Processing SMS shortcuts: The contribution of phonology, orthography and semantics

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Abstract

This thesis explores the question of whether unusual and visually irregular stimuli, such as SMS shortcuts (e.g., *txt*; text, *l8r*; later) are processed in the same way as familiar words. Early computational models such as the Dual Route Cascaded (DRC) Model (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) and the Interactive Activation (IA) model (McClelland & Rumelhart, 1981) implemented a slot based letter coding system that assumed letter positions in a word had to be accurate for word recognition to occur. However, more recent research has demonstrated that subsets of the consonants in a word (e.g., *blcn-BALCON*) are able to access the lexicon, suggesting that the system may be fairly flexible (Duñabeitia & Carreiras, 2011; Peressotti & Grainger, 1999). Further research with familiar abbreviations (e.g., BBC; British Broadcasting Company) suggests that these items are added to the mental lexicon implying that familiarity allows the lexical processor to accommodate visually irregular stimuli (Brysbaert, Speybroeck & Vanderelst, 2009). This finding may be expected to extend to similarly unusual items such as *txt* (text) or *l8r* (later). However, SMS shortcuts are unlike abbreviations because they are alternative spellings of existing words and may not require new lexical entries in order to be processed. As such single word shortcuts, as opposed to initialisms that represent whole phrases (e.g., *lol*; laugh out loud, *tbh*; to be honest), share characteristics with second language cognates (e.g. the English-Spanish cognates *cat* and *gato*) that are also alternative representations of words that already exist in a lexicon. The evidence presented in this thesis supports the suggestion that visually unusual stimuli will be accommodated by the lexical processor if they are familiar and it is likely that they are added to the mental lexicon. In addition the patterns of data exhibited by SMS shortcuts are not dissimilar to those found with second language cognates. This thesis also presents a comprehensive database of SMS shortcuts that provides an indication of the frequency with which these items are currently used by a UK undergraduate population.

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1.1 Overview

The aim of this research is to develop a novel set of stimuli that have high ecological validity and employ them to further current understanding concerning visual word recognition. The stimuli that will be developed and used throughout this body of research are Short Message Service (SMS) shortcuts, such as *txt* (text), *spk* (speak), *m8* (mate) and *l8r* (later). Some of these items were first developed as a way of speeding up online communications via instant messaging, however, as Tagg (2009) points out other forms of shortened words have been apparent in mainstream culture for some time. For example, graffiti and commercial products often contain atypical spellings of familiar words, such as *luvin*[1] (loving) or *kwik* (quick). There are a number of different types of shortcut, some are used to represent whole phrases (e.g., *brb*; be right back or *lol*; laugh out loud), others approximate the phonology of a word (e.g., *wud*; would, *bin*; been), whilst emoticons are used to express emotion (e.g., :-) indicating smiling). However, two specific styles of single word shortcuts are of particular interest to the questions explored in this research. First abbreviated shortcuts such as *txt* (text), *spk* (speak) or *pls* (please) are formed from the consonants in a word and therefore maintain some of the original orthography of their base-words. However, the lack of vowels in these items makes them difficult to decode based on phonology. In other words a system that matches letters (graphemes) to sounds (phonemes) based on the regular rules of English grapheme-to-phoneme correspondence might struggle to process abbreviated shortcuts. On the other hand letter-digit shortcuts such as *l8r* (later), *m8* (mate) or *b4* (before) share little orthography with their base-words and make use of graphemes and digits to represent phonological units (e.g., onset, rhyme or syllables) that correspond to the sounds of their base-words. Thus the visual presentation of these two types of shortcut relies either on orthography or phonology and makes them uniquely positioned to explore questions regarding orthographic and phonological processing during visual word recognition.

[1] See for some examples http://www.ling.lancs.ac.uk/staff/mark/vigo/regspace

However, as SMS shortcuts are alternative versions of existing words that are already represented in the mental lexicon it is possible that they are not processed in the same way as familiar words. Consequently these items raise questions regarding how they are integrated into the lexicon and the links that they form with meaning (semantic information). This research therefore aims to develop two sets of SMS shortcut stimuli that reflect the orthographic and phonological distinctions of abbreviated and letter-digit shortcuts and employ them to investigate the following research questions: 1) Are SMS shortcuts processed like familiar words? 2) What is the contribution of phonology and orthography to SMS shortcut processing? 3) How are SMS shortcuts integrated with semantic information in the mental lexicon? The answers to these questions will not only provide a thorough overview of how SMS shortcuts are processed but also provide insights into the processing of familiar words.

1.2 Introduction

As mentioned above, various forms of shortcut are used in text messages (see Thurlow, 2003; Plester, Wood & Joshi, 2009; Chapter 2 for a review) and they have become familiar to a large number of individuals who regularly use them. In addition, because most of the single word items are easy to decode without requiring prior knowledge they are also known by those who do not use them regularly. Not all words, however, have the potential for being shortened in this way and the single words that are used tend to be of high frequency, short in length and have a low neighbourhood density. Tagg (2009) suggests that a limited set of words are shortened in text messages due to the formulaic nature of text communications. For example, whereas *the* is the most frequent word found in large corpora of words (e.g. the British National Corpus), the most frequent word used in text messages is *you* (see Chapter 2), which is often shortened using the single letter *u.* The research conducted in this thesis will focus on two specific types of shortcut, abbreviated (*txt, msg* etc.) and letter-digit shortcuts (*l8r, 4eva* etc.). The unique orthography of these two types of shortcut combined with the fact that they are recognised by many, makes them ideal stimuli to investigate current questions regarding visual word recognition. More specifically the distinction between orthography and phonology suggested by the abbreviated and letter-digit shortcuts has the potential to inform current debates regarding orthographic and phonological processing.

Researchers investigating the process of visual word recognition generally agree that recognition of a word involves the activation of orthographic and phonological representations that are stored in the mental lexicon and facilitate the rapid processing of visually presented material. However, the proponents of dominant computational models of visual word recognition (e.g., Coltheart & Rastle, 1994; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001; McClelland & Rumelhart, 1981) and strong phonological theorists (see Frost, 2003; Rastle & Brysbaert, 2006; Van Orden, 1990) differ in the role they ascribe to orthographic and phonological information. The dominant computational theory assumes that familiar visually presented words activate a lexical representation that maps onto the spelling of a word (an orthographic representation) from which meaning is accessed. Whereas strong phonological theorists suggest that representations of the sound of words (phonological representations) are rapidly activated and meaning is accessed via phonology not orthography. Rastle and Brysbaert (2006) investigated this issue and concluded that both orthography and phonology are active in visual word processing. However, the DRC model remains an influential model and has yet to be adjusted to accommodate these findings. Researchers who propose that orthography dominates visual word processing assume that once a word becomes familiar an orthographic representation of its spelling is added to the lexicon. Thus according to this theory once SMS shortcuts become familiar, orthographic representations corresponding to the shortcut would be added to the lexicon enabling these items to be processed as rapidly as familiar words. However, as SMS shortcuts are additional spelling variations of familiar words it is possible that they are processed via existing lexical representations of their base-words rather than representations that are specific to the shortcut.

In support of this suggestion researchers working in visual word recognition have discovered that a word can be modified and still recognised (e.g., Franklish & Turner, 2007; Lupker, Perea & Davis, 2008; Perea & Carreiras, 2008; Perea & Lupker, 2003). For example if the letters in a word are transposed such that they form a nonword (e.g., *bahts-BATHS*) the system accommodates the irregularity and processes the word. Furthermore, researchers working from within the perspective of the strong phonological theory have made use of specific nonwords to investigate the potential for phonological information to facilitate word recognition. In such studies pseudohomophones (e.g., *tekst-TEXT*) are used to provide information regarding the phonology of a word without reflecting its orthography. The findings from this research suggest that phonological information in the absence of orthographic information can mediate word recognition (e.g., Drieghe & Brysbaert, 2002; Hino, Lupker, Ogawa, & Sears, 2003; Lukatela, Frost & Turvey, 1998; Rastle & Brysbaert, 2006). It is therefore possible that an orthographic route, which can accommodate transposed letters, may be able to process abbreviated SMS shortcuts and letter-digit shortcuts could be processed via phonological mediation. Alternatively, because SMS shortcuts are familiar to users they might be able to access both routes. The current research aims to investigate the potential for visual stimuli to access different routes with the additional advantage of being based on items that are used in actual human communication rather than nonwords specifically developed to test theories of visual word recognition.

The relative contributions of the different pathways to visual word recognition have been difficult to establish, partly because stimuli that activate one pathway are likely to activate the other, but also because it is assumed that this level of processing happens rapidly, in the first few hundred milliseconds of stimuli being presented (Dien, 2009; Forster, 1998; Holcomb & Grainger, 2006). Thus the challenge for researchers working in this area has been to find a methodology that can reveal these processes. Researchers have therefore, traditionally used the masked priming paradigm because it is assumed that this methodology is able to tap into lexical processes that occur prior to word recognition (Davis, Kim & Forster, 2008; Forster & Davis, 1984; Forster, 1998). In this paradigm a mask (e.g., #####) is presented followed by the prime stimuli (e.g., *text*), which is displayed briefly (e.g., 40-60ms) and replaced by the target stimuli (e.g., *TEXT*). Prime stimuli are presented at durations that are considered sub-optimal, because participants typically report no conscious awareness of seeing them. Consequently this allows for the investigation of early cognitive processing that is outside the conscious awareness of an individual.

The priming paradigm is often combined with the lexical decision task (LDT) or semantic categorisation tasks. In a lexical decision task the participant is asked to respond to the target word by indicating whether they believe it to be a real word that they recognise or not. For example the target word *TEXT* would elicit a 'yes' response and pseudoword foils (legal, pronounceable nonwords, e.g., *DAKE*) are used to elicit a negative 'no' response. This avoids participants responding positively to all stimuli. Reaction times to target stimuli are recorded and related conditions (e.g., *text-TEXT*) are compared to unrelated conditions (e.g., *fish-TEXT*) to gauge the effect that the prime stimulus has on processing the target. A typical finding from a task such as this is that reaction times to target words are faster for related prime-target pairs than unrelated pairs (e.g., Forster, 1998; Forster & Davis, 1984). It is assumed that despite the prime being unavailable to conscious processing, presentation of this stimulus triggers a series of mental processes. In the case of an identity priming paradigm (e.g., *text-TEXT*), both prime and target share orthographic as well as phonological forms resulting in an overlap of the mental processes required to process both stimuli. The result is that related primes produce faster responses to the target word compared to unrelated primes, which do not trigger overlapping mental processes. A lexical decision task requires a response to be made on the basis of whether a word is recognised or not as an existing entry in the lexicon and is therefore used to investigate lexical processing. In contrast semantic categorisation tasks are traditionally used to investigate semantic relationships between concepts. For example, a closely related prime-target pair such as *hawk-EAGLE* has been found to facilitate reaction times compared to less closely related animal pairs such as *mole-EAGLE* (Quinn & Kinoshita, 2008). Priming semantic categorisation tasks use the same trial procedures as lexical decision tasks (e.g., prime stimuli followed by target stimuli), however, a backward mask is often inserted between the prime and target. In this task all target stimuli are real words and participants are instructed to indicate whether the target words fit into a pre-designated category. Target words that fit into the category (for example, *whale* in the category ANIMAL) are known as exemplars and produce a 'yes' response. The foils, used to produce a 'no' response and known as non-exemplars, do not fit into the category (e.g., *door* in the category ANIMAL).

The masked priming methodology has been instrumental in furthering current understanding of the early phases of visual word recognition because it enables researchers to explore cognitive processes that happen a tenth of a second after stimuli have been presented. Researchers have been able to draw conclusions regarding different levels of visual word processing by manipulating the relative similarity of prime and target stimuli in masked priming tasks. For example research demonstrating a priming advantage for identity primes (e.g., *text-TEXT*) suggests that the pre-presentation of an identical word can speed up target processing (e.g., Bodner & Masson, 2001; Forster & Davis, 1984; Forster, 1998; Holcomb, Reder, Misra & Grainger, 2005; Kinoshita, 2006; Monahan, Fiorentino & Poeppel, 2008). Although there is some debate concerning the locus of this effect (see Chapter 3 for a review) the account most regularly cited suggests that stored mental representations of words facilitate processing of visual stimuli (Forster and Davis, 1984)[2]. Thus in the case of identity priming the prime stimulus activates a mental representation that corresponds to the prime and because this is identical to the lexical representation for the target, the relevant mental representation has already been accessed when the target stimulus is presented. The subsequent savings in the time it takes to process the target therefore results in faster reaction times for related stimuli in comparison to unrelated stimuli where the prime and target are not identical.

[2] Forster & Davis (1984) have 445 citations in Scopus, whereas the opposing view of masked priming as an episodic event (Bodner & Masson, 2001) is cited 70 times in Scopus.

In addition to manipulations involving whole words, previous research has also manipulated the level of orthographic overlap between prime and target stimuli using words or pseudowords with overlapping graphemes. The results of this research demonstrate that when pseudowords are used as prime stimuli (e.g., *ible-ABLE*) target processing is facilitated but when familiar words are used as primes (e.g.,*axle-ABLE*) target processing is suppressed (Davis & Lupker, 2006). These results suggest that activation of nodes or units at the letter level can facilitate processing of word stimuli with shared graphemes, however, activation of whole word representations inhibits processing. Research using the masked priming paradigm has also revealed that the position of a letter in a word does not have to be absolute. In other words the letters in a word do not need to be perfectly positioned for word recognition to occur. Rigid computational systems that assumed the position of the letters in a word had to be absolute (e.g., McClelland & Rumelhart, 1981) were developed from early theories of letter recognition. However, a number of studies have shown that prime stimuli with transposed letters (e.g. *bahts-BATHS*) are able to facilitate processing of target words with their letters in the correct positions (Franklish & Turner, 2007; Lupker et al., 2008; Perea & Carreiras, 2008; Perea & Lupker, 2003). Early research in this area suggested that it may be important for the first and last letters of a word to be in the correct position (Humphreys et al., 1990). Subsequently, research has demonstrated that consonants may carry more information than vowels (Berent & Perfetti, 1995; Lee, Rayner & Pollatsek, 2002; Perea & Lupker, 2004) and that it may be more important for consonants, as opposed to vowels, to be in the correct order (Lupker et al., 2008). It has even been found that substituting letters for symbols (e.g., M△T€R!△L-MATERIAL) can facilitate processing of related target stimuli (Perea, Duñabeitia & Carreiras, 2008a). Findings such as these suggest that there is considerable flexibility in the visual word recognition architecture and have revealed that an imperfect orthographic input can still facilitate the processing of visually presented words.

In addition to manipulations of orthographic similarity an equally large body of research has manipulated phonological similarities between primes and targets to investigate phonological processing in silent word reading. Strong phonological theories propose that even if the activation of phonology is not necessary for the completion of a task, phonology is still active. For example in an early study of phonological processing Van Orden (1987) found that participants categorised the homophone *rows* (*rose*) as a flower more often than a non-homophonic control word *robs*. These authors concluded that activation of a phonological representation for homophone stimuli (e.g., *rows-rose*) resulted in the misclassification of these items, suggesting that phonology was active in this task even when it interfered with producing the correct response. More recently a number of researchers have used the masked priming paradigm combined with a lexical decision task to investigate the role of phonology in visual word recognition (see Rastle & Brysbaert, 2006 for a review). The phonological priming paradigm typically employs pseudohomophones (e.g., *groe-grow*) as prime stimuli because these items do not have orthographic representations. It is therefore assumed that they activate a phonological representation of their base-word without accessing an orthographic representation. However, in order to control for orthographic overlap between the pseudohomophone and target stimuli, reaction times for these items are compared to an orthographic control condition. The control condition maintains an equal amount of orthographic overlap between prime and target without corresponding to the sound of an existing word. For example, reaction times to target stimuli preceded by a pseudohomophone (e.g., *groe-GROW*) would be compared to those observed for an orthographic control (e.g., *groi-GROW*). If reaction times to target words preceded by pseudohomophones are faster than those observed for control stimuli it is assumed that this is the result of phonological mediation that has occurred over and above facilitation from graphemic overlap. A number of studies have found that target word processing can be facilitated by primes that reflect the phonology of a word (e.g., see Frost, 1998 for a review; Hino et al., 2003; Perfetti, Bell & Delaney, 1988; Rastle & Brysbeart, 2006). Furthermore evidence of facilitation from brief exposures (40-60ms) of pseudohomophone primes supports the theory that a phonological representation can be activated during the earliest stages of visual word recognition (Drieghe & Brysbaert, 2002; Frost, 2003; Lukatela et al., 1998).

Despite the evidence from phonological priming studies previous researchers have doubted the robustness of these priming effects. However, Rastle & Brysbeart (2006) concluded from a meta-analysis of phonological priming experiments that phonological priming effects do exist in lexical decision tasks.

Consequently there is evidence that an imperfect orthographic presentation of familiar words as well as stimuli that mimic the phonology of existing lexical entries can be accommodated by the visual word processing architecture. Letter-digit shortcuts (e.g., *l8r, b4, 2day*) may therefore be rapidly processed via the activation of existing phonological representations and abbreviated shortcuts (e.g., *txt, spk, msg*) may be recognised due to graphemic overlap between shortcut and existing orthographic representations. Interestingly research also suggests that a subset of the consonants from a word (e.g., *blcn-BALCON*) may provide sufficient information to facilitate word recognition (Duñabeitia & Carreiras, 2011; Peressotti & Grainger, 1999). This finding supports the suggestion that SMS shortcuts with vowels deleted (e.g., *txt, spk, pls*) may be processed via the same mechanisms that allow for consonant subsets to access the lexicon.

To date, a large body of knowledge regarding the various stages of early visual word recognition has been amassed through research such as that mentioned above. Much of this research has used the masked priming paradigm due to its capacity to access processes that are outside conscious awareness and the results have been instrumental in the development of computational models designed to simulate these effects (e.g., Coltheart et al., 2001; Davis, 2010; Davis & Bowers, 2006; Diependaele, Ziegler & Grainger, 2010; Rumelhart & McClelland, 1981; Whitney, 2001). From this research there is sufficient evidence to suggest that letter position within a word does not need to be absolute and that items with overlapping orthography can facilitate or inhibit processing depending on their lexical status. Furthermore, evidence that the consonants in a word can facilitate word recognition suggests that abbreviated SMS shortcuts may be processed via mechanisms dominated by an orthographic route. Likewise letter-digit shortcuts may be processed using mechanisms that are similar to those engaged to process pseudohomophones. However, although fast phonological priming may now be accepted the relative contribution of orthographic and phonological processes in visual word recognition are still debated. Thus the letter-digit and abbreviated styles of shortcut provide a novel but ecologically valid way of investigating this debate and other questions raised by the unusual visual form of these items.

1.3 Theories of visual word recognition

The various levels of visual word recognition (e.g., letter recognition, lexical access, semantic integration etc.) are interconnected and rely upon each other, however, models that have been developed to account for behavioural data in this area often focus on specific functions within the system. For example, the SERIOL model developed by Whitney (2001) and the SOLAR model designed by Davis (2010) focus on the process that codes letters in order to match them to lexical representations. In contrast the Interactive Activation (IA) model of McClelland & Rumelhart (1981) was an early and extremely influential model[3] that describes the process of lexical access from a feature level, representing the shapes of letters, up to a lexical level that accesses whole word lexical representations. Although the IA Model provided the platform on which subsequent computational models were based (e.g., Coltheart et al., 2001; Grainger & Jacobs, 1994; Seidenberg & McClelland, 1989) it did not include mechanisms that provided for phonological or semantic processing. Subsequent models, such as the Dual Route Cascaded model (DRC) and parallel distributed processing (PDP) models therefore present a more complete simulation of visual word processing due to the development of systems that model phonological and semantic pathways. The DRC model (Coltheart et al., 2001) is known as a dual route model because it implements a lexical route for processing visual stimuli via stored orthographic representations and a non-lexical route that maps letters (graphemes) onto their corresponding sounds (phonemes). Thus the model is able to assemble phonological representations of a word via a process termed Grapheme Phoneme Correspondence (GPC)

[3] According to Seidenberg (2011) this article is "now among the most highly cited in the history of Psychological Review" (p.5)

without relying on a stored orthographic representation. The non-lexical route can process unfamiliar words because it allows for the phonology of a word to be assembled. However, it is restricted by rules that govern regular grapheme-to-phoneme conversions and it can only process words with a regular pronunciation. For example, the word *pint* would be processed by this route as if it was pronounced like the word *mint* because the correspondence between graphemes and phonemes in the word *mint* is regular whereas the GPC in the word *pint* is irregular. The lexical route, however, has access to an orthographic lexicon containing stored orthographic representations of familiar words and can therefore process both regular and irregular words once they have become familiar. It is assumed that a skilled reader forms orthographic representations of familiar words and the lexical route therefore dominates visual word processing. Phonological representations of words are stored in a phonological lexicon, which is linked directly to the non-lexical route and also to the lexical route via orthographic and semantic lexicons. However, as the model was designed to simulate reading out loud the phonological lexicon was positioned to allow for the computation of output phonology rather than input phonology.

The DRC model is a localist model in which each word is assumed to have a 'node' dedicated to processing that word. In contrast parallel distributed processing (PDP) models implement word processing via patterns of activation, which would theoretically occur across populations of neurons (e.g., Harm and Seidenberg, 2004; Seidenberg & McClelland, 1989). The principles governing a PDP model such as that implemented by Harm & Seidenberg (2004) are assumed to be general to perception and cognition and not specific to reading. This view is consistent with the observation that reading is a learnt skill that makes use of faculties that did not 'evolve' exclusively to read (Dehaene, 2009). In these models the path to word recognition is viewed as a triangle with orthographic and phonological processing at the base and semantics at the pinnacle. Word processing occurs as the result of inputs from both orthographic and phonological units, which are weighted depending on the exposure that the model receives to visual stimuli. Although a model such as the DRC has a route that can convert graphemes to phonemes it is not possible to process exception words, such as *pint,* using this route. The DRC model therefore requires an alternative route to accommodate the processing of exception words (i.e., the lexical route), which results in the dual routes of the model. Although the PDP model proposed by Seidenberg and McClelland (1989) also implements units that respond to both orthographic and phonological information the meaning of words is computed using phonological codes. Therefore the dual functions performed by the two routes in the DRC are covered by a single route in Seidenberg and McClelland's model. In other words whereas the DRC model processes an irregular word such as *pint* via the lexical route a PDP model can accommodate the differences between the pronunciation of *int* in the words *pint* and *mint* by associating the grapheme *i* with two phonemes, */aI/* for *pint* and */I/* for *mint*. The model treats such inconsistency as part of a continuum of spelling-to-sound correspondence, with 'rule governed' forms at one end and exceptions at the other. The word *mint* is rule governed but inconsistent because the word *pint* is an irregular neighbour, consequently the word *mint* represents an intermediate case.

Harm and Seidenberg (2004) make the point that if phonology was not instrumental in processing the written word there would be no need to associate written symbols with sounds. However, models such as the DRC model assume that the impact of phonology on silent reading is minimal. Nevertheless evidence that phonological codes can be rapidly activated emerged from behavioural studies in the 1980s (e.g., Perfetti et al., 1988; Van Orden, 1987). For example, Perfetti et al. (1988) using a backward masking paradigm found that pseudohomophone primes (e.g., *mayd*) produced faster reaction times to target words (e.g., *MADE*) compared to a graphemic control (e.g., *mard*). Thus these authors concluded that the automatic activation of phonology facilitates word processing. More recently a number of researchers have conducted studies using the phonological priming paradigm and reached the same conclusions (e.g., Drieghe & Brysbaert, 2002; Ferrand & Grainger, 1993; Lukatela et al.,1998; Hino et al., 2003; Rastle & Brysbaert, 2006). Despite this evidence, theoretical perspectives that ascribe a dominant role to orthography have tended to discount the findings from phonological priming studies. Frost (2003) suggests that whilst Coltheart et al. (2001) recognised that evidence of rapid phonological computation could challenge the DRC model they "dismiss them on the grounds that they do not provide a clear set of data" (p.178). A debate has therefore been ongoing between theorists who propose an influential role for phonology (e.g., Drieghe & Brysbaert, 2002; Frost, 1998; Van Orden et al., 1990) and those who ascribe a dominant role for orthography in visual word recognition (e.g., Coltheart et al., 2001; Rastle & Coltheart, 1994). Frost (1998) suggests that in evolutionary terms we have been speaking for a lot longer than we have been reading and phonological representations are therefore more stable with stronger links to meaning than orthographic representations. However, the strong phonological view that phonological activation is necessary to access semantic information is at odds with the assumptions underlying the DRC model. Although the rapid activation of phonological representations is theoretically possible in this model it is generally assumed that these representations are not accessed in the early stages of visual word recognition. In contrast as some PDP models (e.g., Seidenberg & McClelland, 1989) ascribe a dominant role to phonological processing, even for visually presented words, they appear better placed to support a version of visual word processing that is mediated via phonology.

Despite the evidence that has accumulated from phonological priming studies, simulations of these effects have only been run on a couple of models to date (Diependaele et al., 2010; Rastle and Brysbaert, 2006). Rastle and Brysbaert (2006) suggest that a computational model of a strong phonological theory has yet to be implemented and consequently the phenomenon of phonological priming has not been successfully simulated. In addition, despite suggestions that PDP models may be able to account for phonological priming effects (e.g., Hino et al., 2003), simulations of these effects have only been run on models that employ a localist processing architecture. For example, Rastle & Brysbaert conducted a series of phonological priming simulations using the DRC model because it allows for parameter settings that enable a strong version of the phonological theory to be tested against weaker versions. The results of these tests produced a simulation that came "closer than any other theory to resolving the dilemma created by masked phonological priming effects" (Rastle &

Brysbaert, 2006, p.133). In this solution the dual routes in the model were maintained but the non-lexical route was allowed to dominate instead of relying on the lexical route. However, more recently Diependaele et al. (2010) successfully simulated phonological priming effects using a model they term the Bimodal Interactive Activation Model (BIAM). The BIAM is based on the IA model and similar to the DRC model but with the addition of an input phoneme level and a GPC system that is comparable to PDP models (see Chapter 6 for a more detailed description). Following their successful simulation Diependaele et al. concluded that it is the lack of an input phoneme level that hinders the ability of the DRC model to simulate phonological priming effects, rather than the dual route architecture. The relative merits of both localist and distributed models could and probably will be debated for many years to come, however, it is clear that all models need to take the effects found in phonological priming tasks into consideration.

As SMS shortcuts are relatively new additions to language their visual irregularity raises questions for theories of visual word recognition. For example, shortcuts make use of digits and other symbols to represent sounds and therefore challenge the assumption that words contain letters and that those letters need to be in their correct positions. Furthermore, letter-digit shortcuts are written in a format that models of visual word recognition have yet to attempt an account for, in fact it is questionable whether some models could account for the reading of visually unusual items such as *l8r* without adjustment. However, perhaps the most interesting aspect of the two types of SMS shortcut identified here are the natural biases that abbreviated and letter-digit shortcuts have towards the dual routes that are assumed to facilitate word processing. Thus current models of visual word recognition may account for the recognition of these items in distinct ways and the predictions that they make regarding the contribution of orthography and phonology to the processing of SMS shortcuts can be explored. For example, the lexical routes of the DRC model and BIAM seem well placed to process shortcuts that are orthographically similar to their base-words. The finding that subsets of the consonants in a word (e.g., *blcn-BALCON*) can access the lexicon (Peressotti & Grainger, 1999: Duñabeitia &

Carreiras, 2010) has been interpreted within the framework of an IA model (see Chapter 3; Davis & Lupker, 2006). This account suggests that activation of letter units corresponding to the graphemes in the prime stimuli (e.g., *blcn*) are able to access an orthographic representation of the base word (e.g., *BALCON*). Thus it is possible that abbreviated shortcuts such as *txt* also access base word lexical representations via orthographic overlap. On the other hand, a shortcut such as *l8r* does not bear much resemblance to the base-word *later*, however, it does correspond to the phonology of this word and may therefore access a phonological representation of the word *later*. A rigid grapheme-to-phoneme correspondence system such as that implemented in the DRC model would not seem well placed to process such visually unusual stimuli. However, a PDP model or the BIAM with a more flexible mechanism for associating visual stimuli with phonemes may be able to account for processing of these items. Conversely due to the emphasis placed on phonological processing the PDP model implemented by Seidenberg & McClelland (1989) may struggle to account for the processing of phonologically impoverished items such as abbreviated shortcuts (e.g., *txt*). In contrast the later PDP model described by Harm & Seidenberg (2004) may be able to account for the processing of both items due to the implementation of a direct link from orthography to meaning as well as a phonologically mediated pathway. Thus it is predicted that the results of the experiments reported here will provide insight into the areas where each of these models succeeds, or fails, to account for the data. This in turn has the potential to further understanding of the strengths and limitations of popular computational models currently debated in the literature. However, it should also be noted that although it is assumed that the visual representation of these items may bias an orthographic (*txt*) or phonological (*l8r*) style of processing there is also the possibility that they may be processed using either or both routes.

1.4 Organisation of the lexicon; clues from the bilingual lexicon

In addition to the questions raised by the unusual visual representation of SMS shortcuts, it is also of interest to investigate how these items are integrated into the lexicon and access semantic information. SMS shortcuts are alternative versions of words which already have lexical representations that access semantics. Whether shortcuts would develop additional orthographic representations corresponding to their spelling and the extent that these representations access semantics is therefore not clear. However, insight into this question may be gained from research investigating the organisation of the bilingual lexicon. In order to investigate language processing in bilingual individuals researchers have made use of stimuli such as cognate pairs (e.g., Costa, Caramazza & Nuria, 2000; Dijkstra, Koji, Brummelhuis, Sappelli & Baayen, 2010; Sánchez-Casas, Davis & García-Albea, 1992). Cognate words have the same meaning and share either orthography or phonology, or both, in two or more languages. For example the word *lip* is an English-Dutch cognate, it derives from the same root word and therefore has the same meaning as well as the same spelling in both languages (Lemhofer & Dijkstra, 2004). In much of the bilingual literature words that share meaning but are not orthographically identical are also considered to be cognates for example, the Spanish-English pair *rico* & *rich* (Sánchez-Casas et al., 1992) or the Catalan-Spanish pair *gat* & *gato,* meaning cat (Costa et al., 2000). In addition words that share meaning and phonology but not orthography are also considered to be cognates for instance Gollan, Forster, & Frost, (1997) investigated Hebrew-English cognates that were phonologically similar but as they are written in different scripts do not share orthography. SMS shortcuts could therefore be viewed as English-text speak cognates that share their root with and are phonologically or orthographically similar to their base-words. For example abbreviated shortcuts (e.g., *txt, spk, pls* etc) are orthographically similar, letter-digit shortcuts (e.g., *m8, l8r, b4* etc) are phonologically similar and phonological approximations (e.g., *wud, fone, rite* etc) have both orthographic and phonological similarities to their English equivalents.

Although various theories exist to account for the processing of cognate words each of these options assumes that cognates with differing orthography will develop additional lexical representations (see Dijkstra et al., 2010 for a review). Researchers disagree on how these representations are organised within the lexicon (see Brysbaert & Duyck, 2010; Kroll, van Hell, Tokowicz & Green, 2010 for a review); however, some robust findings have emerged from the literature using cognate and translation equivalents as stimuli. For example, in translation tasks, translations from the first language (L1) to the second language (L2) are slower than translations from L2-L1 (Kroll & Stewart, 1994). However, in masked priming lexical decision tasks this pattern is reversed and larger priming effects are found when the prime is in L1 and the target in L2, compared to when the L2 is the prime (Davis, Sánchez-Casas, García-Albea, Guasch, Molero & Ferré, 2010; Gollan et al., 1997; Schoonbaert, Duyck, Brysbaert & Hartsuiker, 2009).

Schoonbaert et al. (2009) suggest that these results are indicative of the fact that both languages are stored in a similar lexicon but the consistent finding that the dominant language is more successful as the prime stimuli suggests that links from the dominant language to the second language (L1-L2) are stronger than in the reverse direction. However, Kroll & Stewart in their Revised Hierarchical Model (RHM) suggest that links between L2 and L1 lexical representations may be stronger than those between L1 and L2. Thus translations from L2-L1 are facilitated by activation of lexical representations and are faster than translations from L1-L2, which are mediated by conceptual information. In contrast Brysbaert and Duyck (2010) argue that if lexical connections between L2-L1 are stronger than those between L1-L2 this should be reflected in the effects from priming tasks. More recently Kroll et al. (2010) suggested that there may be a dissociation between a task that requires production and one that requires recognition. In other words it is possible that when translating from L2 the activation of numerous translation options in the L1 lexicon facilitates translation but in a lexical decision task the same process inhibits recognition. In contrast because L2 translations from L1 items are activated via feedback mechanisms from conceptual information, translation responses are slower but lexical decision latencies are faster. Interestingly, Schoonbaert, Holcomb, Grainger & Hartsuiker (2011) found weaker priming effects in behavioural data from L2-L1 compared to L1-L2 in a masked translation priming experiment, but they found stronger and earlier effects in an N250 ERP component for L2-L1 priming compared to L1-L2 pairs. Holcomb &

Grainger (2006) describe the N250 ERP component as the "sublexical-lexical interface" (p.1640) and suggest that it represents a point in processing where sub-lexical processes map onto whole word lexical representations. Schoonbaert et al. suggest that their results could be an indication of stronger associations in word form representations from L2 to L1, which would support the assumptions made by Kroll & Stewart. In addition the suggestion that L1 targets are able to access more conceptual information than L2 primes resonates with the 'Senses model' proposed by Finkbeiner, Forster, Nicol & Nakamura (2004). According to this theory an L2 prime activates a limited number of concepts but L1 targets have access to all the 'senses' or meanings of a word (see Chapter 8). Consequently L2-L1 priming does not occur due to a limitation on the number of L1 semantic representations that are accessed by the L2 prime. In contrast when a semantic categorisation task is used the context within which processing occurs is focused by the category which effectively narrows the number of senses that need to be accessed by the L1 target. The result of this is that priming advantages are found in this task where they are absent in lexical decision tasks. In the lexical decision task therefore the extra activation of conceptual level information on presentation of L1 targets inhibits target processing. The difference between this theory and that of the RHM is that the interference, which inhibits L2-L1 processing, occurs at the lexical level for the RHM but at the conceptual level for the Senses model. Although the underlying mechanisms that result in this dissociation are disputed, if SMS shortcuts are assimilated into the lexicon like second language cognates they may also be expected to produce a similar asymmetry in a primed lexical decision task.

Evidence of a cognate asymmetry for shortcuts would provide an indication that cognate items that are within a language are assimilated into the lexicon in a similar way as cross language cognates. A recent study presented evidence that within language cognates have links with existing representations of familiar words, however, this relationship was only tested in one direction (Dimitropoulou, Duñabeitia, & Carreiras, 2011b). The stimuli used in this study were alternative written representations of Greek developed specifically to make interactions via the internet more accessible because they are written in Roman characters instead of the Greek alphabet. This alternative way of writing Greek is known as 'Greeklish', for example, the word *Eureka* would be written as *Eyrhka* instead of *Εύρηκα*. The Greeklish words therefore resemble second language cognates with varying degrees of orthographic overlap and as such their relationship to their base-words is similar to that found for SMS shortcuts. For instance a letter-digit shortcut such as *l8r* shares little orthography with the word *later,* in the same way the Greek word *βλήμα* bears little resemblance to the Greeklish equivalent *vlima* (meaning missile). However, both shortcuts and Greeklish share meaning and phonology. In contrast a shortcut such as *txt* has similar orthography to its base-word *text* and likewise the Greek word *σοκάκι* resembles the orthography of the Greeklish word *sokaki* (meaning alley). In a masked priming paradigm Dimitropoulou et al. paired Greeklish prime stimuli with familiar Greek target words that shared high levels of graphemic cross-over (e.g., *sokaki-σοκάκι;* alley) and compared them to identity primes in traditional Greek and an unrelated condition. They found robust priming advantages compared to an unrelated condition for the Greeklish primes, but smaller effects than those found for pure Greek identity primes. These results suggest that this novel form of Greek is processed rapidly, as are traditional words, but despite participants having extensive experience with Greeklish, Greeklish primes were not as effective as identity primes. Masked priming effects are assumed to occur at a lexical level suggesting that activation of lexical representations for Greeklish words facilitated processing of traditional Greek targets. However, it is also possible that sub-lexical processes (both orthographic and phonological) facilitated access to existing lexical representations for traditional Greek targets without the need for additional lexical representations. Nevertheless this study establishes that a link exists between Greeklish and traditional Greek items, which suggests that a similar link may exist between SMS shortcuts and their base-words.

Although there is a lack of concrete evidence for the development of additional orthographic representations for Greeklish, Ganushchak, Krott & Meyer (2010a; 2010b) recently concluded that familiar SMS shortcuts are likely to develop lexical representations. In their first study Ganushchak et al. (2010a) used a parity task that required participants to indicate whether a set of dots represented an odd or even number. The dots were presented with letter-digit shortcuts that either matched the parity of the dots (e.g., *gr8* paired with an even number of dots) or did not match (e.g., *b4* paired with an odd number of dots). The results showed that when compared to a set of pseudo-shortcuts (e.g., *qr8*) the parity of the dots did not affect responses for familiar shortcuts. These results suggest that the digit used in the shortcut did not activate a number concept, implying that the shortcut was processed more like a word than a digit. Ganushchak et al. (2010a) propose that the digit may initially activate a number concept, however, the activation of a lexical representation for the shortcut rapidly suppresses this conceptual information. Support for this suggestion was found in a follow up study where EEG and behavioural data were recorded from an un-primed lexical decision task (Ganushchak et al., 2010b). The task used SMS shortcuts and pseudo-shortcuts as nonword stimuli and participants were instructed to reject anything that was not a real word. Familiar and pseudo-shortcuts therefore formed the negative 'no' response and the 'yes' responses were used as foils. The behavioural results demonstrated that shortcuts were harder to reject as nonwords compared to pseudo-shortcuts and the event related potential (ERP) data suggested that SMS shortcuts activate lexical and semantic representations. Ganushchak et al., (2010b) concluded, "that shortcuts are 'word-like' in the sense that they activate stored lexical information" (p.123) suggesting that shortcuts are processed using the same mechanisms as familiar words.

The finding that SMS shortcuts activate semantic as well as lexical representations suggests that they may develop links with conceptual information and not require activation of base-word representations to process meaning. However, it is also possible that the lexical information accessed by shortcuts is that of the base-word and that this facilitates access to semantic information. The Revised Hierarchical Model (Kroll & Stewart, 1994) assumes that there is a developmental trajectory in second language learning where words learnt in the L2 do not immediately form direct links with semantic information but are processed via links with L1 lexical representations. However, as the bilingual becomes more proficient L2 lexical representations begin to link directly to semantic information. There is evidence that links between semantic information and second languages may not be as strong as links between first languages and semantics (see Kroll et al., 2010 for a review; Schoonbaert et al., 2011). Furthermore, this relationship may be mediated by the level of proficiency exhibited by different individuals (Davis et al., 2010; Guasch, Sánchez-Casas, Ferré, & García-Albea, 2011). If links between L2 and meaning are facilitated via an existing language, as Kroll et al. (2010) suggest, shortcuts may not develop strong links with semantic concepts. However, it is likely that this relationship would be mediated by proficiency of use with SMS shortcuts. In a recent study Ganushchak, Krott & Meyer (2012) tested the extent that shortcuts facilitate processing of associatively related words using a semantic lexical decision task. In this task target words were preceded by briefly presented and forward masked associatively related shortcuts (e.g., *2day-NOW*) and compared to unrelated prime-target pairs as well as word-word pairs (e.g., *today-NOW*). The results showed significant priming effects for target words preceded by both related shortcut and word primes. These results do not support the proposal that SMS shortcuts access semantic information via base-word lexical representations, suggesting instead that shortcuts access semantics directly and are therefore able to facilitate processing of related semantic concepts.

