwyua
SHEORY	yohres	osrhye	hosyer	esoyhr	uwpyba
HICKED	dkiech	kheidc	ikhdce	chkdie	wpauyb
JUMBER	rbuemj	bjeurm	ubjrme	mjbrue	tghhis
NOMEDY	yeodmn	endoym	oenymd	mneyod	isgthh
VARDEN	ndaerv	dveanr	advnre	rvdnae	hgstih
BROVEN	nvreob	vberno	rvbnoe	obvnre	gshhti
PORMAL	lmoarp	mpaolr	omplra	rpmloa	dkuecn
PRIGHT	tgrhip	gphrti	rgptih	ipgtrh	cnkdue
WROFIT	tfriow	fwirto	rfwtoi	owftri	ukndce
WAIRLY	yraliw	rwlayi	arwyil	iwryal	kneudc
SCUPID	dpcius	psicdu	cpsdui	uspdci	rkaelv
LOUGHT	tgohul	glhotu	ogltuh	ulgtoh	lvkrae
MOINTS	snotim	nmtosi	onmsit	imnsot	akvrle
JOUNDS	snoduj	njdosu	onjsud	ujnsod	kvearl
WIGHTS	shitgw	hwtisg	ihwsgt	gwhsit	dnaerj
MOLICY	yioclm	imcoyl	oimylc	lmiyoc	rjndae
VOUGHT	tgohuv	gvhotu	ogvtuh	uvgtoh	anjdre
DROUPS	surpod	udprso	rudsop	odusrp	njeadr
MISELF	feilsm	emlifs	iemfsl	smefil	dairzt
RONEST	teosnr	ersotn	oertns	nretos	ztadir

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SHONES	snheos	nsehso	hnssoe	osnshe	iatdzr
BOUPLE	epolub	pbloeu	opbeul	ubpeol	atridz
HICKED	dkiech	kheidc	ikhdce	chkdie	wpauyb
MECIDE	eiedcm	imdeec	eimecd	cmieed	rptyoh
GICKED	dkiecg	kgeidc	ikgdce	cgkdie	otpyrh
WENCIL	lceinw	cwieln	ecwlni	nwclei	tphoyr

Table 46. *Word references, targets and associated primes used in the "same" condition for the masked-priming same-different task Experiment 10, Chapter 5.*

Reference/ Target	Prime Type				
	3 Shared	4 Contiguous Shared	4 Non-Contiguous Shared	7 Shared	All Letter Different
POLICE	eioclp	ipcoel	oipelc	lpieoc	dubrsa
PLENTY	ynltep	nptlye	lnpyet	epnylt	saudbr
POCKET	tkoecp	kpeotc	okptce	cpktoe	dubrsa
TWENTY	ynwtet	nttwye	wntyet	etnywt	uarbds
CRYING	girnyc	icnrgy	ricgyn	ycigrn	tkaesb
COLUMN	nuomlc	ucmonl	oucnlm	lcunom	sbktae
WORLDS	slodrw	lwdosr	olwsrd	rwlsod	tkaesb
FORMAL	lmoarf	mfaolr	omflra	rfmloa	kbeats
SOCIAL	lioacs	isaolc	oislca	csiloa	tguedb
SAILOR	rlaois	lsoari	alsrio	islrao	dbgtue
SHRINK	kihnrs	isnhkr	hiskrn	rsikhn	tguedb
SHRIMP	pihmrs	ismhpr	hisprm	rsiphm	gbeutd
COMING	gionmc	icnogm	oicgmn	mcigon	rluetb
MOVING	gionvm	imnogv	oimgvn	vmigon	tblrue
WISDOM	mdiosw	dwoims	idwmso	swdmio	rluetb
PSYCHO	ocshyp	cphsoy	scpoyh	ypcosh	lbeurt
FRIEND	dernif	efnrdi	refdin	ifedrn	tgahuc
REMIND	dienmr	irnedm	eirdmn	mriden	ucgtah
BODIES	yreatb	rbaeyt	erbyta	tbryea	tgahuc
SPIDER	rdpeis	dsepri	pdsrie	isdrpe	gchatu
TAKING	giankt	itnagk	aitgkn	ktigan	seorvc
GUILTY	ylutig	lgtuyi	ulgyit	iglyut	vcesor
LAYING	gianyl	ilnagy	ailgyn	yligan	seorvc
KINDLY	ydilnk	dkliyn	idkynl	nkdyil	ecrosv
MINUTE	euitnm	umtien	iument	nmueit	daorwc
SINGLE	egilns	gslien	igsenl	nsgeil	wcador

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ITSELF	fetlsi	eiltfs	teifsl	sieftl	daorwc
GENIUS	sieung	iguesn	eigsnu	ngiseu	acrodw
ASKING	gisnka	iansgk	siagkn	kaigsn	yuetpd
SIGNAL	lniags	nsailg	inslga	gsnlia	pduyet
BORING	sioedb	ibeosd	oibsde	dbisoe	yuetpd
GROANS	sarnog	agnrso	ragson	ogasrn	udteyp
CREDIT	tdriec	dcirte	rdctei	ecdtri	saunmh
BRIDGE	harteb	abtrhe	rabhet	ebahrt	mhasun
PERIOD	dieorp	ipoedr	eipdro	rpideo	saunmh
EDITOR	rtdoie	teodri	dterio	ietrdo	ahnusm
SHOULD	duhlos	uslhdo	husdol	osudhl	tamcpi
SHOWED	dwheos	wsehdo	hwsdoe	oswdhe	piatmc
BURNED	dnuerb	nbeudr	unbdre	rbndue	tamcpi
BURDEN	snrgib	nbgrsi	rnbsig	ibnsrg	aicmtp
THINKS	snhkit	ntkhsi	hntsik	itnshk	rdoeul
SWITCH	htwcis	tscwhi	wtshic	isthwc	uldroe
MIGHTY	yhitgm	hmtiyg	ihmygt	gmhyit	rdoeul
FIGHTS	shitgf	hftisg	ihfsgt	gfhsit	dleoru
SAYING	gianys	isnagy	aisgyn	ysigan	rdoewp
NIGHTS	shitgn	hntisg	ihnsgt	gnhsit	wpdroe
SAVING	gianvs	isnagv	aisgvn	vsigan	rdoewp
FACING	giancf	ifnagc	aifgcn	cfigan	dpeorw
JACKET	tkaecj	kjeatc	akjtce	cjktae	hiusnp
TRAVEL	lvreat	vterla	rvtlae	atvlre	npihus
BARELY	yealrb	eblayr	aebyrl	rbeyal	hiusnp
BACKED	dkaecb	kbeadc	akbdce	cbkdae	ipsuhn
DOUBLE	ebolud	bdloeu	obdeul	udbeol	shitgr
LOCKED	dkoecl	kleodc	okldce	clkdoe	grhsit
PLACED	dcleap	cpelda	lcpdae	apcdle	shitgr
BOUNCE	tgohub	gbhotu	ogbtuh	ubgtoh	hrtisg
MAKING	giankm	imnagk	aimgkn	kmigan	dvoels
BACKUP	pkaucb	kbuapc	akbpcu	cbkpau	lsvdoe

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ACTING	gicnta	iancgt	ciagtn	taigcn	dvoels
BUYING	giunyb	ibnugy	uibgyn	ybigun	vseodl
HUNGRY	ygurnh	ghruyn	ughynr	nhgyur	seolwt
DURING	giunrd	idnugr	uidgrn	rdigun	wtesol
BRANDY	sirnab	ibnrsa	ribsan	abisrn	seolwt
RACING	giancr	irnagc	airgcn	crigan	etlosw
PLAYED	dyleap	ypelda	lypdae	apydle	scrkut
WEAPON	npeoaw	pwoena	epwnao	awpneo	utcsrk
BELONG	goenlb	obnegl	eobgln	lbogen	scrkut
BEHALF	faelhb	ablefh	eabfhl	hbafel	ctkrsu
EXCUSE	euxsce	uesxec	xueecs	ceuexs	girnyt
FAMOUS	soaumf	ofuasm	aofsmu	mfosau	ytigrn
SEXUAL	lueaxs	usaelx	euslxa	xsulea	girnyt
SHAVED	dvheas	vsehda	hvsdae	asvdhe	itnrgy
JUNIOR	riuonj	ijourn	uijrno	njiruo	dhaesw
PUBLIC	cluibp	lpiucb	ulpcbi	bplcui	swhdae
COUNTY	ynotuc	nctoyu	oncyut	ucnyot	dhaesw
INFORM	monrfi	oirnmf	noimfr	fiomnr	hweads
CHARGE	erhgac	rcghea	hrceag	acrehg	snoduw
CARPET	tpaerc	pceatr	apctre	rcptae	uwnsod
ACTIVE	eicvta	iavcet	ciaetv	taiecv	snoduw
NICELY	yeilcn	enliyc	ienycl	cneyil	nwdosu

Table 47. *Nonword references, targets and associated primes used in the "same" condition for the masked-priming same-different task Experiment 10, Chapter 5.*