These results taken together suggest that SMS shortcuts access the lexicon and are linked to semantic information. However, the exact nature of the lexical information accessed by SMS shortcuts has yet to be confirmed. Although models of visual word processing (e.g., the DRC model) would assume that orthographic representations of new words are added to an orthographic lexicon, SMS shortcuts may not require additional representations because they can access existing lexical representations of their base-words. In contrast the distributed architecture of a PDP model does not require a lexical representation to be added and familiarity with these items would be sufficient to produce the kind of rapid access expected from familiar words. If SMS shortcuts do not form additional lexical representations the ERP evidence presented by Ganushchak et al. (2010b) may correspond to lexical access of base-word representations rather than shortcut lexical items. Interestingly these authors did not find a difference in amplitudes for familiar shortcuts compared to pseudo-shortcuts until around 270ms post stimulus onset. In contrast familiar words have been shown to exhibit attenuated amplitudes in components that peak at around 170ms when compared to letter strings (Dien, 2009). This could be an indication that the orthography of familiar shortcuts is not recognised by the visual word system and that sub-lexical processes assemble sufficient information to access base-word lexical representations. Conversely it has been suggested that second language cognates may require longer processing times compared to first languages (Davis et al., 2003; Midgley, Holcomb & Grainger, 2009; Schoonbaert et al., 2009) and this could result in a delay of the usual components found for familiar words. In fact Berger & Coch (2010) discovered that an N400 component found in response to SMS shortcut stimuli peaked a little later for shortcuts compared to familiar words. Thus a component that peaks at 170ms for familiar words may be delayed for shortcuts. In addition Perea et al. (2009) demonstrated that sentences with SMS shortcuts are read more slowly and shortcuts produce longer fixations compared to familiar words.

Although some headway has been made in the exploration of SMS shortcut processing many questions remain unanswered. Answers to those questions have the potential to further understanding of the visual recognition of unusual items such as SMS shortcuts but also to add to current knowledge concerning traditional words. It is therefore anticipated that the results of this research will add to the current literature concerning the nature of the mental lexicon and the type of information that is required to gain rapid lexical and semantic access. Specifically this research aims to explore three areas. Firstly, recent evidence suggests that SMS shortcuts are recognised and processed like familiar words, however, the degree of facilitation provided by sub-lexical or lexical processes has yet to be established. Therefore the extent that familiarity plays a part in the recognition of these items will be investigated using established methodologies with novel but ecologically valid stimuli. Secondly, the natural distinction between abbreviated and letter-digit shortcuts suggests that these items may be processed via lexical routes that favour orthographic or phonological processing. It is anticipated that an investigation of SMS shortcuts will further current understanding of the capacity of each of these pathways and the ability of current computational models to account for the data collected here. Finally, due to their similarity with second language cognates this thesis proposes that SMS shortcuts are analogous to within language cognates and may be processed in a way that reflects bilingual language processing. The extent to which these items exhibit similar patterns of data to cross language cognates will therefore provide insight into the debates concerning the specificity of bilingual language processing and the organisation of the lexicon.

1.5 Summary of the research

The experiments reported here will use established methodologies to gain a thorough understanding of how data gathered from SMS shortcuts compares with data from familiar words as well as traditional control stimuli. However, before using these items as stimuli it is important to develop a set of suitable shortcuts that represent the appropriate orthographic and phonological distinctions between the two styles of shortcut identified by this research. Crucially the stimuli that are selected for use should be items that are currently used by young people when sending text messages. The following chapter (Chapter 2) will therefore detail the results of an extensive series of questionnaires that ran online between 2010 and 2011 and were designed to provide an indication of the frequency with which shortcuts are used. The results of this analysis form the basis for the development of a database representing the frequency with which respondents reported using shortcuts and the frequency of use within genuine text messages. From this database two sets of SMS shortcut stimuli (abbreviated and letter-digit) were selected.

The subsequent chapters in this thesis present experiments that were conducted to provide insight into SMS shortcut recognition and the relative contributions of orthographic, phonological and semantic information to this process. The masked priming paradigm is used throughout this thesis, with the exception of the experiment reported in Chapter 5. Chapter 3 therefore explores the assumptions and theories that underpin this methodology. The experiments detailed in Chapter 4 employ a masked priming lexical decision task to explore all three research questions. In Experiment 1 SMS shortcuts are employed as prime stimuli and their base-words as targets (e.g., *txt-TEXT*), in Experiment 2 the reverse priming direction is used with words as primes and shortcuts as targets (e.g., *text-TXT*). Based on the findings detailed above (Davis et al., 2010; Dimitropoulou et al., 2011b; Ganushchak et al., 2010a; 2010b) it was anticipated that SMS shortcuts would facilitate processing of base-word targets and vice versa. The first research question concerns whether SMS shortcuts are processed like words. Evidence of sub-lexical processing for shortcuts would suggest that they might not be processed like words but via base-word lexical representations. Consequently the experiments reported in Chapter 4 compare priming advantages found for familiar shortcuts against those found for matched unfamiliar shortcuts. For example, unfamiliar abbreviated shortcuts such as *rsk* (risk) are used to investigate the extent that orthographic overlap between shortcut and target facilitates lexical access to base-word representations (e.g., *risk*). Likewise in the letter-digit condition unfamiliar shortcuts such as *cre8* (create) are used to establish whether the phonological information contained in letter-digit shortcuts is sufficient to enable rapid access to lexical representations of base-words (e.g., *create*). If sub-lexical processes are able to rapidly access the lexicon a priming advantage should be found for unfamiliar SMS shortcut stimuli (e.g., *rsk-RISK*) as well as familiar shortcuts (e.g., *txt-TEXT*) and words (e.g., *text-TEXT*). However, if unfamiliar SMS shortcuts fail to produce priming effects this would suggest that graphemic or phonological overlap alone is not sufficient to rapidly access the lexicon. This finding would support the suggestion from previous researchers that items such as SMS shortcuts or familiar abbreviations (e.g., BBC) develop unique lexical representations and are processed like words (Brysbaert, Speybroeck & Vanderelst, 2009; Ganushchak et al. 2010a; 2010b; Perea et al., 2009).

The second research question investigates the relative contribution of phonology and orthography to SMS shortcut processing. Previous researchers have suggested that priming effects in the lexical decision task are dominated by orthographic processing (e.g., Dimitropoulou, Duñabeitia, & Carreiras, 2011a; 2011b). If this is the case smaller priming effects may be seen in the tasks conducted in Chapter 4 for letter-digit shortcuts (e.g., *l8r-LATER*) compared to abbreviated shortcuts (e.g., *txt-TEXT*). In addition priming effects in the lexical decision tasks are tested in both L1-L2 and L2-L1 directions (assuming that the base-word is the L1 and the shortcut the L2). Evidence of an asymmetry in the priming magnitudes found in Experiments 1 and 2 would support the suggestion that shortcuts share characteristics with second language cognates addressing the third research question concerning the integration of shortcuts into the lexicon.

Having explored the extent that familiar SMS shortcuts exhibit priming advantages in an established task that predicts these effects for familiar words, Chapter 5 will further investigate the lexical status of SMS shortcuts. The experiment reported in this chapter departs from the masked priming methodology and instead employs a paradigm designed to test the extent that word stimuli are processed as whole units rather than via sub-lexical processes. The paradigm is based on an assumption that top down processes operating on familiar words interfere with target processing by spreading attention across a whole word (LaBerge, 1983). This results in an inability to distinguish features within the word such as the colour of a specific letter. Conversely due to the requirement to process nonwords via bottom up processes, attention focuses on one letter at a time allowing for features to be correctly combined. For example, if the letters in the word *son* are all presented in different colours it is more difficult to report which colour the letter *o* was presented in, compared to reporting the colour of the middle letter in a nonword (e.g., *nos*). These errors are termed illusory conjunction errors and are produced when stimuli are presented briefly and slightly out of the centre of the fovea (Lindell, Arend, Ward, Norton & Wathan, 2007; Prinzmetal & Millis-Wright, 1984; Prinzmetal, Presti & Posner, 1986). Prinzmetal and Millis-Wright suggest that the presence of a lexical representation for words results in both the wider spread of attention and the illusory conjunction error. Thus it was hypothesised that if SMS shortcuts are processed using unique lexical representations it is likely that they would also be processed as whole units in which case illusory conjunction errors should be found. However, if shortcuts link to an existing representation of their base-words it is likely that they are processed via sub-lexical units which would encourage a letter-by-letter processing style and the effect should not be found. Evidence of an illusory conjunction effect for SMS shortcuts would therefore provide robust evidence for the proposal that these items have lexical representation and are processed like words (Ganushchak et al., 2010a; 2010b; Perea et al., 2009).

Chapter 6 returns to the masked priming paradigm to further explore the second research question concerning the contribution of orthography and phonology to visual word processing. A clear distinction exists between phonologically impoverished abbreviated shortcuts (e.g., *txt*) and phonologically plausible letter-digit shortcuts (e.g., *l8r*). These items are therefore used as target stimuli in a phonological priming paradigm and preceded by either a pseudohomophone (e.g., *tekst-TXT*) that encourages phonological processing or a graphemic control that accounts for orthographic overlap between the pseudohomophone and target (e.g., *tegst-TXT*). Current computational theories, which ascribe a dominant role for orthographic processing, predict that both types of shortcut would be processed via an orthographic lexicon (Coltheart et al., 2001). However, strong phonological theories would predict that both items can be mediated via phonology. Although letter-digit shortcuts may have sufficient phonological information to be processed via a non-lexical or phonological pathway it seems less likely that abbreviated shortcuts can be mediated via phonology. Thus an investigation of the degree to which processing of both types of shortcut is facilitated by phonological information will further current understanding of phonological processing. Furthermore evidence of the rapid assembly of phonological representations or codes for either type of stimuli would present some models of visual word recognition with a challenge (see Rastle & Brysbaert, 2006 for a discussion)

The final research question investigated in this thesis relates to how lexical items integrate with semantic information. The Revised Hierarchical Model of bilingual processing (Kroll & Stewart, 1994; Kroll et al., 2010) suggests that bilinguals with lower levels of proficiency may use lexical representations in their first language (L1) to access semantic information for words in their second language (L2). Bearing in mind the associations drawn here between SMS shortcuts and second language cognates, Chapter 7 will examine the extent that SMS shortcuts develop direct links with semantic information. Previous literature suggests that the usual asymmetry between priming directions for first and second languages found in the bilingual literature is reduced in a semantic categorisation task (Grainger & Frenck-Mestre, 1998; Finkbeiner et al., 2004). Thus the experiment reported in Chapter 7 employs a masked priming semantic categorisation task to test the degree to which shortcut primes can facilitate processing of semantically related target words (e.g., *m8-FRIEND*). Ganushchak et al. (2012) found evidence for such links using SMS shortcuts with associated target stimuli (e.g., *msg-TEXT*) in a primed semantic lexical decision task. However, it has been suggested that associative priming may occur at a lexical rather than semantic level due to links between lexical representations of commonly occurring words (see Ferrand & New, 2004; Wang, 2007). The experiment reported in Chapter 7 therefore extends the previous research by testing semantic relationships between SMS shortcuts and related target words in a semantic categorisation task.

To summarise; using the masked priming paradigm and illusory conjunction methodologies this thesis presents a series of experiments to explore how familiar SMS shortcuts access the lexicon and semantic information in comparison to familiar words. This research has the potential to provide insights into the organisation of the lexicon as well as inform current debates regarding the nature of visual word processing and the contribution of orthographic and phonological information. The findings from this research will have the additional advantage of being based on stimuli that are used in human communications and represent real words, giving this research enhanced ecological validity.

Chapter 2 SMS shortcuts: luv em or h8 em how much are they really used and why?

2.1 Introduction

UK media hype has suggested that the use of SMS shortcuts is widespread and challenges conventional or standard language (see Thurlow, 2006). However, the use of shortcuts may not be as prevalent as suggested (at least amongst university undergraduates) and may decrease as individuals mature (Thurlow, 2003; Ling & Baron, 2007). Furthermore, there is evidence that shortcuts are used by young people who have strong literacy skills, rather than being a sign of the decline of standard language (Plester et al., 2009). The relationship between shortcuts and literacy warrants further investigation, however, as a first step towards understanding these unique and perhaps misunderstood items it is important to establish the frequency with which shortcuts are used as well as the types of shortcut that are preferred. Thus the aim of this research is to establish a database of shortcuts that are currently in use from which two sets of SMS shortcut stimuli, based on abbreviated (e.g., *txt*-text) and letter-digit (e.g., *l8r*-later) shortcuts can be developed. In addition the database will provide an indication of the frequency with which university students use the stimuli developed here, which is a factor that is important for the analyses conducted in subsequent chapters in this thesis.

Mobile phone use in the UK is currently ubiquitous across all ages and demographics. According to a report from OFCOM, 91% of adults in the UK own a mobile phone and the latest data from December 2011 suggests that just 1% of 16 – 54 year olds do not use a mobile phone. Mobile phones are predominantly used for making calls (91%) and sending text messages (84%) with the next most popular activity being taking photos (37%; UK adult's Media literacy, 2010). Over the last decade the number of text messages sent has increased by 2000% and an average of 5 text messages a day per person were sent in the UK in 2010 (The Communications Market, 2011)[4]. Bearing in mind

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[4] http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/cmr11/uk/

the high volume of texting communications it has been suggested that the limitations of the phone keypad led to the use of abbreviations and acronyms that were being used in online forums (Kemp, 2010). However, in her unpublished thesis, which is based on a corpus of 11,000 text messages, Caroline Tagg (2009) points out that a number of shortcut formats were evident in mainstream society before texting or computer mediated communication. For instance *U* has been used to represent the word *you* in the company name *Spud-U-Like* since 1974. In addition letters have been used as homophones for traditional words in band names, such as *XTC* (ecstasy) and *INXS* ('in excess') since the end of the 1970s. Tagg also points out that advertising campaigns use atypical spellings of traditional words to catch our attention, for example the 'Beanz meanz Heinz' campaign was launched in 1967. It is possible therefore that the use of irregular spellings of words and SMS shortcuts in text messages developed from a number of different sources motivated by the method used to input messages as well as the restricted number of characters allowed in text messages on mobile phones.

The use of SMS shortcuts in text messages, sometimes termed 'textisms' (Kemp, 2010; Plester et al., 2009; Thurlow, 2003) appears to be popular amongst those in their early teens or younger. Plester et al. (2008) report that in a sample of 11 year olds, 58% of the content of texts that were produced as part of a study were shortcuts. In a review of their work, Wood et al. (2009) comment that the proportion of shortcuts used increased with age from 21% in year 4 (aged 8), to 47% in year 6 (aged 10). Kemp (2010), conducting research in Australia with undergraduates also found high ratios of shortcuts being used in text messages written by frequent texters (53%). However, these ratios may be slightly inflated because the messages were written as part of an experiment where participants were instructed to use shortcuts. In a slightly more naturalistic study researching genuine text messages sent by 9 -10 year olds, Wood, Jackson, Hart, Plester & Wilde, (2011) report an average ratio of 17% for 'novice' texters who had only just received a phone. In contrast lower ratios of shortcuts have been found in studies with undergraduate populations. For example, Thurlow (2003) analysed a corpus of 544 genuine text messages from undergraduates and reports that just 19% of the content consisted of shortcuts. Ling and Baron (2007) analysed the content of text messages sent by 25 undergraduates over a 24 hour period and found that less than 5% were shortcuts. These findings suggest that there are considerably more shortcuts used in text messages sent by pre-teen children compared to undergraduates. Kemp (2010) suggests that cost may still be a concern for younger phone owners hence the high proportion of shortcuts to words used by this age group.

Although previous research has investigated the nature of SMS shortcuts used in text messages, analysis of the frequency with which shortcuts are used has not been undertaken. Thurlow (2003) was one of the first researchers to look at the types of shortcut that are used in text messages and from a corpus of text messages he developed a system of categories (see Table 2.1 below).

Table 2.1 Categories of shortcut with examples and base-words based on Thurlow (2003)

Category	**Example Shortcut**	**Base-word**
Shortenings	*sis*	Sister
	tho	Though
Contractions	*txt*	Text
	pls	Please
G-clippings	*goin*	Going
	comin	Coming
Other clippings	*hav*	Have
	wil	Will
Acronyms	*BBC*	British Broadcasting Company
	UK	United Kingdom
Initialisms	*lol*	Laughing out loud
	lmao	Laughing my arse off
Symbols	;-)	Smiling
	@	At
Letter/number homophones	*l8r*	Later
	wuu2	What you up to?
Non conventional spellings	*fone*	Phone
	skool	School
Accent stylisation	*wiv*	With
	anuva	Another
Misspellings	*are*	Our

Plester et al. (2009) found examples of all the categories listed by Thurlow, as well as an additional category that they termed omitted apostrophes (e.g., *cant, wont*) and Coe and Oakhill (2011) identified 8 of Thurlow's categories in text messages written by participants.

Although there are some conflicting findings in the literature concerning the specific types of shortcut used, overall the most frequently used shortcuts appear to be those based on the phonology of their base-words. For example, letter/number homophones (e.g., *l8r*) rely on the sounds of letters or numbers or combinations of both to represent the phonology of a word whereas phonological approximations (e.g., *fone*) respell words to make their orthography more transparent and accent stylisations (e.g., *anuva*) are direct transcriptions of linguistic variations in different dialects. Plester & Wood (2009) found that a high number of letter-digit shortcuts (e.g., *l8r*) and letter/number homophones, such as *r* (are), *u* (you) and *2* (to) were used in genuine text messages. In contrast when participants were asked to translate a sentence written in standard English into a text message, a large number of phonological approximations (e.g., *nite*-night, *wot*-what) and accent stylisations (e.g., *wiv*-with, *da*-the) were used as well as letter/number homophones. Similarly letter/number homophones have been found to be the most frequently used shortcuts in other studies of both undergraduate and pre-teen text messages (Coe & Oakhill, 2011: Ling and Baron, 2007). Thurlow (2003) also reports that the most frequently used shortcuts had a strong phonological element, for example, accent stylisations, phonological approximations and onomatopoeic exclamations such as *haha, arrrrgh, yay*. However, letter/number homophones such as *ru* (are you) or *gr8* (great) were used relatively infrequently[5]. In addition Kemp (2010) found evidence of a distinction between frequent and infrequent texters such that frequent texters used more shortcuts based on the phonology of a word than shortcuts based on the orthography of their base word. Participants in this study were divided into frequent and infrequent texters and the frequency with which they used shortcuts based on the phonology of a word (e.g., *no*-know; *wot*-what) was compared to the frequency with which they used

[5] Out of a total of 1401 examples of shortcuts 73 were letter/number homophones.

shortcuts reflecting the orthography of the same base word (e.g.. *knw*; *wht*). The results demonstrated that frequent texters used more phonological approximations compared to abbreviations whereas infrequent texters used both types of shortcut with equal regularity. This suggests that the more experienced you are with creating and reading these items the more likely you are to use shortcuts that emphasise the sound of a word rather than its spelling. This finding adds support to the suggestion that text speak is more characteristic of a spoken form of language as opposed to a written form (Crystal, 2008; Tagg, 2009; Thurlow, 2003).

Although the evidence suggests that text speak is dominated by phonological representations of the written word, this assumption is based on previous literature that has tended to elicit text messages from participants in an experimental setting. The majority of the text messages analysed as part of the research conducted by Plester & Wood and colleagues as well as Kemp (2010; Kemp & Bushnell, 2011) and Coe and Oakhill (2011) were produced by participants as part of lab based experiments and may not represent the frequency or ratio with which shortcuts are used in genuine text messages. Although the research conducted by Thurlow (2003) provides a study of genuine text messages, the analysis is limited and due to rapid changes in technology may not be applicable today. Additionally frequencies of use that are reported in the literature appear to differ across studies, which may reflect different time scales or demographics. A systematic investigation of the frequency with which SMS shortcuts are used has the potential to inform current debates concerning the prevalence of shortcut use and also provide some insight into the psycholinguistic characteristics of these items. For example psycholinguistic research has shown that the ability of the cognitive system to recognise words can be influenced by the frequency with which they are used (*cf.* Adleman & Brown, 2008; Forster & Murray, 2008). Therefore information regarding how frequently SMS shortcuts are used by UK undergraduates will allow for an estimation of the relative frequencies for the stimuli used here to be calculated. This will not only facilitate the appropriate analysis of these stimuli (taking their relative frequencies into account) but also allow for an investigation of the relationship between frequency of use and recognition speed for SMS shortcuts.

In the absence of an existing frequency database for SMS shortcuts the current research launched a series of surveys designed to gather information regarding SMS shortcuts that are known and used by a population of university undergraduates. The finding that there are smaller ratios of shortcuts to words found in texts written by undergraduate students (Thurlow, 2003; Ling & Baron, 2007) compared to school aged children (Wood, Plester & Bowyer, 2009; Plester, Wood & Bell, 2008) suggests that there is a shift in the use of shortcuts between school and university. The surveys detailed in the following analysis therefore aimed to produce a database of familiar SMS shortcuts and also investigate any changes in shortcut use experienced by respondents since they began texting. In the first instance a series of pilot surveys (Morgan & Weighall, 2008) provided an indication of the SMS shortcuts that were known and used by a group of undergraduate students attending Sheffield Hallam University. The results of these surveys formed the basis for the development of two sets of stimuli, one based on contractions (hereafter referred to as 'abbreviated shortcuts' e.g., *txt*) the other based on letter-digit homophones (e.g., *l8r*). As detailed in Chapter 1 these two specific types of shortcut were selected due to a distinction that can be drawn between the phonological and orthographic nature of their visual presentation. Following the pilot surveys additional surveys were conducted spanning two years (2010 & 2011), from which two frequency measures were produced, one based on respondents self-reports of SMS shortcut use and a second frequency measure based on an analysis of genuine text messages.

2.2 Method

2.2.1 Participants

The participants for the pilot surveys were recruited from a psychology undergraduate course. In total 296 participants responded to the pilot surveys of whom 93 were male and 203 were female. The average age was 23 with a range from 17 to 57 years of age.

The participants for the subsequent surveys were recruited from Sheffield Hallam University and either completed a questionnaire on text messaging habits at the end of an experiment or they were recruited via an online questionnaire. In total 709 students responded to both online and post-test surveys, of whom 458 responded to online surveys with 247 participants providing genuine text messages. A total of 251 participants responded to post-test surveys of whom 57 provided genuine text messages. Across all participants the mean age was 24 with a range of 18-71 years of age and a total of 163 male and 524 female participants.

As the post test surveys were completed by participants who took part in an experiment it is possible to state that the majority of these participants were undergraduate 1st year psychology students who received course credits for their participation with the exception of a few participants who were students from different courses. The online surveys were available to all students across the university and completed anonymously.

2.2.2 Design and materials

The pilot surveys consisted of two pages and were developed for use as a post-test questionnaire for experiments that were run prior to the beginning of this research programme (see Appendix 2.1). The questionnaire asked respondents to fill in details regarding how they use their mobile phone, how many text messages they send in a week and whether they use SMS shortcuts. The questionnaire also presented respondents with a list of shortcuts and asked them to indicate by ticking a box whether or not they used them or received them from others. Participants were also asked to write down any additional SMS shortcuts that they use (see Appendix 2.2 for a frequency list from the pilot surveys).

The subsequent online surveys followed this format with the exception that participants were not presented with a list of shortcuts but asked to produce (write down) shortcuts that they use or receive. Additional questions were added to these surveys that asked respondents to provide information regarding any changes in their use of SMS shortcuts and requested them to provide 5 text messages that they had sent and 5 that they received. In the instructions participants were advised to omit any details from these messages that could identify them or any third parties. The final section of these surveys presented participants with a forced choice task that required them to choose one version of a shortcut out of three (see Appendix 2.3).

2.2.3 Procedure

Online surveys were made available to participants via a link on the University's virtual online learning site and were accessible by all students and staff. Post-test surveys were presented to participants who took part in the subsequent experiments reported in this thesis after completion of an experimental task.

2.2.4 Results

All SMS shortcuts collected from all surveys were listed and sorted into frequency lists, with the exception of the pilot surveys which were used to develop stimuli lists and therefore only single word SMS shortcuts were analysed (e.g., *txt, l8r*). For the remaining surveys (online or post-test), two frequency lists were compiled, one representing respondents self-reports of SMS shortcuts that they use or receive (Self-produced Frequency List; see Appendix 2.4 for a full list) and a second list for SMS shortcuts that were extracted from genuine text messages (Genuine Usage Frequency List; see Appendix 2.5 for a full list).

SMS shortcuts from each source (Self-produced lists and Genuine text messages) were further coded into type of shortcut. In order to allow for comparisons to be made with previous literature the classifications used by Thurlow (2003) and Plester et al. (2009) were employed with the following exceptions; the categories 'nonconventional spellings' (e.g., *fone, rite*) and 'other clippings' (e.g., *hav*, *wil*) were felt to produce items that could be considered phonological approximations and were therefore assimilated into a new category termed 'phonological approximations'. Misspellings of words were difficult to identify (due to the fact that they could have been typos) and were not categorised. In addition to the categories identified by Thurlow and Plester et al. three new categories were created. 'Interjections' were used to describe exclamations such as *phew, aw* and *ahhh*. 'Dialectual' shortcuts were those that were specific to the Yorkshire dialect (e.g., *aup*-aye up) and distinct from accent stylisations from other dialects (e.g., *anuva*-another) and finally words with extra letters added such as *hellllllo* and *whatttttttt* were categorised as 'extensions' (see table 2.2).

Table 2.2 Final categories used in the current study

Category	**Example Shortcut**	**Base-word**
Shortenings	*bro*	Brother
	sis	Sister
Abbreviations (Contractions)	*txt*	Text
	pls	Please
G-clippings	*goin*	Going
	comin	Coming
Omitted apostrophes	*cant*	Can't
	wont	Won't
Acronyms	*BBC*	British Broadcasting Company
	UK	United Kingdom
Initialisms	*lol*	Laughing out loud
	lmao	Laughing my arse off
Symbols & smileys	;-)	Smiling
	@	At
Letter-digit homophones	*l8r*	Later
	wuu2	What you up to?
Phonological approximations	*u*	You
	wud	Would
Accent stylisation	*wiv*	With
	anuva	Another
Dialectual shortcuts	*owt*	Anything
	aup	Aye up
Interjections	*phew*	Phew (relief)
	ahhh	Ahhh (understanding)
Extensions	*hellllllllo*	Hello
	yeahhhhhhhhh	Yes

Shortcuts that could be placed in more than one category were categorised according to the first change made, but if they were potentially motivated by phonology they were categorised as phonological approximations. For example the shortcut *tho* is used to represent the word *though*, it is a shortening of the word *though* but it also represents the sound of the word. This item was therefore categorised as a phonological approximation rather than a shortening.

2.2.4.1 Pilot surveys (Experimental stimuli)

The analysis conducted on the pilot surveys aimed to develop two sets of experimental stimuli, namely a set of abbreviated shortcuts (e.g., *txt*) and a set of letter-digit shortcuts (e.g., *l8r*). The results from the pilot surveys produced a list of 181 items from 269 respondents of which 89 had a frequency of 1 (i.e., just one participant listed this shortcut). These items were often alternative spellings of more commonly used items, for example the shortcut *2dy* used to represent the word *today* is included in this set of shortcuts whereas the more common spelling, *2day,* has a frequency of 201.

There were 31 items with a frequency of 2, consisting of unusual shortcuts such as *nta* used to represent the word *enter* as well as alternative spellings for more popular shortcuts, for instance, *tday*, used for *today*. Surprisingly this set also contained shortcuts that might be considered well known, such as *w8* (wait), *whn* (when) and *twn* (town). It should be noted, however, that these items were not included in the list of shortcuts presented to participants and therefore received fewer mentions compared to items that did appear in the list. 12 shortcuts were listed with a frequency of 3 and included items that use less common forms of spelling such as *myt* (might) and *lyk* (like). Four shortcuts had a frequency of 4 and 47 shortcuts were listed with a frequency of 5 or above. There were 29 shortcuts that generated a frequency of 50 or above (see Appendix 2.2 for a full list). Almost all of the items that were on the list presented to participants are included in the top 29 shortcuts. The exceptions are *fstr* (faster), *ez* (easy), *xlnt* (excellent) and *nta* (enter) and the only item in the top 29 from shortcuts that participants produced is the shortcut *u* (you). Other popular shortcuts that were not listed but self-produced include, *c* (see), *luv* and *lv* (love), *2* (to/too/two), *r* (are), *4* (for) and *l8r* (later).

The designs of the subsequent experiments (reported in Chapters 4, 5, 6 and 7), require stimuli that represent a single word and are based on either the orthography or the phonology of a word. It was therefore important to select items that were pure abbreviations, such as *txt* (text) or *tlk* (talk) and letter-digit shortcuts that reflect the phonology of their base-words without sharing the orthography, such as *b4* (before) or *gr8* (great). All the appropriate shortcuts listed in the top 29 items were therefore selected for use as stimuli resulting in a total of 12 abbreviated and 11 letter-digit shortcuts (see tables 2.3 & 2.4).

Table 2.3 Final set of stimuli selected for use in the 'abbreviated' condition

Item	SMS shortcut	Meaning	Frequency
1	whn	When	2
2	wknd	Weekend	155
3	msg	Message	186
4	txt	Text	229
5	spk	Speak	89
6	pls	Please	172
7	tlk	Talk	107
8	wt	What	4
9	lv	Love	16
10	yday	Yesterday	113
11	prbly	Probably	68
12	wrk	Work	126
13	nxt	Next	169
14	gd	Good	139
15	bk	Back	147
16	hw	How	5
17	ppl	People	186
18	twn	Town	2

The remaining items, *ne1, no1, thx, fwd* and *u* were not used as they were considered to be unsuitable for the task. For example, although *ne1* ranks 19 out of 29 it did not perform well in a pilot study, resulting in high identification error rates. The shortcuts *no1* and *thx* were omitted because it is unclear whether they represent two words or a single word. The shortcut *u* was not used as it is a single letter and in isolation may not be recognised as a shortcut.

Table 2.4 Final set of stimuli selected for use in the 'letter-digit' condition

Item	SMS shortcut	Meaning	Frequency
19	2moro	Tomorrow	210
20	2nite	Tonight	196
21	2day	Today	201
22	b4	Before	213
23	l8	Late	125
24	l8r	Later	8
25	h8	Hate	4
26	m8	Mate	124
27	gr8	Great	138
28	4ward	Forward	1
29	4get	Forget	135
30	w8	Wait	3
31	2gether	Together	2
32	d8	Date	1
33	4eva	Forever	113
34	every1	Everyone	2
35	sum1	Someone	132
36	in2	Into	94

Finally the shortcut *fwd* was not used because the letter-digit shortcut *4ward* was required as an item in the letter-digit condition. Additional shortcuts were selected from the popular self-report shortcuts such that an even number of stimuli were included in each shortcut condition. The final selection of stimuli and their respective frequency counts are listed in tables 2.3 and 2.4. Although mean frequencies and word lengths differed between the two conditions (abbreviated and letter-digit shortcuts) *t*-tests conducted on these variables indicated that there were no significant differences (frequency $t<1$; length $t(27)=1.59$, $p=.124$).

2.2.5 Post-test and online surveys

2.2.5.1 Self report frequency list

Subsequent to the development of appropriate experimental stimuli, a series of online and post-test surveys were conducted to obtain an indication of how frequently these and other SMS shortcuts are used. The surveys asked respondents to list shortcuts that they use (Self-report measure) and to provide a sample of five genuine text messages that they had sent (Genuine Usage measure). The results of an analysis of the self-report measure resulted in a list of 1371 shortcuts produced by 709 respondents. However, just 10 of those shortcuts have a frequency over 100, suggesting that they are used with any kind of regularity (see Appendix 2.4). The most frequently listed shortcut is *u* (you) followed by the initialism *lol* (laugh out loud). This set also included popular single letter/number homophones *2* (to/two/too), *r* (are) and *4* (for), but the only abbreviated item in this set is *txt* (text).

A further 15 items have a frequency over 50, suggesting some degree of conformity in the spelling and use of these items. For example, the shortcut *2moro* (tomorrow) is part of this set but there are also 19 alternative spellings of this shortcut listed with frequencies ranging from 57 to 1. This illustrates the large amount of variety in the spelling and form of SMS shortcuts. A number of the shortcuts that were used as experimental stimuli are also in this set as are the more well known initialisms, for example *lmao* (laughing my arse off), *brb* (be right back) and *tbh* (to be honest). In the remaining items, 53 have a frequency above 20, this set contains a further 8 shortcuts that were used as stimuli. There are 93 shortcuts with a frequency between 10 and 20 of which 7 are items selected as stimuli. A further six of the stimuli are in a set of 105 shortcuts with a frequency between 5 and 10. A large number of shortcuts (375) have a frequency between 2 and 5 and the final shortcut used as a stimulus item (*prbly* – probably) is amongst the 693 individual shortcuts listed with a frequency of 1 (see Appendix 2.4 for a partial list).

2.2.5.2 Genuine Usage frequency list

A total of 309 respondents provided genuine text messages from which a list of 732 unique shortcuts and other unusual spellings were identified (see Appendix 2.5). Over half of these items had a frequency of 1 (495) illustrating the huge amount of variation in the spelling of SMS shortcuts and the widespread use of unique shortcuts in individual text messages. The most popular shortcut is *u* (you), which is consistent with the Self-produced frequency list, however, in the present list the smiley face emoticon, :) was found to be the second most popular item. This finding illustrates that symbols, especially smiley faces, are used with high frequency in genuine texts but their absence from self-produced lists suggests that respondents do not consider them to be shortcuts. Words with the apostrophe omitted also appear to be used frequently in genuine texts. A number of specific items with omitted apostrophes were found with a high frequency, for example *im* (I'm), *its* (it's) and *dont* (don't). A further feature of genuine texts is that interjections are regularly used and the following items were found to have the highest frequencies, *haha, yeah, hey* and *hiya*. However, if these differences are disregarded (i.e., emoticons, omitted apostrophes and interjections), the rank order of shortcuts that were listed by respondents and those extracted from natural text messages is comparable. For example, the initialism *lol* (laugh out loud) is ranked 2nd in self-produced lists and 3rd in the genuine frequency list. Other similarities include the single letter and number items such as *r* (are), *2* (to/two/too) and *c* (see), which have corresponding rankings in both lists. Points of divergence, however, are found amongst abbreviated shortcuts such as *txt* and *pls,* which appear with relatively high frequency in the self produced list but have a low frequency in genuine texts. Furthermore, a number of abbreviated shortcuts (e.g., *ppl*-people, *wknd*-weekend) do not appear at all in the list developed from genuine text messages but were reported by a number of respondents in self-produced lists. Additionally some letter-digit items that were listed with a high frequency by participants, such as *m8* (mate), *b4* (before) and *l8r* (later) appear to be used in genuine text messages with a much lower frequency.

The total word count for genuine text messages was 16,086 of which 2,359 items were shortcuts. The proportion of shortcuts used in genuine texts was calculated as a percentage and just 15% of words used in genuine text messages were found to be shortcuts. The average number of shortcuts used by respondents per text message is 1.5, however, the data suggest that respondents either use a large number of shortcuts in their texts or tend to not use shortcuts at all. Out of the 309 respondents who provided genuine text messages across all surveys a total of 23 (8%) respondents did not use any shortcuts or extensions in their texts and 43 (14%) respondents only used emoticons or interjections. The remaining 243 respondents all used at least 1 recognised shortcut in their text messages.

2.2.6 Comparison of experimental stimuli within each frequency list

As mentioned in the introduction it is critical to the design and analysis of the subsequent experiments reported in this thesis that the SMS shortcut stimuli are known by the participants and are used with relatively equal frequency. A comparison of the frequencies obtained for the experimental stimuli across the three frequency measures (Pilot, Self-produced and Genuine Usage) was therefore conducted. Tables 2.5 and 2.6 show a comparison of the frequencies obtained for the experimental stimuli from the pilot surveys and the new frequencies obtained from this larger sample for each SMS shortcut condition.

Table 2.5 Frequency counts from Pilot, Self-Produced and Genuine Usage frequency lists for Abbreviated shortcut stimuli

	SMS shortcut	Meaning	Pilot Frequency	Self-produced Frequency	Genuine Usage Frequency
1	whn	When	2	6	1.0
2	wknd	Weekend	155	21	0.0
3	msg	Message	186	76	5.0
4	txt	Text	229	132	1.0
5	spk	Speak	89	19	1.0
6	pls	Please	172	84	5.0
7	tlk	Talk	107	16	0.0
8	wt	What	3	13	2.0
9	lv	Love	16	40	3.0
10	yday	Yesterday	113	31	1.0
11	prbly	Probably	68	1	0.0
12	wrk	Work	126	26	5.0
13	nxt	Next	169	46	7.0
14	gd	Good	139	78	9.0
15	bk	Back	147	81	11.0
16	hw	How	5	20	3.0
17	ppl	People	186	58	0.0
18	twn	Town	2	9	0.0

Table 2.6 Frequency counts from Pilot, Self-Produced and Usage frequency lists for Letter-digit shortcut stimuli

	SMS shortcut	Meaning	Pilot Frequency	Self-Produced Frequency	Genuine Usage Frequency
19	2moro	Tomorrow	210	76	7.0
20	2nite	Tonight	196	85	3.0
21	2day	Today	201	84	4.0
22	b4	Before	213	104	2.0
23	l8	Late	125	71	2.0
24	l8r	Later	8	92	4.00
25	h8	Hate	4	30	1.00
26	m8	Mate	124	108	3.0
27	gr8	Great	138	66	3.0
28	4ward	Forward	1	12	1.0
29	4get	Forget	135	17	2.0
30	w8	Wait	2	22	0.0
31	2gether	Together	2	3	1.0
32	d8	Date	1	6	0.0
33	4eva	Forever	113	10	0.0
34	every1	Everyone	2	7	0.0
35	sum1	Someone	132	13	0.0
36	in2	Into	94	8	0.0

An assessment of the highest frequency items that would be appropriate to use as experimental stimuli from the Self-produced frequency list suggests that the majority of the shortcuts selected from the pilot surveys remain the most appropriate shortcuts to use. However, a comparison of the frequencies for the experimental stimuli produced from the different sources illustrates some differences between them. The mean frequencies for abbreviated (M=3) and letter-digit shortcuts (M=2) based on genuine texts are considerably lower than those for either the pilot surveys (M=106 & 95 respectively) or self-report lists (M=42 & 45 respectively).

Abbreviated shortcuts make up 48% of all shortcuts in self produced lists whereas in genuine texts they account for just 13% of all shortcuts. Letter-digit shortcuts produce similar figures accounting for 51% of shortcuts in self-produced lists and 1% of shortcuts from genuine texts. A mixed plot 2x3

ANOVA with the Raw Frequency count as the dependent variable, Shortcut type (abbreviated and letter-digit) as the between participants variable and Frequency (Pilot, Self-report and Genuine Usage) as the within participants variable reveals that there is a main effect of Frequency ($F(2,68)=48.02$, $p<.001$) but no other main effects or interactions are significant. Post hoc analysis to investigate the main effect of Frequency reveals that Self-produced frequencies are significantly lower than the original frequency calculated from the pilot surveys ($t(35)=5.71$, $p<.001$) and Genuine Usage frequencies are significantly lower than Self-produced frequencies ($t(35)=6.98$, $p<.001$). Further analysis based on the proportions of these items from all shortcuts in the later frequency lists confirms this finding. The results of a 2x2 ANOVA with Proportion of shortcuts as the dependent variable, Shortcut type (abbreviated and letter digit) as a between participants variable and Frequency (Self-report and Genuine Usage) as the within participants variable reveals that there is a main effect of Frequency ($F(1,34)=40.09$, $p<.001$) but no other main effects or interactions are significant. This confirms that there are no differences between the frequencies of the abbreviated or letter-digit shortcuts for either the original Pilot frequency, the Self-report frequency or the Genuine Usage frequency. Furthermore these analyses suggest that significantly more shortcuts are listed when respondents are asked to report shortcuts compared to the numbers of shortcuts that are actually used in text messages. This could be an indication that participants generally know more shortcuts than they actually use.

2.2.7 Type of shortcut

All the shortcuts, from both the Self-produced and the Genuine Usage frequency lists were further categorised into type of shortcut (e.g., letter-digit homophones, phonological approximations, abbreviations, and so on, see above for a breakdown) and ordered by frequency of type (see Figures 2.1 and 2.2).

2.2.7.1 Self-produced shortcuts

The analysis of self-produced shortcuts revealed that the most frequent types of shortcut listed were phonological approximations.