Reference/ Target	Prime Type (Number Of Shared Bigrams)				
	3 Shared	4 Contiguous Shared	4 Non-Contiguous Shared	7 Shared	All Letter Different
FOLICE	eioclf	ifcoel	oifelc	lfieoc	dumrsa
CLENTY	ynltec	nctlye	lncyet	ecnylt	saudmr
BOCKET	tkoecb	kbeotc	okbtce	cbktoe	muadsr
SWENTY	ynwtes	nstwye	wnsyet	esnywt	uarmds
BRYING	girnyb	ibnrgy	ribgyn	ybigrn	tkaesp
DOLUMN	nuomld	udmonl	oudnlm	ldunom	spktae
VORLDS	slodrv	lvdosr	olvsrd	rvlsod	akptse
GORMAL	lmoarg	mgaolr	omglra	rgmloa	kpeats
POCIAL	lioacp	ipaolc	oiplca	cpiloa	tguedm
CAILOR	rlaoic	lcoari	alcrio	iclrao	dmgtue
THRINK	kihnrt	itnhkr	hitkrn	rtikhn	ugmtde
CHRIMP	pihmrc	icmhpr	hicprm	rciphm	gmeutd
JOMING	gionmj	ijnogm	oijgmn	mjigon	rluetf
BOVING	gionvb	ibnogv	oibgvn	vbigon	tflrue
HISDOM	mdiosh	dhoims	idhmso	shdmio	ulfrte
PLYCHO	oclhyp	cphloy	lcpoyh	ypcolh	lfeurt
CRIEND	dernic	ecnrdi	recdin	icedrn	tgahuw
SEMIND	dienms	isnedm	eisdmn	msiden	uwgtah
JODIES	sioedj	ijeosd	oijsde	djisoe	agwtuh
SHIDER	rdheis	dsehri	hdsrie	isdrhe	gwhatu
PAKING	giankp	ipnagk	aipgkn	kpigan	seorvj
HUILTY	ylutih	lhtuyi	ulhyit	ihlyut	vjesor
MAYING	gianym	imnagy	aimgyn	ymigan	oejsvr
WINDLY	ydilnw	dwliyn	idwynl	nwdyil	ejrosv
SINUTE	euitns	ustien	iusent	nsueit	daorwp
LINGLE	egilnl	gllien	iglenl	nlgeil	wpador

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ATSELF	fetlsa	ealtfs	teafsl	saeftl	oapdwr
KENIUS	sieunk	ikuesn	eiksnu	nkiseu	aprodw
ANKING	ginnka	ianngk	niagkn	kaignn	yuetpb
MIGNAL	lniagm	nmailg	inmlga	gmnlia	pbuyet
JORING	gionrj	ijnogr	oijgrn	rjigon	eubypt
CROANS	sarnoc	acnrso	racson	ocasrn	ubteyp
PREDIT	tdriep	dpirte	rdptei	epdtri	saunml
CRIDGE	edrgic	dcgrei	rdceig	icderg	mlasun
WERIOD	dieorw	iwoedr	eiwdro	rwideo	ualsmn
ADITOR	rtdoia	taodri	dtario	iatrdo	alnusm
THOULD	duhlot	utlhdo	hutdol	otudhl	tafcpi
PHOWED	dwheop	wpehdo	hwpdoe	opwdhe	piatfc
WURNED	dnuerw	nweudr	unwdre	rwndue	faitpc
CURDEN	nduerc	dceunr	udcnre	rcdnue	aicftp
SHINKS	snhkis	nskhsi	hnssik	isnshk	rdoeuf
SPITCH	htpcis	tscphi	ptshic	isthpc	ufdroe
WIGHTY	yhitgw	hwtiyg	ihwygt	gwhyit	odfrue
KIGHTS	shitgk	hktisg	ihksgt	gkhsit	dfeoru
CAYING	gianyc	icnagy	aicgyn	ycigan	rdoewl
PIGHTS	shitgp	hptisg	ihpsgt	gphsit	wldroe
GAVING	gianvg	ignagv	aiggvn	vgigan	odlrwe
HACING	gianch	ihnagc	aihgcn	chigan	dleorw
WACKET	tkaecw	kweatc	akwtce	cwktae	hiusnb
CRAVEL	lvreac	vcerla	rvclae	acvlre	nbihus
PARELY	yealrp	eplayr	aepyrl	rpeyal	uibhns
DACKED	dkaecf	kfeadc	akfdce	cfkdae	ibsuhn
FOUBLE	eboluf	bfloeu	obfeul	ufbeol	shitgv
TOCKED	dkoect	kteodc	oktdce	ctkdoe	gvhsit
BLACED	dcleab	cbelda	lcbdae	abcdle	ihvsgt
LOUNCE	enocul	nlcoeu	onleuc	ulneoc	hvtisg
GAKING	giankg	ignagk	aiggkn	kgigan	dvoelp
HACKUP	pkauch	khuapc	akhpcu	chkpau	lpvdoe

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ASTING	gisnta	iansgt	siagtn	taigsn	ovpdle
CUYING	giunyc	icnugy	uicgyn	ycigun	vpeodl
MUNGRY	ygurnm	gmruyn	ugmynr	nmgyur	seolwn
BURING	giunrb	ibnugr	uibgrn	rbigun	wnesol
SRANDY	ynrdas	nsdrya	rnsyad	asnyrd	oenswl
GACING	giancg	ignagc	aiggcn	cgigan	enlosw
BLAYED	dyleab	ybelda	lybdae	abydle	scrkus
MEAPON	npeoam	pmoena	epmnao	ampneo	uscsrk
HELONG	goenlh	ohnegl	eohgln	lhogen	rcssuk
VEHALF	faelhv	avlefh	eavfhl	hvafel	cskrsu
AXCUSE	euxsca	uasxec	xuaecs	cauexs	girnyb
LAMOUS	soauml	oluasm	aolsmu	mlosau	ybigrn
FEXUAL	lueaxf	ufaelx	euflxa	xfulea	ribgyn
CHAVED	dvheac	vcehda	hvcdae	acvdhe	ibnrgy
LUNIOR	riuonl	ilourn	uilrno	nliruo	dhaesk
HUBLIC	cluibh	lhiucb	ulhcbi	bhlcui	skhdae
MOUNTY	ynotum	nmtoyu	onmyut	umnyot	ahkdse
ANFORM	monrfa	oarnmf	noamfr	faomnr	hkeads
THARGE	erhgat	rtghea	hrteag	atrehg	snodul
MARPET	tpaerm	pmeatr	apmtre	rmptae	ulnsod
ECTIVE	eicvte	ievcet	cieetv	teiecv	onlsud
PICELY	yeilcp	epliyc	iepycl	cpeyil	nldosu

Table 48. *Word references, targets and associated primes used in the "different" condition for the masked-priming same-different task Experiment 10, Chapter 5*

		Prime Type (Number Of Shared Bigrams)				
Reference	Target	3 Shared	4 Contiguous Shared	4 Non-Contiguous Shared	7 Shared	All Letter Different
almost	FINGER	rgienf	gfeirn	igfrne	nfgrie	sldtua
sounds	HIGHER	rhiegh	hheirg	ihhrge	ghhrie	ualsdt
laughs	RECKON	nkeocr	kroenc	ekrnco	crkneo	sldtua
guards	HOCKEY	ykoech	kheoyc	okhyce	chkyoe	latdsu
around	SIMPLY	ypilms	psliym	ipsyml	mspyil	rhoetb
mother	VISUAL	luiasv	uvails	iuvlsa	svulia	tbhroe
behind	CAMPUS	spaumc	pcuasm	apcsmu	mcpsau	rhoetb
strike	CANYON	nyaonc	ycoann	aycnno	ncynao	hbeort
worked	HAVING	gianvh	ihnagv	aihgvn	vhigan	tkuecb
weight	PARDON	ndaorp	dpoanr	adpnro	rpdnao	cbktue
market	LOSING	gionsl	ilnogs	oilgsn	sligon	tkuecb
others	FLYING	gilnyf	ifnlgy	lifgyn	yfigln	kbeutc
ladies	ENOUGH	hungoe	uegnho	nuehog	oeuhng	silmac
island	FORGET	tgoerf	gfeotr	ogftre	rfgtoe	acislm
safety	WONDER	rdoenw	dweorn	odwrne	nwdroe	silmac
hardly	TONGUE	snhkit	ntkhsi	hntsik	itnshk	icmlsa
closed	FATHER	rhaetf	hfeart	ahfrte	tfhrae	suldoc
signed	BREATH	ynrdab	nbdrya	rnbyad	abnyrd	ocusld
stolen	PERMIT	tmeirp	mpietr	emptri	rpmtei	suldoc
dreams	HEIGHT	tgehih	ghheti	eghtih	ihgteh	ucdlso
thanks	FIGURE	euirgf	ufrieg	iufegr	gfueir	tboamc
eating	SURELY	yeulrs	esluyr	uesyrl	rseyul	mcbtoa
nature	FIELDS	slidef	lfdise	ilfsed	eflsid	tboamc
talked	INJURY	yunrji	uirnyj	nuiyjr	jiuynr	bcaotm
ground	FILTHY	ytihlf	tfhiyl	itfylh	lftyih	eposrc
lawyer	KNIGHT	tgnhik	gkhnti	ngktih	ikgtnh	rcpeos
closer	MAGNUM	mnaugm	nmuamg	anmmgu	gmnmau	eposrc
closet	UNFAIR	ranifu	auinrf	naurfi	fuarni	pcsoer
movies	METHOD	dheotm	hmoedt	ehmdto	tmhdeo	gianyp