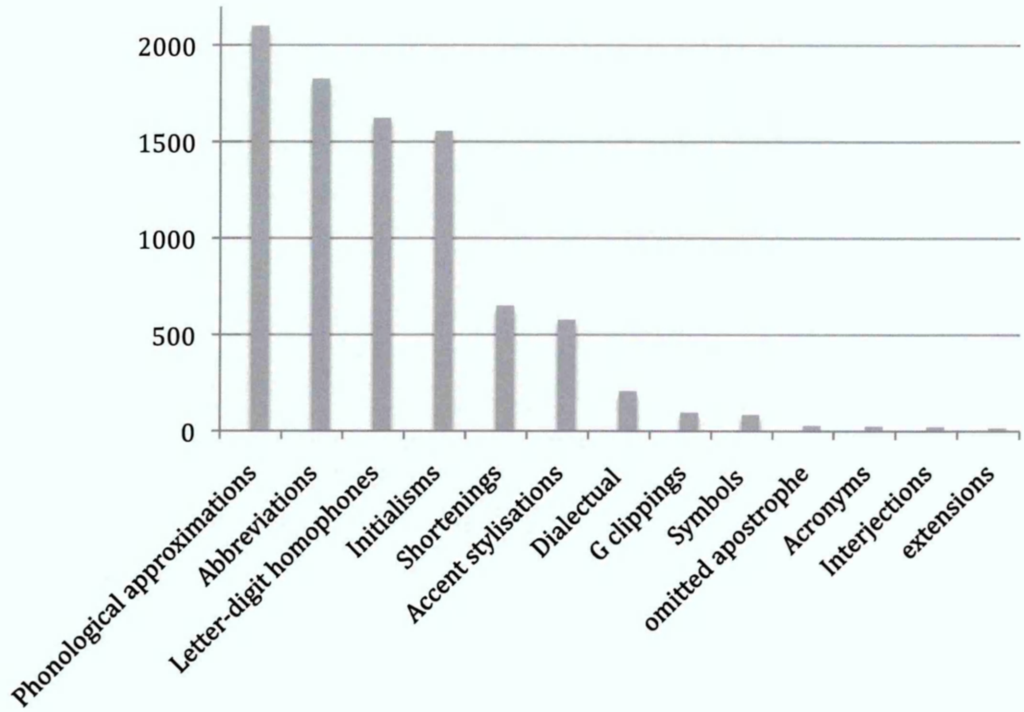

Figure 2.1 Frequency count for type of shortcut from Self-produced frequencies

In total 2,100 shortcuts were categorised as phonological approximations accounting for 29% of all shortcuts. The most common shortcuts in this category were the single letter shortcuts such as, *u* (you), *r* (are), *ur* (your) and *c* (see). Phonological approximations that alter irregular vowel combinations or strip out redundant letters were also frequently listed. For example, *wen* (when), *nite* (night) and *wot* (what). The second most popular type of shortcut were abbreviations, in total 1826 shortcuts were categorised as an abbreviation accounting for 21% of all shortcuts. The most popular items in this category were *txt* (text), *pls* (please), *bk* (back), *gd* (good) *msg* (message) and *ppl* (people). Letter-digit shortcuts were the third most popular type of shortcut, a total of 1624, accounting for 18% of all shortcuts were listed. Popular items in this category were the single number homophones, *2* (two/to/too) and *4* (for), followed by *m8* (mate), *b4* (before), *l8r* (later), *2nite* (tonight), *2day* (today) and *2moro* (tomorrow). Initialisms were the fourth most frequently listed shortcuts with a total of 1556 accounting for 18% of all shortcuts. The most popular items were, *lol* (laugh out loud), *omg* (oh my God), *lmao* (laughing my arse off), *brb* (be right back), *tbh* (to be honest) and *btw* (by the way). The 5th most popular shortcuts were words that have been shortened, a total of 651 items accounting for 7% of all shortcuts were reported with the most popular items being *k* (OK), *probs* (problems) *bout* (about) and *ye* (yes). Accent stylisations were the 6th most commonly reported items. A total of 578 items accounting for 7% of the data were categorised as accent stylisations, the most common items were *plz* (please), *thx* (thanks), *kk* (OK), *defo* (definitely) and *soz* (sorry). The more well known accent stylisations such as *lyk* (like), *nyt* (night), *da* (the) and *kwl* (cool) appear with lower frequencies. The next most popular type of shortcut were those that were categorised as dialectual, this set included items such as *alr8* (alright), items with the initial 'h' dropped such as *av* (have) and unusual items such as *tha* (the), *nowt* (nothing) and *aup* (aye up). There were a total of 208 dialectual shortcuts accounting for 2% of the data. The remainder of the categories each represent 1% or less of the total number of shortcuts used and feature in the following order, G-clippings, symbols, omitted apostrophes, acronyms, interjections and extensions.

2.2.7.2 Genuine text messages

The results of the analysis based on shortcuts identified in genuine text messages show that as with self-produced shortcuts phonological approximations were the most commonly used and the single letter shortcuts *u* (you) *r* (are) and *c* (see) were the most popular. A total of 710 shortcuts were identified as phonological approximations accounting for 30% of the data, with higher frequency items making up 75% of those. The next most popular category was abbreviated shortcuts representing 11% of the data. In total 256 abbreviated shortcuts were identified but only 32% of those were included in the list of high frequency items. There were a large number of items in this category with a frequency of 1, such as *cnfusd* (confused), *fbk* (facebook) and *frm* (from). This illustrates the high levels of individuality in this category; however, in contrast to self-produced lists there were fewer variations of abbreviated shortcuts used in genuine texts. The third most commonly used shortcuts were words with apostrophes missing and they accounted for 10% of all shortcuts. A total of 234 items were identified in this condition with the most popular items being *im* (I'm), *its* (it's), *dont* (don't), *ill* (I'll) and *il* (I'll).

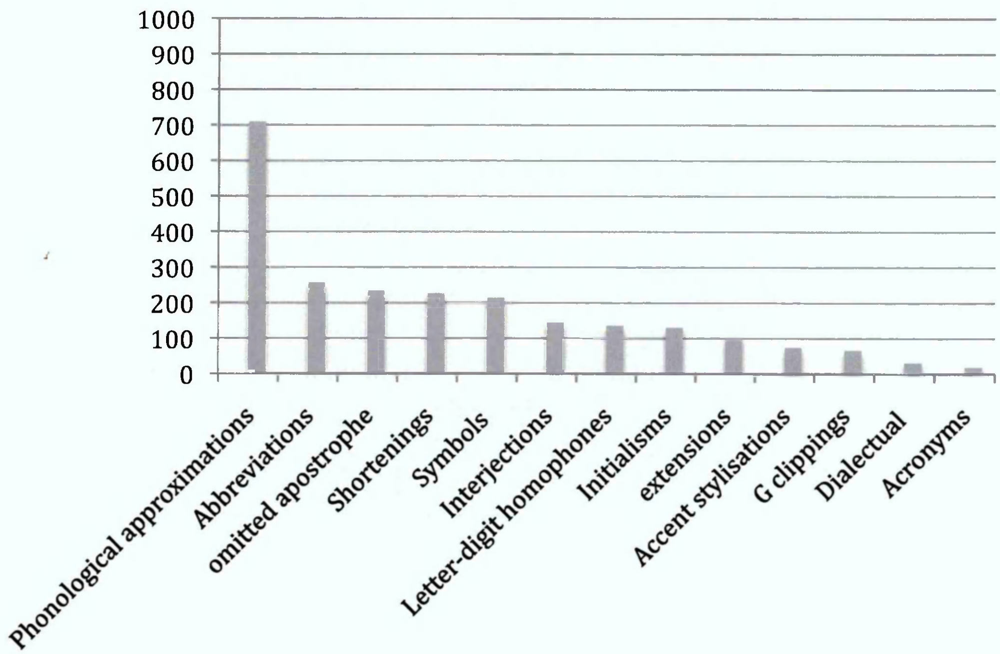

Figure 2.2 Frequency count for type of shortcuts extracted from genuine text messages

The next category of shortcut used frequently in text messages were shortened words with a total of 287 shortenings identified that account for 10% of all shortcuts. The most popular item was *uni* (University), which reflects the sample population, followed by *til* (until), *mins* (minutes), *hun* (hunny) *jus* (just) and *t* (to). Symbols were the fifth most commonly used items accounting for 9% of all shortcuts with 214 total symbols being used. The most popular symbol was a smiley face :) followed by a sad face :(, a face with the tongue out :P , the at mark @, a symbol that represents a huge grin :D , an alternative smiley face (with a nose) :-) and finally a wink ;). The analysis revealed that interjections, letter-digit shortcuts and initialisms all accounted for roughly 6% of the data. The most popular interjections were *haha*, followed by *hey*, *aw*, *aww* and *hmmm*. The most frequently used letter-digit shortcuts were *2* (to/two/too) and *4* (for), followed by *2moro* (tomorrow), *2day* (today) and *l8r* (later). Some items in this category that might be considered well known shortcuts and were listed fairly frequently by participants in self-produced lists were found with lower frequencies in genuine texts; namely, *b4* (before), *l8* (late) and *h8* (hate). Interestingly *w8* (wait) was not found at all in any of the genuine texts although a variant was present *w8n* (waiting). The most popular initialism, *lol* (laugh out loud) mirrored that found in self-produced lists and items with higher frequencies in genuine texts were also listed with higher frequencies in self-produced lists, for example *cya* (see you) and *wuu2* (what you up to). However some items reported with a high frequency by participants were not found in genuine texts, for instance *omg* (Oh my God), *brb* (be right back), *tbh* (to be honest) and *wtf* (what the f***).

In contrast to the self-produced lists, where very few extensions (e.g., *heellloooooo*) were reported, these items were found to be the ninth most popular shortcut used in genuine texts and represented 4% of all shortcuts used. Although these items tend to be unique and few are exactly the same the following items were found to be the most popular, *soooooooo* and *oooooooo*. These were followed by items such as *yooouuuuu, heyyyyyy* and even *loool,* which was used to represent laughing out loud a lot! The final four categories were found in the following order accent stylisations followed by G clippings, dialectual shortcuts and acronyms. Accent stylisations and dialectual shortcuts are by their nature unique and therefore not many high frequency items were found however, *hows* (how is/are) was found to be the most popular accent stylisation with items such as *boi* (boy), *dis* (this) and *innit* (isn't it) appearing with low frequencies. Dialectual shortcuts were found that relate to the Yorkshire dialect such as *al* (I'll), *ey up* (hello) and *nowt* (nothing) but the most popular items were *ta* (thanks) *av* (have) and *ome* (home). These items could arguably be found in other dialects as well as the Yorkshire dialect in the UK. Surprisingly few G-clippings were found representing just 3% of all shortcuts with the most popular being *goin* (going), *doin* (doing) and *comin* (coming). Finally just 10 different acronyms were identified with only *ASAP* (as soon as possible) being used with any regularity.

2.2.8 The changing face of SMS shortcut use

2.2.8.1 Explanations for a reduction in the use of SMS shortcuts

A single question included in the surveys attempted to investigate how the use of SMS shortcuts may have changed over time for the respondents to this survey. This question asked respondents to indicate if they have increased or decreased their use of SMS shortcuts at any time, if so at what age and why. A content analysis was conducted on the responses and the themes are presented in table 2.7, with a frequency count and percentages of respondents who mentioned each theme.

Table 2.7 Themes extracted from responses to the question of changes in SMS shortcut usage with frequencies of mention and percentage of respondents who mentioned each theme

THEMES	Frequency	% of respondents
Usage		
Change in use		
Decreased use but used between the ages of 12 - 20	142	48%
Increased use	24	8%
No change	57	19%
Reason for use: Savings	**93**	**31%**
Space	33	11%
Money	26	9%
Time	34	11%
Reason for change		
New Technology	**76**	**26%**
Perception of texter	**68**	**23%**
Looks immature	26	9%
Looks unintelligent/chavy	23	8%
Was cool	9	3%
Don't like the way they look	10	3%
Social pressure	**15**	**5%**
Comprehension	**20**	**7%**
Impact on formal writing	**18**	**4%**
Language switching	**26**	**9%**

Three main headings were identified from the analysis, *Usage*, *Reasons for change* and *Language switching.* Under the heading of *Usage* there were two themes, *change in use* and *reason for use.* Under the theme of *change in use* three sub themes were identified; *decreased use*, *increased use* and *no change.*

Out of a total of 297 respondents 48% suggested that they had decreased their use of shortcuts, but that they had used them at some point between the ages of 12 – 20. Just 8% suggested that their usage had increased and 19% reported that they had not changed their use of shortcuts. Of the 8% whose usage had increased the average age was 31 whereas the mean age of those who had decreased use was 21, suggesting that older individuals may increase their usage whereas younger respondents decreased usage.

Under the theme representing reasons for using shortcuts there were three subthemes that related to savings in space, time or money. A fairly large percentage of respondents (31%) mentioned traditional reasons for using shortcuts such as space saving and reduced costs:

> *I always use shortcuts becus its quika, and especially wen running out of credit to make texts smaller.*

Respondents also suggested that shortcuts are faster to type into some mobile phones compared to traditional words and some respondents reported that although they generally do not use shortcuts if they are in a rush they will use them:

> *I occasionally use shortened forms now such as 'cuz' and 'wanna' to save time.*

Under the main heading of *Reason for change* five themes were identified relating to reasons why the use of SMS shortcuts had decreased, they are; *new technology*, *the perception of the texter*, *social pressure*, *comprehension* and *impact on formal writing*. The most frequently mentioned reason for change was that the advent of new technology makes the use of shortcuts redundant (26%):

> *I decreased the amount I used when I got an iphone as it uses a qwerty keyboard, making it faster to type real words.*

One respondent suggested that the smart phone buttons are too close together to allow shortcuts to be keyed in and a number of respondents reported that it is difficult to continue to use shortcuts because smart phones auto-correct abbreviations:

> *when I got my iphone, it automatically corrects abbreviations, like 'im' to 'I'm' etc.*

The use of predictive text and unlimited text packages were also cited as reasons for decreasing the number of shortcuts used:

> *I now have unlimited texts and so saving space is not a priority.*

However, an almost equal number of respondents (23%) suggested that using shortcuts projects a negative image of the texter. Under the theme *Perception of texter* there were four subthemes that represent comments made suggesting that the use of SMS shortcuts makes the texter look immature or unintelligent. A number of respondents suggested that when they were younger using shortcuts was considered the 'cool' thing to do but that it now appears immature or 'silly':

> *When I was around 12-15 I probably used more shortcuts in texts as it was much quicker and as stupid as it sounds "cooler".*

> *when younger (16-18ish) used more shortcuts because i thought it was cool, now they're just annoying!*

Under the main theme of *reasons for change* a few respondents (5%) mentioned social pressures as reasons for using or not using shortcuts:

> *Yes, When I was approx 14-16 years old. Probably to fit in with others*

Respondents mentioned the importance of using correct grammar to fit in socially, a remark that links to comments that respondents stopped using shortcuts when they got to University or started a job:

> *there was a phase when texting really began when everybody used shortcuts,*

> *i feel i have mostly grown out of that and the grammar has become more important socially*

A further 7% of respondents felt that using shortcuts made text messages difficult to read:

I am also conscious of the function of texting - communication - and I want to be sure that all recipients fully understand the message.

shortcuts are hard to read and could be misinterpreted.

A very small percentage of respondents (4%) suggested that the use of shortcuts may affect formal writing. Of those just 7 respondents reported that they had experienced a negative impact on their formal writing and had therefore stopped using shortcuts:

It definitely came to light when a piece of coursework had been returned and I had used a shortcut instead of the actual word. From then on, I have written the full words in texts

A final theme identified in this data represents a comment made by a few respondents that they tailor their text messages to the recipient and limit their use of shortcuts to a specific audience. This is termed *Language switching*.

My style changes depending who I'm texting.

i use them quite a bit use different ones now to when was younger and use them for different people.

Overall the data gathered in response to the question of changing use suggest that the majority of students used SMS shortcuts when they were younger but now they are University undergraduates their use of these items has decreased. The reasons given for this decrease centred around the fact that new technology has made it difficult to use shortcuts or that they project a negative image of the texter. This negative image appears to be the result of a consensus that using shortcuts was something that was done when young and therefore makes the texter look juvenile or uneducated.

2.3 Discussion

2.3.1 Development of experimental stimuli

The initial aim of the research detailed here was to establish a set of commonly used SMS shortcuts to employ as experimental stimuli. The aim of subsequent online and post-test surveys was to develop a database of SMS shortcuts that are currently known and in use by undergraduates in the UK. The resulting database enabled two frequency lists to be developed, one based on self-reports of SMS shortcut use and another on genuine texts. In turn the frequency lists allowed for comparisons to be made between the relative frequencies for the abbreviated and letter-digit stimuli used in this thesis, as well as a detailed analysis of shortcuts that are currently used by UK undergraduates.

From the outcomes of the pilot surveys a set of 18 abbreviated and 18 letter-digit shortcuts were selected for use as experimental stimuli. In order to provide as much control over the experimental conditions as possible the stimuli were restricted to items that describe a single word and represent either the orthography (e.g., *txt, pls*) or the phonology (e.g., *l8r, b4*) of a word. Items that consisted of single letters or numbers, such as *u* (you), *2* (to/two/too) *c* (see) and *4* (for) as well as items that could represent two words, such as *thx* (thank you) and *no1* (no one) were avoided. Items that combined phonological approximation with orthographic abbreviation such as *xlnt* (excellent) and *nta* (enter) were also excluded.

Due to the design of the pilot surveys some shortcuts received a frequency count that was not representative of how much they are actually used. For example a large number of respondents to the pilot surveys indicated that they use the following shortcuts *prbly* (probably), *4get* (forget) *and 4eva* (forever), however, these items have a low frequency in the frequency lists developed from the later surveys. Other items received a disproportionately low frequency from the results of the pilot surveys due to not being included in a list of shortcuts that were presented to respondents. The self-produced and genuine usage frequency lists therefore provided a more reliable measure of the frequency with which shortcuts are actually used due to their design and larger sample. However, despite the discrepancies between the original pilot frequencies and the later surveys the majority of the original experimental shortcut stimuli remained the same according to the frequency counts produced from the later surveys. In addition, it was important to establish the relative frequencies with which abbreviated and letter-digit shortcuts are used due to the finding that recognition of familiar word stimuli can be affected by the frequency with which they are used (Keuleers, Lacey, Rastle & Brysbaert, 2012). Therefore in order to compare the results observed for abbreviated and letter-digit shortcuts in tasks designed to record reaction times it was imperative to establish whether there are differences in the frequencies between these two sets of stimuli. Analyses conducted on the frequency counts from the Pilot surveys, the Self-produced frequency and the Genuine Use frequency revealed that there are no significant differences between the two types of shortcut or the three different frequency measures.

The outcomes of these surveys not only establish the first known database of SMS shortcuts but also confirm that the shortcut stimuli employed in this thesis are taken from items currently in use by UK undergraduates that are of comparable frequency. As a consequence because the participants who take part in the following experiments are drawn from the same demographic it is likely that the stimuli will be familiar to them.

2.3.2 Comparisons to previous literature

The list of SMS shortcuts compiled from those produced by respondents (Self-produced list) shows that there are just 10 items out of 1371 that are listed by over 100 respondents. This pattern of data suggests that there are very few SMS shortcuts that are regularly used by most respondents. Conversely the high number of unique items that are listed by just one respondent suggests that the use of SMS shortcuts tends to be dominated by a high variety of items that are used with little consistency. This trend is mirrored in the frequency list compiled from genuine text messages where over half of all shortcuts identified had a frequency of one and just 2 items appeared more than 100 times across 1545 text messages. SMS shortcuts are by their very nature unique and those who use them have been found to be individuals who are more comfortable with language and perhaps more creative (Plester, Wood and colleagues, 2008; 2009; 2011). It is perhaps not surprising therefore to find that there are hundreds of SMS shortcuts used by single individuals that are not used or listed by any others and that many of these unique items are highly inventive, for example the use of an item like *gawjus* to represent the word *gorgeous*.

However, the analysis conducted here also suggests that a few high frequency SMS shortcuts are used consistently and many of these overlap with those identified by previous research. One syllable single letter or digit shortcuts such as *r* (are), *c* (see), *2* (to/two/too) and *4* (for) were found with similar proportions in both of the frequency lists reported here (Self-produced and Genuine Usage) and in studies conducted by Kemp (2010) and Plester and Wood and colleagues (Plester et al., 2008; Plester & Wood, 2009). However, the most popular and consistently used shortcut in the data reported here and in previous literature (e.g., Ling and Baron, 2007; Plester, Wood and colleagues, 2008; 2009) is the shortcut *u* (you). This item was the most frequent item found in both the Self-produced and Genuine Usage frequency lists. Conversely, Thurlow (2003) makes no specific mention of the shortcut *u* reporting that just 5% of shortcuts identified in his study were letter/number homophones. In the current study the shortcut *u* alone accounts for nearly 10% of all shortcuts and 1.4% of all words in genuine text messages.

A comparison of the Self-produced and Genuine Usage frequency lists suggests that when asked to produce shortcuts respondents list a large variety of shortcuts, however, the proportion of shortcuts to words that are actually used in text messages appears to be relatively small. This finding resonates with the suggestion made by Plester & Wood (2009) that in genuine texts children use a limited selection of shortcuts compared to those found in texts that have been elicited in an experimental environment. In the data reported here the ratio of shortcuts to words in genuine text messages was found to be just 15%, which equated to an average of 1.5 shortcuts per message. The proportions reported here appear similar to those found in previous research with undergraduate students (e.g., Holtgraves, 2011; Thurlow, 2003). However, in a younger demographic higher ratios of shortcuts to words have been found (e.g., Coe & Oakhill, 2011; Wood and colleagues, 2008; 2009). These findings suggest that there is a decrease in the use of SMS shortcuts between school age and university. Furthermore the similar ratios of shortcuts to words observed by Thurlow and the current research suggest that amongst UK undergraduates the percentage of shortcuts used in natural text messages has not changed much since 2003.

2.3.3 Analyses of type of shortcut.

The shortcuts listed by participants and those extracted from their text messages were further categorised into type of shortcut in order to investigate linguistic distinctions between the different types of shortcut used. For instance abbreviated shortcuts rely on the traditional spelling of their base-words (e.g., *txt*-text) whereas phonological approximations alter the spelling of the base-word using regular grapheme-to-phoneme correspondences (e.g., *wen*-when). Previous literature has found that the most frequently used categories of SMS shortcut are those that correspond to the phonology of their base-words (Coe & Oakhill, 2011; Plester & Wood, 2009; Thurlow, 2003). Results reported here of an analysis of type of shortcut demonstrated that, as with previous research, shortcuts based on the phonology of their base words dominated both the Self-produced and Genuine Usage lists. However, in contrast to previous research abbreviations ranked second in both frequency lists. The use of the same categorisations as Thurlow and Plester et al. (2009) allows comparisons to be drawn between previous literature and the data reported here. However, the letter-digit homophone category in the research reported here only included items that used numbers or letters and numbers, such as *4* (for), *l8r* (later) and *b4* (before), but not letter homophones without numbers such as *r* (are) and *u* (you) etc. SMS shortcuts were initially coded in this way to provide an indication of the relative frequency with which abbreviated and letter-digit shortcuts are used. Therefore in order to make the comparison between this study and previous research more accurate, the letter-number homophone category was re-coded to include letter homophones without digits, such as *u, r* and *b.* The re-analysis of the data reveals that in both self-produced lists and genuine texts letter-number homophones outstrip phonological approximations (see figures 2.3 & 2.4).

The repositioning of letter-digit homophones as the most frequent items is in line with the findings from previous literature suggesting that these items are the most frequently used type of shortcut regardless of the age (pre-teen or undergraduate) or location (UK or USA) of the participant (Coe & Oakhill, 2011; Ling & Baron, 2007; Plester & Wood, 2009).

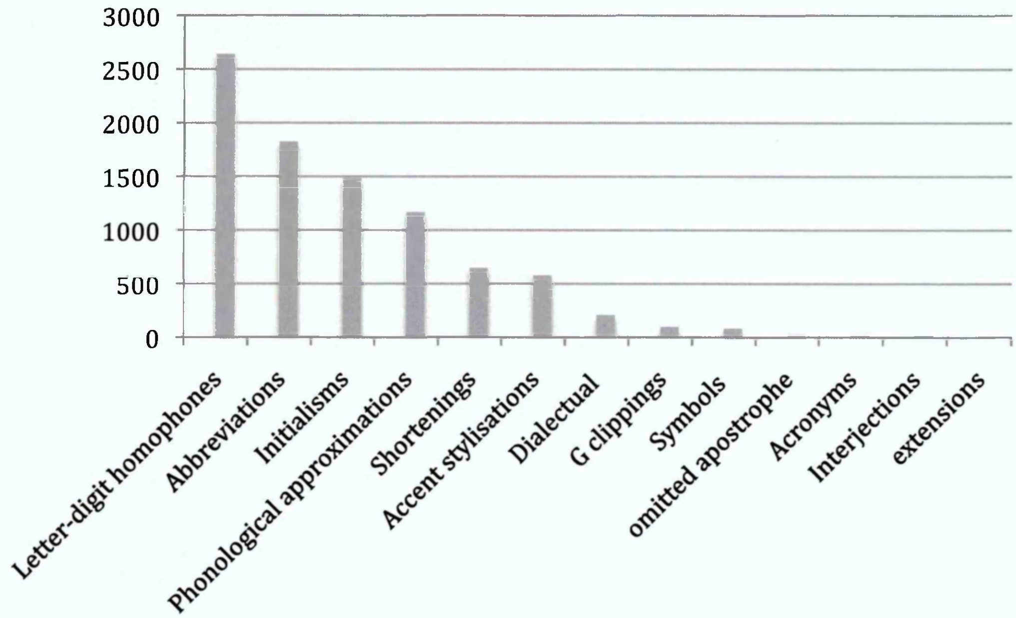

Figure 2.3 Frequency count for categories of type of shortcut from Self-produced frequency lists with letter-digit homophones re-coded to include single letter homophones

However, in contrast to previous literature and across all analyses in the current study abbreviations were reported and used with a relatively high frequency. Thurlow (2003) does not mention abbreviations, but Kemp (2010) suggests that as individuals become more familiar with texting they use shortcuts that represent the sound of a word more frequently than abbreviations that are developed from the spelling of a word. In the reanalysis of the data collected here from genuine text messages, abbreviations were found to be less frequent than both phonological approximations and letter-digit shortcuts suggesting support for Kemp's assumptions. Furthermore it would seem that when respondents write text messages they tend to use more shortcuts based on the phonology of a word than those based on orthography.

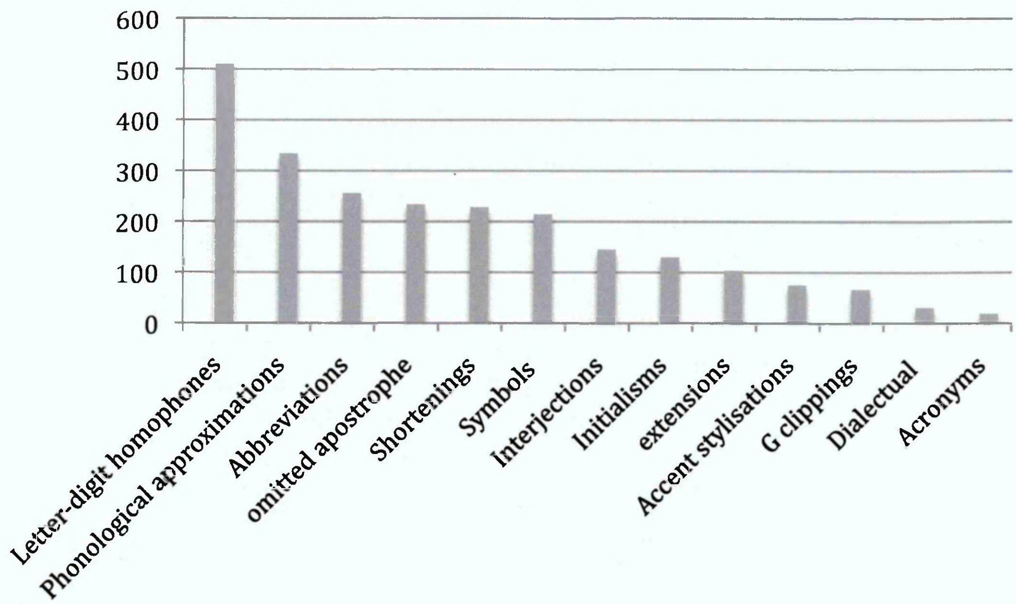

Figure 2.4 Frequency count for categories of type of shortcut extracted from Genuine text messages with letter-digit homophones re-coded to include single letter homophones

However, when asked to produce shortcuts respondents listed more abbreviations compared to phonological approximations. Nevertheless items from the self-produced lists that have orthographic (e.g., *whn*) and phonological (e.g., *wen*) variants illustrate that the phonological version has a higher frequency compared to the orthographic version. For instance in self-produced lists *whn* has a frequency of 6 compared to *wen* which has a frequency of 56, *wot* has a frequency of 48 but *wt* has a frequency of 13 and *no* has a frequency of 24 compared to *knw* with a frequency of 14. These results support the suggestion that phonological forms of shortcuts are used more frequently than abbreviated items and also add weight to suggestions that SMS shortcuts and 'text speak' have a closer relationship to the spoken word than a written format (e.g., Crystal, 2008; Tagg, 2009).

2.4 Conclusions

As a result of this investigation of SMS shortcuts two sets of experimental stimuli based on abbreviated and letter-digit shortcuts were developed and a detailed database of SMS shortcuts currently used by UK undergraduates produced. The large numbers of unique shortcuts reported by a single respondent highlights the considerable amount of variety within shortcut use and the database enabled the development of two frequency lists based on Self-reports and genuine texts. Contrasts conducted on the two frequency lists suggest that participants know significantly more shortcuts than they actually use in text messages. Nevertheless, the proportions of shortcuts to words found in the current research are comparable to those found in previous research conducted with undergraduate students (Ling & Baron, 2007; Thurlow, 2003). As with previous research phonological forms of shortcuts were found to dominate the types of shortcut used. However, phonological approximations, letter-digit homophones and abbreviations were found with relatively equal frequencies for undergraduate students in the current sample. In contrast previous research has found that homophones dominate text messages sent by younger age groups. Consequently despite the prevalence of shortcuts based on phonology, no differences were found between the relative frequencies of the abbreviated and letter-digit sets of stimuli developed in this chapter.

Interestingly despite a number of respondents suggesting that the advent of smart mobile phones and predictive texting makes the use of shortcuts redundant the proportions of shortcuts being used in text messages by undergraduates does not appear to have altered much since 2003 (Ling & Baron, 2007; Thurlow, 2003). However, smaller proportions of shortcuts were found in text messages written by undergraduates compared to school aged students (Plester & Wood, 2009). The reasons for a decrease in the use of SMS shortcuts as students get older appears to be grounded in the use of new technology and an image of the texter that is projected by the use of SMS shortcuts. Previous research into the sociolinguistic aspects of SMS shortcuts has suggested that they may be used to solidify group identities in the same way that slang is used by groups to identify individuals as members of the same gang (Crystal, 2008; Tagg, 2009). Some respondents mentioned that it was considered 'cool' to use shortcuts when they were younger but that now they seem a bit 'silly', suggesting that shortcuts were used by the 'cool gang' during the teen years. Furthermore in direct contrast to shock headlines in the media (see Thurlow, 2006 for a discussion) and the suggestions of Rosen et al. (2011) that shortcuts have a detrimental impact on formal writing very few respondents suggested that they had experience of SMS shortcuts impacting in this way.

In conclusion it seems that the use of SMS shortcuts is an activity that is generally undertaken between the ages of 12 and 16 but not past the age of 20, when students have either acquired a more advanced mobile phone or feel that they have matured. Although individuals appear to know a large number of possible shortcuts and may use an even greater number of shortcuts that are unique to them, a limited set of SMS shortcuts are used with any regularity in genuine text messages. For the purposes of the stimuli used in the subsequent experiments, however, it is encouraging to find that both abbreviated and letter-digit types of shortcut are used with roughly equal frequencies by the demographic from which the majority of the participants in the following experiments are drawn.

Chapter 3 Methodology: Masked priming

3.1 Introduction

The masked priming paradigm has had a huge impact on current understanding of visual word recognition because it provides insight into early cognitive processes that occur within milliseconds and outside the conscious awareness of an individual. In this methodology target stimuli are presented after a prime that has been displayed briefly and preceded or followed by a mask that is designed to obscure the prime from conscious processing. Thus a typical procedure would involve presentation of a forward mask (e.g., ####) followed by a prime (e.g., *text*), which would be replaced with a target word (e.g., *TEXT*; see figure 3.1). Prime stimuli that have been masked by forward or backward masks are considered to be subliminal due to the lack of conscious awareness typically exhibited by participants because they are "presented below the 'limen' or threshold for conscious perception" (Kouider & Dehaene, 2007, p.857).

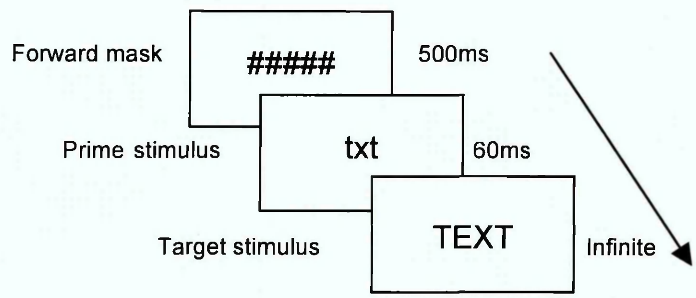

Figure 3.1 Typical priming procedure in an identity priming paradigm

Despite a lack of prime awareness, research has shown that if the prime and target words are associated (by meaning or form) a facilitatory effect is found such that reaction times are faster to target stimuli that have been preceded by related primes. The difference in reaction times to related prime-target pairs (e.g., *text-TEXT*) compared to unrelated pairs (e.g., *ship-TEXT*) is termed the priming effect and is calculated by subtracting reaction time latencies to related pairs from those found for unrelated stimuli. Positive priming effects reflect facilitation of response times to targets whereas negative priming effects suggest that the prime has inhibited processing of the target. Researchers have used the priming paradigm to investigate properties of visual word recognition by manipulating the degree to which primes and targets overlap either orthographically (e.g., *txt-TEXT*), phonologically (e.g., *tekst-TEXT*), morphologically (e.g., *texted-TEXT*) or semantically (e.g., *message-TEXT*). Early priming experiments demonstrated the extent of lexical information that is accessed prior to word recognition. For example, the development of the Cohort model of spoken word recognition (Marslen-Wilson& Tyler, 1980) was based on the suggestion that comprehension of the spoken word involves activation of all words that fit the acoustic input. In other words if the word to be processed is *captain,* words that match the initial sounds of that word such as *captive* will receive some activation in the mental lexicon. Although this competition between words is not available to conscious awareness the words that are initially activated can be revealed using priming experiments. For example, Zwitserlood (1989) used a priming paradigm to demonstrate that words with overlapping phonology (e.g., *captive*) are accessed when participants hear a phonologically related word (e.g., *captain*). In addition this activation occurs despite contextual information from sentence meaning and the fact that the words are semantically unrelated. Data gathered from masked priming experiments using a visual paradigm have also revealed that words with overlapping orthography can compete with each other (e.g., Davis & Lupker, 2006; Pastizzo & Feldman, 2009). Davis & Lupker (2006) demonstrated that a prime stimulus such as *ible* (that is not represented in the lexicon) can facilitate lexical decision latencies for a target word such as *ABLE* due to the overlapping letters, but the word *able* used as a prime inhibits processing of the target word *AXLE*. These results suggest that whereas the nonword facilitates processing, words that have a lexical representation compete with each other. Thus in investigations of both speech recognition and visual word recognition priming experiments have been instrumental in revealing the scope and nature of activation occurring in the mental lexicon; even when those processes occur before an individual is aware that a word has been presented.

However, interpretations of experimental results are based on the assumptions that underpin the methods used to collect the data. It is therefore important to fully explore those assumptions before embarking on experiments using these paradigms. This chapter therefore aims to provide an overview of the masked priming paradigm and explore the assumption that it is an effect that occurs due to lexical activation. In addition this chapter will explore methodological differences between priming studies such as the use of different control measures and prime durations as well as outline the use of backward masks between the prime and target stimuli.

3.2 Masked Priming – lexical activation or episodic memory trace?

Current explanations of the masked priming effect favour the view that activation of representations in the mental lexicon corresponding to prime stimuli influence reaction times to target stimuli. Presentation of a prime that is identical to the target (e.g., *text-TEXT*) produces faster reaction times because the mental representation corresponding to the target (e.g., *TEXT*) has been pre-activated by the prime stimulus and is therefore already active when the target is presented. Explained from the perspective of an Interactive Activation (IA) model of visual word recognition (McClelland and Rumelhart, 1981) priming is the result of lexical nodes activated by the prime overlapping with those activated by the target. The Dual Route Cascaded model has a lexical route that is similar to the IA model and Coltheart et al. (2001) suggest that providing the lexical representation activated by the prime is not reset and the target word is presented to a system that is already active, residual activation can affect target processing. Forster (1998) describes this process as being akin to opening a file on a computer, once it has been opened by the prime it remains active and target processing is therefore facilitated. However, there is an alternative argument, which suggests that priming may be due to episodic memory traces of the prime (Bodner & Dypvik, 2005; Bodner & Masson, 2001; also see Forster, 1998 for a review). Under this account identity priming (otherwise termed repetition priming), in which the prime and target are identical (e.g., *text-TEXT*), is the result of target stimuli accessing an episodic memory trace of the prime. Bodner & Masson (2001) argue that in order to recognise items in everyday life we need to recruit memory systems that combine memories of previous experience with current encoding circumstances.

Therefore it does not seem logical to propose that word recognition occurs as an event that is separated from memory or prior experience and instead relies on activation of abstract word representations.

Bodner and colleagues (Bodner & Dypvik, 2005; Bodner & Masson, 2001; Masson & Bodner, 2003) suggest that exposure to related prime-target pairs results in a learning experience that alters episodic memory and they propose that this change may be reflected by the addition of a new representation in memory or a change in connection weights. Bodner & Dypvik (2005) expand on this idea suggesting that in response to processing stimuli a memory trace is encoded which can be used to facilitate responses to target stimuli, if the same processing mechanisms are used for both prime and target. Research investigating the properties of memory suggests that the context surrounding an encoding event can affect subsequent retrieval (e.g., Godden & Baddeley, 1975). Consequently the explanation of priming effects proposed by Bodner and colleagues would be sensitive to the context within which encoding takes place. Evidence of context specific effects in priming studies therefore supports an account of priming based on memory systems rather than abstract word representations (Bodner & Masson, 2001). In support of this suggestion previous research has shown that priming effects can be affected by the characteristics of surrounding stimuli. For example if the foils in a lexical decision task are pseudohomophones (e.g., *brane-brain*) latencies to words become slower than in tasks where the foils are nonwords (Ferrand & Grainger, 1996). The inclusion of items that are difficult to reject as nonwords (e.g., pseudohomophones) therefore changes the context within which words are processed consequently altering the process of word recognition. Based on this premise Bodner and colleagues manipulated the context of masked priming experiments by altering the ratio of positive to negative responses or congruent and incongruent trials within a block. In lexical decision and semantic categorisation tasks stimuli are usually ordered into blocks for presentation. For example, in a task with a total of 128 individual trials, the trials might be ordered into 4 blocks each containing 32 trials. Half of those 32 trials would be stimuli that prompted positive ‘yes’ responses and half would be stimuli that prompted negative 'no' responses. Bodner and colleagues manipulated the context for word processing by either increasing or decreasing the ratio of 'yes' to 'no' responses or the ratio of incongruent to congruent trials in a block. Using this technique they demonstrated that larger priming effects were found if the ratio of positive or congruent trials in a block outweighed the number of negative or incongruent trials (Bodner & Dypvik, 2005; Bodner & Masson, 2001; Bodner, Masson & Norann, 2006). For example, Bodner & Dypvik (2005) used a parity task that required participants to decide if the target was an even number or an odd one. Prime stimuli used in this task were either congruent (e.g., *one-THREE*) or incongruent (e.g., *two-THREE*) and blocks were biased such that either 80% or 20% of the trials were congruent. The results demonstrated that when the ratio of congruent trials outweighed incongruent trials a robust priming effect was found for congruent trials. However, when the bias was towards incongruent trials no priming effects were found. Bodner & Masson (2001) suggest that due to the weighting of congruent and incongruent trials the system 'learns' to rely more or less on prime information. Therefore in a priming experiment where the majority of trials are congruent more priming should be seen for congruent trials because the system is relying on the prime to provide information related to the target. Conversely incongruent trials suffer due to the increased reliance on prime stimuli to process the target, which in the case of an incongruent trial is not advantageous. These authors suggest that theories of priming which centre on lexical access cannot provide an account for this data as they are unable to alter the degree of facilitation provided by a prime stimulus depending on the context within which it appears.