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toward	HUSTLE	etulsh	thlues	uthesl	shteul	ypigan
tricky	SHOWER	rwheos	wsehro	hwsroe	oswrhe	gianyp
images	COURSE	erosuc	rcsoeu	orceus	ucreos	ipnagy
taught	SECOND	doencs	osnedc	eosdcn	csoden	yialmf
waited	PERSON	nseorp	spoenr	espnro	rpsneo	mfiyal
client	POWERS	seorwp	eprosw	oepswr	wpesor	yialmf
failed	SOURCE	erocus	rscoeu	orseuc	usreoc	iflaym
busted	REASON	nseoar	sroena	esrnao	arsneo	tglhif
toilet	SCARED	drceas	rsecda	crsdae	asrdce	ifgtlh
winter	SQUARE	eaqrus	asrqeu	qaseur	usaeqr	tglhif
loving	SPREAD	depars	esapdr	pesdra	rsedpa	gfhlti
theirs	PLAGUE	egluap	gpulea	lgpeau	apgelu	dboirf
monkey	VALUES	suaelv	uveasl	auvsle	lvusae	rfbdoi
theory	PLACES	scleap	cpelsa	lcpsae	apcsle	dboirf
duties	PLANET	tnleap	npelta	lnptae	apntle	bfiodr
advice	STRONG	gotnrs	osntgr	tosgrn	rsogtn	ebulmh
hearts	SPRING	gipnrs	isnpgr	pisgrn	rsigpn	mhbeul
golden	STRING	gitnrs	isntgr	tisgrn	rsigtn	ebulmh
pilots	WAKING	luiasv	uvails	iuvlsa	svulia	bhluem
master	BOXING	enocub	nbcoeu	onbeuc	ubneoc	ryreap
buried	MONTHS	stohnm	tmhosn	otmsnh	nmtsoh	apyrre
target	COUSIN	nsoiuc	scionu	oscnui	ucsnoi	ryreap
forced	INSULT	tunlsi	uilnts	nuitsl	siutnl	yperra
freaks	NOTICE	eioctn	incoet	oinetc	tnieoc	ywuabs
wished	LONGER	rgoenl	gleorn	oglrne	nlgroe	bswyua
judges	THRONE	eohnrt	otnher	hotern	rtoehn	ywuabs
auther	NICKED	dkiecn	kneidc	ikndce	cnkdie	wsauyb
studio	NUMBER	rbuemn	bneurm	ubnrme	mnbrue	tglhis
listen	COMEDY	yeodmc	ecdoym	oecymd	mceyod	isgtlh
mostly	WARDEN	ndaerw	dweanr	adwnre	rwdnae	tglhis
stayed	PROVEN	nvreop	vperno	rvpnoe	opvnre	gshlti
united	NORMAL	lmoarn	mnaolr	omnlra	rnmloa	dkuecs
silver	BRIGHT	edrgib	dbgrei	rdbeig	ibderg	cskdue
caused	PROFIT	tfriop	fpirto	rfptoi	opftri	dkuecs
object	FAIRLY	yralif	rflayi	arfyil	ifryal	kseudc

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change	STUPID	dptius	psitdu	tpsdui	uspdti	rkaelw
raised	BOUGHT	gionrb	ibnogr	oibgrn	rbigon	lwkrae
danger	POINTS	snotip	nptosi	onpsit	ipnsot	rkaelw
lately	POUNDS	snodup	npdosu	onpsud	upnsod	kwearl
broken	LIGHTS	shitgl	hltisg	ihlsgt	glhsit	dnaerw
wanted	POLICY	yioclp	ipcoyl	oipylc	lpiyoc	rwndae
anwser	FOUGHT	tgohuf	gfhotu	ogftuh	ufgtoh	dnaerw
handle	GROUPS	surpog	ugprso	rugsop	ogusrp	nweadr
hoping	MYSELF	feylsm	emlyfs	yemfsl	smefyl	dairzw
remain	HONEST	teosnh	ehsotn	oehtns	nhetos	zwadir
direct	PHONES	snheop	npehso	hnpsoe	opnshe	dairzw
dating	COUPLE	spoeuc	pceosu	opcsue	ucpsoe	awridz
fourth	PICKED	dkiecp	kpeidc	ikpdce	cpkdie	ytohrw
amount	DECIDE	eiedcd	iddeec	eidecd	cdieed	rwtyoh
fatser	LICKED	dkieck	kkeidc	ikkdce	ckkdie	ytohrw
slower	PENCIL	lceinp	cpieln	ecplni	npclei	twhoyr

Table 49. *Nonword references, targets and associated primes used in the "different" condition for the masked-priming same-different task Experiment 10.*

Reference	Target	Prime Type: 3 Shared	Prime Type: 4 Contiguous Shared	Prime Type: 4 Non-Contiguous Shared	Prime Type: 7 Shared	Prime Type: All Letter Different
ilmost	KINGER	rgienk	gkeirn	igkrne	nkgrie	slbtua
jounds	VIGHER	rhiegv	hveirg	ihvrge	gvhrie	ualsbt
maughs	LECKON	nkeocl	kloenc	eklnco	clkneo	blasut
tuards	MOCKEY	ykoecm	kmeoyc	okmyce	cmkyoe	latbsu
amound	CIMPLY	ypilmc	pcliym	ipcyml	mcpyil	rhoetd
vother	MISUAL	luiasm	umails	iumlsa	smulia	tdhroe
lehind	HAMPUS	spaumh	phuasm	aphsmu	mhpsau	ohdrte
scrike	PANYON	nyaonp	ypoann	aypnno	npynao	hdeort
lorked	KAVING	gianvk	iknagv	aikgvn	vkigan	tkuecl
meight	FARDON	ndaorf	dfoanr	adfnro	rfdnao	clktue
sarket	GOSING	gionsg	ignogs	oiggsn	sgigon	ukltce
athers	FUYING	giunyf	ifnugy	uifgyn	yfigun	kleutc
padies	EDOUGH	hudgoe	uegdho	duehog	oeuhdg	silmaf
esland	KORGET	tgoerk	gkeotr	ogktre	rkgtoe	afislm
pafety	MONDER	rdoenm	dmeorn	odmrne	nmdroe	lifsam
bardly	DONGUE	egound	gduoen	ogdenu	ndgeou	ifmlsa
plosed	CATHER	rhaetc	hceart	ahcrte	tchrae	suldog
bigned	PREATH	hartep	aptrhe	raphet	epahrt	ogusld
sholen	BERMIT	tmeirb	mbietr	embtri	rbmtei	lugsod
preams	JEIGHT	tgehij	gjheti	egjtih	ijgteh	ugdlso
chanks	WIGURE	euirgw	uwrieg	iuwegr	gwueir	tboamn
nating	HURELY	yeulrh	ehluyr	uehyrl	rheyul	mnbtoa
lature	CIELDS	slidec	lcdise	ilcsed	eclsid	obntma
palked	ENJURY	yunrje	uernyj	nueyjr	jeuynr	bnaotm
cround	JAMILY	yialmj	ijlaym	aijyml	mjiyal	eposrw
mawyer	KEIGHT	tgehiK	gKheti	egKtih	iKgteh	rwpeos
choser	FAGNUM	mnaugf	nfuamg	anfmgu	gfnmau	opwers
croset	ANFAIR	ranifa	aainrf	naarfi	faarni	pwsoer
hovies	WETHOD	dheotw	hwoedt	ehwdto	twhdeo	gianyc

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zoward	FUSTLE	etulsf	tflues	utfesl	sfteul	ycigan
pricky	THOWER	rwheot	wtehro	hwtroe	otwrhe	aicgyn
omages	POURSE	erosup	rpsoeu	orpeus	upreos	icnagy
saught	HECOND	doench	ohnedc	eohdcn	choden	yialmt
laited	BERSON	nseorb	sboenr	esbnro	rbsneo	mtiyal
plient	KOWERS	seorwk	ekrosw	oekswr	wkesor	aityml
gailed	FOURCE	erocuf	rfcoeu	orfeuc	ufreoc	itlaym
nusted	LEASON	nseoal	sloena	eslnao	alsneo	tglhic
woilet	SLARED	drleas	rselda	lrsdae	asrdle	icgtlh
binter	SHUARE	eahrus	asrheu	haseur	usaehr	lgctih
joving	SHREAD	dehars	esahdr	hesdra	rsedha	gchlti
sheirs	CLAGUE	egluac	gculea	lgceau	acgelu	dboirt
ponkey	PALUES	suaelp	upeasl	aupsle	lpusae	rtbdoi
cheory	SLACES	scleas	cselsa	lcssae	ascsle	obtdri
juties	CLANETS	tnleac	ncelta	lnctae	acntle	btiodr
Odvice	SHRONG	gohnrs	osnhgr	hosgrn	rsoghn	ebulmc
Learts	SHRING	gihnrs	isnhgr	hisgrn	rsighn	mcbeul
holden	STOING	gitnos	isntgo	tisgon	osigtn	ubceml
Nilots	ZAKING	giankz	iznagk	aizgkn	kzigan	bcluem
Paster	LOXING	gionxl	ilnogx	oilgxn	xligon	ryreas
Luried	LONTHS	stohnl	tlhosn	otlsnh	nltsoh	asyrre
Barget	POUSIN	nsoiup	spionu	ospnui	upsnoi	rysrae
morced	ONSULT	tunlso	uolnts	nuotsl	soutnl	yserra
Treaks	GOTICE	eioctg	igcoet	oigetc	tgieoc	ywuabp
Vished	HONGER	rgoenh	gheorn	oghrne	nhgroe	bpwyua
mudges	SHEORY	yohres	osrhye	hosyer	esoyhr	uwpyba
muther	HICKED	dkiech	kheidc	ikhdce	chkdie	wpauyb
Shudio	JUMBER	rbuemj	bjeurm	ubjrme	mjbrue	tghhis
Kisten	NOMEDY	yeodmn	endoym	oenymd	mneyod	isgthh
Fostly	VARDEN	ndaerv	dveanr	advnre	rvdnae	hgstih
shayed	BROVEN	nvreob	vberno	rvbnoe	obvnre	gshhti
Anited	PORMAL	lmoarp	mpaolr	omplra	rpmloa	dkuecn
Milver	PRIGHT	tgrhip	gphrti	rgptih	ipgtrh	cnkdue
gaused	WROFIT	tfriow	fwirto	rfwtoi	owftri	ukndce
Eject	WAIRLY	yraliw	rwlayi	arwyil	iwryal	kneudc