However, Kinoshita, Mozer & Forster, (2011) argue that if this was the case faster latencies should be seen for incongruent items (e.g., *two-THREE*) in blocks with a low proportion of congruent trials (e.g., *one-THREE*) because incongruent primes would provide a more reliable measure on which to base processing. Furthermore, if the proportion of congruent trials in a block is equal to the proportion of incongruent trials there is no information concerning the probability that the prime is related to the target and facilitation should not be found under these conditions. Counter to this logic in masked priming studies robust facilitation is seen for congruent trials compared to incongruent trials in blocks constructed with equal numbers of congruent and incongruent prime-target pairs (e.g., Forster, 2004; Quinn & Kinoshita, 2008; Van den Bussche, Van den Noortgate & Reynvoet, 2009). Kinoshita et al. demonstrated that when using visible primes in a parity task their predictions based on the suggestions made by Bodner and colleagues were supported. A 'reverse' congruency effect was found for blocks consisting of more incongruent trials than congruent trials with incongruent trials (e.g., *two-THREE*) producing *faster* latencies. Furthermore for blocks that had equal numbers of congruent and incongruent trials no priming effects were found. However, when primes were presented briefly and masked the usual congruency effect was found for blocks containing equal numbers of congruent and incongruent trials. In other words congruent trials were responded to more quickly than incongruent trials. These findings support those of previous research conducted using a primed stroop task (Merikle, Joordens & Stolz, 1995; Merikle & Joordens 1997). Merikle and colleagues presented participants with primes consisting of coloured patches followed by a colour word (e.g., *blue*). They found that if the number of incongruent trials (e.g., a colour patch in red followed by the word *blue*) were increased they could reverse the usual priming effect when primes were visible (150ms), but not with primes that were presented briefly (50ms). These results challenge the view that masked priming is sensitive to the processing context but support the suggestion that episodic memory traces may influence priming effects when prime stimuli are visible.

The evidence suggests that when prime stimuli are subject to conscious processing participants are able to use information regarding prime utility (defined as the probability that the prime is related to the target) to aid processing of target stimuli. Conversely the robust congruency effect found with masked primes when blocks contain equal numbers of congruent and incongruent trials suggests that participants are unable to use the same information when processing masked primed stimuli. According to the interpretation presented by Kinoshita et al., a bias towards incongruent trials in a block should encourage facilitation for incongruent prime-target pairs.

However, although Bodner & Dypvik (2005) demonstrated larger masked priming effects when ratios of congruent trials were higher, they observed equal latencies for both congruent and incongruent trials with masked primes in a task where 80% of the trials were incongruent. Kinoshita et al. suggest that information regarding how quickly evidence was gathered on previous trials may be used to set a response threshold for current trials. Therefore the harder the task is the longer the threshold will be set. Latencies to congruent trials could therefore be sufficiently protracted as to render them equivalent to incongruent primes if all responses are delayed by an increased response threshold. Furthermore, in line with the finding that reaction times are slower if you make the task harder (e.g., by using pseudohomophone foils in a lexical decision task) in the experiment conducted by Bodner & Dypvik slower latencies were observed overall in blocks with a bias towards incongruent trials. These results suggest that for masked priming experiments mechanisms other than episodic memory traces may be required to form a full account of the data.

3.3 Masking – does it reduce the effects of episodic memory?

In their original investigation of masked priming effects Forster & Davis (1984) suggested that the use of a mask reduces the potential for episodic memory traces to form. Their assumptions were based on earlier research conducted by Balota (1983) who demonstrated that masked primes presented sub-optimally (such that their presence was not detected by the participant) resulted in a lack of episodic recognition effects. Balota presented participants with a lexical decision task using semantically related prime-target pairs with homographic target words. For example YARD was used as a target word and paired with two primes that biased the context of the target such as *inch* or *fence*. Two versions of the lexical decision task were conducted, in one version the prime stimuli were visible and no mask was employed, in the other version prime durations were set to avoid conscious detection of the prime using a 15ms prime duration and a pattern mask presented after the prime (backward mask). Following the lexical decision task participants were asked to complete a recognition task where they were presented with both prime and target stimuli either in the same context as the lexical decision task (e.g., *inch-YARD* presented during lexical decision and in the recognition phase) or in the alternative context (e.g. *fence-YARD*). Balota found that for participants taking part in the task with visible prime stimuli there was a clear effect of context during the recognition phase. Participants were more accurate at identifying target items with pairings that were consistent with the lexical decision task. However, for participants who completed the lexical decision task with masked primes there was no such effect. These findings suggest that when primes were visible an episodic memory trace of the stimuli may have been encoded within a specific context (e.g., YARD as either a measurement or garden). However, when primes were masked and presented briefly no such memory trace was formed.

Bodner & Masson (2001; Masson & Bodner, 2003) argue that masking a prime does not prevent the formation of a memory trace but it does make it inaccessible to conscious processing and they marshal evidence from the mere exposure effect in support of their suggestion (e.g., Whittlesea & Price, 2001). Whittlesea & Price conducted a series of experiments using a rapid serial visual presentation (RSVP) paradigm where a series of pictures are presented for brief durations. The rapid presentation of a series of items effectively masks these stimuli making them comparable to masked prime stimuli. Whittlesea & Price presented images for 40ms and tested participants using an implicit preference task that requires them to indicate which item they prefer out of a series of items. These authors found evidence of a familiarity effect for stimuli that had been presented (old) compared to stimuli that had not been presented (new). It is assumed that the familiarity effect occurs because processing 'old' items appears easier or more fluid compared to processing 'new' items due to the retrieval of a memory of the old stimuli. More recently Breuer, Masson, Cohen & Lindsay (2009) suggested that processing visual stimuli does not stop with the presentation of subsequent items but continues until a memory of the event has been encoded. Thus evidence of familiarity effects in response to old stimuli provides evidence of memory encoding. However, in direct contrast to this, Holcomb et al. (2005) suggest that an SOA of 500ms with prime durations of 40, 80 and 120ms may not be sufficient for episodic memories to form. Based on findings that a difference is found in late ERP amplitudes (post N400) for participants who are amnesic and those who are not these authors suggest that activity at an epoch later than the N400 may reflect episodic processing. In a task testing identity priming using both visible and sub-optimally presented forward and backward masked primes ERP amplitudes beyond the N400 were not found for masked primes. Holcomb et al. propose that this provides evidence that an episodic memory trace was not formed, or that the immediate repetition of stimuli (resulting from the identity priming paradigm) may make the retrieval of a memory episode unnecessary.

Although the mere exposure paradigm presents support for a familiarity effect the evidence from Holcomb et al. (2005) suggests that the RSVP task may not reflect masked priming. In addition the stimuli used in this paradigm are often unfamiliar pictures, which may engage different processing systems compared to familiar words. Interestingly when Breuer et al. (2009) conducted an experiment using the mere exposure paradigm with words in the RSVP task and pictures in the test phase they did not obtain a priming effect. The authors suggest that a 75ms presentation may not be long enough for 'conceptual' processing of words to take place in order to effectively prime a picture. Viewed from within the framework proposed by Bodner and colleagues priming effects from words to pictures could be absent due to the lack of processing similarities between the two. If this were the case it would be predicted that pictures followed by words would also fail to exhibit a priming advantage, however, Breuer et al. found priming effects when pictures were presented during the RSVP phase and words during the test phase. In addition there is convincing evidence that when words are presented at both study and test phases they do not produce mere exposure effects (Butler, Berry & Helma, 2004). Butler et al. suggest that positing a link between the mere exposure effect and identity priming is "intuitively appealing" (p.759) because it allows for both phenomena to be explained using one system. These authors tested words and nonwords in a typical mere exposure paradigm on the assumption that nonwords should exhibit mere exposure effects but words may not. In a study phase words and nonwords were presented overtly for 1000ms each, followed by a test phase where old and new items were presented and participants were asked to indicate which stimuli they preferred. The results revealed a mere exposure effect for nonwords but not for words suggesting that mere exposure does not have an impact on familiar word stimuli.

In summary the suggestion that masking stimuli prevents the formation of an episodic memory trace appears to be supported by early research (e.g., Balota, 1993) and more recent findings from EEG studies (Holcomb et al., 2005). Whereas the lack of a mere exposure effect for words does not support the view that episodic memories are formed during tasks using word stimuli. Conversely there is evidence that mere exposure may be sufficient to produce an effect for nonwords with long stimulus exposures (Butler et al., 2004). Consequently if episodic memory traces can be formed during masked priming tasks, nonwords might be expected to exhibit priming advantages in masked priming studies, as well as mere exposure tasks[6].

3.4 Nonword Priming

Evidence of identity priming effects with nonwords (e.g., *tovid-TOVID*) would not only support an episodic explanation of priming but also challenge the view that priming is the result of lexical processes and not sub-lexical processing. The dominant account of masked priming assumes that priming effects are the result of lexical access. As nonwords do not have lexical representations evidence of comparable priming effects for words and nonwords would suggest that lexical activation is not the locus of the effect. Thus evidence of identity priming advantages for nonwords would suggest that priming may be influenced by sub-lexical processes or the encoding and retrieval of similar memory traces. In their seminal paper on masked priming Forster and Davis (1984) concluded that priming effects were "not produced by some sub-lexical process such as letter priming, because no repetition effects were observed for nonwords" (p.693).

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[6] Unless the priming effect for words is the result of converging memories of past processing events in which case it could be argued that nonwords would exhibit a reduced effect due to a lack of previous processing episodes, but would still produce an effect based on mere exposure.

However, evidence of nonword identity priming has been found in previous research (e.g. Butler et al., 2004) and in a later study Forster (1998) suggests that a small nonword identity priming effect may exist. In an analysis of 40 studies that used briefly presented masked primes Forster reports finding significant results for nonword identity primes in three studies. According to Forster 2 out of 40 studies may be expected to find significant outcomes by chance alone, which would suggest that nonwords do not produce reliable priming effects. However, a small but significant effect (around 9ms) was observed in a meta-analysis conducted on the results from all of the studies. Interestingly Peressotti and Grainger (1999) found a robust nonword priming effect for primes constructed from consonantal subsets. For example, the prime *blcn* facilitated responses to the target word BALCON in a word priming condition and in a comparable condition using nonwords, that differed from words by 1 letter, priming advantages were found for primes made up from the consonants in the nonword. In contrast Duñabeitia & Carreiras (2011) found no evidence of nonwords being primed by their consonants but words were effectively primed by subsets of the consonants in a word (e.g., *frl* – *farol* for the Spanish word meaning *lantern*). Forster (1998) suggests that priming effects found for nonwords that differ from real words by just one letter may be the result of lexical activation because there is enough letter overlap to access the real word neighbour in the lexicon. Thus nonword identity priming effects, which appear to be due to sub-lexical processing, could in fact be the result of lexical activation. In support of this suggestion Holcomb & Grainger (2006) suggest that evidence of N400 attenuation in ERP amplitudes for word-like nonword primes (e.g., those that differ from real words by one letter) may be due to activation of existing lexical representations.

The consensus amongst recent researchers seems to be that identity priming effects are found for nonwords, however, they are relatively small compared to the equivalent effect found for words (e.g., Butler et al., 2004; Perea, Gomez & Fraga, 2010; Perea & Lupker, 2003). This suggests that sub-lexical or episodic memory processes may have some influence but do not fully explain the masked priming effect. For example, although Butler et al. (2004) found evidence of nonword priming effects in a recognition task, significantly more words compared to nonwords were correctly identified. In addition Perea et al. (2010) recently found a small but significant priming advantage (11ms) for nonwords that differed from real words by two letters preceded by identity primes (e.g., *didupado-DIDUPADO*). However, a much larger priming advantage was found for familiar words preceded by identity primes (55ms). These findings correspond to those of Perea and Lupker (2003) who also found larger identity priming effects for words compared to nonwords. Furthermore, the magnitude of the nonword priming advantage observed by Perea et al. is similar to that found by Forster (1998). These results suggest that identification of target words is facilitated by the prior presentation of an identical item for familiar words and nonwords in both recognition and masked priming tasks. However, although this may be influenced by sub-lexical or episodic processes, an additional mechanism acts to increase the effect for words.

An additional question in relation to masked priming effects for nonwords concerns the influence that a negative response may have on latencies in priming tasks. Nonword identity priming has generally been investigated in tasks that compare nonword to word identity primes in a lexical decision task and as such the response to the nonword is negative. Forster (1998) suggested that priming advantages for nonwords might not be detected if a 'no' response is based on a threshold for making such decisions. Initial implementations of the Dual Route Cascaded model simulated lexical decision data on the assumption that a 'no' decision is made if a word matching the input has not been found by a certain response threshold (Coltheart et al., 2001). Coltheart et al. further suggest that this threshold is sensitive to the overall activation of items in the lexicon, thus if an item produces a large amount of activation and is likely to be a word the threshold is increased. False positives are therefore avoided by providing longer to perform a thorough search of the lexicon before a response is made. Consequently a word-like nonword would be responded to on the basis of a threshold rather than facilitated by overlapping graphemes. Recently Perea et al. (2010) explored the suggestion that 'yes' and 'no' decisions may be based on different response criteria by comparing a negative response to nonword stimuli in a lexical decision task with a positive response to nonword stimuli in a go/no-go task where participants were instructed to respond when the target was a nonword and refrain from responding when the target was a word. The results demonstrated that masked identity priming effects for nonwords were the same regardless of the task and response style. Perea et al. suggest that these outcomes provide evidence that decision making criteria do not differ between negative and positive responses. The priming effect found for nonwords (e.g., Forster, 1998; Perea et al., 2010) is therefore likely to be representative of facilitatory processing of target stimuli in response to related prime stimuli and not the result of a response threshold. Consequently there is evidence for a small nonword priming effect, which may be facilitated by activation of overlapping letter units despite the lack of lexical representation for these items. However, the consistent finding that priming advantages for nonwords are overshadowed by those found for words suggests that lexicality facilitates processing of words over nonwords.

3.5 Sub-lexical priming - form primes.

In addition to nonword priming effects, evidence of priming advantages for prime-target stimuli with a large amount of graphemic overlap could be interpreted as representing sub-lexical processing (e.g., Ferrand & Granger, 1992; Forster, 1999; 1998; Humphreys, Evett & Quinlan, 1990). Form priming usually refers to priming between prime-target pairs that are orthographic neighbours, or in other words that differ from each other by one letter (Coltheart's N; Coltheart, Davelaar, Jonasson & Besner, 1977). For example, in the following prime-target pairs, the primes would all be considered form primes, *wold-WORD, ward-WORD*, *wo#d-WORD* (see Davis, 2003; Davis & Lupker, 2006; Forster, Mohan & Hector, 2003). However, a more distant relationship between prime and target could also be considered part of this set. For example there is evidence to suggest that priming effects can be obtained from prime stimuli that differ from the target by two letters (Franklish & Turner, 2007; Lupker et al., 2008; Perea & Lupker, 2003; Perea & Lupker, 2004). One example of this is transposed letter priming (e.g., *anamil-ANIMAL*) where the prime is formed from the target word but the positions of two of the letters have been switched. It could be argued that priming effects from primes that are not identical but have large amounts of orthographic overlap may be the result of sub-lexical processes such as letter matching. However, Forster (1998) suggests that evidence of cross script priming from primes and targets without graphemic overlap indicates that form overlap cannot account for all masked priming effects. In other words if priming effects relied on sub-lexical processes it would be unclear how prime-target pairs written in different scripts (e.g., カイワ - 会話) or using semantically related words (e.g., boat-SHIP) could occur.

Nevertheless, there is evidence from previous research to suggest that form priming effects may influence priming, but only in the early stages of visual word processing. Ferrand & Grainger (1992; 1993) demonstrated that orthographic priming effects using nonword form primes (e.g., *lonc-LONG*) were apparent with prime exposures up to 50ms but with longer exposures (e.g., 67, 83 & 100ms) these effects disappeared. Forster et al. (2003) also report that the magnitude of priming advantages found for form primes levelled out with prime durations that were longer than 30ms. In contrast a linear rise in priming advantages was observed for identity primes with the magnitude of these effects increasing with longer prime durations. In addition, Holcomb & Grainger (2006) found evidence that form primes (e.g., *teble-TABLE*) and identity primes (e.g., *table-TABLE*) produced similar ERP amplitudes in an early time window but diverged at a later point. These results suggest that the form prime activated similar processes to the identity prime in the earlier stages of processing but not at a later time frame. However, in contrast to the facilitation found from nonword primes with overlapping orthography, when word primes are used facilitation becomes inhibition. For example, Pastizzo & Feldman (2009) found that prime stimuli such as *coat* produced slower reaction times to target stimuli such as *BOAT* compared to a control condition. Davis & Lupker (2006) also found that word primes with graphemic overlap (e.g., *able-AXLE*) were inhibitory in an experiment that directly tested nonword primes with graphemic overlap against comparable word primes.

The finding that stimuli with overlapping forms can facilitate processing could be interpreted as evidence of sub-lexical processes. However, Davis (2003) explains the dissociation in priming effects between word and nonword form primes as an effect that occurs at a lexical level. Viewed from the perspective of the Interaction Activation (IA) Model (McClelland and Rumelhart, 1981) a nonword prime such as *ible* excites words (lexical representations) with overlapping graphemes such as *ABLE*. Thus the word level representation that corresponds to the target is already activated and facilitates processing when the target is presented. Conversely, a word prime such as *able* excites the lexical representation of the word *able* and sends inhibitory signals to all other words at that level. Consequently processing of the target word *AXLE* is inhibited when it is presented as the target word. The dissociation between nonword and word form primes is therefore due to the inhibition that exists between items at the lexical level. However, both facilitation and inhibition of target processing are accounted for by lexical activation rather than a match of sub-lexical elements such as graphemes, phonemes or syllables.

The evidence suggests that form priming effects are the result of lexical access, in addition if these effects were facilitated by sub-lexical processes it might be expected that similar effects would be found for nonwords as well as word targets. However, whereas identity priming effects have been found for nonwords, form priming effects have not (Davis & Lupker, 2006; Duñabeitia & Carreiras, 2011; Perea & Lupker, 2003). For example, Duñabeitia & Carreiras (2011) found that prime stimuli formed from just the consonants of a nonword did not facilitate responses to nonword targets. It seems likely that whereas the consonants in prime stimuli can activate corresponding word representations in the lexicon and facilitate processing the same effect is not found with items that are not in the lexicon. Forster et al. (2003) conclude that a pre-lexical priming effect may produce a 10ms priming advantage for stimuli with overlapping graphemes. This effect may explain the nonword priming effect found in some studies but it is not strong enough to produce the larger priming effects seen for familiar words in most masked priming experiments.

In summary sub-lexical processes may influence priming effects especially in the early stages of processing. However, form priming effects from nonword primes as well as priming advantages from related word primes are likely to be driven by lexical processes.

3.6 To forward and to backward mask? That is the question

The majority of masked priming experiments investigating the early processes of visual word recognition such as form, orthographic and phonological processing use a forward mask only (e.g., Ferrand & Grainger, 1993; Forster, 2003; Forster & Davis, 1984; 1991; Hino et al., 2003; Kim & Davis, 2002; Lukatela et al., 1998; Perea & Carreiras, 2008). In this version of the paradigm a pattern mask, such as a row of hash marks (#####) is presented, followed by prime stimuli and then target stimuli. However, researchers investigating semantic processing using the masked priming paradigm often include a backward mask. Van den Bussche et al. (2009) report that out of a total of 88 studies conducting a semantic priming task 72 used a backward pattern mask, whereas 16 had no backward mask and presented the target directly after the prime stimulus. Forster et al. (2003) suggest that a backward mask could be used to distinguish the prime stimuli from the target but they also state that "in our experience, this usually leads to an increase in the visibility of the prime and to a weaker priming effect." (p.5). Instead researchers typically use lower case and uppercase letters to make the prime and target physically distinct. McClelland & Rumelhart (1981) used a backward pattern mask to distinguish prime from target stimuli based on the assumption that the mismatch between letter feature representations and the pattern mask would allow letter level activity to drop to resting level. More recently Davis & Lupker (2006) suggest that this would effectively reset the system thus distinguishing prime from target stimuli. In simulations run by these authors the best fit to behavioural data was found with a model that did reset letter activation levels on presentation of target stimuli. However, Davis & Lupker do not suggest that a backward mask is necessary to achieve this.

The reduction in prime awareness afforded by a backward mask or direct presentation of target stimuli may be due to disruption of the usual processes of visual word recognition (Balota, 1983; Holcomb & Grainger, 2006; Kouider & Dehaene, 2006). According to these accounts 'higher-order' processes such as phonological or semantic processing continue despite disruption of the sensory representation of the prime. Thus related information contained in the lexicon can be accessed and facilitate target processing whilst the participant remains unaware of the prime stimulus. Holcomb and Grainger (2006) further suggest that if a target word is used as a backward mask it may interrupt feedback mechanisms and lateral inhibition within the lexicon. In turn this may result in a lack of awareness of the prime stimuli. Kouider & Dehaene (2006) suggest that masking stimuli prevents conscious recognition by reducing the strength of the input from bottom up processes. These authors conducted a review of data from both behavioural experiments and neuroimaging studies which revealed that that neurological responses to bottom-up stimuli are reduced when stimuli are masked. This results in the usual forward cascade of activity being reduced such that amplitudes decrease and neural activity does not reach a sufficient level of activation to trigger conscious recognition.

Although researchers may disagree on the exact mechanism underpinning the masking effect, evidence of a priming effect and low levels of prime awareness from lexical decision tasks that do not employ backward masks suggest that in this task a backward mask is unnecessary. In support of this suggestion the inclusion of a backward mask in a lexical decision task has been found to be neither advantageous nor detrimental. Monahan et al. (2008) recorded magneto encephalography (MEG) data and behavioural data in an identity priming paradigm comparing the use of forward and backward masks. In the behavioural data a priming advantage was found for identity primes regardless of the presence or absence of a backward mask, the only differences were in the magnitude of the priming effects. For the first experiment using only a forward mask there was a 76ms priming advantage compared to a 40ms effect for the second experiment with a backward mask. In the MEG data a component reflecting an earlier peak for related primes compared to unrelated primes was found at around 225ms for both versions of the experiment. These results suggest that there were no differences in cortical activity based on the presence or absence of a backward mask, however, the behavioural data provide support for the suggestion that priming effects from paradigms using backward masks may be smaller (Forster et al., 2003)[7].

In contrast the finding that most researchers employing semantic categorisation tasks include a backward mask (see Van den Bussche et al., 2009) suggests that it may be important to further mask the prime from the target in these tasks. Finkbeiner et al. (2004) report that in a version of a semantic categorisation task where a backward mask was not used priming effects were not observed, but in the same task with a backward mask priming effects were observed. However, Wang & Forster (2010) tested the efficacy of a backward mask in facilitating priming effects and showed that the same effects were observed whether the procedure included a backward mask or not. It is unlikely that priming effects emerge during the 40 or 50ms that prime stimuli are displayed and it is therefore probable that processing of primes continues whether a backward mask or a target word is presented after the prime. Wang & Forster suggest that providing the duration of the prime is long enough to access the lexicon, it is immaterial whether it is followed by a mask or the target. Interestingly a positive correlation between priming effects and stimulus onset asynchrony (SOA; the duration from onset of prime stimulus to onset of target stimulus) was found in a recent meta analysis of priming effects, suggesting that studies employing longer SOAs produce larger priming effects (Van den Bussche et al., 2009). Thus it is possible that the backward mask in semantic categorisation studies is instrumental in extending the SOA, which allows priming effects to emerge.

The evidence suggests that in some cases the use of a backward mask may not have an impact whereas in other situations effects may not be found without one. In addition it may be advisable to use a backward mask with stimuli that require longer processing times. However, it has also been suggested that

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[7] However, in contrast Wang & Forster (2010) found smaller priming effects for a task without a backward mask compared to those found with a backward mask.

backward masks may increase prime visibility rather than reduce prime awareness (see Forster et al., 2003). Wang & Forster (2010) recently suggested that using forward and backward masks that are visually the same (e.g., both masks consisting of a row of hash marks) may cause prime stimuli to be more visible via a 'pop out' mechanism. Finkbeiner et al. (2004) explain that this effect occurs because the masks form a perceptually consistent background from which the prime appears to stand out. In contrast to this Grainger, Diependaele, Spinelli, Ferrand & Farioli, (2003) suggest that if the backward mask is made from symbols that are perceptually similar to the prime (e.g., random consonants) conscious awareness of most prime stimuli can be reduced. They report the findings from a series of studies that found significant priming effects with prime durations of 53ms and 67ms using a backward mask constructed from random consonants. The level of prime awareness exhibited by participants in this study was tested after each experimental task using a measure of prime visibility developed from signal testing theory (*d'*). Grainger et al. correlated the level of prime awareness for each participant against their priming effect and found no relationship between the two, suggesting that priming effects were not a reflection of prime awareness. However, in their third experiment using a prime duration of 67ms they found that most participants were able to report at least one prime in a post-test of prime awareness. Grainger et al. therefore divided the group into those with low prime awareness (average of 6.3% of primes reported) and those with high prime awareness (47.2% of primes reported). The corresponding *d'* scores were calculated for each group and correlations demonstrated that individual *d'* scores did not correlate with priming advantages. The authors suggest that despite the apparent increase in awareness for primes displayed for 67ms the majority of these primes were still unavailable for conscious processing and did not affect the priming advantages observed.

In summary the literature seems divided on the necessity for a backward mask and the degree to which it makes prime stimuli more or less visible. In some studies the use of a backward mask appears to be redundant (Monahan et al., 2008; Wang & Forster, 2010), however, for studies testing semantic relationships it may be vital (Finkbeiner et al., 2004). Additionally studies that require longer prime durations may benefit from the use of a perceptually similar backward mask, which may help to disguise prime stimuli from conscious processing (Grainger et al., 2003).

3.7 The baseline measure

In order to calculate priming effects in a masked priming paradigm a control condition must be employed against which to measure effects found in response to prime manipulations. Most masked priming experiments use an unrelated prime-target pair as the control measure, subtracting reaction times to target words in the experimental condition from those observed in the control condition. For example Forster (1998) used identity prime-target pairs as the experimental condition (e.g., *industry-INDUSTRY*) and compared reaction times for these stimuli to the reaction times for unrelated prime-target pairs (e.g., *sapphire-INDUSTRY*). However, in studies where it is important to gain an impression of whether the priming observed is facilitatory or inhibitory a baseline measure with a neutral prime is used. For example Neely (1977) used a string of crosses (XXXX) to determine whether priming in a semantic lexical decision task was due to facilitation or inhibition, whereas Ferrand, Segui & Humphreys, (1997) and Schiller (1999) used percent signs (*%%%%-BALCONY*) to establish whether syllabic priming effects were inhibitory or facilitatory. A neutral prime can also be used to avoid problems with congruency effects in categorisation tasks. For example, if testing the semantic relatedness of two words using a narrow category such as BODY PARTS an unrelated prime-target pair would have to be incongruent (e.g., *door-ARM*) whereas a neutral prime (e.g., *%%%-ARM*) is neither congruent nor incongruent. The neutral prime therefore provides a measure against which facilitatory or inhibitory effects can be plotted and Naccache & Dehaene (2001) demonstrated this in an experiment using a neutral prime made up from dollar signs (e.g., $). Masked primed congruent and incongruent number stimuli (e.g., *seven-9* or *two-9*) were employed in a task that required participants to indicate whether the target numbers were larger or smaller than a value of 5. The results showed that both the congruent condition and neutral primes produced reaction times that were equivalent and faster than the incongruent trials. This finding suggests that the incongruent condition inhibited processing and consequently that priming effects between congruent and incongruent stimuli were the result of inhibition rather than facilitation.

Although neutral primes can provide an indication of facilitatory or inhibitory effects, it has been proposed that the use of such stimuli fails to reflect the usual cost that is associated with transfer of perception from prime to target (Forster et al., 2003; Kinoshita & Hunt, 2008). In other words neutral primes, unlike unrelated primes, do not activate lexical representations and responses to target stimuli preceded by non-linguistic primes are therefore faster. The cost of perceptual transfer may be the result of inhibitory connections at the word level (as predicted by an interactive account of priming, see below), which would be present for all word stimuli both related and unrelated. Thus priming effects that are measured against unrelated prime stimuli take into account the processing cost of activating lexical representations for both prime and target stimuli. Kinoshita and Hunt (2008) investigated this issue by conducting an experiment using the number '*5*' or a single hash mark '*#*' as neutral prime stimuli. The task required participants to categorise masked primed target numbers as higher or lower than 5. The neutral prime stimuli consisting of the number '*5*' therefore required perceptual transfer from the prime to the target, however, the prime stimuli formed from a hash mark did not. They found no significant differences between latencies to neutral primes that were meaningful (e.g., *5*) and those formed from a symbol (e.g., #). However, a further analysis using Gaussian distributions suggested that the symbol primes produced significantly faster reaction times compared to the neutral number prime. The authors suggest that this provides evidence of a processing cost associated with the transfer of perception from prime to target stimuli that is not reflected by symbol primes. The consequence of using such prime stimuli as a neutral prime could therefore be that facilitatory effects are underestimated and interference effects are over estimated. For instance if a baseline measure produced a latency of 650ms and an identity priming condition produced a latency of 615ms the priming effect would be 35ms. However, if the identity prime is compared to an unrelated prime condition with latencies that were slower than the baseline (e.g., 665ms) the priming effect would increase to 50ms.

Forster et al. (2003) suggest that the lexical status of a prime (i.e., word or nonword) is not influential in target processing and therefore unrelated primes do not inhibit target processing. This assumption is based on the proposal that if lexicality was a factor a difference would be observed between nonword and word primes. For example, processing of a target word following an unrelated word prime (e.g., *boys-TEXT*) would be slower than following an unrelated nonword that is not represented in the lexicon (e.g., *biys-TEXT*). Forster et al., suggest that, "Our own experience has been that there is little or no difference between these conditions" (p.6). In contrast, Davis (2003) reports evidence of faster reaction times to target words preceded by neutral primes (e.g., >>>>>>> or &&&&&&) compared to unrelated word primes, suggesting that unrelated word primes may inhibit target processing. A competitive model such as the IA model (McClelland & Rumelhart, 1981) predicts that connections between items within a level are inhibitory. For example, the prime *pony* would excite words that had the letter *p* in the first letter position and inhibit words with different initial letters. If a target word such as *ABLE* is subsequently presented and the system resets so that the first letter position is now exciting words beginning with the letter *a* there should be limited delay in processing the target word. However, if activation persists at the letter level for the previous stimuli (e.g., the letter *p* in word initial position), processing of the word ABLE will be inhibited by residual activation in the letter *p*. In addition if all words are inhibited by word level inhibition, as assumed in the original IA model, once a lexical representation has reached a certain threshold, target word processing will suffer. Thus activation of a word such as *pony* could inhibit processing of the target word even though the two words are unrelated and there is no letter overlap.

However, inhibition from word primes predicted by the IA model would exist for both related and unrelated stimuli, therefore if the amount of inhibition is equal across both stimuli priming effects measured against unrelated prime-target pairs should reflect accurate priming advantages. Conversely, it could be argued that if related and unrelated prime stimuli are not matched the amount of inhibition (or perceptual transfer) may vary. Matching stimuli on all the psycholinguistic variables known to affect visual word processing is an imprecise art and subject to error. Even if achieved it is possible that there are as yet unknown variables that affect word processing in unexpected ways. Thus if related and unrelated prime stimuli are not matched priming effects measured against an unrelated condition could be inflated or underestimated. For example, Hutchison, Balota, Cortese & Watson (2008) suggest that in a semantic categorisation task, prime stimuli with fewer lexical neighbours produce faster semantic categorisation latencies. It is therefore possible that higher numbers of neighbours could result in slower decision latencies. For example, the words *text* and *boys* are matched on frequency, however, *text* has fewer neighbours than *boys.* Consequently if an identity prime (e.g., *text-TEXT*) was compared to an unrelated condition (e.g., *boys-TEXT*) the higher number of neighbours in the prime of the unrelated condition could slow down processing of the target word resulting in an overestimation of priming effects[8]. Therefore in the absence of absolute matching the use of a neutral prime provides a conservative estimate of facilitatory priming effects whilst also providing an indication of inhibitory effects. A final point worth mentioning here is that in the identity priming paradigm it has been suggested that prime and target stimuli form one perceptual event (Grainger, Lopez, Eddy, Dufau & Holcomb, 2012). If the prime and target are perceived as one stimulus they will both promote processing of the same lexical representation and may not incur a processing cost as a result of perceptual transfer. In this case a neutral baseline that represents lexical decision latencies in the absence of prime-target perceptual transfer may be preferable.

[8] Although Yates (2009) reports that a high number of phonological neighbours facilitates lexical decisions whereas high numbers of orthographic neighbours inhibit lexical decisions. In addition recent research from Andrews & Hersch (2010) suggests that the relationship between the facilitatory and inhibitory effects of neighbouring words can vary depending on the spelling and reading ability of the participant.

3.8 Prime exposure - duration

Across different studies the durations used to display prime stimuli vary considerably. However, there is some evidence that orthographic effects are found with shorter prime durations (e.g., 17-50ms) and phonological effects emerge with longer prime durations (e.g., 50ms or longer). For example Ferrand and Grainger (1992; 1993) used prime-target stimuli that were either phonologically and orthographically similar (e.g., *lont-LONG*; *lont* is pronounced the same as *long*), just orthographically related (e.g., *lonc-LONG*) or unrelated (e.g., *tabe-LONG*). The distinctions between these stimuli allowed the authors to demonstrate that priming effects were apparent for the orthographically similar stimuli with prime durations up to 50ms. However, priming effects that could not be accounted for by orthographic overlap did not appear for the phonologically similar stimuli until primes had been displayed for more than 50ms. Ferrand and Grainger interpreted their results from the perspective of an IA model (McClelland & Rumelhart, 1981) and suggested that presentation of the prime stimuli results in activation at an orthographic sub-lexical level, which excites units at a phonological sub-lexical level. In turn both the orthographic and phonological sub-lexical units excite lexical representations at the lexical level. With brief prime presentations orthographic effects are found because the phonological sub-lexical units have not yet received sufficient activation to show a priming effect. With longer prime presentations combined activation from orthographic and phonological units accesses lexical representations, which in turn inhibit processing of alternative lexical representations including the target. However, phonological units continue to be activated despite the inhibition from lexical level representations and are therefore able to influence target processing (if phonologically related). Thus Ferrand and Grainger (1993) predicted that orthographic information would access the lexicon before phonological information.

The research conducted by Ferrand and Grainger (1992; 1993) suggests that longer prime durations may prevent orthographic priming effects from emerging. In support of this suggestion Forster et al. (2003) report that form priming effects decrease after prime durations of 30ms. Consequently studies investigating orthographic processing have tended to use short prime durations of 40 – 50ms (e.g., Dimitropoulou et al., 2011; Perea & Lupker 2003). For example Duñabeitia & Carrieras (2011) used prime durations of 50ms to investigate priming effects from subsets of the vowels or consonants contained in a word (e.g., *frl-FAROL*), which would be expected to facilitate target processing via an orthographic route. However, Davis and Lupker (2006) observed form priming effects that are assumed to be orthographic (e.g., *ible-ABLE*) using a prime duration of 57ms and Johnston & Castles (2003) predicted that both orthographic and phonological effects would be observed with a prime duration of 57ms. Furthermore, despite the suggestion that phonological effects may not be seen with brief prime presentations studies investigating phonological priming have also used a wide range of different prime durations. For example, Drieghe & Brysbaert (2002) found that both homophones and pseudohomophones facilitated lexical decision latencies with a prime duration of 57ms. More recently Rastle & Brysbaert (2006) demonstrated phonological priming effects with a prime duration of 58ms. Conversely Lukatela et al. (1998) found that orthographically similar pseudohomophones (e.g., *klip-CLIP*) facilitated lexical decisions at a prime duration of 29ms. Kim & Davis (2002) also found a positive phonological priming effect with short prime presentations of 42.6ms and Hino at al. (2003) found strong phonological priming at 32ms using two types of Japanese script.

Although the evidence suggests that both orthographic and phonological priming effects can be found with various prime durations, phonological priming effects have been fairly elusive in English. For example, Holyk and Pexman (2004) employed pseudohomophone primes that were displayed for just 15ms (e.g., *krest-CREST*) in two identical lexical decision tasks and found a phonological priming effect in one experiment but not in the other. Due to the contradictory nature of their findings they ran further experiments to test the hypothesis that individual differences in phonological processing impact on phonological priming effects. Their results suggest that with brief prime durations phonological priming effects are only found with participants who have higher phonological processing skills. More recently a meta-analysis of masked phonological priming effects in English inlcuded five studies that employed prime durations ranging from 15ms (Holyk & Pexman, 2004) to 72ms (Lukatela et al., 1998) and observed phonological priming effects with varying degrees of success (Rastle & Brysbaert, 2006). Nevertheless, Rastle & Brysbaert (2006) concluded that a significant phonological priming effect was found across all studies. These results suggest that phonological priming occurs in studies with English stimuli and with a wide range of different prime durations.

In conclusion despite differences in the literature overlapping orthographic form seems to be facilitatory with very brief prime durations (e.g., 30ms) and this facilitation continues to be observed with prime durations up to 57ms, depending on the stimuli. For example nonword form primes may facilitate with prime presentations of 57ms but word primes that are orthographically related may inhibit (e.g., Davis & Lupker, 2006). Conversely phonological priming effects have been observed with brief prime durations but this may only apply to individuals with higher phonological processing skills. Consequently these effects are perhaps more likely to emerge with longer prime presentations (around 60ms). Interestingly Forster and Davis (1984) used a prime duration of 60ms in their original investigation of masked priming using an identity priming paradigm and Forster et al. (2003) report that identity priming effects increase with longer prime durations. Thus the prime durations selected by previous researchers have reflected the effects they are hoping to find, however, a large amount of variation is found amongst studies investigating both phonological and orthographic effects.

3.9 Conclusions

Since Forster and Davis (1984) presented their original description of the lexical account of masked priming effects there has been a lively debate in the literature over the source of these effects. The discussion centres on the question of whether priming effects are prospective (i.e., activation cascades forwards such as in the lexical account) or retrospective (i.e., priming is the result of retrieving previous memory events). Masson & Bodner and colleagues have responded to each point raised by Forster and Davis (see Masson &

Bodner, 2003 for a review) and conducted experiments spanning the different types of masked priming tasks currently used. According to the prospective account activation of stored, stable mental representations facilitates priming effects and word recognition. Whereas, the retrospective account assumes that the retrieval of episodic memories influences priming effects. Data gathered over the last three decades provides evidence in favour of both accounts and it is possible that both systems are influential in visual word recognition. Researchers agree that there is a role for episodic memory in long-term priming, however, the evidence is less clear when applied to masked priming effects. For example, Kinoshita et al. (2011) demonstrated that effects, which can be attributed to episodic memory, are apparent with visible prime stimuli but not when primes are masked and briefly presented. These results suggest that the role of episodic memory in masked priming tasks may be reduced if not completely absent.

In addition convincing arguments have been presented that support the masked priming effect as an index of lexical access as opposed to sub-lexical processes (Davis, 2003; Davis & Lupker, 2006; Forster, 1998). Although both nonword and sub-lexical effects appear to be consistent and average around 10ms (Forster, 1998; Forster et al., 2003; Perea et al., 2010), they may only be apparent in the early stages of visual word recognition (Ferrand & Grainger, 1993; Holcomb & Grainger, 2006) and are consistently found to be smaller than the equivalent effect for familiar words (Butler et al., 2004; Perea et al., 2010). Thus nonword and form priming may be driven by processes that contribute to word priming effects, but they do not account for all of the effect.

In early accounts of masked priming researchers suggested that the mask prevents conscious awareness of primes by disrupting the visual record of prime stimuli (Balota, 1983; Forster & Davis, 1984). More recently Kouider & Dehaene (2006) performed a thorough critique of masked priming studies and suggest that masking may not serve the function of making prime stimuli truly ‘invisible’. However, Forster et al. (2003) suggest that instead of asking whether priming effects can be observed *despite* the lack of prime awareness researchers should "ask whether the strength of the effect is correlated with degrees of awareness" (p.32). The answer to this question would provide an indication of whether masked priming is distinct from other types of conscious priming. Interestingly studies that have investigated this issue have failed to find correlations between measures of prime awareness and priming effects (e.g., Grainger et al., 2003; Naccache & Dehaene 2001; Quinn & Kinoshita, 2008; Van den Bussche, 2009), suggesting that even if masking stimuli does not render them completely subliminal it does serve to reduce effects that may be present for visible stimuli.