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Thange	SCUPID	dpcius	psicdu	cpsdui	uspdci	rkaelv
Kaised	LOUGHT	tgohul	glhotu	ogltuh	ulgtoh	lvkrae
wanger	MOINTS	snotim	nmtosi	onmsit	imnsot	akvrle
Kately	JOUNDS	snoduj	njdosu	onjsud	ujnsod	kvearl
croken	WIGHTS	shitgw	hwtisg	ihwsgt	gwhsit	dnaerj
Hanted	MOLICY	yioclm	imcoyl	oimylc	lmiyoc	rjndae
inswer	VOUGHT	tgohuv	gvhotu	ogvtuh	uvgtoh	anjdre
Pandle	DROUPS	surpod	udprso	rudsop	odusrp	njeadr
noping	MISELF	feilsm	emlifs	iemfsl	smefil	dairzt
femain	RONEST	teosnr	ersotn	oertns	nretos	ztadir
Kirect	SHONES	snheos	nsehso	hnssoe	osnshe	iatdzr
Lating	BOUPLE	epolub	pbloeu	opbeul	ubpeol	atridz
mourth	HICKED	dkiech	kheidc	ikhdce	chkdie	ytohrp
emount	MECIDE	eiedcm	imdeec	eimecd	cmieed	rptyoh
Gatser	GICKED	dkiecg	kgeidc	ikgdce	cgkdie	otpyrh
Plower	WENCIL	lceinw	cwieln	ecwlni	nwclei	tphoyr

Appendix E: Stimuli used in Chapter 6

Table 50. *Ascender words, with position of ascender, used in Experiments 12 & 14.*

Position 1	Position 2	Position 3	Position 4	Position 5	Non-Ascender
Trace	alien	eaten	socks	ranch	curse
Beans	charm	motor	costs	civil	wives
Diner	shave	widow	sends	wreck	crown
Lemon	shove	safer	sorts	cried	minor
Drawn	stare	ashes	meets	novel	inner
Hears	slice	outer	reads	smack	areas
Fears	stove	rider	winds	wired	arrow
Laser	chess	rides	crabs	canal	occur
Lease	clues	meter	roots	cured	naive
Disco	stain	medic	coats	naval	erase
Tease	choir	rodeo	realm	crank	moose
Truce	claws	maker	sushi	waist	noses
Karma	elves	mates	ranks	scarf	caves
Finer	clams	ratio	macho	asset	manor
Diver	ulcer	roles	necks	vocal	recon
Dense	slams	males	weeds	vouch	crows
Torso	adieu	usher	sacks	waved	amuse
Downs	chemo	cubes	carts	crock	scans
Doses	whine	nitro	suede	crumb	roars
Havoc	slows	eater	reeks	wench	snore
Twins	clown	sides	suits	crush	sauce
Frame	shown	sales	souls	cared	roses
Brass	steam	skate	nails	moral	waves
Basin	abuse	sober	scale	wrist	comic
Drown	chaos	codes	roads	roast	error
Bonus	adore	votes	meals	smash	minus
Drain	skies	refer	aisle	react	nicer
Lions	items	wakes	risks	scrub	wires

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Timer	straw	cakes	waits	scent	worms
Towns	steer	audio	masks	crook	viens
Dames	sheer	unite	seeds	vomit	seize
Donor	alias	valve	crate	camel	views
Beams	slime	sites	cooks	snuck	semen
Tours	skins	ruler	exits	scoot	arise
Dares	clone	cutie	sails	roach	exams
Fours	rhino	satin	moods	crest	racer
Hires	slain	robes	nerds	vivid	waive
Farce	atoms	rites	exile	aimed	versa
Firms	stair	mater	evils	moist	amaze
Foxes	stems	wiles	warts	mural	newer