A number of procedural differences are apparent in masked priming studies, for example, the function of a backward pattern mask, choice of control conditions and variation in prime durations. The use of different types of masks in masked priming tasks appears to have received little attention in the literature. However, it is likely that a backward mask extends the SOA allowing sufficient processing time to enable priming effects to emerge with stimuli that take longer to process (e.g., Finkbeiner et al., 2004). On the other hand, it has also been suggested that a backward mask may increase prime visibility rather than reduce it (Forster et al., 2003; Wang & Forster, 2010). The choice of a control condition centres on the issue that neutral primes (e.g., %%%% or >>>>>>) fail to reflect perceptual transfer between prime and target stimuli resulting in underestimated priming effects. Current experiments are more likely to use an unrelated word condition, however, it is possible that unrelated word primes inhibit target processing more than related word primes if stimuli are not well matched. Consequently, it is possible that priming effects will be overestimated if compared to unrelated prime conditions. Finally, the evidence suggests that there may be a progression from form priming with brief prime presentations (e.g., 30ms) to identity priming effects that increase in line with prime durations. However, it is likely that the effects of orthographic and phonological processing will be seen at intermediary prime durations spanning 40-60ms.

In summary, the aim of this chapter was to explore the assumptions that underpin masked priming experiments. The evidence suggests that lexical accounts of these effects provide a more complete explanation of the data than episodic accounts or sub-lexical processes. As such the conclusions drawn in the following chapters will be based on a lexical account of masked priming. In the following chapter (Chapter 4) prime stimuli include familiar SMS shortcuts (e.g. *txt-text*, *l8r-later*) as well as unfamiliar shortcuts (e.g., *rsk-risk*, *cre8-create*) and it was felt that a slightly longer SOA would therefore facilitate prime processing. Consequently prime durations are set at 60ms and in addition to a forward mask a 60ms backward mask is also used. The experiments reported in Chapters 6 and 7 differ from this procedure slightly; the backward mask is omitted from the lexical decision task employed in Chapter 6 and in Chapter 7 a backward mask that was perceptually different to the forward mask was used to limit the potential that stimuli would become more visible (Wang & Forster, 2010). Furthermore to avoid the confound of using unrelated word primes in the following experiments a neutral prime is used as a baseline measure (e.g. %%%%). An additional consideration in this decision was that as prime stimuli include SMS shortcuts it would be challenging to find a set of matched controls. Partly due to the limited numbers of shortcuts available, but also due to a lack of detailed information regarding the psycholinguistic characteristics of these items. The use of a neutral baseline also allows for inhibitory effects to be measured and as the stimuli used in this thesis (both familiar and unfamiliar SMS shortcuts) have not previously been investigated using the tasks detailed here, there was a possibility that inhibitory effects may be seen. As a consequence priming effects observed in the experiments that follow may be underestimated. However, as Davis (2003) has pointed out some effects may be inhibitory if measured against a baseline prime but facilitatory if measured against an unrelated prime and it was felt that a conservative figure was preferable to overestimating effects.

Chapter 4 Hw dyu txt? Evidence from masked priming lexical decision tasks

4.1 Introduction

It is often assumed that SMS shortcuts (e.g., *txt, l8r*) are used to save time and effort when composing a text message. Recently Kemp (2010) found that composing a sentence using SMS shortcuts is faster than composing the same sentence using traditional English. However, reading sentences (out loud) with SMS shortcuts took nearly twice as long[9] as reading sentences in conventional English. In addition early research conducted on shortcuts using an eyetracking paradigm demonstrated that SMS shortcuts were fixated on for longer than familiar words suggesting that decoding SMS shortcuts is cognitively demanding (Perea, Acha & Carreiras, 2009). It therefore seems that savings made by the sender in terms of time to compose the message may incur a cost to the receiver in comprehension time. These results suggest that SMS shortcuts may not access the lexicon rapidly in the same way as familiar words. Consequently the two experiments reported here were designed to investigate whether or not text message shortcuts can access the lexicon, in a way that is analogous to familiar words, or whether there is a processing cost associated with decoding these irregular items.

Various forms of shortcut are used in text messages (see chapter 2) however, for the purposes of this study there are two distinct categories of single word shortcuts that are of particular interest; abbreviated shortcuts created by the removal of vowels (e.g., *txt, msg*) and letter-digit shortcuts that use combinations of digits and letters to represent phonological information, such as phonemes, syllables and rhymes (e.g., *l8r, 4eva*). As mentioned in Chapter 1 these two types of shortcut are of interest due to their inherent bias towards either the orthography or the phonology of their base-words. For example whilst abbreviated shortcuts maintain much of the orthography of their base-words (i.e., the shortcut *txt* is only missing the vowel 'e' from the base-word *text*), the

[9] However it should be noted that the shortcut messages contained 70% shortcuts, which is an unusually high number for genuine text messages (see Chapter 2).

amount of phonological information conveyed by these shortcuts is reduced. In contrast shortcuts that use digits and letters to reproduce the phonology of their base-words (e.g., *l8r*) successfully convey phonological information but their orthography does not overlap with their base-words. Previous literature suggests that stimuli constructed from subsets of the consonants in a word (e.g., *blcn-BALCON*) can rapidly access the lexicon (Duñabeitia & Carreiras, 2011; Peressotti & Grainger, 1999). For example, Peressotti and Grainger (1999) found that presenting *blcn* as the prime for the French word *BALCON* produced a priming effect relative to a neutral baseline (%%%%) and that this did not differ to the effects obtained for a prime that maintained the absolute position of the letters (e.g., *b-lc-n*). In addition there may be a processing difference between consonants and vowels, with consonants carrying more salient information for visual word processing (e.g., Lupker et al., 2008; Perea & Lupker, 2004). For example, Lupker et al. (2008) presented evidence that modifying the consonants in a word has a larger impact on word processing compared to vowels. In a priming paradigm Lupker et al. employed a Transposed Letter (TL) prime that switched the position of the internal consonants in a word (e.g., *aminal-ANIMAL*) and compared this to a prime with the consonants replaced (e.g., *asiral- ANIMAL*). In a contrasting condition the same manipulations were performed with the vowels in a word to form a vowel TL prime (e.g., *anamil- ANIMAL*) or replaced vowel prime (e.g., *anemol-ANIMAL*). The results showed that consonant TL primes produced faster reaction times compared to primes with the consonants replaced, however, vowel TL primes resulted in equivalent reaction times compared to primes with the vowels replaced. This finding suggests that there was no effect on target processing regardless of whether vowels were transposed or replaced, whereas replacing the consonants had a detrimental effect on the ability to process the target word compared to transposing the consonants. If information regarding consonants is assembled before information from vowels the primes in the vowel conditions (e.g., *anamil ; anemol*) are rendered orthographically equivalent to the target.

More recently Duñabeitia & Carreiras (2011) explored the extent that a subset of either the vowels or the consonants in a word would facilitate processing of base-word targets. In a masked priming lexical decision task either the vowels or consonants of a word were used as prime stimuli. For example, the words *farol* (meaning lantern) or *acero* (meaning steel) were preceded by primes that consisted of just their consonants (e.g., *frl*) or vowels (e.g., *aeo*). The results showed that subsets of the consonants were effective prime stimuli and produced significant priming advantages compared to unrelated primes. However, the primes constructed from a subset of vowels produced reaction times that did not differ from unrelated primes. In conclusion these authors suggest that the consonants in a word may provide more information that is pertinent to lexical access compared to the vowels in a word. If this is the case the consonants contained in any word may provide enough information for lexical access and an abbreviated shortcut (e.g. *txt*) may be able to rapidly access an existing lexical representation for a base-word (e.g., *text*).

The letter coding system employed by the Dual Route Cascaded model (DRC: Coltheart, et al., 2001) would preclude it from being able to process an abbreviated shortcut such as *txt*. However, previous authors (e.g., Peressotti & Grainger, 1999; Duñabeitia & Carreiras, 2010) have suggested that a model implementing a more flexible letter coding system and a lexical architecture resembling the Interactive Activation model (McClelland & Rumelhart, 1981) may be able to account for the facilitation found from consonant subset primes such as *blcn-BALCON* or *frl-FAROL*. Under this account the consonants contained in the prime stimuli activate existing lexical items with overlapping consonants. Consequently the target word is accessed resulting in facilitatory lexical decision latencies. It is possible that abbreviated shortcuts also access existing base-word lexical representations via a similar mechanism. However, if shortcuts are acquired in the same way as real words the DRC model would predict that once SMS shortcuts become familiar, mental representations corresponding to the unique visual format of the shortcut would be added to the mental lexicon.

Conversely letter-digit shortcuts are orthographically irregular and therefore unlikely to link to an orthographic representation of their base-word. However, they include numbers and letters that map directly onto the phonology of their base-word (e.g., *l8r*) and it is therefore possible that these items access the lexicon via their phonology. As mentioned in Chapter 1 evidence from the phonological priming paradigm suggests that phonological codes can be activated rapidly enough to facilitate the kind of lexical access seen with familiar words (for a discussion see Rastle & Brysbaert 2006). For example in a lexical decision task with a 15ms priming duration pseudohomophone prime stimuli (e.g., *krest-CREST*) produced a priming advantage compared to orthographic control primes (e.g., *crost-CREST*; Holyk & Pexman (2004). These results suggest that phonological codes can be rapidly accessed and facilitate processing of target words. Consequently the phonological information conveyed by letter-digit shortcuts may be able to access lexical representations of base-words, precluding the need to develop a unique orthographic representation. Perea et al. (2009) investigated shortcut processing using an eye tracking paradigm and found longer fixations to phonological approximations (e.g., *wud*) embedded in sentences compared to abbreviated shortcuts. This finding prompted the authors to suggest that processing of phonological shortcuts is delayed due to a requirement to activate phonological representations. This view supports the suggestion that letter-digit shortcuts may be processed via the assembly of sub-lexical phonology and if this is the case letter-digit shortcuts may take longer to process compared to abbreviated shortcuts. Furthermore, evidence of slower reading times may be an indication that SMS shortcuts are processed via access to base-word lexical representations.

In contrast the results of a recent study suggest that the visual irregularity of letter-digit shortcuts does not prevent them from being processed like a word and accessing lexical representations (Ganushchak et al., 2010a). Ganushchak et al. used a parity task to test the extent that the digit used in letter-digit shortcuts is processed like a digit or more like a word. In this task familiar letter-digit shortcuts were displayed alongside congruent or incongruent displays of dots. For example, a shortcut (e.g., *l8r*) would be displayed with a row of even dots (e.g., 2 or 4 dots) for the congruent condition and a row of uneven dots (e.g., 1 or 3 dots) for the incongruent condition. Participants were instructed to state whether the parity of the shortcut matched the dots. Two different display durations were used with the shortcuts appearing simultaneously in one version of the experiment and 250ms before the dots in a second version of the experiment. The results indicated that when the shortcut was displayed with the dots, reaction times were slower for the incongruent condition, however, when the shortcut was displayed before the dots no differences were found between incongruent and congruent conditions. In contrast control items made up from nonsense letters and numbers (e.g., *qu8*) displayed slower response latencies to incongruent conditions regardless of whether the items were displayed with the dots or with a 250ms delay. Ganushchak et al. interpreted this outcome as evidence that the digit used in letter-digit shortcuts initially activates a number concept but this is rapidly suppressed by the activation of a lexical representation for the shortcut. Thus when shortcuts preceded the digits by 250ms the number concept had already been suppressed. This indicates that activation of a lexical code occurs rapidly in response to presentation of shortcuts but it is possible that this could either be an orthographic representation that is specific to the shortcut, a phonological representation or a combination of both.

Although previous research indicates that both abbreviated and letter-digit shortcuts could rapidly access the lexicon without specific lexical representations previous authors have concluded that these items may develop unique representations and be processed like familiar words (Ganushchak et al., 2010a; 2010b; Perea et al., 2009). Ganushchak et al. (2010b) found evidence in data from event related potentials (ERP) to suggest that SMS shortcuts access lexical representations and Berger & Coch (2010) suggest that SMS shortcuts access semantic information in much the same way as familiar words. In addition Morgan & Weighall (2008) using a masked priming paradigm demonstrated that SMS shortcuts facilitate target processing and may therefore be able to rapidly access the lexicon. Although the evidence suggests that SMS shortcuts are able to access the lexicon, the extent that this is facilitated by lexical representations that are specific to the shortcut has not been established. For example, if a subset of the consonants in a word (e.g., *frl-FAROL*) can rapidly access the lexicon despite participants having no experience with these items there seems to be no reason why the consonants in any word would not be able to do the same. Thus it seems likely that the consonants *hgh* would be able to access a lexical representation for the word *high* via activation of the overlapping graphemes between the two stimuli. Likewise evidence that unfamiliar pseudohomophone stimuli can facilitate processing of target words (e.g., *krest-CREST*) suggests that the phonological information conveyed by unfamiliar stimuli such as *cre8* may also be able to access a lexical representation of the word *create*. Evidence that stimuli such as *hgh* or *cre8* facilitate responses to their base-words (e.g., *hgh-HIGH*; *cre8-CREATE*) would provide evidence that SMS shortcuts may be processed via sub-lexical assembly of graphemes or phonemes rather than a unique lexical representation. However, evidence that unfamiliar stimuli such as *hgh* or *cre8* do not facilitate lexical access would suggest support for the assumptions underlying the DRC that familiar items are processed via specific orthographic representations.

The aim of Experiment 1 was therefore to investigate the extent that orthographic information in abbreviated shortcuts or the phonology of letter-digit shortcuts facilitates processing of these items in the absence of familiarity. It is assumed that a set of unfamiliar shortcuts would not have a specific lexical representation forcing them to be processed via the activation of base-word lexical representations from sub-lexical units. Consequently, in the following experiments familiar SMS shortcuts are compared to a set of unfamiliar SMS shortcuts and familiar words in a masked priming lexical decision task. The unfamiliar shortcuts followed the conventions of real shortcuts, for example unfamiliar abbreviated shortcuts were created by removing the vowels from a word (e.g., *hgh-HIGH, rsk-RISK*) and unfamiliar versions of letter-digit shortcuts made use of numbers to represent sounds (e.g., *cre8-CREATE, 4bid-FORBID*). The target words in Experiment 1 are the base-words for both the familiar and unfamiliar shortcut stimuli and are preceded by three types of prime stimuli. In both the Familiar and Unfamiliar shortcut conditions primes are either: shortcuts (e.g., *txt, l8r or rsk, cre8*); their base words (*text, later or risk, create*); or a baseline condition (%%%%). Consequently, word primes form an identity priming condition (i.e., *text-TEXT*) and when compared to baseline primes (i.e., *%%%-TEXT*) would be expected to produce a priming advantage in both the Familiar and Unfamiliar conditions. If familiar shortcuts are processed like words they would be expected to facilitate lexical decision latencies to base-word targets (e.g., *txt-TEXT*) and result in priming advantages of a similar magnitude to words when compared to the baseline condition. However, if familiar SMS shortcuts are processed via sub-lexical assembly of orthographic or phonological information they would be expected to produce priming effects that are comparable to unfamiliar shortcut stimuli (e.g., *rsk-RISK*). Based on previous research it is predicted that both familiar and unfamiliar abbreviated shortcuts (e.g., *txt* and *rsk*) will be able to access the lexicon. However, if familiar SMS shortcuts access base-word lexical representations via their consonants differences between the priming magnitudes for these two types of prime should be small. Conversely if large differences are found between priming effects for familiar versus unfamiliar shortcuts (both abbreviated and phonological) this would suggest that a level of familiarity is required before SMS shortcuts can rapidly access the lexicon and support the assumptions made by previous researchers that SMS shortcuts have a unique lexical representation (e.g., Ganushchak et al., 2010b; Perea et al., 2009).

In addition previous authors have suggested that orthographic processing dominates visual word recognition (e.g., Coltheart et al., 2001; Dimitropoulou et al., 2010a; 2010b; Rastle & Coltheart, 1994). If this is the case familiar abbreviated shortcut stimuli should exhibit larger priming advantages compared to letter-digit shortcuts due to their increased orthographic similarity. However, although Perea et al. (2009) found a processing advantage for abbreviated shortcuts over phonological approximations (e.g., *wud*), Ganushchak et al. (2010b) found no differences in ERP responses to letter-digit shortcuts compared to other types of shortcut. Additionally, whereas the DRC model predicts larger priming magnitudes for abbreviated shortcuts, a PDP model such as the one developed by Harm & Seidenberg (2004) proposes that both routes contribute equally to visual word processing and would therefore predict no differences between the different types of shortcut. Thus if abbreviated shortcuts display greater priming advantages this would provide support for models such as the DRC model but equal priming advantages for both types of shortcut would support a model with an even division of labour between the two routes (e.g., Diependaele et al., 2010; Harm & Seidenberg, 2004).

In conclusion, the present study addressed three main issues; first, are familiar SMS shortcuts processed as efficiently as familiar words? If so, then they should prime their related base word to the same extent as their real word counterparts. Second, is the consonantal or phonological information contained in shortcuts sufficient to gain lexical access, in the absence of familiarity? If so, unfamiliar shortcuts should elicit priming effects of the same magnitude as familiar SMS shortcuts. Finally, are different patterns of results observed for the two shortcut types (letter-digit vs abbreviations), which would suggest that orthographic processing may dominate in the lexical decision task?

4.2 Experiment 1

4.2.1 Method

4.2.1.1 Participants

72 participants (57 females; 15 males. Mean age = 21.0 years old, range = 18 - 50 years old) were recruited from Sheffield Hallam University undergraduate or graduate diploma programmes. All participants had English as their first language, were naïve of the subject of the study and had normal or corrected-to-normal vision. None of the participants had any known reading impairment and undergraduate psychology students received course credit in return for their time.

4.2.1.2 Design and materials

Experiment 1 employed a within-participants experimental design. A masked priming paradigm was used incorporating a forward and backward mask combined with a lexical decision task. The independent variables were Shortcut type (Abbreviated or Letter-digit), Prime type (Shortcut, Word or Baseline) and Familiarity (Familiar or Unfamiliar) with lexical decision reaction time as the dependent variable.

A total of 72 experimental target words were used, in the Familiar condition 18 targets were based on familiar abbreviated shortcuts (e.g., *TEXT-txt*) and 18 on familiar letter-digit shortcuts, (e.g., *LATER-l8r*). A further 36 target words were employed in the Unfamiliar condition, 18 were based on abbreviated shortcuts, (e.g., *HIGH-hgh*) and 18 on letter-digit shortcuts, (e.g., *STATE-st8*; see Appendix 4.1 for a full list). The familiar shortcuts were developed from a series of questionnaires that established two sets of SMS shortcut stimuli that are currently in use by UK undergraduates (see Chapter 2). The unfamiliar shortcuts were developed from words that could be modified to form shortcuts and were matched to the base-words of the familiar shortcuts on measures of frequency (Leech, Rayson & Wilson, 2001), length, imageability (Coltheart, 1981) and neighbourhood density (Balota et al., 2007). As the data for these measures were non-parametric[10] Mann-Whitney non-parametric tests of difference were conducted and no significant differences were found between the familiar and unfamiliar word sets on any of these measures. For frequency, U=.142.50, p=.732, in the abbreviated set and, U=137.0, p=.825 for the phonological set. For neighbourhood density, U=143.0, p=.545, in the abbreviated set and U=145.0, p=.581 for the phonological set. For imageability, U=.81.50, p=.448 for the abbreviated word set and U=.61.0, p=.625 for the phonological word set. For length, U=.156, p=.864 in the abbreviated set and, U=.157.50, p=.888 for the phonological set. In addition the unfamiliar shortcuts selected for use did not appear in the SMS shortcut frequency lists detailed in Chapter 2. To test that the unfamiliar shortcuts would be associated with the intended base-word a list of these shortcuts was included in an online survey and respondents were asked to write down the first word that the shortcut

[10] Positively skewed for frequency, with a number of outliers; positively skewed for neighbourhood with 1 outlier; positively skewed for length with numerous outliers and both positive and negatively skewed for imageability.

brought to mind. The results from 105 total respondents[11] suggested that accuracy levels were high for most items, in other words the majority of respondents wrote the intended word against the appropriate shortcut (e.g., *hgh* elicited the response *high*). On average 79% of respondents wrote down the intended word with the following items producing a low average of 28%; *mng* (meaning), *sm* (some), *dn* (down).

In addition post-test questionnaires were used to test the participant's knowledge of both the familiar and unfamiliar shortcuts. Participants were presented with a list of all stimuli used in the experiment and asked to provide the appropriate base-word as well as indicating whether or not they used or recognised this shortcut. The responses show that comprehension levels were high with 97% of familiar shortcuts and 76% of unfamiliar shortcuts being correctly identified. This suggests that the majority of the shortcuts used triggered the base-word they were intended to represent. Participants reported using 40% of familiar shortcuts compared to 6% of the unfamiliar shortcuts, suggesting that the majority of the unfamiliar shortcuts were not being used by these participants.

Each target word in both the Familiar and Unfamiliar conditions was combined with three types of prime; 1) SMS shortcut prime, either abbreviated (e.g. *txt - TEXT*) or letter-digit shortcuts (e.g. *l8r - LATER*); 2) Identity Word primes (e.g., *text - TEXT* ; *later - LATER*) and 3) Baseline primes consisting of a row of % signs (e.g.,*%%% - TEXT*). Prime and targets were presented in black on a white background in Courier New type font. Primes were in lower case, point size 18 and target words in upper case. In addition an equivalent number of filler non-words were created that matched the length and format of the real target words and were combined with prime stimuli that matched the conditions of the experimental trials. For example, the non-word *WUDGE* was combined with the prime *wdg* for the SMS condition, *wudge* for the word condition

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[11] Of the 105 respondent 33 were male and 72 were female with an average age of 26 and an age range from 18 to 60

and *%%%* for the baseline condition (see Appendix 4.1). Table 4.1 represents the study design.

Table 4.1 Experimental design with examples of the stimuli used in each level and within each condition

Familiarity	**Familiar**		**Unfamiliar**	
Shortcut type	**Abbreviated**	**Letter-digit**	**Abbreviated**	**Letter-digit**
Prime type				
SMS shortcut	txt	l8r	rsk	cre8
Word	text	later	risk	create
Baseline	%%%	%%%	%%%	%%%
Target	TEXT	LATER	RISK	CREATE

The experimental trials and the non-word filler trials were combined to make three different versions of the experiment based on the three priming conditions so that each participant was only exposed to each target word once. Presenting the stimuli in this way avoids confounds that may be introduced if participants see the same stimuli more than once. For instance priming effects have been shown to be affected by repeated presentation of stimuli due to implicit associations being drawn between the stimuli and the response (see Naccache & Dehaene, 2001 for a discussion). Trials were randomly combined such that each version of the experiment contained an equal number of primes from each condition. Each version of the experiment had a total of 144 trials with 72 experimental trials ('yes' responses) and 72 filler trials ('no' responses). All trials were divided into four blocks of 36 trials and randomly ordered to control for practice and order effects. Each block contained an equal number of experimental and filler trials and an equal number of experimental trials from each condition.

All blocks began with a filler trial and no more than three trials that required the same response were presented in a row. Prime stimuli with the same onsets, if in the same block, were separated to allow at least 3 trials between each one. Prime stimuli that are similar such as *l8 - LATE* and *m8 – MATE* were also separated by at least 3 trials in order to control for the possibility of form priming across trials. The order of appearance for the four blocks in each version of the experiment was also rotated using a pseudo Latin square design.

4.2.1.3 Procedure

Participants were tested individually under the same conditions. Participants were instructed that a word would appear on the monitor in front of them and they should use the response box to indicate whether they thought the word was a real word or a 'made up word' (non-word). The buttons on the response box were clearly labelled, with the 'no' response operated by the left hand and 'yes' response operated by the right hand. Participants were asked to respond as accurately and quickly as possible.

Each participant was initially presented with a practice block of trials consisting of 18 trials. The practice block contained 9 experimental trials ('yes' responses) and 9 filler trials ('no' responses) that were not used in the main experiment. The practice trials were randomly ordered in exactly the same way as a block of trials within the main experiment and feedback ('correct' or 'incorrect') was provided for the practice block only. On completion of the practice block, providing a considerable number of errors were not made, the researcher checked that the participant was happy with the procedure and started the main experiment. Most participants completed the task, including the practice trials, in around 10 minutes.

The visual presentation of each trial proceeded in the following order; forward mask (e.g., #####) displayed for 500ms followed by the prime stimulus (e.g., *txt*) for 60ms, followed by a backward mask (e.g., #####) also displayed for 60ms and finally the target word was presented (e.g., *TEXT*) until the participant selected 'YES' or 'NO' as part of the lexical decision task. Forward and backward masks were of equal length and matched the length of the target word which was in all cases as long as or longer than the prime stimuli. A visual representation of the trial procedure can be seen in figure 4.1.

The experiment was controlled using E-Prime 2 experiment presentation software (Schneider, Eschman and Zuccolotto, 2002), which was run on a standard PC in an experimental room. On completion of the reaction time task each participant completed a post-test questionnaire to establish text message usage and comprehension of the shortcuts used in this study.

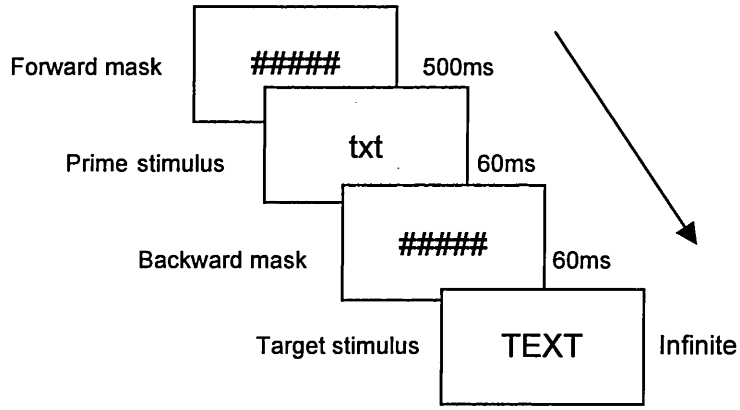

Figure 4.1 A schematic representation of the procedure for a trial in the familiar abbreviated SMS priming condition.

4.2.2 Results

Lexical decision latencies were analysed using SPSS. The data from each participant was subjected to a trim that eliminated reaction times + or – 2 standard deviations away from that participant's grand mean (see Forster & Davis, 1991 & Schoonbaert et al., 2009 for a similar procedure). Errors were removed from the analysis and any participants who lost more than 33% of their data overall or more than 50% of the values from any individual condition were omitted. Three participants were removed from the analysis, due to data loss, leaving 69 participants in total. As a result 2% of data was excluded due to error and 10% of data due to data trim. An analysis of the means for each item revealed that three of the unfamiliar SMS shortcuts also lost a considerable amount of data and the following items were removed from the analysis; SHOULD, FORBID and ONTO.

Table 4.2 presents means and standard deviations for each experimental condition. Separate analyses were run on the abbreviated and letter-digit SMS type conditions due to unavoidable differences between the base-words used in the two shortcut conditions. For example, it was not possible to match the base-words used as targets in the abbreviated SMS type condition (e.g., *TEXT*) to the base-words in the phonological SMS type condition (e.g., *LATER*) due to the restricted set of shortcuts available. Separate analyses were conducted on the subject (F_1) and item (F_2) means. The results of an analysis of errors employing a 2x (Shortcut Type; Abbreviated and Letter-digit) 2x (Familiarity; Familiar or Unfamiliar) 3x (Prime Type; Identity, SMS shortcut or Baseline) ANOVA resulted in no significant outcomes. These results suggest that the number of errors made in each of the experimental conditions were roughly equal.

Table 4.2 Mean reaction times (ms) to target words in each priming condition (standard deviations in parentheses)

	Familiarity		**Familiar**		**Unfamiliar**	
	Prime Type	**Example**	**Mean**	**% error**	**Mean**	**% error**
Abbreviated shortcut	SMS shortcut	[txt] TEXT	551.27 (77.92)	3.6	584.35 (89.83)	3.55
	Identity primes	[text] TEXT	534.31 (92.51)	0.93	547.29 (96.71)	2
	Baseline	[%%%%] TEXT	571.14 (82.28)	1.17	589.19 (85.80)	2.26
Priming effect	Shortcut - Identity	txt v text	17ms		37ms	
	Identity - Baseline	text v %%%	37ms		42ms	
	Shortcut - Baseline	txt v %%%	20ms		5ms	
Letter-digit shortcut	SMS shortcut	[l8r] LATER	564.60 (89.47)	1.19	617.18 (98.32)	3.50
	Identity primes	[later] LATER	544.65 (90.40)	1.17	580.44 (87.62)	2.95
	Baseline	[%%%%] LATER	584.02 (92.27)	3.10	611.78 (86.86)	2.67
Priming effect	Shortcut - Identity	L8r v later	20ms		37ms	
	Identity - Baseline	Later v %%%	39ms		31ms	
	Shortcut - Baseline	L8r v %%%	19ms		-5ms	

4.2.2.1 Analysis of abbreviated SMS shortcuts (txt - TEXT)

A repeated measures, 2x (Familiarity; Familiar or Unfamiliar) 3 (Prime type; Identity, SMS shortcut or Baseline) ANOVA was run on lexical decision time data collected from the abbreviated stimuli set only. The results of the ANOVA show that there was a significant main effect of Familiarity ($F_1(1,68)=12.90$, $p=.001$, $F_2(1,33)=11.34$, $p=.002$), indicating that lexical decision times were slower in the Unfamiliar compared to the Familiar real condition.

A main effect of Prime type was also observed ($F_1(2,136)=26.53$, $p<.001$, $F_2(2,66)=11.27$, $p<.001$). Global *t* tests revealed that word primes were responded to significantly faster than shortcuts ($t_1(68)=4.84$, $p<.001$, $t_2(34)=3.29$, $p=.002$), shortcut primes were responded to significantly faster than the baseline primes according to subjects but not items ($t_1(68)=2.25$, $p=.027$, $t_2<1$), and word primes were responded to significantly faster than baseline primes ($t_1(68)=7.73$, p<.001, $t_2(34)=4.40$, $p<.001$). No Prime type x Familiarity interaction was observed ($F_1(2,136)=2.29$, $p=.105$, $F_2<1$).

Planned contrasts conducted on the priming effects found for familiar SMS shortcuts (+20ms) compared to unfamiliar shortcuts (+5ms) revealed that a significant priming effect was observed for familiar SMS shortcuts ($t_1(68)=3.17$, $p=.002$, $t_2(17)=2.22$, $p=.040$), but not for the unfamiliar shortcuts ($t_1<1$, $t_2<1$). Identity primes (*text-TEXT*) produced significantly faster reaction times compared to baseline primes in both the Familiar ($t_1(68)=5.23$, $p<.001$, $t_2(17)=3.57$, $p=.002$) and Unfamiliar conditions ($t_1(68)=5.24$, $p<.001$, $t_2(16)=2.70$, $p=.016$). In addition shortcuts were responded to with reaction times that were significantly slower than identity primes in the Familiar ($t_1(68)=2.13$, $p=.037$, $t_2(17)=2.58$, $p=.019$) and Unfamiliar conditions ($t_1(68)=5.25$, $p<.001$, $t_2(16)=2.34$, $p=.033$).

4.2.2.2 Analysis of letter-digit SMS shortcuts (l8r - LATER)

Data from the letter-digit stimuli set were subjected to the same analyses. The results of the ANOVA yielded a significant main effect of Familiarity ($F_1(1,68)=77.04$, $p<.001$, $F_2(1,32)=24.79$, $p<.001$), with lexical decision times being slower in the Unfamiliar condition compared to the Familiar condition. A main effect of Prime type was also found ($F_1(2,136)=17.57$, $p<.001$, $F_2(2,64)=8.31$, $p=.001$). Further analyses showed that word primes were responded to significantly faster than shortcut primes ($t_1(68)=4.27$, $p<.001$, $t_2(33)=2.96$, $p=.006$) and baseline primes ($t_1(68)=5.48$, $p<.001$, $t_2(33)=4.47$, $p<.001$), but shortcut primes were no different to baseline primes ($t_1<1$, $t_2<1$). The interaction between Prime type and Familiarity reached significance according to the subjects analysis, but not the items analysis ($F_1(2,136)=3.19$, $p=.044$; $F_2<1$). Planned contrasts conducted on the Familiar and Unfamiliar stimuli indicate that identity primes (*later-LATER*) produced a significantly faster reaction time compared to baseline primes in both the Familiar ($t_1(68)=4.69$, $p<.001$, $t_2(17)=3.28$, $p=.004$) and Unfamiliar conditions ($t_1(68)=3.86$, $p<.001$, $t_2(15)=2.94$, $p=.010$). In addition, lexical decision latencies were significantly faster for Familiar SMS shortcuts (*l8r-LATER*) compared to the Baseline condition according to the subjects analysis, but not items ($t_1(68)=2.82$, $p=.006$, $t_2(17)=1.16$, $p=.263$). Responses to SMS shortcut primes were also significantly slower than the Identity condition according to the subjects analysis, but not by items ($t_1(68)=3.27$, $p=.002$, $t_2(17)=1.63$, $p=.121$). Unfamiliar SMS shortcuts (e.g., *st8-STATE*), however, did not perform differently to Baseline, ($t_1<1$, $t_2<1$) and were significantly slower than Identity primes ($t_1(68)=3.60$, $p=.001$, $t_2(15)=2.56$, $p=.022$).

To summarise, a robust Identity priming effect (e.g., *text-TEXT*) was found compared to the Baseline measure in both the Familiar and Unfamiliar conditions for real words. A priming effect was also found for Familiar SMS shortcuts (e.g., *txt-TEXT*), but not for Unfamiliar items (e.g., *rsk-RISK*). In addition the priming advantages found for familiar abbreviated SMS shortcuts (+20ms) were comparable to those found for familiar letter-digit shortcuts (+19ms). Finally lexical decision latencies were faster when the prime was a word compared to an SMS shortcut.

4.3 Discussion

The aims of Experiment 1 were to test whether SMS shortcuts are processed like words or whether sub-lexical assembly of orthographic or phonological information alone can facilitate access of base-word lexical representations. The data demonstrated that familiar SMS shortcuts exhibited a significant priming advantage compared to baseline whereas unfamiliar shortcuts did not. These results suggest that a degree of familiarity is required for rapid lexical access. As mentioned above, in online surveys respondents generally produced the intended word in response to the unfamiliar shortcuts. This finding indicates that these items are able to access their base-words given sufficient time, however, unfamiliar shortcuts are unable to access the lexicon rapidly enough to produce the kind of priming effects seen with familiar words and shortcuts. Nevertheless, slower reaction times were found to targets preceded by familiar shortcuts compared to familiar words, suggesting that shortcuts do not access the lexicon as efficiently as real words. Consequently it seems that there is a small cost associated with processing shortcuts compared to words. Finally, in direct contrast to the predictions made by theories that ascribe a dominant role to orthography in visual word processing, larger priming magnitudes were not found for abbreviated shortcuts compared to letter-digit shortcuts when compared to the baseline measure.

This latter finding suggests that both abbreviated and letter-digit shortcuts access the lexicon equally efficiently. However, a direct comparison of the two types of shortcut was not possible because their base words were unmatched. Thus Experiment 2 was designed with two aims; firstly reversing the priming direction and using SMS shortcuts as the target items in a masked priming lexical decision task enables the two types of shortcut to be directly compared on the basis of the frequency measures developed in Chapter 2. Secondly, as familiar SMS shortcuts are alternative representations of existing lexical entries they share characteristics with second language cognates (see Chapter 1). Thus, reversing the priming direction such that base-words become the prime stimuli is analogous to priming from a first language (L1) to a second language (L2). Investigations of cognate priming in the bilingual literature suggest that L1-

L2 priming is more robust than L2-L1 priming (e.g., Davis et al., 2010; Gollan et al., 1997), as a result using SMS shortcuts as target stimuli may produce more consistent results and/or larger priming effects.

4.4 Experiment 2

4.4.1 Introduction

Masked priming experiments that make use of non-word stimuli typically use the non-words as prime stimuli and familiar words as target stimuli allowing participants to respond to familiar words. Thus in Experiment 1 a typical priming direction was used with familiar words as targets and SMS shortcut stimuli as primes. This design has the advantage that participants are unaware of the prime stimuli and not affected by the fact that some of these stimuli are unfamiliar items such as those used in the unfamiliar SMS shortcut condition (e.g., *cre8*). However, a restricted set of SMS shortcut stimuli are available for use amongst both abbreviated and letter-digit shortcuts and it was therefore not possible to match their base-words on measures such as frequency and neighbourhood density. In contrast the frequency measures developed in Chapter 2 indicated that across three different measures abbreviated and letter-digit shortcuts proved to be used with equal frequencies, allowing for the two types of shortcut to be directly compared. Consequently the priming direction in Experiment 2 was reversed to mimic previous research that has employed stimuli such as pseudohomophones as targets with their base-words as primes (e.g., *flame-FLAIM*; Johnston & Castles, 2003).

The data from Experiment 1 suggest that familiar SMS shortcuts are able to access the lexicon in a way that is similar to familiar words. However, the priming effects observed for shortcuts were of a smaller magnitude compared to familiar words and reaction times were slower than words. The weaker priming effects found for shortcuts compared to familiar words are analogous to similar effects found for second language cognates. For example Davis et al. (2010) found larger priming effects for identity primes in Spanish (e.g., *rico-RICO*) with Spanish-English bilinguals compared to a cognate priming condition using English cognates as primes (e.g., *rich-RICO*). The conditions used by Davis et al. can be likened to the conditions used in Experiment 1, in both cases identity primes represent the same word as the target, whereas cognate or shortcut primes share meaning and some phonology and orthography with the target, but are distinct items. Thus a comparison was drawn between SMS shortcuts and second language cognates. In addition to finding larger priming effects for identity primes over cognate primes research using cognate pairs in priming paradigms consistently finds that priming effects are larger if the direction of priming is from the first language (L1) to the second (L2) compared to the reverse priming direction (e.g., Davis et al. 2010; Gollan et al., 1997, Ibrahim & Aharon-Peretz, 2005). The evidence from Experiment 1 suggests that SMS shortcuts are processed like words but not as efficiently as familiar words and it is therefore hypothesised that SMS shortcuts may be assimilated into the lexicon and processed in a way that is analogous to second language cognates. If this is the case SMS shortcuts may also exhibit a cognate-like priming asymmetry in lexical decision tasks.

Experiment 2 was designed to test this hypothesis by using the same stimuli as experiment 1 but with the priming direction reversed. The target stimuli in Experiment 2 were familiar SMS shortcuts with priming conditions consisting of (1) a Shortcut identity prime (*txt-TXT*), (2) a Word prime (*text-TXT*) and (3) a Baseline prime (*%%%-TXT*). As with experiment 1 the familiar SMS shortcuts were compared to a set of matched unfamiliar shortcuts (e.g., *risk-RSK*). This condition provides a comparison to the familiar SMS shortcuts with the point of interest being whether unfamiliar shortcuts exhibit similar patterns of data to familiar shortcuts. Based on previous research and the outcomes from Experiment 1, it is predicted that the Identity priming condition (e.g., *txt-TXT*) will display priming effects in relation to the baseline condition for both types of familiar SMS shortcuts. In addition no differences in priming magnitudes are expected for either abbreviated or letter-digit familiar shortcuts. It is further predicted that stronger priming advantages will be found for word primes paired with shortcut targets (e.g., *text-TXT*) compared to shortcut primes with word targets (e.g., *txt-TEXT*; Experiment 1).

4.4.2 Method

4.4.2.1 Participants

105 participants (79 females; 26 males. Mean age = 21.0 years old, range = 18 - 44 years old) were recruited from Sheffield Hallam University undergraduate, masters or PhD programmes. All participants had English as their first language, were naïve of the subject of the study and had normal or corrected-to-normal vision. None of the participants had any known reading impairment and psychology undergraduate participants received course credit in return for their time.

4.4.2.2 Design and materials

The design of Experiment 2 was the same as for Experiment 1 except that the priming direction was reversed. A within-participants experimental design was employed with a masked priming paradigm combined with a lexical decision task. The independent variables were SMS shortcut type (Abbreviated or Letter-digit), Prime type (SMS shortcut, Word or Baseline) and Familiarity (Familiar or Unfamiliar) with lexical decision time as the dependent variable. The experimental design was exactly the same as for experiment 1 with the exception that the target was the SMS shortcut and each shortcut was combined with three types of prime; 1) Shortcut Identity prime, either abbreviated (e.g. *txt - TXT*) or letter-digit shortcuts (e.g. *l8r – L8R*); 2) Word primes (e.g., *text - TXT* ; *later – L8R*) and 3) Baseline primes consisting of a row of % signs (e.g., *%%% - TXT*).

As in Experiment 1 a total of 72 experimental target words were employed with 36 items in the Familiar condition, 18 abbreviated and 18 letter-digit shortcuts and 36 matched items in the Unfamiliar condition. The materials for the Familiar condition used in Experiment 2 were the same as Experiment 1. However in the Unfamiliar condition half the shortcuts were replaced due to the finding that they did not elicit their intended base-word in an online survey (see details in the methods section for Experiment 1) or they lost a substantial amount of data in Experiment 1. Additionally two items that were used as unfamiliar shortcuts in Experiment 1 were replaced because they appeared in a list of familiar SMS shortcuts provided by respondents to surveys (see Chapter 2) that were completed after Experiment 1 had been conducted (see Appendix 4.2 for a full list of stimuli for Experiment 2).