Table 51. *Ascender nonwords, with position of ascender, used in Experiments 12 & 14.*

Position 1	Position 2	Position 3	Position 4	Position 5	Non-Ascender
Teace	elien	saten	vocks	rench	vurse
Trame	chown	rales	wouls	sared	moses
Biner	chave	vidow	nends	waeck	srown
Dasis	ebuse	nober	seale	srist	nomic
Trawn	slare	eshes	miets	wovel	anner
Donus	edore	wotes	weals	snash	cinus
Feers	slove	nider	vinds	vired	errow
Fions	atems	vakes	visks	sorub	vires
Fease	alues	neter	noots	sured	maive
howns	sleer	nudio	sasks	srook	vains
hease	shoir	modeo	wealm	craok	voose
tonor	elias	malve	ceate	namel	niews
harma	alves	nates	cinks	soarf	maves
dours	stins	culer	axits	scuot	srise
biver	alcer	woles	niaks	vecal	mecon
bours	ahino	matin	moads	ceest	wacer
horso	edieu	asher	secks	wived	emuse
harce	itoms	nites	axile	wimed	wersa
boses	whane	Sitro	ceude	wrumb	zoars
doxes	shems	ciles	werts	sural	mewer
tains	slown	cides	cuiite	srush	cauce
keans	sharm	notor	voste	cevil	sives
drass	sleam	vakes	cails	miral	zaves
hemon	chove	mafer	vorts	sried	vinor
trown	shaos	zodes	coads	soast	arror
lears	clice	suter	ceads	smick	wreas
frain	chise	sefer	nisle	roack	vicer
daser	shess	mides	srabs	conal	accur

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himer	scraw	nakes	naits	sient	vorms
bisco	shain	wedic	soats	neval	crase
bames	sleer	enite	veeds	vamit	ceize
druce	chaws	naker	cushi	vaise	coses
keams	shime	vites	sooks	smuck	vemen
biner	chams	catio	micho	isset	sanor
lared	chone	sutes	sanls	noach	axams
bense	stams	nates	ceeds	wouch	srows
bires	alian	wobes	nirds	mivid	zaive
lowns	shemo	vubes	cirts	wrock	smans
lirms	slair	sater	avils	viost	emaze
favoc	clows	nater	rieks	nench	anore

Table 52. *Descender words, with position of descender, used in Experiments 13 & 15.*

Position 1	Position 2	Position 3	Position 4	Position 5	Non-Ascender
pizza	agree	sugar	range	among	scare
grass	opera	super	songs	swing	owner
prior	spoon	argue	corps	creep	minor
jeans	spine	wagon	sings	swamp	areas
pains	spies	organ	amigo	noisy	mines
genie	apron	ropes	verge	crisp	canoe
germs	spree	wager	craps	annoy	mourn
prone	spins	cages	crops	curry	smear
poses	spawn	urges	siege	scamp	ozone
giver	cynic	wipes	surge	icing	manic
peace	space	magic	rings	enemy	cream
prime	spare	mayor	image	scary	rooms
goose	opens	signs	wings	mercy	nerve
grams	sperm	anger	cargo	sweep	error
pause	spice	cigar	scope	scoop	erase
grain	spear	eager	camps	rainy	arena
genes	opium	vague	reign	cramp	exams
gowns	specs	rogue	snaps	snoop	rinse
groin	spurs	vogue	ninja	array	renew
pines	squaw	caper	wraps	swoop	moans

Table 53. *Descender nonwords, with position of descender, used in Experiments 13 & 15.*

Position 1	Position 2	Position 3	Position 4	Position 5	Non-Ascender
pezza	igree	vugar	ronge	omong	smare
gress	apera	nuper	congs	sning	awner
priom	spoom	orgue	cirps	sreep	cinor
jeams	spime	nagon	mings	sramp	aneas
paims	spaes	argan	anigo	woisy	mives
gemie	opron	wopes	werge	crosp	camoe
garms	spren	wiger	crups	ennoy	wourn
prane	spims	coges	srops	nurry	scear
pises	spown	orges	miege	scomp	azone
gover	cynim	nipes	nurge	iming	canic
peawe	spave	sagic	nings	inemy	crean
prome	spawe	vayor	emage	snary	nooms
goome	apens	migns	vings	sercy	merve
groms	sparm	onger	cango	smeep	arror
pauce	spime	migar	smope	smoop	emase
graim	speam	sager	samps	zainy	orena
genec	apium	wague	reigm	cromp	exoms
gowms	spacs	nogue	smaps	sroop	cinse
groim	spums	vigue	nonja	orray	senew
pimes	squam	saper	sraps	sroop	zoans