In order to allow for a comparison of familiar and unfamiliar shortcuts these items were designed to elicit a 'yes' response, consequently both familiar and unfamiliar shortcuts were employed as the experimental targets. It was therefore important that the unfamiliar items were as recognisable as possible. Filler stimuli designed to elicit a 'no' response were created that matched the length and format of the target shortcuts but did not represent a real word in English. For example, *XTT* was designed to match the length and format of the abbreviated shortcut *txt* and *R8L* was used as a match to the target shortcut *l8r*. Each filler shortcut was combined with prime stimuli that matched the conditions of the experimental trials. For example, the filler shortcut *XTT* was combined with the prime *xtt* for the Shortcut identity condition, *xett* for the Word condition and *%%%* for the Baseline condition (see Appendix 4.2).

Due to the lack of available data it is difficult to be sure that the abbreviated and letter-digit shortcuts are matched on all the properties that have been shown to affect familiar words (i.e., imageability, length, neighbourhood density etc.). However, the results of tests of differences for the two types of shortcut based on the frequency lists developed in Chapter 2 suggest that there are no significant differences between the frequencies or lengths of the abbreviated and letter-digit shortcuts.

4.4.2.3 Procedure

The procedure was exactly the same as Experiment 1 with the exception that participants were instructed to use the response box to indicate whether they thought the shortcut presented on the screen represented a real English word or not. The buttons on the response box were clearly labelled, with the 'no' response operated by the left hand and 'yes' response operated by the right hand. Participants were asked to respond as accurately and quickly as possible and it was stressed that some of the shortcuts may be unusual so participants were asked to consider each item carefully but respond as quickly as they could.

The procedure continued in the same way as Experiment 1 with each participant completing a practice block before starting the main experiment. Most participants completed the task, including the practice trials, in around 10 minutes.

The visual presentation of each trial was the same as Experiment 1 and was run on a standard PC in an experimental room. On completion of the reaction time task each participant completed a post-test questionnaire to establish text message usage and comprehension of the shortcuts used in this experiment.

4.4.3 Results

Lexical decision latencies were analysed using SPSS. The data was subjected to a trim that eliminated any reaction times + or – 2 standard deviations away from an individual participant's grand mean. Any participant who lost more than 33% of their data overall or more than 50% of the values from any individual condition was omitted from the analysis. As a result a relatively large percentage of participants lost substantial amounts of data from the experimental conditions due to problems identifying the unfamiliar SMS shortcuts. After removal of these participants a total of 75 participants remained with a loss of 29% (31) of participants[12]. After errors were removed 9% of data was lost and 5% of data was lost due to the trim. An analysis of the means for each item revealed that six of the unfamiliar SMS also lost considerable amounts of data and the following items were removed; *bys* (boys), *stimes* (sometimes), *hgh* (high), *4ces* (forces), *re4m* (reform) *ox4d* (oxford). Table 4.3 presents means and standard deviations for each experimental condition.

In the first instance a repeated measures, 2x (Familiarity; Familiar or Unfamiliar) 3x (Prime type; Identity, SMS shortcut or Baseline) 2 (SMS shortcut type; Abbreviated or Letter-digit) omnibus ANOVA was conducted on the lexical decision time data.

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[12] As a comparison Davis et al. (2008) eliminated 13 out of 45 participants (29%) due to error.

Table 4.3 Mean reaction times (ms) to target shortcuts in each priming condition (standard deviations in parentheses)

	Familiarity		Familiar	Unfamiliar
	Prime Type	**Example**	**Mean**	**Mean**
Abbreviated shortcut	SMS shortcut Identity	[txt] TXT	767 (165)	946 (326)
	Word primes	[text] TXT	754 (189)	874 (275)
	Baseline	[%%%] TXT	806 (190)	934 (303)
Priming effect	Shortcut - Word	txt v text	13ms	72ms
	Word - Baseline	text v %%%	52ms	60ms
	Shortcut - Baseline	txt v %%%	39ms	-12ms
Letter-digit shortcut	SMS shortcut Identity	[l8r] L8R	779 (208)	1136 (466)
	Word primes	[later] L8R	742 (161)	950 (259)
	Baseline	[%%%] L8R	819 (187)	1131 (392)
Priming effect	Shortcut - Word	l8r v later	37ms	186ms
	Word - Baseline	later v %%%	77ms	181ms
	Shortcut - Baseline	l8r v %%%	40ms	-5ms

The results of this analysis showed all main effects and interactions to be significant for both subjects and items analysis, apart from the three way interaction between Familiarity, Prime type and SMS shortcut type for subjects (see table 4.4 for all figures). The results from experiment 1 suggest that no differences will be found between the shortcut types which would allow data from the two types of shortcut to be collapsed in subsequent analysis. Consequently an analysis of lexical decision latencies for the familiar shortcuts was conducted before analysis comparing Familiar and Unfamiliar conditions. Separate analyses were conducted on the subject (F_1) and item (F_2) means.

4.4.3.1 Analysis of Familiar SMS shortcuts

A repeated measures, 2x (SMS shortcut type; Abbreviated or Letter-digit) 3 (Prime type; Identity, Word or Baseline) ANOVA was run on lexical decision time data collected from the familiar SMS shortcut stimuli.

Table 4.4 Subjects and items analysis for 2x (Familiarity; Familiar or Unfamiliar) 3x (Prime type; Identity, SMS shortcut or Baseline) 2 (SMS shortcut type; Abbreviated or Letter-digit) ANOVAs

Subjects Analysis	**Degrees of freedom**	***F***	**Sig**	**Partial Eta squared**
Main effects				
SMS shortcut Type	1, 74	35.40	<.001	0.32
Familiarity	1, 74	133.04	<.001	0.64
Prime Type	2, 148	18.22	<.001	0.20
Interactions				
SMS shortcut Type * Familiarity	1, 74	39.54	<.001	0.35
SMS shortcut Type * Prime Type	2, 148	3.85	.023	0.05
Familiarity * Prime Type	2, 148	4.71	.010	0.06
SMS shortcut Type * Familiarity * Prime Type	2, 148	1.20	.303	0.02

Items Analysis	**Degrees of freedom**	***F***	**Sig**	**Partial Eta squared**
Main effects				
SMS shortcut Type	1, 62	10.47	.002	0.14
Familiarity	1, 62	46.89	<.001	0.43
Prime Type	2, 124	19.60	<.001	0.24
Interactions				
SMS shortcut Type * Familiarity	1, 62	9.21	.004	0.13
SMS shortcut Type * Prime Type	2, 124	4.51	.013	0.07
Familiarity * Prime Type	2, 124	6.92	.001	0.10
SMS shortcut Type * Familiarity * Prime Type	2, 124	3.96	.022	0.06

The results of the ANOVA show that neither SMS shortcut type nor the interaction between SMS shortcut and Prime type reached significance (all F_1<1, F_2 <1). However, there was a significant main effect of Prime type (F_1(2,148)=10.06, *p*<.001, F_2(2,68)=5.09 *p*=.014). These results suggest that there are no differences between the two types of SMS shortcut but there are significant differences between the different types of prime. Consequently in the following analyses the data will be collapsed across SMS shortcut type and *t* tests conducted to explore the significant main effect of prime type in the familiar condition are reported below.

4.4.3.2 Analysis of Familiar and Unfamiliar SMS shortcuts (data collapsed across the abbreviated and letter-digit conditions).

Having collapsed the data across SMS shortcut type (see table 4.5 for revised mean values) a repeated measures, 2x (Familiarity; Familiar or Unfamiliar) 3 (Prime type; Identity, Word or Baseline) ANOVA was conducted on lexical decision time data collected from both the Familiar and Unfamiliar SMS shortcuts.

Table 4.5 Mean reaction times (ms) to target shortcuts in each priming condition with data collapsed across abbreviated and letter-digit shortcut conditions (standard deviations in parentheses)

Familiarity		**Familiar**			**Unfamiliar**		
Prime Type	**Example**	**Mean (SD)**	**% error**	**Priming effect** (compared to baseline)	**Mean (SD)**	**% error**	**Priming effect** (compared to baseline)
IDENTITY	[txt] TXT	773 (169)	4.87	40	1033 (324)	13.37	3
WORD	[text] TXT	749 (155)	1.94	64	907 (225)	7.89	129
BASELINE	[%%] TXT	813 (170)	5.16		1036 (318)	18.80	

The results of the ANOVA yielded a significant main effect of Familiarity (F_1(1,74)=13.37, p<.001, F_2(1, 64)=37.49, p<.001), with mean lexical decision times being 214ms slower in the unfamiliar condition compared to the familiar condition. A main effect of prime type was also found (F_1(2,148)=18.85, p<.001, F_2(2,128)=17.97, p<.001) and the interaction between familiarity and prime type was significant (F_1(2,148)=4.84, p=.009, F_2(2,128)=6.35, p=.002).

The interaction was explored with post hoc *t* tests contrasting the three prime types in the Familiar and Unfamiliar SMS shortcut conditions. The results of an analysis conducted on the data in the Familiar condition revealed no significant differences between SMS shortcut Identity primes and Word primes (t_1(74)=1.66, p=.101, t_2(35)=1.19, p=.242). Familiar SMS shortcuts preceded by Identity primes were responded to significantly faster than baseline primes (t_1(74)=2.85, p=.006, t_2(35)=2.52, p=.016) and Word primes demonstrated a priming advantage over baseline primes (t_1(74)=4.532, p<.001, t_2(35)=2.957, p=.006). The results in the Unfamiliar condition showed that latencies to unfamiliar SMS shortcuts were significantly longer when preceded by an unfamiliar SMS shortcut Identity prime (e.g., *rsk-RSK*) compared to a Word prime (e.g., *risk-RSK*; $t_1(74)=3.96$, $p<.001$, $t_2(29)=4.40$, $p<.001$). However, Word primes were responded to significantly faster than baseline primes ($t_1(74)=4.35$, $p<.001$, $t_2(29)=4.43$, $p<.001$) and no significant differences were found between Unfamiliar SMS shortcut Identity primes and baseline primes ($t_1<1$, $t_2<1$).

4.4.3.3. Error analysis

In addition to the analysis based on reaction times an analysis of errors was conducted. Overall the errors analysis matched the reaction time data with the exception that no main effect of shortcut type was found from an initial repeated measures, 2x (Familiarity; Familiar or Unfamiliar) 3x (Prime type; Identity, SMS shortcut or Baseline) 2x (SMS shortcut type; Abbreviated or Letter-digit) ANOVA (see table 4.6). Consequently, as with the reaction time data, subsequent analyses were conducted with the data collapsed across the shortcut type variable.

With the data collapsed across shortcut types a repeated measures, 2x (Familiarity; Familiar or Unfamiliar) 3x (Prime type; Identity, Word or Baseline) ANOVA was conducted on number of errors made. The results yielded a significant main effect of Familiarity ($F_1(1,69)=45.26$, $p<.001$, $F_2(1, 51)=13.96$, $p<.001$), with more errors made in the unfamiliar condition (M=3.01) compared to the familiar condition (M=1.23). A main effect of prime type was also found ($F_1(2,138)=19.09$, $p<.001$, $F_2(2, 102)=13.58$, $p<.001$) and the interaction between familiarity and prime type was significant for subjects but not items ($F_1(2,138)=4.20$, $p=.017$, $F_2(2,102)=2.16$, $p=.121$).

The significant interaction for the subjects analysis was investigated using post hoc *t* tests. The results show that in the familiar condition significantly more errors were made following baseline and identity primes compared to word primes ($t_1(69)=3.20$, $p=.002$ and $t_1(69)=3.73$, $p<.001$ respectively). No differences were found between identity primes and baseline primes ($t_1<1$).

Table 4.6 Subjects and items analysis for errors; 2x (Familiarity; Familiar or Unfamiliar) 3x (Prime type; Identity, SMS shortcut or Baseline) 2 (SMS shortcut type; Abbreviated or Letter-digit) ANOVAs

Subjects Analysis **Main effects**	**Degrees of freedom**	***F***	**Sig**	**Partial Eta squared**
SMS shortcut Type	1, 69	<1	0.93	0
Familiarity	1, 69	45.26	<.001	0.40
Prime Type	2, 138	19.09	<.001	0.22
Interactions				
SMS shortcut Type * Familiarity	1, 69	18.31	<.001	0.99
SMS shortcut Type * Prime Type	2, 138	<1	.56	0.008
Familiarity * Prime Type	2, 138	4.20	.017	0.06
SMS shortcut Type * Familiarity * Prime Type	2, 138	<1	.50	0.01

Items Analysis **Main effects**	**Degrees of freedom**	***F***	**Sig**	**Partial Eta squared**
SMS shortcut Type	1, 49	0.28	0.598	0.006
Familiarity	1, 49	15.764	.000	0.243
Prime Type	2, 98	12.725	.000	0.206
Interactions				
SMS shortcut Type * Familiarity	1, 49	4.237	0.045	0.08
SMS shortcut Type * Prime Type	2, 98	<1	0.826	0.004
Familiarity * Prime Type	2, 98	2.126	0.125	0.042
SMS shortcut Type * Familiarity * Prime Type	2, 98	<1	0.720	0.007

In the unfamiliar condition significantly more errors were made following baseline primes compared to both word primes ($t_1(69)=5.36$, $p<.001$) and identity primes ($t_1(69)=2.73$, $p=.008$). In addition significantly more errors were made following identity primes compared to word primes ($t_1(69)=2.86$, $p=.006$).

The results from the errors analysis suggest that an even number of errors were made to both abbreviated and letter-digit types of shortcut and overall more errors were made to target items in the unfamiliar condition compared to the familiar condition. Post hoc analyses indicate that conditions with slower lexical decision latencies resulted in more errors suggesting that there was no accuracy versus time trade off.

The results from the reaction time data suggest that both Word and SMS shortcut primes produced latencies that were statistically equivalent and significantly faster than Baseline primes. However, the magnitude of the priming advantage for familiar Word primes (65ms) was larger than for familiar SMS shortcut primes (40ms). Additionally, as predicted by the cognate literature, a numerically larger priming advantage of 63ms was found for an L1-L2 priming direction (e.g., *text-TXT*) in Experiment 2 compared to the 20ms priming advantage found in Experiment 1 with the reverse priming direction (e.g., *txt-TEXT*). In addition, although latencies to unfamiliar shortcuts preceded by an identity prime (e.g., *rsk-RSK*) were equivalent to baseline, when unfamiliar shortcuts were preceded by a real word (e.g., *risk-RSK*) a priming advantage was observed.

4.5 General Discussion

The experiments detailed in this Chapter aimed to answer three initial questions; 1) are familiar SMS shortcuts processed as efficiently as familiar words? 2) Is the consonantal or phonological information contained in shortcuts sufficient for lexical access, even in the absence of familiarity? 3) Do we observe a different pattern of results for the two shortcut types (letter-digit vs abbreviations). Experiment 1 addressed these questions and subsequently Experiment 2 was designed to further investigate whether familiar SMS shortcuts are processed like words and whether they exhibit patterns of priming that are analogous to second language cognates. The results from Experiment 1 demonstrated that both familiar abbreviated and letter-digit shortcuts are able to rapidly access the lexicon and facilitate processing of target base-words. In contrast unfamiliar shortcuts provide no more facilitation than a neutral prime. In addition lexical decision latencies to familiar word targets were slower when preceded by a familiar SMS shortcut prime compared to a familiar word identity prime. These results suggest that SMS shortcuts are not decoded via sub-lexical processes alone and that they are processed like words, albeit not as efficiently. The results from Experiment 2 replicated the finding from Experiment 1 that priming effects for both abbreviated and letter-digit shortcuts are equivalent, suggesting that abbreviated shortcuts do not have a processing advantage over letter-digit shortcuts. In addition the priming asymmetry found between Experiments 1 and 2 supports the suggestion that SMS shortcuts may function in a way that is analogous to second language cognates.

Interestingly previous research has found similar patterns using stimuli that are comparable to the stimuli employed here. Dimitropoulou et al. (2011b) used an alternative written form of Greek that was developed for computer mediated interaction (Greeklish) and paired them with familiar Greek targets. The Greeklish stimuli are similar to SMS shortcuts in that they are both alternative written forms of standard familiar words. In addition Greeklish primes with little graphemic overlap (e.g. *βλήμα- vlima*; meaning missile) can be likened to letter-digit shortcuts (e.g., *m8-MATE*), whereas prime-target pairs with high levels of orthographic overlap (e.g., *σοκάκι- sokaki;* meaning alley) can be likened to abbreviated shortcuts (e.g., *txt-TEXT*). However, despite differing degrees of orthographic overlap both SMS shortcuts and Greeklish share phonology and meaning with their standard language counterparts. An initial experiment conducted by Dimitropoulou et al. employed a masked priming lexical decision task with primes constructed from Greeklish words that had large amounts of orthographic overlap with their traditional Greek targets. The results showed that Greeklish primes facilitated processing of familiar Greek target words but these effects were smaller than the priming effects found for an identity priming condition using familiar Greek words. In their second experiment Dimitropoulou et al. compared latencies for Greeklish prime stimuli that had large amounts of graphemic overlap with their traditional Greek targets, to prime-target pairs with less orthographic similarity. The results of this experiment revealed that both types of Greeklish prime produced significant priming advantages compared to a matched unrelated condition. These results can be directly related to those found in Experiment 1 of the current research. SMS shortcut primes (e.g., *txt-TEXT*) also exhibited smaller priming effects compared to an identity priming condition employing familiar words (e.g., *text-TEXT*) and shortcuts with more and less orthographic overlap with their target words facilitated target processing. Consequently these findings suggest that both SMS shortcuts and Greeklish are able to rapidly access the lexicon and facilitate processing of base-word targets. However, in contrast to the findings detailed in the current research, Dimitropoulou et al. found that priming advantages for items with larger graphemic overlap were greater (28m) than those with less orthographic similarity (12ms). Conversely, the results of both Experiment 1 and 2 in the current research suggest that priming magnitudes for abbreviated and letter-digit shortcuts are comparable. Dimitropoulou et al. conclude that the effects they observed for Greeklish are driven by graphemic overlap, indeed they suggest that “graphemic overlap is a prerequisite for their [priming effects] appearance” (p.734). In contrast the results reported here would suggest that priming advantages for SMS shortcuts are not dominated by orthographic processing and are equally as robust for visually unusual letter-digit shortcuts.

However, differences between abbreviated and phonologically plausible or letter-digit shortcuts have been reported in previous research. For example, Ganushchak et al. (2010b) report that letter-digit SMS shortcuts were rejected as non-words in a lexical decision task faster than abbreviated shortcuts. In addition Perea at al. (2009) found that Spanish abbreviated shortcuts were processed faster than phonological approximations (i.e., *wud-would*). The results observed by Perea at al. and Dimitropoulou et al. (2011b) support the assumptions of computational models that ascribe a dominant role for orthographic processing (e.g., the DRC model), which would predict that abbreviated shortcuts should have a processing advantage over letter-digit shortcuts. However, the data presented here do not support this assumption. Viewed from the perspective of the DRC model this finding suggests that both types of shortcut are processed via an orthographic representation that is specific to the shortcut. Although the DRC model can theoretically accommodate the rapid activation of phonological information it is assumed that the non-lexical route lags behind the lexical route. Thus if letter-digit shortcuts were processed via assembly of their phonology, processing for these items might be delayed in comparison to abbreviated shortcuts. Thus the lack of a difference in priming magnitudes found in the current experiments suggests that both shortcuts may be processed via a lexical route.

Further support for the suggestion that SMS shortcuts access specific lexical representations is demonstrated by the lack of priming advantages found for the shortcut stimuli used in the Unfamiliar condition. It was hypothesised that if SMS shortcuts are processed via their base-word lexical representations the consonantal or phonological information contained in familiar items may be sufficient to provide lexical access. This suggestion was supported by previous research demonstrating that subsets of the consonants in a word can facilitate processing of target base-words (e.g., *frl-FAROL*; Duñabeitia & Carreiras, 2011) and evidence that pseudohomophone stimuli can facilitate processing of phonologically related target words (e.g., *krest-CREST*; Holyk & Pexman, 2004). However, the results of both experiments reported here suggest that unfamiliar shortcut stimuli are unable to rapidly access the lexicon. Whilst it could be argued that unfamiliar letter-digit stimuli (e.g., *cre8*) failed to access the lexicon due to their visual irregularity, unfamiliar abbreviated shortcuts share a considerable amount of orthography with their traditional word counterparts. However, in Experiment 1 and in direct contrast to the findings of Duñabeitia & Carreiras (2011), unfamiliar abbreviated shortcut primes (e.g., *rsk*) produced lexical decision latencies that did not differ from neutral baseline primes. These results suggest that when presented briefly and masked subsets of the consonants of the words used in the current experiment were unable to access lexical representations of their base-words. However, the results of an online survey conducted to check that the unfamiliar prime stimuli are associated with their indented base-word, suggest that given sufficient time both types of unfamiliar shortcut access the relevant lexical representation. As unfamiliar items are assumed to not have lexical representation the only route they have available to access meaning is via activation of base-word lexical representations. Thus if sub-lexical processes are able to rapidly access lexical representations of shortcut base-words and influence the effects seen in the task reported here priming effects should be seen for unfamiliar shortcuts paired with base-word targets (e.g., *rsk-RISK*). In addition evidence of priming effects for these items used in an identity priming condition (e.g., *rsk-RSK*) would support suggestions that sub-lexical matching of letters or phonemes can faciliate priming advantages (see Chapter 3 for a discussion of non-word and form priming). However, no priming advantages were observed for unfamiliar shortcut Identity primes in Experiment 1 or shortcut primes in Experiment 2, suggesting that form overlap did not influence the priming advantages in this task. Thus evidence that a sub-lexical route is unable to facilitate rapid lexical access to base-word lexical representations in a masked priming paradigm using a 60ms prime duration suggests that an additional mechanism influenced the priming effects seen here for familiar SMS shortcuts. This conclusion leads to the obvious alternative, which is that familiar SMS shortcuts have a lexical representation that is specific to the shortcut.

However, a second explanation for the priming effects seen in response to familiar SMS shortcuts is that these items are able to rapidly access base-word lexical representations because the lexical processor has experience with them. A model such as the DRC may struggle to account for a familiarity effect such as that described above because it assumes that familiar items develop specific orthographic lexical representations. However, parallel distributed processing (PDP) models of visual word recognition (e.g., Seidenberg & McClelland 1989) are based on the assumption that familiarity with stimuli adjusts the weightings on units that respond to those stimuli. These models would therefore predict that the effects seen for familiar SMS stimuli are the result of familiarity rather than lexical representations per se. Nevertheless, whether the effects occur due to lexical representation or familiarity or a combination of both the results of the experiments reported here suggest that familiar SMS shortcuts are processed like words. Furthermore, the finding that both types of familiar shortcut exhibit comparable priming advantages supports models of visual word processing that do not assume orthographic dominance such as the BIAM developed by Diependaele et al. (2010) or a PDP model such as the one proposed by Harm and Seidenberg (2004).

An additional aim of the research reported here was to investigate the suggestion that SMS shortcuts are analogous to second language cognates. The priming asymmetry found for SMS shortcuts and their base-words between Experiments 1 and 2 suggests that these items do display similar effects to cognates. In addition a similar pattern of priming to that observed in Experiment 2 was found in a study conducted by Davis et al. (2010) investigating cognate priming. Although an identity priming paradigm might be expected to produce the fastest reaction times in a priming paradigm, in Experiment 2, when shortcuts were used as target stimuli word primes rather than identity primes exhibited larger priming effects and faster lexical decision latencies. Davis et al. (2010) do not report the statistical significance of the following effects, however, in a masked priming lexical decision task when identity primes were in the first language (L1), which would be comparable to familiar word identity primes in the current research (e.g., *text-TEXT*) faster latencies are reported compared to L2 primes with L1 targets (e.g., *txt-TEXT*). In contrast, when the identity primes were in the second language and therefore comparable to shortcut identity priming (e.g., *txt-TXT*) they produced slower latencies compared to L1 primes with L2 targets (e.g., *text-TXT*). Davis et al. tested participants who were Spanish-English bilinguals and only obtained this pattern of data for unbalanced bilinguals who were not proficient in their second language. This not only provides further evidence that SMS shortcuts exhibit patterns of priming that are similar to second language cognates but also that levels of proficiency may interact with priming effects in tasks such as this. Thus the slower latencies seen for shortcut primes compared to word primes in both Experiments 1 and 2 could be the result of lower levels of proficiency with familiar SMS shortcuts compared to familiar words. Perea et al. (2009) also suggest that slower reading times and longer fixations found for shortcuts compared to familiar words could be due to a lack of familiarity with shortcuts compared to words. The discrepancies found between words and shortcuts in this and Perea et al.'s (2009) study could therefore be due to the fact that even regular texters will have been exposed to shortcuts less often than their familiar word counterparts

In addition Davis et al. (2010) investigated the degree to which language proficiency interacts with priming directions. They found that the size of a cognate priming advantage for Spanish-English bilinguals did not differ depending on priming direction except for beginner bilinguals. In other words L1-L2 cognate pairs (e.g., *rico-RICH*) produced equivalent priming advantages to L2-L1 cognates pairs (e.g., *rich-RICO*) unless the bilinguals were not balanced. In the current experiments larger priming advantages were found in L1-L2 priming compared to the L2-L1 priming direction, suggesting that SMS shortcuts may be assimilated into the lexicon in a way that is analogous to second language cognates. In addition the finding that priming effects for SMS shortcuts were robust in both directions suggests that the majority of the participants who took part in the current research were reasonably proficient English-text speak bilinguals but they were not balanced.

The evidence presented to date suggests that shortcuts can be integrated into a sentence but produce a processing cost (Perea et al., 2009), that the number in a shortcut does not hold up processing (Ganushchak et al., 2010a), shortcuts are harder to classify as non-words (Ganushchak et al. 2010b) and the experiments reported here have shown that a level of familiarity is required for the rapid recognition of SMS shortcuts. In conclusion, familiar SMS shortcuts produced a pattern of priming consistent with the hypothesis that in the early stages of recognition these items access the lexicon more effectively than a set of viable shortcuts that are not in current use. This finding suggests that lexical access for real SMS shortcuts is not solely mediated by the consonantal or phonological information conveyed by these shortcuts and that familiarity with these items is required to facilitate lexical access. A small processing cost for shortcuts does appear evident from the finding that words access the lexicon more efficiently than shortcuts, but this is consistent with cognate literature indicating that words from the first language access the lexicon more efficiently than words from the second language. Finally SMS shortcuts were shown to produce priming advantages that are comparable to second language cognates suggesting support for the hypothesis that these items may be assimilated into the lexicon like a second language cognate. Evidence of a processing cost for SMS shortcuts is therefore not evident and these items appear to be processed in the same way as words.

Chapter 5 Illusory conjunctions: Are they real and what can they tell us about visual word processing?

5.1 Introduction

The conclusions reached in the previous chapter suggest that SMS shortcuts are processed like words and there are no differences in the speed with which the two types of very different shortcuts are processed. Influential computational models such as the Dual Route Cascaded model (DRC) assume that for familiar words lexical access is achieved via orthographic representations. Consequently if viewed from this perspective the findings detailed in Chapter 4 suggest that both abbreviated and letter-digit shortcuts are processed via activation of specific orthographic representations. This hypothesis supports assumptions made by previous authors in regards to SMS shortcuts and familiar abbreviations (Brysbaert et al., 2009; Ganushchak et al., 2010a; 2010b; 2012; Perea et al., 2009). However, in contrast to the lexical account of SMS shortcut processing it was also suggested in Chapter 4 that familiar SMS shortcuts may be able to access base-word lexical representations rapidly because they are regularly used. Conversely unfamiliar shortcuts fail to access the lexicon because they are novel items that participants have no experience with. This proposal requires a lexical processor that can adjust mental activity in line with experience and as such fits the architecture of a PDP model (e.g., Seidenberg & McClelland, 1986) rather than a model such as the DRC[13]. In addition, despite the evidence that SMS shortcuts exhibit word-like properties these items are consistently processed more slowly than familiar words. It is possible that lower levels of exposure to shortcuts compared to familiar words culminate in an effect that is analogous to second language cognates. However, it is also possible that the extra time required to process SMS shortcuts is the due to the necessity to access base-word lexical representations in order to access meaning.

[13] See Lazlo & Federmeier 2007 for the suggestion that familiarity is represented in models such as Harm & Seidenberg 2004 whereas orthographic regularity "constitutes a key gating factor for word recognition in dual-route models" (p.1158).

Although it is beyond the scope of this research to distinguish between a localist architecture such as the DRC and distributed PDP models, the aim of the current chapter is to further explore the extent that SMS shortcuts are processed via top down processes such as lexical units. In order to achieve this goal a paradigm is employed here which was developed by Prinzmetal & Millis-Wright (1984) to investigate a phenomena they termed illusory conjunction errors. Illusory conjunction errors are errors that are made when processing visually presented stimuli such as words and involve the misattribution of features within a word. Prinzmetal and Millis-Wright discovered that if visual stimuli were presented with their letters in different colours participants found it difficult to correctly identify the colour of specific letters in familiar words and abbreviations but not in nonwords. Prinzmetal and Millis-Wright hypothesised that this effect was the result of top down processes activated in response to familiar stimuli (e.g., words and abbreviations) interfering with the perception of letter colours. In contrast because nonwords do not have lexical representations each letter is processed individually allowing letters to be correctly co-joined with their colour. Consequently it is possible that a similar effect will be seen for familiar SMS shortcuts as that found for words, which would provide further evidence that these items have a specific lexical representation.

LaBerge (1983) suggested that when visually processing words a different attentional focus may be used for familiar words compared to nonwords. According to this theory when words are encountered the focus of attention is spread across the whole word, whereas nonwords are processed via a narrow focus that is concentrated on each letter. LaBerge presented participants with words and unpronounceable nonwords and instructed them to respond when the middle letter was from a set including A-G. This procedure was used to focus the attentional spotlight on a single letter. To focus the attentional spotlight across a whole word, participants were also presented with words but asked to respond when the word was a name. After seeing the words or nonwords a probe appeared in one of five positions to which participants were asked to respond. The results suggest that in the letter condition, where participants were asked to respond to a middle letter they were faster to respond to probes appearing in the middle position compared to probes appearing in any other letter position. However, in the word condition where participants were asked to respond to names there were no differences in response times for all probe positions. LaBerge suggests that this is an indication that the attentional spotlight can assume different widths depending on task requirements. In addition, Treisman & Schmidt (1982) suggested that features from inside an attentional focus may become combined, whereas features from outside the focus will not be confused with features within the focus of attention. Cohen & Ivry (1989) found that letters within the focus of attention were susceptible to the illusory conjunction effect regardless of how far apart they were. This finding supports the suggestion that the attentional focus can expand to accommodate stimuli of varying sizes and that features are more likely to be confused within that focus compared to features that are outside the attentional focus. More recent research suggests that the distribution of attention across words may be hemisphere specific with the left hemisphere distributing attention evenly across a letter string and the right hemisphere using a sequential processing style involving the analysis of each individual letter (Lindell et al., 2007).

Based on these ideas Prinzmetal and Millis-Wright (1984) hypothesised that the features of individual letters (i.e., colour) within a word may be confused because the attentional focus on a word is spread across the whole word. Thus if each letter in a word is presented in a different colour and the whole word is the focus of attention the specific colour of a single letter may not be perceived correctly and colours may drift between letters. However, in a nonword, because the attentional focus would only encompass a single letter, features from neighbouring letters would not migrate. In order to test their hypotheses Prinzmetal and Millis-Wright designed a modified Stroop task that required participants to identify a particular letter within a word and state its colour. If words are processed via top down activation of whole word units and the attentional focus is spread across the whole word, more illusory conjunction errors involving the migration of colour within a stimulus display (termed 'ON errors') would be expected when word stimuli are presented compared to when nonword stimuli are presented. Prinzmetal and Millis-Wright predicted that features (i.e., colour) within a nonword would not migrate because the stimulus would be processed via bottom up processes and the attentional focus would be on a single letter. However, features that were not in the stimulus display, such as colours or letters that were not included, may erroneously be reported (termed 'OFF errors'). The authors conducted five experiments that compared words (e.g., GOT) to unpronounceable nonwords (e.g., GDF) and also manipulated pronounceability, familiarity and the presence or absence of vowels. The findings from the first experiment, comparing words and nonwords, were in line with the predictions. More ON errors were found for words compared to nonwords, whereas the proportion of OFF errors was the same for both words and nonwords. The authors concluded that this effect represents a 'word inferiority effect' and is consistent with the suggestion that words are processed as units that are larger than a single letter. Furthermore, the authors argue that the colour rotations used in the experiment prevented participants from guessing the colour of the letters. For example the stimuli were always three letter words or nonwords and four different colours were used. Consequently even if a participant knew two out of the three colours presented the third letter could be in one of two colours. In addition some items were presented with each letter in a different colour but other items had two out of the three letters in the same colour. Therefore the design of the colour rotations meant that a participant could not predict the colours that would appear and if they were guessing there would be more OFF errors than ON errors.

The outcomes of Prinzmetal & Millis-Wright's (1984) first study therefore supports the view that words are processed as whole units based on lexical entries. The authors likened this finding to the word superiority effect but instead termed it a 'word inferiority effect'. The word superiority effect is assumed to be an index of top down processes such as the activation of lexical representations. Reicher (1969) and Wheeler (1970) developed a task that is often used to investigate this effect, in which a word is presented very briefly, up to around 40ms and followed by a backwards mask. Participants are subsequently presented with two letters and asked to indicate which letter was present in the previous display. For example the word WORK would be displayed and the participant asked to choose between D and K. This condition is contrasted with a nonword condition using stimuli with the letters rearranged (i.e., RKWO). Typically it is found that responses to words are more accurate when compared to responses to nonwords (e.g., McClelland & Johnston, 1977). The paradigm controls for a straightforward word bias by employing two letters in the forced choice that would form a different word if found in the same serial position (e.g., WORK/WORD). Therefore if the findings were the result of guessing it would be expected that D would be selected as often as K. The word superiority effect has been explained from the perspective of an IA model (McClelland & Rumelhart, 1981), which suggests that bidirectional excitatory connections exist between lexical and letter level processes. Consequently activation of a lexical representation can excite letter units via feedback activation as well as letter units being able to activate lexical nodes via feed forward processes. In the Reicher-Wheeler task word stimuli are presented briefly and bottom up input is therefore removed before the word can be fully processed. However, due to the activation of lexical representations letters that correspond to the active lexical representation receive a boost from feedback activation despite the lack of bottom up input. The effect is reliant on brief exposures and fewer errors are made to nonwords with longer presentations, suggesting that longer presentations allow for each of the letters in the nonword to be fully processed. Consequently this task is assumed to illustrate the effects of top down processing because with brief exposures it is not possible to process each of the letters in a display. Research conducted over the last 40 years suggests that the effect is certainly robust, however, the underlying mechanisms are still debated (see Balota et al., 2006; Grainger & Jacobs, 2005; Lazlo & Federmeier, 2007).

However, in the word superiority literature evidence of a similar effect was found for pseudowords as well as familiar words (e.g., Lazlo & Federmeier, 2007) casting doubt on the lexical locus of this effect. Pseudowords are words that are pronounceable and formed from combinations of letters that would normally be found in a given language. They are also termed nonwords because they are unfamiliar items, however, nonwords can also be letter strings that are not pronounceable. For example a nonword such as DAKE would form a pseudoword, whereas stimuli such as GHTS would be considered a nonword. Evidence of pseudoword effects in the Reicher-Wheeler task challenge the view that the locus of this effect is lexical because pseudowords do not have lexical representations and should therefore not excite letters via top down feedback. The finding of a 'pseudoword superiority effect' has therefore prompted researchers to propose alternative mechanisms to explain this phenomenon. For example Lazlo & Federmeier (2007) suggest that phonological representations of words or chunks of words may be activated by orthographically regular pseudowords, which presumably enable feedback activation to orthographic units representing the pseudoword. Grainger and Jacobs (2005) suggest that pseudowords activate lexical neighbours of familiar words. For example, a French pseudoword such as JOUDI may be misperceived as JEUDI (meaning Thursday) because the real word and pseudoword are neighbours (i.e., they have just one letter different). Grainger and Jacobs tested this idea by presenting participants with a pseudoword (e.g., JOUDI) followed by a forced choice that included letters that distinguished between the pseudoword and the real word neighbour (e.g., E and O) or were either present or absent in both the pseudoword and the real word neighbour (e.g., D and T). For example, the letter D is present in both the pseudoword and the real word neighbour whereas the letter T is not present in either stimulus. Participants should therefore be accurate in this condition, which was termed the 'target present' condition. In contrast the letter O is present in the pseudohomophone, JOUDI, but E is only present in its real word neighbour JEUDI. Therefore if the real word neighbour is accessed by the pseudohomophone participants should be less accurate in this condition, termed the 'target absent' condition. The results showed that participants were less accurate in the 'target absent' condition (57.7%) compared to the target present condition (82%). This finding suggests that the real word neighbour was accessed and interfered with processing in the target absent condition but facilitated responses in the target present condition.

Evidence from research into the pseudoword superiority effect therefore suggests a role for orthographic regularity in visual word recognition and Prinzmetal and Millis-Wright (1984) hypothesised that commonly occurring combinations of letters may form individual perceptual units. Furthermore if this is the case an illusory conjunction error should be found for pseudowords as well as words. However, if the locus of the effect is lexical more illusory conjunction errors would be expected with word stimuli compared to pseudowords. The results of the third experiment conducted by Prinzmetal and Millis-Wright showed that the proportion of ON errors made to words and pseudowords were equal with both types of stimuli producing significantly more errors compared to nonwords. Although these results suggest that orthographic regularity rather than lexicality may drive this effect, Prinzmetal and Millis-Wright considered the possibility that pronounceability may mask effects of lexicality. In other words it is possible that the lexical status of familiar words contributes to the effect but not over and above that of a pronounceable letter string. Consequently the presence of one or the other would be sufficient to obtain a word/pseudoword superiority or illusory conjunction effect. In order to test this proposal Prinzmetal & Millis-Wright conducted a fourth experiment comparing abbreviations with nonwords. Their rationale was that abbreviations are familiar, implying that they have lexical representations, but are orthographically irregular and therefore difficult to pronounce.

The abbreviations used in Prinzmetal and Millis-Wright's (1984) fourth experiment were familiar to the participants, for instance NYC (New York City) or CBS (Columbia Broadcasting System) and the nonwords employed were meaningless three letter strings such as HTU. The results showed that the percentage of trials where participants reported a non target colour that was in the display (ON error) were greater for abbreviations compared to nonwords. However, the percentage of trials on which participants reported a non target colour that was not in the display (OFF error) did not differ between abbreviations and nonwords. These findings mirrored those found for words and pseudowords and suggest that items, which are familiar and meaningful but not necessarily regular or pronounceable, are susceptible to the illusory conjunction effect. Prinzmetal and Millis-Wright concluded that items such as abbreviations, despite their lack of orthographic regularity, are also processed as a single perceptual unit, which in turn, encourages the migration of colour features between letters. In addition research using the Reicher–Wheeler task and associative priming techniques has found evidence of top down processing and lexical access for familiar abbreviations (Brysbaert et al., 2009; Lazlo & Federmeier, 2007). These findings suggest that orthographic regularity may not be as crucial as familiarity in visual word processing.

The evidence from studies of attentional focus, word superiority effects and illusory conjunctions therefore supports the notion that words may be processed as a single perceptual unit, or at least via commonly occurring letter clusters. In addition data from studies investigating abbreviations have found that they are susceptible to the illusory conjunction effect and word superiority effects, which suggests that despite a lack of orthographic regularity these items are also processed as a single perceptual unit. It may follow therefore that SMS shortcuts, which have been shown to behave very much like words (see Chapter 4), may also be susceptible to the illusory conjunction effect and if so this could provide evidence that they are processed as a single perceptual unit. The paradigm developed by Prinzmetal and Millis-Wright (1984) was therefore employed in the following experiment to investigate the extent that SMS shortcuts are processed via top down processes which would indicate that they have a lexical representation. It was predicted that more illusory conjunctions would be found to SMS shortcuts compared to unpronounceable nonwords. Word stimuli were also included in the experimental design and were expected to produce illusory conjunctions that were either equivalent to or above the proportion of errors found for SMS shortcuts.

5.2 Method

5.2.1 Participants

25 participants were recruited from Sheffield Hallam University, the majority of whom were undergraduate 1st year psychology students who received course credits for their participation with the exception of two participants who were

students from different courses. The mean age was 21 with a range of 18-55, comprising of 5 male and 20 female participants all of whom had English as their first language and were naïve of the subject of the study. All participants had no known reading difficulty and had normal or corrected-to-normal vision. Responses to a post-test questionnaire indicated that 51% of these participants sent 50 or more text messages per week, 23% sent 30-50, 21% sent 10-30 text messages and the remaining 5% sent less than 10 messages per week.

5.2.2 Design and materials

The design detailed by Prinzmetal and Millis-Wright (1984) was followed exactly with the exception that the stimuli used in the current research were SMS shortcuts instead of abbreviations. Due to the use of SMS shortcuts the words and nonwords used in this experiment were also changed, however, the length of the word and nonword stimuli was maintained.

A within-participants experimental design was employed using a modified Stroop task. There was one independent variable, stimulus type with 3 conditions, 1) SMS shortcut (*SPK;* meaning speak), 2) Word (*SON*), 3) Nonword (*KPS*). The dependent variable was the number of errors made, with critical responses being errors of the type termed illusory conjunction errors (ON errors), which involved the substitution of the target colour with another colour from the display.

The stimulus sets contained six items per condition, each of which was a three letter item with three of the six items containing the letter 'S' and three containing the letter 'W'. The critical letter (S or W) appeared in each letter position in each item with equal regularity. For example, in the SMS stimulus set the SMS shortcuts containing the letter S were *spk, jst* and *pls*, each shortcut, therefore, contained the letter S in word initial, medial and final positions. The W stimulus set contained the shortcuts *wrk, twn* and *knw*. The SMS shortcuts used were drawn from a database of shortcuts identified via an online survey (see chapter 2). The items used were selected based on frequency of occurrence and position of the target letter and only abbreviated shortcuts were used in this task because the positions of the critical letters (e.g., S or W) was matched across both shortcut and word stimuli. The word and nonword stimulus sets also were also comprised of six items, three of which contained the letter S and three the letter W. For example, in the word set the S stimuli were; *son, use* and *gas,* the W stimuli were; *win, own* and *now*. The nonwords were formed by altering the order of the letters in the SMS shortcut stimuli such that they became unpronounceable nonwords (e.g., *sjt*; see Appendix 5.1 for a full list). A filler item was used in each condition that did not contain either the letter S or W. In the SMS shortcut condition this item was a shortcut that is not commonly used, *frm,* in the word condition the word *for* was employed and *fmr* formed the nonword filler. This item was intended to make sure participants concentrated on the task and they were instructed to respond 'no' whenever the filler item appeared. Post-test questionnaires were used to test the participant's knowledge of both commonly used shortcuts and the shortcuts used in this experiment (see Appendix 2.3). The responses indicate that on average 83% of the stimuli used in this experiment were correctly identified by the participants. In addition this cohort of participants correctly identified 75% of the most commonly used shortcuts from a list of frequent shortcuts.

The stimuli were either presented with each letter in a different colour or two letters in the same colour and the third letter in a different colour. The stimuli presented with two letters in the same colour were included to avoid participants being able to use a strategy to guess the colours. The colour rotations were kept faithful to the original rotations used by Prinzmetal & Millis-Wright such that there were 12 rotations per item based on a Latin square rotation such that each colour appeared in each letter position with equal frequency. Two trials per item had the target letter in one colour and the other two letters in the same colour and 4 trials per item had the target letter in the same colour as the final letter (see Appendix 5.2). The colours were based on the original colours used by Prinzmetal and Millis-Wright (1984) and selected from the following colours; red, purple, green and brown. The colours correspond to the RGB numbers #E17381 (red), #B0A8DE (purple), #C7846D (brown) and #80BC95 (green) and as with the original colours they were pastel type colours of similar brightness and saturation[14]. In total there were 18 different colour rotations per stimuli and 18 items (6x SMS shortcut, 6x Word and 6x Nonword stimuli), 36 filler items were also used making a total of 360 trials. The trials were divided into 10 blocks with 36 items per block and the stimulus order was randomised for each participant.

The stimuli were presented using E-Prime experiment presentation software, which was run on a standard PC in an experimental room. Each letter string was displayed at a distance of 2.7cm either above or below a central fixation point on a white background. Voice onset reaction times were also recorded via a microphone attached to a serial response box. The visual presentation of each trial began with a fixation cross for 500ms followed by the stimulus for 150ms, this was then replaced by a second fixation cross that remained on screen until voice onset was detected. Once voice onset was detected a third fixation cross that was slightly larger than the second cross appeared and remained on screen until the participant pressed the space key to move onto the next trial.

5.2.3 Procedure

Participants were tested individually under the same conditions. Participants were instructed that SMS shortcuts, words and nonsense would appear on the monitor in front of them with each letter in a different colour and in each of these items the letter S or W would appear. Participants were asked to monitor the display for the letter S or W and identify the colour of the letter. They were specifically instructed to report the target letter first and then the colour. Participants were also told that occasionally items without an S or a W would appear and when this item was encountered they were told to say 'no' or 'nothing'. Responses were recorded by the experimenter and also recorded on a digital voice recorder for later analysis. Voice onset reaction time was recorded by E-Prime software via a microphone connected to a response box.

[14] These colours are also on the edge of a colour boundary and some participants therefore identified the red as pink, the purple as blue and the brown as orange. Interestingly the green was always identified as green.

Each participant was initially presented with a practice block of 36 trials. The practice block contained 12 experimental items and 3 filler items that were not used in the main experiment with 4 items in each of the SMS shortcut, word and nonword conditions and colour rotations that were equivalent to the type of colours used in the main experiment. On completion of the practice block the researcher checked that the participant was happy with the procedure and started the main experiment. Most participants completed the task, including the practice trials, in around 60 minutes.

5.2.4 Results

As the filler trials (i.e., *frm, for*) were only included to maintain focus on the task these trials were excluded from the analysis. All errors made by participants in reporting the letter or colour of the target items were coded and a total of 19 different types of error were identified (see Appendix 5.3 for a full list). As reported in previous studies letter identification errors were minimal (Lindell et al., 2007; Prinzmetal & Millis-Wright, 1984) and comprised 4% of all errors. Feature errors involving reports of features not in the stimulus display (referred to as OFF errors) comprised just 3% of all errors whereas conjunction errors (referred to as ON errors) made up 27% of all errors. The remaining errors included no response, reporting two colours or two letters and reporting a different letter and colour from the display. On a number of trials participants also initially reported the wrong letter or colour but quickly corrected themselves. As the proportions of all errors except ON errors were so small these errors along with all other error types were excluded from the analysis. Consequently only errors considered to be true conjunction errors were included in the analysis; two participants who made no conjunction errors were removed from the analysis. Table 5.1 illustrates the numbers of errors made in each of the experimental conditions.

5.2.5 ON error analysis

As the data proved to be non-parametrically distributed, due to negative skew in all conditions and an outlier in the Word condition, a related samples

Friedman's analysis of variance was conducted to compare the three experimental conditions (SMS shortcut, Words and Nonwords).

Table 5.1 Numbers and percentages of illusory conjunction errors

Experimental condition	Example	No. of conjunction errors (mean in parenthesis)	percentage of all errors
SMS shortcut	*spk*	35 (1.40)	10%
Word	*son*	34 (1.36)	9%
Nonword	*sjt*	28 (1.12)	8%

The median values in each of the conditions are 1 and the results of the inferential test clearly indicate that there are no significant differences between any of the three conditions ($X^2(2)$=1.584, N=23, *p*=.453)[15].

5.2.6 Voice onset reaction time analysis

Voice onset was also recorded to provide an indication of the extent that a traditional Stroop effect (such that naming would be delayed for words compared to nonwords) would be found in a study design such as this. The reaction time data were therefore analysed after removal of errors and a trim that eliminated any reaction times + or - 2 standard deviations away from participant means. This resulted in a total loss of 5% of data. No participants lost more than 33% of data overall. Table 5.2 details the mean reaction times for each experimental condition.

Table 5.2 Mean reaction times for voice onset data in ms (standard deviations in parenthesis)

Experimental condition	Example	Mean reaction time
SMS shortcut	*spk*	658 (192)
Word	*son*	652 (182)
Nonword	*sjt*	635 (176)

A one way repeated measures ANOVA was conducted with the experimental conditions as within participant variables (SMS shortcut, Word & Nonword) and reaction time as the dependent variable. The results of the ANOVA were significant (*F*(2,48)=4.56, *p*=.015) and post hoc *t* tests revealed that letter and

[15] Results of an ANOVA produced similar outcomes (*F*(2,48)=.37, *p*=.694)

colour naming was significantly slower for SMS shortcuts compared to nonwords ($t(24)=2.99$, $p=.006$). However, there was only a trend in the predicted direction for words, with reaction times to these stimuli being 17ms slower than nonwords ($t(24)=1.90$, $p=.070$). No significant differences were found between words and SMS shortcuts ($t<1$).

5.3 Discussion

The aim of this experiment was to test the extent that SMS shortcuts would exhibit an illusory conjunction effect that has been found for words, pseudowords and abbreviations (Prinzmetal & Millis-Wright, 1984). SMS shortcuts were therefore compared to words and nonsense letter strings using a modified Stroop task developed by Prinzmetal & Millis-Wright (1984). It was predicted that words would exhibit significantly more illusory conjunctions when compared to nonwords and if SMS shortcuts are processed like words (i.e., using a single perceptual unit) that they would also exhibit more illusory conjunctions compared to nonwords. The results showed slight differences in the number of ON errors (errors where the participant reported a colour that was not the target colour but present in the display) made to SMS shortcuts (35) and words (34) in comparison to nonsense letter strings (28). However, none of these differences resulted in a significant effect. Furthermore, in contrast to the original study conducted by Prinzmetal & Millis-Wright there were no OFF errors (i.e., reporting the correct letter but combining it with a colour not present in the display). Conversely a few participants reported the correct colour but combined it with a letter that was not in the display. However, if ON errors that were later corrected (i.e., the participant reported a colour present in the display but not the target colour and then corrected themselves) are included in the analysis a slight trend indicating that more ON errors were made to SMS shortcuts compared to nonwords emerges for SMS shortcuts ($T=24.50$, $N=25$, $p=.073$), but not for words ($T=104$, $N=25$, $p=.482$). The results of this experiment therefore do not support the findings from the original study. Even if the slight trend for SMS shortcuts to exhibit this effect was considered promising, the lack of an effect for words compared to nonwords precludes the ability to draw any conclusions regarding top down processes for words or SMS shortcuts.

A secondary analysis of naming reaction times was conducted to test the extent that a design such as this would elicit delayed naming latencies for words. Interestingly the results of this analysis show a clear effect for SMS shortcuts such that naming of target letters and colours was significantly slower when they were embedded in SMS shortcuts, but only a marginal effect for words compared to nonsense letter strings. Stroop effects are assumed to be the result of automatic top down processes (see Ehri, 2005; Frost, 1998 for a discussion) interfering with the ability to name a colour. For instance in a standard Stroop task a colour word (e.g., *blue*) is written in ink that either matches the colour word (e.g., *blue* written in blue ink) or a colour that mismatches (e.g., *blue* written in red ink). A participant is asked to name the colour of the ink rather than the word and their reaction time is recorded. Typically the results of this task demonstrate that naming in the mismatching condition is slower than in the matching condition. It is assumed that the delay in naming is caused by interference from top down processes (e.g., lexical representations) that have been automatically accessed in response to the word and affect the ability to name the colour. McWilliam, Schepman and Rodway, (2005) also conducted a modified Stroop task that employed SMS shortcuts and compared them to words, pronounceable pseudowords, nonwords and symbol strings. The stimuli were presented in one of four colours and participants were instructed to name the colour but ignore the content of the stimuli. Interestingly the results were similar to those found in the current experiment with SMS shortcuts producing latencies that were slower than all other stimuli. Furthermore, no differences in naming latencies were found for familiar words pseudowords and nonwords[16]. McWilliam et al. suggest that the larger interference exhibited by SMS shortcuts may be due to lower levels of exposure and frequency of use. In addition they suggest that the lack of differences between words and nonwords can be accounted for on the basis that all word-like stimuli will cause Stroop like interference.

These findings are a little contradictory as the reaction time data suggest that automatic top down processes do interfere with colour naming when the stimuli

[16] both pronounceable nonwords and non pronounceable nonwords.

are SMS shortcuts, however, the illusory conjunction errors did not match this pattern. These results suggest that neither words nor SMS shortcuts are being attended to as single perceptual units, or alternatively that nonwords are processed in the same way as words and SMS shortcuts. Nevertheless there is a difference in the speed of colour naming between nonwords and SMS shortcuts that may be attributable to top down processes such as lexical access. A thorough search of the literature, however, reveals that as far as this researcher is aware only one other study has employed this paradigm using words and nonwords as stimuli[17]; namely Lindell et al. (2007). Interestingly, although Lindell et al. concluded that their results provided evidence in favour of a single unit processing style for the left hemisphere, they also failed to find an illusory conjunction effect when words and nonwords were compared. In fact they found the reverse effect with significantly more ON errors made to nonwords (3.21%) compared to words (2.70%). This finding would support the suggestion that the focus of attention when processing nonwords is much the same as that found for words.

In the original study, conducted by Prinzmetal & Millis-Wright (1984), stimuli were presented just above or below a fixation point and the length of presentation was adjusted for each participant. Lindell et al. (2007) used exactly the same stimuli as Prinzmetal & Millis-Wright but the style and length of their presentation differed. They attribute their lack of a ‘word inferiority effect’ to the location of their stimuli, which was peripheral (due to the necessity to present stimuli to one hemisphere at a time) rather than foveal. According to the theory underpinning the illusory conjunction paradigm features that are within or outside the attentional focus may be incorrectly combined but features will not cross an attentional boundary (Treisman & Schmidt, 1982). Although Lindell et al. (2007) offer no further explanation as to why a peripheral display may have affected their outcomes it could be suggested that this display may affect the degree to which the attentional spotlight can be focused on the stimuli. However, Prinzmetal et al. (1986) used a peripheral presentation of stimuli and found that

[17] A number of studies that employ the illusory conjunction task exist but none of them compare words with nonwords.

illusory conjunction errors were made regardless of whether attention was directed towards the stimuli or not. Consequently it may be assumed that a peripheral presentation should not prevent the incidence of illusory conjunctions. In addition neither Lindell et al. nor the current experiment adjusted the duration of the stimulus display for each participant. In contrast Prinzmetal and Millis-Wright adjusted the length of time stimuli were displayed in line with each participant's performance to maintain a certain level of error. In both the current experiment and that of Lindell et al. the stimulus display was uniform for each participant. On average the stimuli in the original Prinzmetal study were displayed for 168ms, consequently in the experiment reported here stimuli were presented for 150ms and Lindell et al. displayed stimuli for 119ms. It is possible therefore that the duration of the display allowed participants in this experiment and that of Lindell et al. sufficient time to correctly combine the features of letters in the word stimuli such that they did not make illusory conjunction errors.

Much of the literature investigating the illusory conjunction effect has presented stimuli using limited exposure durations and tasks designed to load attentional processing (e.g., Easterman, Prinzmetal & Robertson, 2004; Ivry & Prinzmetal, 1991; Prinzmetal, Henderson & Ivry,1995). It could be suggested that the illusory conjunction effect therefore relies on an environment where attentional processing is heavily loaded and stimuli are only just perceived. Prinzmetal et al. (1995) conducted a study to investigate the extent that attention and duration of exposure affect illusory conjunctions. In a series of experiments they manipulated stimuli exposure and attentional load by varying exposure durations between 1500ms and 9ms and asking participants to conduct a secondary task or not. The stimuli were presented peripherally and consisted of just two letters, one of these letters was always an 'O' the other letter could be an X, T, or L. The letters were flanked by a 0 on each side and were always in combinations of red, green and blue (i.e., 0XO0). In the first experiment participants were presented with a distracter task consisting of the rapid display of 30 digits at fixation, which they had to respond to by pressing a button whenever a 0 appeared. During this task the critical stimuli were displayed for 1500ms in peripheral vision. In the second experiment the stimuli were displayed for 1500ms and the same participants either conducted the secondary task or did not and in experiment 3 the stimulus display was varied to be either 1500ms or 9ms and no secondary task was performed. The authors found that regardless of stimulus display duration, or the completion of a secondary task, illusory conjunction errors were still made and the percentages of those errors did not dramatically differ between conditions[18]. It would appear therefore that lengthening the stimulus display and holding it constant for each participant does not affect the incidence of illusory conjunction errors. However, in each of these tasks the degree of eccentricity with which the stimuli were displayed was adjusted for each participant. In other words the position of the stimuli was adjusted outwards from the centre of the screen until participants were only 75% accurate. Furthermore Prinzmetal et al. report that the eccentricities used in experiments 2 and 3 differed significantly between conditions such that the stimuli were presented closer to the centre of the screen when a secondary task was being completed or display durations were shorter. The results were therefore only obtained from a trade-off between eccentricity and display duration or eccentricity and secondary task. This suggests that in order to obtain illusory conjunction effects some element of the stimulus display must make it difficult to perceive, be that duration of display, position of stimuli or attentional load and it may be vital to tailor at least one of these elements to each individual in order to achieve this aim.

The theoretical underpinnings of the illusory conjunction effect as outlined by Prinzmetal & Millis-Wright (1984) suggest that the features of an object or letter may become erroneously combined if they are within a perceptual unit. Thus the finding that nonwords resulted in more illusory conjunction errors compared to words in the study conducted by Lindell et al. (2007) suggests that the nonwords were processed as a perceptual unit. Accordingly the results of the current study suggest that either words, nonwords and SMS shortcuts were all

[18] In experiment 1 a mean of 17% of ON errors and 6% OFF errors were made. In experiment 2 the condition without a secondary task resulted in a mean of 15% ON errors which is compared to a mean of 10% all other errors, the condition with a secondary task resulted in a mean of 14% of ON errors and a mean of 11% all other errors. Finally in experiment 3 a mean of 18% ON errors were made in the 90ms condition compared to a mean of 19% ON errors in the 9ms condition. It should be noted, however, that Prinzmetal et al (1995) do not report any statistical probabilities for these percentages.

processed via a perceptual unit or none of them were. These results resonate with those of McWilliam et al. (2009) who suggest that a lack of differences between words, pseudowords and nonwords in naming latencies found in a Stroop task may be due to the fact that all word-like stimuli will exhibit Stroop like interference. In addition, evidence from word and pseudoword superiority effects suggests that both familiar and unfamiliar stimuli may be processed via lexical activation or clusters of orthographically regular letters. In line with these findings illusory conjunction errors are also found for nonwords, although greater effects are found for words and pseudowords. In the word superiority effect paradigm correct identification of the target word is often above 50% for nonwords (Chase & Tallal, 1990; Coch & Mitra, 2010; McClelland & Johnston 1977). In the experiments presented by Prinzmetal & Millis-Wright there is an average of 36% of conjunction errors made to nonwords[19]. In the experiment reported here 29% of all conjunction errors were made to nonwords and Lindell et al. (2007) found that more errors were made to nonwords compared to words. Theoretically the rapid presentation of stimuli in the Reicher-Wheeler task precludes the processing of each letter serially and this produces poorer performance with nonwords compared to words. In tasks designed to elicit conjunction errors, however, the mechanisms underlying differences found between words and nonwords are unclear. If the mechanism that produces illusory conjunctions in words is assumed to be the result of an attentional spotlight falling across the entire word and a lack of the illusion in nonwords the result of the attentional spotlight falling on individual letters, it should be difficult to obtain the illusion in nonwords. However, nonwords and pseudowords have been found to exhibit fairly large percentages of errors in data from both the illusory conjunction paradigm and pseudoword superiority tasks as well as displaying similar latencies to words in a Stroop task (e.g., McWilliam et al. 2009). It seems likely therefore that the illusory conjunction effect will occur in any stimulus containing two features where a lack of sufficient time, perception or attentional resources may prevent features being combined correctly, regardless of lexical status.

[19] Calculated by taking the percentage of conjunction errors to nonwords from the total no. of conjunction errors and averaging them across 4 experiments.

In later studies Prinzmetal suggests that correct identification of the location of different features rather than attentional focus is vital for correct feature combination (Prinzmetal & Keysar, 1989; Prinzmetal et al., 1995). This revision of the mechanisms underlying the effect assumes that colour and identity features are initially coded separately but that there is a degree of uncertainty concerning the locations of each feature. However, the findings from the superiority effect suggest that information regarding the location of letters within words is highly specified. It would therefore be expected that spatial awareness for letter locations in word stimuli as compared to nonword stimuli would be accurate, even if the stimulus display precluded full processing of the word. Presumably therefore top down processes would be able to activate the letters within a perceptual unit but not facilitate information regarding the location of different colours within that unit. Thus the location of letters in word stimuli would be correctly identified but colour may be less efficiently encoded and result in conjunction errors. Nonwords would not activate perceptual units therefore in conditions where the stimulus display precluded full processing of the location of items, information concerning letters and colours may be missing. As a consequence it would be predicted that more misperceptions of letter identity as well as colour would be made to nonwords compared to words. However, Prinzmetal & Millis-Wright did not find that more letter or feature errors (e.g., OFF errors) were made to nonwords compared to words. Furthermore identification of the target letter for all types of stimuli was highly accurate in the current experiment, original study and that reported by Lindell et al. (2007). Letter location information therefore seems unaffected regardless of lexicality or orthographic regularity of the stimuli and only colour information appears to be misperceived. It seems unclear therefore how theories of feature integration interact with visual word processing. The theory of an attentional spotlight (e.g., Treisman & Schmidt, 1992) and the proposal that poor location information are at the root of the illusion can account for a larger effect being found in words compared to nonwords. However, theories of an attentional spotlight cannot account for the effect in nonwords and poor location information does not result in more letter identity errors to nonwords. Although manipulations of lexicality, pronounceability, orthographic regularity and syllable boundaries have been used to illustrate how linguistic properties affect the illusion, evidence of a robust effect for meaningless letter strings coupled with the lack of a statistically significant effect in the current experiment suggests caution should be exerted in the interpretation of these findings.

Finally, perhaps the most obvious criticism to be made of research using the illusory conjunction paradigm is that the effect could be the result of guesswork (Butler & Morrison, 1984; Donk, 1999). Prinzmetal et al. (1995) developed three mathematical models to test the extent to which their results may be produced by guesswork, two of these models assume that illusory conjunctions do not occur and that errors are the result of guessing and the third model allows for the notion that illusory conjunctions do occur. The authors find that the third model fits their data more closely than either of the first two models with the exception of data from one participant who made no conjunction errors. The paradigm reported in the current experiment controlled for guessing by using unpredictable rotations of colours presented randomly thus preventing participants from employing strategies. It therefore seems unlikely that the errors made in this paradigm are the result of guesswork. However, a further criticism of the paradigm is the suggestion that features may migrate over time as well as space. In a task that presents a sequence of characters one at a time using the rapid serial visual presentation (RSVP) paradigm it was demonstrated that illusory conjunction type errors could appear between different presentations (Keele, Cohen, Ivry, Liotti & Yee, 1988). In this paradigm single letters in different colours were rapidly displayed above and below a fixation point. Occasionally a single digit appeared and participants were instructed to report the colour of the digit. On occasion the wrong colour was reported for the digit and this colour came from a previous display. The authors suggest that features which appear in the same location but at different times may therefore become conjoined. More recently Botella, Narvaez, Suero & Julola, (2007) investigated the likelihood that on trials where focal attention fails to integrate information contained in the stimuli any available feature information may be used to generate a response, including information from previous trials. The authors conclude that features from previous trials can remain active and be used as the basis for 'sophisticated guesses' thus when a colour is misreported it could be the result of a pure guess, a sophisticated guess or an illusory conjunction. The design of the paradigm reported here and used by Prinzmetal & Millis-Wright involves the rapid display of the same stimuli repeatedly in the same locations but in a number of different colour combinations. It is therefore possible that illusory conjunctions could occur not just within a single display but participants could be carrying colour information across from a previous display. If this was shown to be the case it would question the assumption that such effects can be used to inform our understanding of visual word recognition.

In conclusion the results reported here suggest that the same percentage of illusory conjunction errors are made to words, SMS shortcuts and nonwords and do not support the findings from Prinzmetal & Millis-Wright (1984). In addition, the results of the current study do not support the finding that more errors are made to nonwords compared to words (Lindell et al., 2007). Conversely delayed naming latencies were observed for SMS shortcuts, supporting previous literature, which has found Stroop-like interference effects for SMS shortcuts (McWilliam et al. 2009). It could be argued that differences in the stimulus display may be the cause of the lack of illusory conjunctions in both the results found here and Lindell et al. However, the nature of illusory conjunctions has yet to be fully resolved and the extent to which these effects can be used to inform aspects of visual word recognition are therefore questionable. Future research is required to establish the exact nature of the illusory conjunction effect and investigate the possibility that a presentation style equivalent to the original Prinzmetal studies would produce comparable effects.

Chapter 6 Hw dyu txt? Phonological priming is real for SMS shortcuts too.

6.1 Introduction

Although theories of visual word recognition agree that words are recognised via activation of orthographic and phonological mental representations, a debate has been ongoing in the literature concerning the relative contributions of phonological and orthographic pathways. The research presented in this thesis has explored whether two specific styles of shortcut that have an intrinsic bias towards orthography (e.g., *txt*) or phonology (e.g., *l8r*) exhibit different effects in a lexical decision task. The results show that no differences were found (see Chapter 4), which does not support the suggestion that orthographic processes dominate visual word recognition (e.g., Coltheart et al., 2001; Dimitropoulou et al., 2011a; 2011b). In contrast, strong phonological theorists (e.g., Frost, 1998; Van Orden et al., 1990) propose that visual word stimuli are processed via phonological mediation which leads to the prediction that SMS shortcuts would be processed via this route regardless of the phonological information that they convey. Previous literature using the phonological priming paradigm has demonstrated that phonological codes can be rapidly activated and influence target processing (see Chapter 1 and Drieghe & Brysbaert, 2002; Ferrand & Grainger, 1993; Hino et al., 2003; Lukatela et al.,1998; Rastle & Brysbaert, 2006). Thus the aim of the current experiment is to test the assertion of strong phonological theorists that visual word stimuli will be processed via phonological mediation.

In the following experiment masked pseudohomophone primes will be paired with SMS shortcut targets (e.g., *mait-M8*) to investigate the extent that the phonological representation associated with a shortcut can facilitate shortcut processing. Pseudohomophones are designed to reflect the phonology of a word with as little orthographic overlap as possible (e.g., *groe-GROW*). However, as both prime and target are often presented in the same script phonological priming studies could be criticised on the grounds that the prime and target share a large amount of orthography (e.g., *mait* and *MATE* share 3 graphemes and this amount of overlap is quite typical). The current experiment therefore has the advantage that due to the unusual orthography of shortcuts, using these items as targets reduces the amount of orthographic overlap between prime and target (e.g., *mait* and *M8* only share 1 grapheme). Consequently if phonological priming effects are observed for SMS shortcut targets that have been preceded by pseudohomophone primes this should reflect activation of phonology and not orthography. Such a finding would support the assumptions of strong phonological theorists

The idea that the sound of a word can affect the visual recognition of that word has been considered highly contentious. Van Orden (1987) stated that the claim that phonology has a role to play in visual word recognition "has been repeatedly both affirmed and denied" (p.181). Early dual access theories of visual word recognition proposed that dual routes based on orthographic and phonological processing both contribute to visual word recognition but were divided between those who assumed that phonology was not activated during skilled silent reading (e.g., Coltheart et al., 2001) and those who proposed that orthography and phonology were activated simultaneously (e.g., Seidenberg & McClelland, 1989; van Orden, 1987). In 2004 Harm and Seidenberg attempted to resolve the issue by implementing a version of a parallel distributed processing (PDP) model that not only translated print to sound, but also print to meaning in a way that is comparable to the 'direct access' provided by the lexical route proposed by Coltheart et al. (see Chapter 1). Harm and Seidenberg found that a model with the properties of both routes produced the best fit to behavioural data. However, the architecture through which this was achieved is quite distinct to that proposed by models such as the DRC model (Coltheart et al., 2001; Rastle & Coltheart, 1994).

The DRC model has two discrete routes, one lexical route involving whole word representations in a mental lexicon and the other non-lexical route that converts graphemes into phonemes. Coltheart et al. (2001) opposed the idea that these two routes compete with each other and instead suggested that both routes contribute to reading out loud. However, whereas the lexical route provides activation to output phonemes from all letters simultaneously, the non-lexical route assembles phonology and therefore proceeds more slowly from left to right. In practice this means that a word is likely to be uttered before the non-lexical route has finished assembling phonology; leading to the conclusion that a route offering direct access to an orthographic lexicon will result in faster naming and presumably recognition compared to the non-lexical route. Harm & Seidenberg, (2004) however, propose that the phonological and direct access pathways cooperate and are dependent on each other. A further distinction between the two models is that whereas phonological assembly via the non-lexical route in the DRC model is a serial process, phonological mediation in the PDP model operates in parallel and is as rapid as orthographic processing. Thus rapid activation of phonology, which is a function of a PDP model, can account for the findings from phonological priming experiments that suggest phonology can be rapidly assembled during silent reading.

Behavioural evidence for the activation of phonology in silent reading has been demonstrated using tasks such as semantic categorisation tasks (Cho & Chen, 1999; van Orden, 1987) and masked phonological priming (Ferrand & Grainger, 1994; 1996; Hino et al., 2003; Lukatela et al., 1998; Rastle & Brysbaert, 2006). A frequently cited early example of phonological priming was conducted by Lukatela et al. (1998) who showed that when priming the target word CLIP, a pseudohomophone condition *klip*, produced a stronger priming effect than a rhyme condition *plip*. Furthermore in their final experiment a very short prime duration of 29ms was employed and priming effects were still observed from the pseudohomophone condition. This suggests (as indicated in Chapter 3) that phonological mediation can occur rapidly. The authors concluded that as *klip* is a more efficient prime for CLIP than *plip,* phonological, rather than orthographic overlap, mediated the lexical decision. Ferrand & Grainger (1992) found further evidence of phonological priming in French using pseudohomophones such as *lont* as the prime stimuli for a target word LONG. Although the orthography of the prime and target differ both would be pronounced the same in French. This condition was compared to an orthographic control prime such as *lonc,* which has the same amount of orthographic overlap with the target as the pseudohomophone but would be pronounced differently. Although these studies demonstrated larger priming effects for pseudohomophone prime stimuli over orthographic control stimuli, both types of prime still share a large amount of orthographic overlap with the target. For instance the pseudohomophone *lont* shares three graphemes with the target LONG and if it is assumed that *lon* activates all words in the lexicon beginning with the letters *L, O* and *N* it is difficult to conclude that a speeded response to the target word is the result of phonological activation alone. The orthographic control stimuli therefore provide a measure of how much facilitation is afforded by orthographic overlap. For example the control prime *lonc* also shares the same three initial graphemes with the target LONG as the pseudohomophone *lont*. If priming advantages are mediated by orthographic activation this condition should demonstrate a priming advantage that is comparable to the pseudohomophone. Thus allowing for the assumption that any priming seen over and above the control condition is the result of phonological processing. However, priming advantages for pseudohomophones are likely to benefit from a combination of orthographic *and* phonological mediation, which may produce greater facilitation than either route alone. Lukatela et al. (1998) suggest that an additive effect of orthographic similarity may increase priming effects seen for prime and target stimuli that have identical phonology. In support of this suggestion Grainger and Ferrand (1994) found that orthographically similar homophones (e.g., *fois-FOIE*) produced greater priming compared to homophones that are orthographically dissimilar (e.g., *quand-CAMP*). These results suggest that the increase in orthographic overlap produced larger priming effects leading Ferrand and Grainger to conclude that both orthographic and phonological pathways mediate in lexical decisions.

In an attempt to counter the problem of orthographic overlap and isolate phonological effects, researchers have exploited natural distinctions that exist between orthography and phonology in logographic languages. The advantage with using logograms, such as Chinese characters, is that homophonic characters can be found that do not overlap orthographically. For example the character for the number 5 (号) and the character for midday (午) are both pronounced */wu/* but are orthographically distinct and a character such as 牛, meaning cow, which is orthographically similar but pronounced differently */niu/* can be used as the control stimuli. Thus in a task where 午 (meaning midday) is used as the target stimuli, priming advantages found following phonologically similar but orthographically different characters (e.g., 号) can be compared to latencies following orthographically similar but phonologically different prime stimuli (e.g., 牛). Shen and Forster (1999) conducted a study using Chinese characters in this way and found that both the homophonic pair and orthographically similar characters produced a priming effect in a primed naming task, but in a lexical decision task only the orthographically similar primes produced an effect. Shen & Forster (1999) concluded that the evidence from the naming task suggests that phonological mediation is possible for logographic characters, but the lack of phonological priming effects in the lexical decision task suggests that phonology may only be activated if the task requires articulation.

However, the results from Shen and Forster (1999) stand in contrast to priming studies that have found evidence of phonological priming using a lexical decision task with prime and target stimuli written in two different scripts (cross script priming). For instance Lukatela, Carello and Turvey (1990) conducted a lexical decision task in Serbo-Croatian, which can be written using a Roman or Cyrillic script. They found that real word homophone prime target pairs produced inhibitory effects whereas pseudohomophone primes facilitated word recognition. This suggests that the effects observed by Shen and Forster may be specific to logographic characters which both have meaning. For example, a homophonic character pair such as those used by Shen and Forster would be similar to cross script homophonic word pairs in that both primes and targets share phonology but not orthography or semantics. Therefore activation at a semantic level could reduce the influence of phonology by disambiguating the prime stimuli before a response is made to the target. Alternatively if viewed from the perspective of an IA model inhibition between lexical representations could inhibit target processing for word targets preceded by word primes (see Davis, 2003; Davis & Lupker, 2006; Chapter 3 for a discussion of lexical inhibition). In contrast pseudohomophones do not have lexical representations, which results in facilitation rather than inhibition. However, it might be expected that both the homophonic and the orthographically similar characters would inhibit target processing since both types of character have meanings that are distinct from the target stimuli, unless the orthographically similar character was mistaken for the target character. Cho and Chen (1999) suggested that this might be the case in an experiment they conducted to test phonological processing using Chinese character stimuli. In other words it is possible that because the visually similar characters used by Shen and Forster (1999) were extremely similar they may have been misidentified, resulting in this condition being analogous to an identity priming condition.

Chen, Tamaoka & Vaid, (2007) further investigated the lack of priming found from homophonic logographic pairs using the Japanese language, which can be written in 3 different scripts. Japanese uses Chinese characters, known as kanji (e.g. 牛) as well as two syllabic alphabets known as hiragana (e.g. うし) and katakana (e.g., ウシ). In their first experiment Chen et al. preceded kanji targets (e.g., 展示 */tenji/* meaning 'display') with homophonic kanji primes that were not semantically related (e.g., 点字 */tenji/* meaning 'braille') or semantically related kanji primes that were not homophonic (e.g., 陳列 */chinritsu/* meaning 'display') and unrelated primes. The results replicated those of Shen and Forster (1999) and showed that no priming advantages were observed for the homophonic kanji pairs. However, semantic priming was observed with prime durations of 85ms and 150ms. In a second experiment exactly the same conditions were employed except the prime stimuli were constructed using hiragana transcripts of the kanji words used in the previous experiment (e.g., てんじ - 展示). In contrast to the first study homophonic priming advantages were found in the second experiment and at both prime durations (85ms and 150ms) whereas semantic priming was only observed at the longer prime duration. These results suggest that logographs may be processed differently to alphabetic or syllabic scripts and rely more heavily on direct access to meaning than phonological activation.

However, Hino et al. (2003) demonstrated that phonology may influence processing of logographs by using kanji and katakana scripts and reversing the priming direction so that kanji characters were used as the prime stimuli. Traditionally the katakana script is used to represent words in Japanese that have been borrowed from another language (loan words), whereas kanji and hiragana are used to write traditional Japanese words. Hiragana can be used to write any words but is often used to inflect verbs and for this reason Hino et al. decided to use the katakana script. As katakana has a more restricted use, compared to hiragana, using this script allows for stimuli that are more like pseudohomophones to be created, but with the advantage that there is no orthographic overlap. In a masked lexical decision task with prime durations of 32ms kanji primes (i.e., 会話 */kaiwa/* meaning conversation) were paired with katakana target words that shared phonology but not orthography (i.e., カイワ */kaiwa/*) and the reverse priming direction was also used. Priming advantages were found in all conditions but they were larger for kanji primes paired with katakana targets (e.g., 会話—カイワ) compared to katakana primes with kanji targets (e.g., カイワ—会話). The authors suggest that cross script priming occurs due to the activation of shared phonological units and therefore evidence of priming effects from kanji primes to katakana targets suggests that phonology may be activated during the reading of logographs because the katakana targets would not be expected to have a lexical representation.

Taken together, these findings suggest that phonological priming effects are found for non-word primes with phonologically related word targets regardless of the amount of shared orthography. However, if both prime and target are familiar words (or logographs) that do not share meaning but are phonologically related inhibition rather than facilitation is found despite phonological overlap (Chen et al., 2007; Lukatela et al., 1990; Shen and Forster, 1999). This finding resonates with research investigating orthographic form priming effects from familiar words and non-words demonstrating that familiar words inhibit target processing even though they share orthography (see Chapter 3; Davis & Lupker, 2006; Pastizzo & Feldman, 2009). In contrast if the prime and target share semantics as well as phonology but not orthography priming effects are found. For example, Kim & Davis (2002) presented prime stimuli in a Korean alphabetic script and targets in their equivalent Chinese characters (e.g. 강-江 */kang/* meaning 'cove') and demonstrated that these items produced a robust priming effect compared to control stimuli. In a similar vein SMS shortcuts share semantics and phonology with their base-words but have differing degrees of orthographic overlap. The evidence from Chapter 4 suggests that SMS shortcuts facilitate processing of their base-words and vice versa regardless of orthographic overlap. In other words abbreviated shortcuts (e.g., *txt*) facilitate processing of base-word targets to the same extent as letter-digit shortcuts (e.g., *l8r*). Although abbreviated shortcuts share a larger amount of orthography with their base-words, letter-digit shortcuts are visually distinct and could be likened to cross script primes. It is possible therefore that the priming advantage seen for these items in Chapter 4 was phonologically mediated. However, it seems less likely that abbreviated shortcuts are processed via phonology due to the impoverished phonological information that they convey. The priming effects found in Chapter 4 would therefore support the suggestion that either abbreviated shortcuts are mediated via an orthographically dominated route and letter-digit shortcuts by a phonological route or both routes contribute to processing. In contrast strong phonological theorists would assume that both types of shortcut are mediated via a phonological pathway. As it is not possible to tease these mechanisms apart from the previous experiments the current experiment employs a phonological priming paradigm with a masked primed lexical decision task to investigate the question of whether processing of either or both types of SMS shortcut can be mediated by phonology.

In the following experiment pseudohomophone primes, formed to reflect the phonology of an SMS base word (i.e., *laita-LATER*) are used as prime stimuli with SMS shortcut targets (e.g., *laita-L8R*) and compared to graphemic controls (e.g., *laute-L8R*), identity primes (e.g., *l8r-L8R*) and neutral primes (e.g., *%%%-L8R*). If letter-digit shortcuts are processed phonologically, larger priming advantages would be expected for these shortcuts preceded by a pseudohomophone prime compared to abbreviated SMS shortcuts. However if both types of shortcut can be processed via phonological mediation no differences would be expected. Conversely if neither type of shortcut can be processed via phonological mediation no priming advantages would be expected.

6.2 Method

6.2.1 Participants

40 participants were recruited from Sheffield Hallam University, 21 were undergraduate 1st year psychology students who received course credits for their participation the remainder were postgraduate psychology students or students from other disciplines. The mean age was 25 with a range of 18-60, comprising of 6 male and 32 female participants all of whom had English as their first language and were naïve to the subject of the study. All participants had no known reading difficulty and had normal or corrected-to-normal vision.

6.2.2 Design and materials

A within-participants experimental design was employed using a forward masked lexical decision task. There were two independent variables: 1) SMS type with 2 conditions; Abbreviated and Letter-digit SMS shortcuts; and 2) Prime type with 4 conditions; SMS shortcut (*txt-TXT)*; Pseudohomophone (*tekst-TXT*); Graphemic control (*tegst-TXT*) and baseline (*%%-TXT*). The dependent variable was the lexical decision latency to an SMS shortcut target measured in milliseconds.

The target shortcuts used were 36 SMS shortcuts identified via an online survey that asked respondents to list shortcuts that they currently use (see Chapter 2). Frequency of occurrence was calculated from the survey and the highest scoring single word shortcuts that conformed to the format of the abbreviated (*txt*) or letter-digit (*l8r*) SMS shortcuts were selected for use in this experiment. Half of the SMS shortcuts were abbreviated shortcuts (i.e., *txt*) and the remaining half letter-digit shortcuts (i.e., *l8r*). Each shortcut was combined with a prime from each of the four conditions making a total of 144 experimental trials. An equivalent number of filler trials were created, by re-ordering the letters and digits used in the real SMS shortcuts to make 'nonsense' shortcuts that did not represent an existing English word (i.e., *ya2d*). Each 'nonsense' shortcut was combined with prime stimuli that matched the conditions of the experimental trials. As one set of 36 filler trials was used for all experimental blocks the non-words were not primed by an equivalent number of primes from each of the experimental conditions, however, an even number of each prime condition was created to remain consistent with the experimental trials (see Appendix 6.1).

In order to reduce the chance that form priming would confound the results the pseudohomophone stimuli were designed to limit orthographic overlap between the prime and target and also between the prime and base-word orthography. For example the pseudohomophone *werc,* designed to reflect the phonology of the base word *work,* only has 2 graphemes overlapping with both the base word and the target shortcut *wrk*. Thus the overlap between pseudohomophone, target shortcuts and base word orthography was kept to a minimum. Harm & Seidenberg's (2004) simulation of pseudohomophone processing suggests that pseudohomophones with a small neighbourhood density and orthographic structure that is close to their base-words may activate a direct route from orthography to semantics rather than encourage phonological processing. Thus as a number of the base-words for the shortcuts used in this study have small neighbourhoods it was imperative to reduce orthographic overlap between prime, target and base word. The graphemic control stimuli were developed to control for any remaining shared orthographic overlap between pseudohomophone prime and target stimuli. For example *warc* was the graphemic control for the pseudohomophone *werc* used in the prime-target pair *werc-WRK*. The *W* and *R* overlaped between the pseudohomophone (*werc*), graphemic control (*warc*), SMS shortcut (*WRK*) and the base-word (*work*). In addition the relative position of the overlapping graphemes was kept as faithful as possible across all prime stimuli whereas the vowel changed to distinguish graphemic controls from pseudohomophones.

The experimental and non-word trials were combined to make four different lists of stimuli where each target appeared once. Each version comprised 72 trials with 36 experimental trials ('yes' responses) and 36 filler trials ('no' responses). The 72 trials were divided into two blocks of 36 and randomly ordered to control for practice and order effects. Each block of 36 trials contained an even number of experimental and filler trials and an equal number of experimental trials from each condition. Each participant experienced an equal number of 'yes' and 'no' responses and an identical number of trials from each of the four conditions without seeing a target item more than once.

All blocks began with a filler trial to give the participant time to settle into making a response and no more than three trials that required the same response were presented in a row. Prime stimuli with the same onsets, if in the same block, were separated to allow at least three trials to occur in between each one. Prime stimuli that could be considered neighbours such as *l8* (*late*) and *m8* (*mate*) were also separated by at least 3 trials in order to control for form priming across trials. The order of the two blocks in each group was randomised using a pseudo Latin square design to create two different versions of each of the four stimuli lists, making a total of 8 different versions of the experiment.

6.2.3 Procedure

Participants were tested individually under the same conditions. Participants were instructed that SMS shortcuts would appear on the monitor in front of them and they should use the response box to indicate whether they thought the shortcut was a real shortcut or 'nonsense'. The target stimuli remained on screen until the participant made a decision. The buttons on the response box were clearly labelled, with the 'no' response operated by the left hand and 'yes' response operated by the right hand. Participants were asked to respond as accurately and quickly as possible.

The visual presentation of each trial proceeded in the following order; forward mask for 500ms followed by the prime stimulus for 57ms and immediately following this the target was presented until the participant selected 'YES' or 'NO' as part of the lexical decision task. Forward masks consisted of a row of hash marks (#####). Primes were presented in lower case in Courier New type font, point size 18 and targets in upper case. The experiment was controlled using E-Prime experiment presentation software, which was run on a standard PC in an experimental room. The PC was connected to an Ilyama MM904UT CRT monitor with an 85hz refresh rate. Lexical decision response latencies were recorded via a push button response box.

Each participant was initially presented with a practice block of 18 trials. The practice block contained 9 experimental trials ('yes' responses) and 9 filler trials ('no' responses) that were not used in the main experiment. The practice trials were randomly ordered in exactly the same way as a block of trials within the main experiment and feedback ('correct' or 'incorrect') was provided for the practice block only. On completion of the practice block, providing a considerable number of errors were not made, the researcher checked that the participant was happy with the procedure and started the main experiment. Most participants completed the task, including the practice trials, in less than 10 minutes.

On completion of the E-Prime task participants were asked to fill in a questionnaire that was designed to provide an indication of their knowledge of SMS shortcuts (see Appendix 2.3). The responses show that comprehension levels were high with each participant correctly identifying an average of 73% of the shortcuts used in this experiment.

6.2.4 Results

Lexical decision latencies were analysed using SPSS. A global trim eliminating reaction times less than 300ms and greater than 1500ms was conducted in order to eliminate participants with reaction times that were exceptionally slow. In addition the data from each participant was subjected to a trim that eliminated reaction times + or – 2 standard deviations away from participant and item means (see Rastle & Brysbaert, 2006 for a similar procedure). Errors were removed from the analysis and any participants who lost more than 33% of their data overall or more than 50% of the values from any individual condition were omitted. Nine participants were removed from the analysis, due to data loss, leaving 31 participants in total. An analysis of the means for each item revealed that seven of the SMS shortcuts also lost a considerable amount of data and the following items were removed from the analysis; *nt* (not), *spk* (speak), *hw* (how), *wt* (what), *nw* (now), *d8* (date) & *in2* (into). As a result 8% of data was excluded due to error and 15% due to trimming making a total of 23% of data overall. Table 6.1 and figure 6.1 presents means and standard deviations for each experimental condition.

Table 6.1 Means and Standard deviations for latencies (in ms) in each experimental condition

Prime type Example	Mean (SD)	Priming advantage (compared to baseline)	Percentage of errors
Abbreviated			
Identity primes (pls – PLS)	738 (139)	50	1.61
Pseudohomophone (pliez - PLS)	754 (129)	34	2.44
Graphemic control (plaif - PLS)	791 (139)	-3	5.13
Baseline (%%% - PLS)	788 (182)		6.96
Letter-digit			
Identity primes (gr8 - GR8)	739 (132)	61	0
Pseudohomophone (grait - GR8)	746 (109)	54	0
Graphemic control (graot - GR8)	802 (147)	-2	1.92
Baseline (%%% - GR8)	800 (166)		3.23

Separate analyses were conducted on the subject (F_1) and item (F_2) means. A repeated measures 2x (SMS type; Abbreviated or Letter-digit) 4 (Prime type; Identity, Pseudohomophone, Graphemic control or Baseline) ANOVA was run with reaction time as the dependent variable. The results of the ANOVA show that there was a significant main effect of Prime type only ($F_{(1)}(3,90)=5.30$, $p=.002$, $F_{(2)}(3,81)=2.91$, $p=.040$). Neither the main effect of SMS type ($F_{(1)}<1$; $F_{(2)}<1$) nor the interaction between SMS type and prime type reached significance ($F_{(1)}$<1; $F_{(2)}$<1). These results suggest that no differences in lexical decision latencies were observed for either type of SMS shortcut but differences between the prime types did emerge.

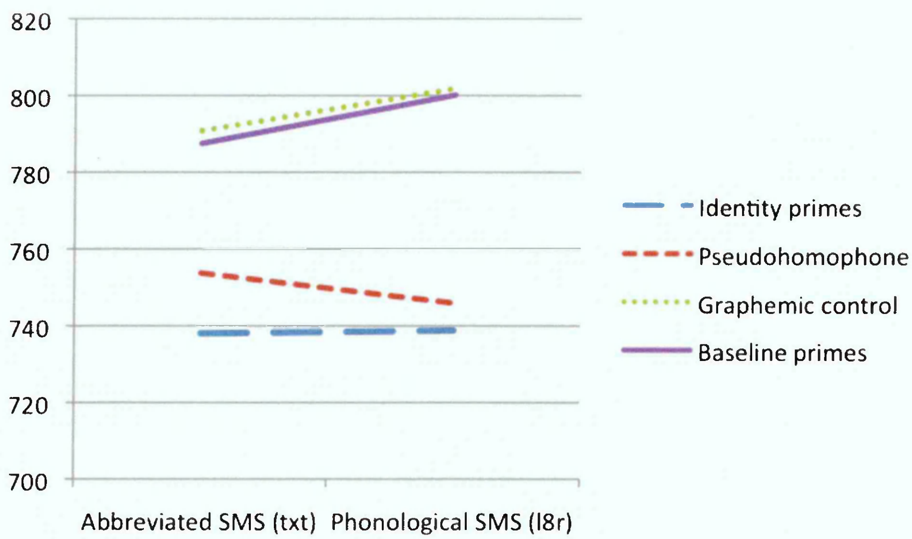

Figure 6.1 Graphical depiction of mean values for abbreviated and phonological types of shortcut in each priming condition.

Post hoc *t* tests were conducted with the data collapsed across SMS type to investigate the main effect of prime type. It was found that identity primes were responded to significantly faster than baseline primes ($t_{(1)}(30)=2.58$, $p=.015$, $t_{(2)}(28)=2.26$, $p=.032$) and pseudohomophone primes produced significantly faster latencies compared to graphemic control primes ($t_{(1)}(30)=2.78$, $p=.009$, $t_{(2)}(28)=2.12$, $p=.044$). Furthermore identity primes and pseudohomophone primes produced equivalent priming advantages (all *t*'s <1) and graphemic controls performed no better than baseline primes (all *t*'s <1).

6.2.4.1 Error analysis.

In addition to the analysis conducted on reaction time data an errors analysis was conducted. Repeated measures 2x (SMS type; Abbreviated or Letter-digit) 4 (Prime type; Identity, Pseudohomophone, Graphemic control or Baseline) ANOVAs were run for both subjects and items. The results of this analysis yielded a significant main effect of shortcut type in the subjects but not the items analysis ($F_{(1)}(1,13)=6.87$, $p=.021$, $F_{(2)}$<1). The means indicate that in the subjects analysis more errors were made to abbreviated stimuli (M=.339) compared to phonological stimuli (M=.143), however, for the items analysis both types of shortcut resulted in similar mean scores (abbreviated M=.679 and letter-digit M=.600).

These results suggest that participants in this experiment were less able to correctly identify the abbreviated style of shortcut compared to the letter-digit shortcuts. It is possible that this is the result of letter-digit shortcuts lack of ambiguity compared to the potentially ambiguous abbreviated shortcuts. For example, a shortcut such as *bk* could be considered ambiguous as it potentially represents a number of familiar words such as *book* or *black* as well as *back*. In contrast a letter-digit shortcut can only represent the word that it sounds like, such as *2day*, which clearly represents the word *today*.

The subjects analysis also resulted in a significant main effect of Prime Type ($F_{(1)}(3,39)=4.42$, $p=.026$) but this was not reflected in the items analysis ($F_{(2)}(3, 30)=1.90$, $p=.152$). To investigate the main effect of Prime Type in the subject's analysis post hoc t tests were conducted. The results indicate that significantly more errors were made to targets preceded by baseline primes compared to identity primes ($t(13)=2.797$, $p=.015$). However, no other contrasts resulted in significant outcomes, although there was a slight trend for more errors following graphemic control primes compared to pseudohomophone primes ($t(13)=1.883$, $p=.082$). No differences were found between identity primes compared to pseudohomophone primes ($t<1$) or graphemic controls and baseline primes ($t<1$). This pattern of data suggests that more errors were made in conditions with slower reaction times indicating that there was no accuracy versus reaction time trade off. The interaction between shortcut and prime type was not significant for either subjects or items analysis ($F_{(1)}<1$; $F_{(2)}<1$).

In summary, for the reaction time data no significant differences in lexical decision latencies were found between the two types of SMS shortcut. However, a significant difference was observed between prime types such that identity primes were processed significantly faster than baseline primes and pseudohomophone primes produced latencies that were significantly faster than graphemic control primes[20]. These findings suggest that activation of a phonological representation that is associated with SMS shortcuts facilitates recognition of the shortcut regardless of shortcut type.

6.3 Discussion

This experiment aimed to test the assumptions of strong phonological theorists that all visually presented stimuli can be processed via phonological mediation. The specific question posed by the current experiment was whether prime stimuli that represent the phonology of an SMS base-word (e.g., *grait*) would facilitate recognition of the corresponding shortcut (e.g., *gr8*) and whether this would be more prominent for either abbreviated (e.g., *txt*) or letter-digit SMS shortcuts (e.g., *l8r*). The results show that prior presentation of a pseudohomophone facilitates lexical decision latencies to both types of shortcut. Such a finding is in line with data presented in Chapter 4 where no differences were found in latencies between the two types of shortcut. The pseudohomophone priming effect demonstrated in this and previous studies (e.g., Rastle & Brysbaert, 2006) controlled for orthographic overlap between prime and target by comparing the effect of a pseudohomophone prime to a graphemic control. In addition the current experiment benefited from lower levels of orthographic similarity between primes and targets due to the unusual orthography of the SMS shortcut targets. The effects observed here are therefore assumed to represent phonological activation and as such support the assertions of strong phonological theorists that visual word stimuli can be mediated by phonology (e.g., Frost, 1998; Van Orden et al., 1990). Furthermore, this effect does not seem to be influenced by the degree of phonological information conveyed by the stimuli. In other words processing of abbreviated shortcuts was facilitated by a pseudohomophone to the same extent as letter-digit shortcuts.

The current experiment also employed two supplementary control conditions, a baseline condition and an identity priming condition. These additional control

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[20] The priming advantage found for pseudohomophone primes is high (44ms), however, Grainger et al (2003) found similar priming advantages for pseudohomophone primes (36ms) compared to controls.

conditions allowed for a comparison of pseudohomophone priming with identity primes and graphemic controls against a baseline measure. The results of these comparisons show that pseudohomophone primes produced priming advantages that were equivalent to an identity priming condition and the graphemic controls performed no better than baseline, in other words these stimuli were equivalent to no prime being presented. In addition the results of this study provide a replication of the finding that shortcut identity primes (e.*g.,* *txt-TXT*) produce latencies that are significantly faster than a baseline condition (see Chapter 4; experiment 2). The lack of any observed differences in lexical decision latencies to shortcuts preceded by either an identity prime or a pseudohomophone prime could be an indication that SMS shortcuts encourage a phonological style of processing. However, it is equally possible that identity priming advantages are the result of orthographic processing and/or phonological processing. In turn the lack of any priming advantages for the graphemic control suggests that orthographic overlap between primes and targets did not facilitate target processing. This suggests that graphemic control primes did not have sufficient orthographic overlap to access lexical representations of either the shortcut or the base-word. Consequently these results support the proposal that phonological codes can be rapidly activated even in silent reading (Frost, 1998; Hino et al., 2003; Lukatela et al., 1998; Van Orden, et al., 1990,) and that this is true for SMS shortcuts as well as traditional words.

Evidence in favour of the rapid activation of phonological codes is often cited as supporting a PDP model (e.g., Hino et al., 2003) such as those proposed by Seidenberg & McClelland (1989) and Harm & Seidenberg (2004) with the secondary assumption that the DRC model does not allow for phonology to be rapidly activated. However, in order to explain priming effects from pseudohomophones Rastle and Coltheart (1994) describe how a phonological code could be rapidly activated in a model employing the architecture of the DRC model. They suggest that the non-lexical route, which assembles phonology from rules associated with grapheme-to-phoneme correspondences (GPC), can rapidly activate a whole word phonological representation in the phonological output lexicon. Thus the phonemes represented by a pseudohomophone (i.e., *werc*) could activate a phonological representation of an existing word (i.e., *work*) via links between phonemes and phonological representations in an output lexicon. The phonological representation in the output lexicon would consequently excite the orthographic representation of the base-word in the orthographic lexicon and produce a priming effect. In the case of SMS shortcuts the assumptions underlying the DRC model would predict that with experience 'skilled' shortcut readers would develop unique orthographic representations for SMS shortcuts. Presumably therefore a phonological representation of a base-word activated in the output lexicon would excite the orthographic representation for an SMS shortcut resulting in faster reaction times to shortcuts preceded by pseudohomophones compared to graphemic controls. Consequently the phonological priming effect seen in this experiment could be accounted for by the DRC model, if it is assumed that SMS shortcuts develop a unique orthographic representation.

However, Rastle and Brysbaert (2006) demonstrated that the architecture underpinning the DRC model can only simulate phonological priming effects if it is assumed that all lexical decisions are made on the basis of processing via the non-lexical route. In other words if the phonological route rather than the orthographic route is allowed to dominate. However, grapheme-to-phoneme correspondence (GPC) in the DRC model is based on rules that govern regular relationships between graphemes and phonemes. Consequently if the model parameters are set to favour the non-lexical route processing of exception words such as *pint* that have irregular grapheme-to-phoneme correspondences becomes difficult. A fine balance between the lexical and non-lexical routes is therefore required in order for this model to rapidly access phonology and still allow for the processing of irregular words. In contrast a PDP model learns from experience of decoding familiar words to associate orthographic units (representing the letters in a word) with particular phonemes as well as associating commonly occurring combinations of letters with particular phonological codes. Thus the weightings on connections between orthographic units and phonological codes activated by a pseudohomophone such as *mait* and the word *mate* would have been adjusted through experience in a direction that would facilitate pseudohomophone processing. For example the word *mate* is processed via the activation of orthographic units that have become associated with phonemes that correspond to the word */mait/* and therefore activate a phonological code that links to the meaning of the word *mate*. The pseudohomophone *mait* activates different orthographic units but they correspond to the same phonemes (e.g., */mait/*) that overlap with the phonological code for the word *mate* (see Seidenberg & McClelland, 1989 for a full explanation). Thus units activated in response to pseudohomophone primes in the current study would overlap with the phonology associated with SMS shortcuts and facilitate processing of the shortcuts.

Theoretically a model such as this would therefore learn to associate the letters and digits used in SMS shortcuts with their corresponding phonology, which would enable phonological mediation. However, on first presentation a PDP model with a single route mediated via phonology (e.g., Seidenberg & McClelland, 1989) may struggle to process phonologically impoverished abbreviated shortcuts. Conversely, a PDP model such as that proposed by Harm and Seidenberg (2004) may be able to accommodate the initial processing of abbreviated shortcuts because it would allow for items with overlapping orthography to access the system. For example, Harm and Seidenberg (2004) suggest that word-like nonwords may activate orthographic and phonological codes of familiar words via orthographic and/or phonological overlap. Thus a model such as this could account for subset primes (e.g., *frl-FAROL*) accessing existing semantic information via orthographic overlap with units that respond to their base-words. Such a PDP model therefore appears to be able to account for the initial and subsequent processing of SMS shortcuts as well as the findings from phonological priming studies. In contrast the DRC model appears to be limited by a rigid grapheme-to-phoneme interface and position dependent letter coding system that hinders its ability to account for the data reported here and from phonological priming studies.

However, recently Diependaele et al. (2010) demonstrated that a dual route localist model with a very similar architecture to the DRC is able to simulate phonological priming effects. The bimodal interactive activation model (BIAM) differs to the DRC model due to the implementation of sub-lexical input phonemes that interact with a phonological lexicon. Therefore printed words activate letter units that link directly with whole word orthographic representations and also activate input phonemes via a grapheme phoneme interface. Thus input phonemes can activate whole word phonological representations as well as phonemes in an output layer. Diependaele et al. suggest that the phonological priming effect is driven by the input phoneme representations and that the BIAM is therefore able to simulate fast phonological priming via powerful phonological sub-lexical processing whilst maintaining an orthographic route from grapheme to whole word orthographic representations. This results in the simulation of phonological priming effects without any loss of performance on lexical decisions or exception words. The authors conclude that the inability of the DRC model to reproduce these effects is located in the requirement for phonological mediation to go via output phonology rather than its underlying architecture.

To summarise, although the DRC model provides a theoretical explanation for phonological priming it struggles to reproduce the effect and consequently provide an account of the current findings. Conversely the PDP model of Harm & Seidenberg (2004) appears to provide a better fit to the data, however, as this model has not been used to simulate phonological priming this is a purely theoretical position. In contrast the BIAM proposed by Diependaele et al. (2010) is able to accommodate the findings from phonological priming studies. In addition this model implements a grapheme-to-phoneme interface that is based on a learning algorithm similar to that used by PDP models. This flexibility allows the model to potentially account for the processing of visually unusual stimuli such as SMS shortcuts and familiar acronyms that do not follow the strict rules employed by the grapheme-to-phoneme correspondence or letter coding system currently implemented in the DRC model.

However, it must be noted that evidence that recognition of SMS shortcuts can be facilitated by phonological information does not discount the alternative view that orthographic processing influences recognition of these items. Additionally it is equally possible that the route to recognition may differ depending on the style of shortcut and the task in hand. For example using pseudohomophones as prime stimuli may encourage phonological processing, whereas priming with an identity prime may encourage orthographic processing. Thus studies employing technologies such as magnetoencephalography (MEG) or electroencephalography (EEG) with high temporal resolutions may be better placed to resolve this question. However, to date only two studies have used these methodologies in investigations of SMS shortcut processing. One of these only reports data pertaining to semantic processing (Berger & Coch, 2010) and the other study found evidence of lexical access but no evidence of sub-lexical phonological or orthographic processing (Ganushchak et al., 2010b). In the latter study although all types of shortcut displayed similar ERP amplitudes suggesting that they access the lexicon, it is unclear whether this reflected access of a base-word lexical representation or a unique representation of the shortcut. However, the findings from ERP studies investigating reading processes differ considerably with respect to the point at which it is assumed orthographic or phonological processing occurs. For instance in a review of recent literature Dien (2009) describes a 'standard model of reading comprehension' (p.12) that assumes phonological activation peaks at around 300ms. Whereas, Ganushchak et al. had predicted that evidence of a sub-lexical phonological code would be found at around 250ms. Dien further proposes that after the presentation of visual stimuli, a series of cascaded activations occur in the first 250ms of processing that are focused on identification of the stimuli and culminate in the linking of information from orthographic and phonological routes (termed an 'estimation phase'). Following the estimation phase a second phase of processing (termed 'the resonance phase') begins where information is integrated and coordinated in parallel across a neural network encompassing the whole brain. Dien suggests that a cascaded model such as the DRC model may describe the estimation phase whereas PDP models may better describe the resonance phase. If this is the case the BIAM (Diependaele et al., 2010) might provide a better fit to the data from this experiment than the PDP model proposed by Harm & Seidenberg (2004). Further studies employing technologies with high temporal resolutions may be able to resolve this and other questions.

In conclusion the results of the current experiment demonstrated that a pseudohomophone based on the phonology associated with a shortcut (e.g., *mait-M8*) can facilitate recognition of an SMS shortcut. As such this experiment supports the finding that pseudohomophone primes can facilitate visual recognition of phonologically related target words even when graphemic overlap is reduced (e.g., Kim & Davis, 2002; Hino et al., 2003). These results also suggest that the pseudohomophone priming effect is not restricted to the activation of traditional words but can be observed for unusual items such as SMS shortcuts. Consequently these data add support to the suggestion that SMS shortcuts have word-like qualities and are processed in the same way as words (see Chapters 4 & 5). In addition the results of the current experiment support models of visual word recognition that accommodate phonological mediation, such as PDP models (Harm & Seidenberg, 2004; Seidenberg & McClelland, 1987) or the BIAM (Diependaele et al., 2010). However, although the evidence presented here suggests that both types of shortcut can be processed via phonological codes it does not necessarily follow that shortcuts are processed via phonology. Previous research has tended to focus on attempting to demonstrate that either phonological processing or direct access dominates visual word processing. Subsequently various explanations for the contradictions found in the literature have been proposed, however, the answer could be as simple as the fact that both routes are used depending on the stimuli presented and the task in hand.

Chapter 7 Hw dyu knw wt it means; do SMS shortcuts link directly to semantics?

7.1 Introduction

As detailed in the previous chapters current computational models assume that information either cascades through the visual word recognition system accessing lexical and then semantic representations (e.g., Coltheart et al., 2001); or that distributed patterns of data are activated in parallel via complimentary pathways that provide access to a conceptual level of information (e.g., Harm & Seidenberg, 2004). Thus in localist terminology, a single lexical representation links to a concept (which could correspond to a group of features or a single node), except when items such as homophones (e.g., *bank*; meaning place to keep money or a river bank) or homographs (e.g., *polish*; a person from Poland or to buff up silverware) are encountered. A homophone would have two conceptual level representations that link to one phonological and orthographic representation (if the spelling is the same), whereas a homograph would have one orthographic representation but two phonological and conceptual level representations. In contrast as SMS shortcuts are alternative spellings of existing words it is likely that they share phonological and semantic representations with their base-words but have a distinct orthographic representation (see Chapter 4 for a discussion). In this sense SMS shortcuts and their base-words share characteristics with cognate word pairs found in two separate languages (see Chapter 1 for a description). Previous researchers have drawn similar comparisons between cognates and stimuli that are analogous to SMS shortcuts. For example, Dimitropoulou et al. (2011b) suggest that words written in an alternative form of Greek, using the Roman script instead of the Greek alphabet (Greeklish) are cognates of traditional Greek equivalents (e.g., *sokaki-σοκάκι;* meaning 'alley'). Due to the parallels between cognates and SMS shortcuts, research into cognates in the bilingual literature may provide some insight into how SMS shortcuts are assimilated into the lexicon and link to semantic information.

Studies investigating cognate words and the bilingual lexicon have used techniques similar to those employed in Chapter 4, combining lexical decision tasks with the masked priming paradigm and employing cognate prime-target pairs (e.g., *book-BOEK*). Researchers using this methodology with cross script cognates (e.g., 펀-pen) have interpreted their results as providing an indication of semantic processing (e.g., Kim & Davis, 2003). However, due to overlapping forms between cognate prime-target pairs it is difficult to be certain that facilitation is due to semantic overlap and not form overlap (either orthographic or phonological or both). In contrast semantic priming combined with the lexical decision task provides a methodology that allows for assumptions to be made regarding semantic processing.

In a typical semantic priming experiment reaction times to prime-target pairs with different degrees of semantic relatedness are compared to unrelated pairs. Semantic relatedness can be defined by associative relationships based on words that commonly occur together such as *bread-butter*, or semantic relationships for example *boat-ship,* both of which refer to sea faring vessels. An unrelated pair would be formed from words without any semantic associations such as *fire-ship*. The results of experiments using this paradigm combined with lexical decision tasks reveal that lexical decision latencies to related prime-target pairs are generally faster than to unrelated pairs (e.g., Bueno & Frenck-Mestre, 2008; De Groot & Nas, 1991; Quinn & Kinoshita, 2008). Due to the lack of overlapping form it is assumed that related primes facilitate target processing via connections at a semantic level (see Neely, 1991 for a review). In bilingual tasks the two words are presented in different languages for example the prime is presented in L1 and a semantically associated word is presented as the target in L2, or vice versa (e.g., *book-AUTEUR*; meaning *author*). Thus for priming effects to emerge in this task it is not only necessary for the prime to access semantic information and link to associated concepts, but the associated concept must also activate lexical representations in a second language. For example, in order for the English word *book* to facilitate processing of the Dutch word *AUTEUR,* conceptual features corresponding to the words *book* and *author* would need to be accessed and activation fed back to the lexical level for the Dutch representation of the word author (*auteur*).

However, it has also been suggested that links between associatively related words may exist at a lexical level rather than a semantic level (see Bueno & Frenck-Mestre, 2002; Ferrand & New, 2004). For example, within a distributed network a model learns to associate words with semantic features. However, if two words commonly occur together the model will also learn to associate the two words with each other based on the fact that they often co-occur rather than on activation at a semantic level (Ferrand and New, 2004; Plaut, 1995). Nevertheless, previous research using this paradigm has found evidence of links between semantically related words as well as associated words in two different languages (De Groot & Nas, 1991; Guash et al., 2011; Perea, Duñabeitia & Carreiras, 2008b). The finding that a prime in one language can facilitate processing of a semantically or associatively related target in another language therefore suggests that if SMS shortcuts are assimilated into the lexicon like a cognate they may also be able to directly access semantic information.

A recent study conducted by Ganushchak et al. (2012) supports this assumption. In a semantic priming lexical decision task SMS shortcuts were used as prime stimuli and associatively related words, written in traditional English, formed the target stimuli (e.g., *msg-TEXT*). The shortcut primes were compared to word primes (e.g., *message-TEXT*) and both of these conditions were compared to an unrelated control condition. The results demonstrated that both word and shortcut primes facilitated target processing compared to the unrelated condition, furthermore, shortcuts were found to produce priming advantages that were equivalent to familiar words. These results suggest that SMS shortcuts are able to directly access semantic information and activate semantically related concepts. However, the use of a lexical decision task with associatively related stimuli may have resulted in facilitation at a lexical level rather than a semantic level. Consequently, the aim of the current experiment is to extend this investigation and explore whether SMS shortcuts facilitate responses to target words using a semantic categorisation task that is assumed to encourage semantic rather than lexical processing.

In semantic categorisation tasks participants are presented with a category and asked to indicate if words that subsequently appear are members of that category or not. Thus category exemplars, for instance *ship* in the category MODES OF TRANSPORT provide the positive 'yes' response and non-exemplar foils that do not fit into the target category (e.g., *ribbon*) provide the negative 'no' response. In masked priming categorisation tasks the exemplar or non-exemplar is preceded by prime stimuli that can be congruent or incongruent depending on the response they generate. For example the prime-target pair *boat-SHIP* is termed a congruent exemplar because both items are members of the category and the target promotes a positive response. However, the pair *milk-SHIP* is considered an incongruent exemplar because, although the target is an exemplar, the prime is not, resulting in response incongruency. On the other hand the pair *cheese-RIBBON* is a congruent non-exemplar because neither prime nor target are members of the category and they both produce negative responses. In contrast, the pair *train-RIBBON* is an incongruent non-exemplar because although the target is a non-exemplar the prime is an exemplar and consequently this pair produces incongruent responses. The results from semantic categorisation tasks have shown that reaction times to target words can be facilitated by semantically related primes compared to unrelated pairs (see meta-analysis from Van den Bussche et al., 2009).

A number of models have been proposed to explain the underlying mechanisms that facilitate semantic priming. For example spreading activation (Collins & Loftus, 1975), feature based theories (Smith, Shoben & Rips, 1974) and the Interactive Activation (IA) model (McClelland, 1987; McClelland & Rumelhart, 1981) have all been put forward as viable alternatives. However, Ferrand & New (2004) suggest that the theory of spreading activation is perhaps one of the most popular accounts of semantic priming. According to this theory conceptual information is stored in a network of interconnected nodes in semantic memory. Each concept corresponds to a single node and activation of a node results in a spread of activation to associated concepts. Thus nodes with lots of interconnections to related concepts will produce more activation across the network. For example, activation of a concept node corresponding to the word *red* would spread activation to nodes representing other colours. The nodes corresponding to colour concepts would be interconnected and also spread activation to each other resulting in a gradual spread of activation across the network in decreasing gradients and strengths from the original node. Concepts that are linked because they are associated with the colour red, such as cherries, fire engines and roses would also be activated but because they are not interlinked the amount of activation that spreads to these items would be reduced. In addition concepts that are regularly accessed together will have stronger connections between nodes. Priming advantages should therefore be stronger for concepts that regularly co-occur and prime-target pairs that share a large number of inter-related concepts.

Early support for spreading activation was presented by Neely (1977) who conducted a lexical decision task with visible prime stimuli that were presented for varying SOAs[21]. Neely used category superordinates as primes paired with exemplar targets (e.g., *BODY-arm*). Participants were told that if the prime stimulus was *BIRD* the word following would usually be a type of bird. However, if the prime was the word *BODY* they should expect the target to be related to parts of buildings and if it was *BUILDING* they should expect the target to be parts of the body. Neely found that at shorter SOAs a priming advantage was found for semantically related prime-target pairs such as *body–ARM* despite the instructions. However, at longer SOAs priming advantages that were in line with participant expectations were observed for the unrelated pairing (e.g., *body–DOOR*). These findings suggest that at short SOAs activation spreads to related concepts automatically despite the context provided by the instructions. However, with longer SOAs conscious control can be exerted over the semantic network eliminating the priming advantage for related prime-target pairs. More

[21] Primes were always presented for 150ms and the SOA was varied using longer or shorter interstimulus intervals (ISI) between the offset of the prime stimulus and the onset on the target. The SOAs varied from 250ms to 2000ms.

recently evidence that is consistent with this theory has been found in ERP data using short and long SOAs (Hill, Strube, Roesch-Ely & Weisbrod, 2002). However, the most convincing support for spreading activation has been found using mediated priming. This paradigm is based on the assumption that semantic activation can spread from directly associated concepts to more indirectly associated concepts via a mediating concept (e.g., Jones, 2012; Lorc, 1982). For example it is assumed that priming effects for prime-target pairs such as *iceberg-HOT* are found because activation from the prime, *iceberg,* spreads to the concept *cold* and from *cold* activation spreads to the target, *hot.* Jones (2012) conducted a continuous primed lexical decision task, in which the prime stimuli are visible and demonstrated a priming advantage for prime–target pairs with highly associated mediators (e.g., *pasture–MILK* mediated via *cow*). These results support the assumption that activation from one concept can spread out to related concepts and facilitate lexical decisions.

Further support for theories which incorporate spreading activation has been found from measures such as forward and backwards associative strength (FAS and BAS). FAS is judged by measuring the proportion of people who list a particular target when presented with a prime stimulus. For example the first associate for the word *good,* according to The Edinburgh Associative Thesaurus[22] is *bad,* with 80% of respondents listing this word. The pair *good-bad* would therefore have a high measure of FAS. BAS is measured using the same technique but the target word is presented instead of the prime and the proportion of people producing the prime is measured. Correlations between priming advantages and measures of FAS or BAS support the proposal that associative strength between concepts facilitates reaction times. Jones (2012) found a correlation between reaction times and a measure of feed-forward associative strength and Hutchison et al. (2008) found that items with higher FAS proportions produced larger priming advantages at short SOAs. However, although these results support the suggestion that semantic priming is the result of associative relationships this evidence is also consistent with theories of feature overlap.

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[22] http://www.eat.rl.ac.uk/

In contrast to semantic networks (Collins and Loftus, 1975) where each concept is represented by a single node, a feature model assumes that the meaning of a word emerges from the activation of associated features. Theories of feature overlap therefore lend themselves to distributed models of processing and various computational models have been developed that successfully simulate semantic priming effects (e.g., Hinton & Shallice, 1991; O'Connor et al., 2009; Plaut & Shallice, 1993). Feature models were initially based on the finding that a robin is considered a more typical exemplar of a bird than a chicken suggesting that concepts are represented by collections of semantic features rather than a single concept node (Smith et al., 1974). Viewed from within this framework priming effects occur due to the activation of features that overlap between the prime and the target. For example the word *pig* (an exemplar of the category ANIMAL) would activate features such as [soft], [moves], [on ground] and [found on farms]. These features would overlap with units representing other animals that share the same features and priming would occur because activation of the features for pig would attract concepts with overlapping features. Thus the finding that FAS scores correlate with reaction times is consistent with a theory that suggests words are activated on the basis of feature overlap, as well as spreading activation. However, mediated priming provides evidence for spreading activation rather than feature overlap based on the assumption that it is unlikely that a prime such as *pasture* would share features with a target such as *milk.*

The interactive activation model may not initially appear to be a good candidate for explaining the mechanisms underlying semantic priming, however, Ferrand & New (2004) suggest that a version of this model with a semantic level (see McClelland, 1987; Stolz & Besner, 1996) can provide an account of these effects. The IA model described by McClelland (1987) assumes that connections between levels are excitatory but within levels they are inhibitory. As such word representations at a lexical level inhibit processing of other words and semantic representations also inhibit processing of other semantic concepts. This system effectively disables any sort of spreading activation from operating within levels but not between levels. Therefore to account for semantic priming access of semantic information and related concepts has to come from the word level. For example presentation of the word *spider* would not only send excitatory feed forward signals from a lexical level to the conceptual representation for *spider* but also to related concepts such as *web*. Semantic priming is therefore conceptualised as being the result of pre-activated related concepts (e.g., *web*) facilitating responses to target words (e.g. *WEB*) by reducing the amount of processing required to access semantic representations on presentation of the target. Alternatively activation of related concepts may feed back via top down connections to the lexical level, activating lexical representations of related words.

Evidence in favour of all three models has been demonstrated in previous research, for example, Ferrand and New (2004) present evidence that both semantic and associative relationships produce reliable priming effects and suggest that they can be accounted for by either spreading activation, feature based models or an IA model. In contrast Forster et al. (2003) did not find priming advantages for related prime-target pairs (e.g., *shark-ROBIN*) in a categorisation task, prompting these authors to suggest that semantic categorisation judgements are made on the basis of a category search. However, Quinn and Kinoshita (2008) demonstrated that priming advantages could be obtained using a similar task to that employed by Forster et al. (2003). Quinn and Kinoshita argued that the exemplars used by Forster et al. did not share many features (e.g., *shark-ROBIN*) and the lack of a priming advantage could therefore be attributed to a lack of feature overlap. Consequently, Quinn and Kinoshita used prime-target pairs with more semantic overlap (e.g., *hawk-EAGLE*) and found priming advantages compared to category congruent exemplars that did not share as many features (e.g., *mole-EAGLE*). The category congruent condition used by Quinn and Kinoshita (e.g., *mole-EAGLE*) is comparable to the related condition employed by Forster et al. (e.g., *shark-ROBIN*) and demonstrates that if prime-target pairs do not share sufficient features, priming will not be observed. In contrast if related pairs with high feature overlap are used (e.g., *hawk-EAGLE*) priming effects can be found. Although neither Quinn and Kinoshita nor Forster et al. discuss their results from the perspective of a semantic network this model can also account for their findings. Forster et al. used stimuli such as *shark-ROBIN,* which may be related via a superordinate concept such as ANIMAL but would have few inter-related connections. For example the prime stimuli *shark* would link to concepts related to other underwater creatures such as *fish, whale, piranha* etc. These inter-related connections would be activated in response to the prime, producing high levels of activation between the interrelated concepts and back to the superordinate concept ANIMAL. However, a concept such as *robin* would only be connected to the concept for *shark* via the superordinate concept ANIMAL and may not produce sufficient activation to promote priming effects. The comparable congruent stimuli used by Quinn & Kinoshita (e.g., *mole-EAGLE*) would also not be closely linked in a semantic network. However, more closely related stimuli such as *hawk-EAGLE* would be connected via interconnections to each other along with other associated concepts such as *dove, falcon, buzzard* etc. as well as linking with the superordinate concept ANIMAL. The numerous interconnections found between *hawk* and *eagle* would increase the total amount of activation available to process these stimuli resulting in priming advantages. However, although spreading activation provides an account of these results, Quinn and Kinoshita interpret their findings and those of Forster et al. from the perspective of a feature based model.

If information spreads automatically to related concepts, as suggested by semantic network theories there seems to be no reason why a priming effect should not be found for non-exemplars as well as exemplars in a semantic categorisation task. Non-exemplars in this task usually form the foils or filler stimuli and are used as the non-experimental condition. These items are therefore typically category congruent rather than semantically related, in other words prime and target both produce a negative response but may not share any features. For example, if the category is ANIMAL the prime-target pair *cheese-RIBBON* would be category congruent but not semantically related. However, Quinn & Kinoshita (2008) included a non-exemplar experimental condition employing prime-target pairs with varying degrees of semantic overlap. For example the pair *boots-RIFLE* are not members of the category ANIMAL and are therefore congruent non-exemplars, but they are slightly semantically related. In contrast the pair *pistol-RIFLE* are closely related but still congruent non-exemplars. Quinn & Kinoshita found that semantically related non-exemplar prime-target pairs (e.g., *pistol-RIFLE*) produced faster negative reaction times compared to category congruent non-exemplars with less feature overlap (e.g., *boots-RIFFLE*). These results suggest that related primes can facilitate responses to non-exemplar as well as exemplar targets and support the suggestion that activation of semantically related concepts occurs automatically (*cf.* Neely, 1977).

In conclusion, the evidence from monolingual and bilingual semantic priming studies using categorisation tasks suggests that prime stimuli can facilitate responses to related targets providing there is sufficient feature overlap and regardless of the exemplar status of the target. In addition, findings from the bilingual literature suggest that cross language semantic priming with cognates and translation equivalents is robust for items with both associative and semantic relatedness (De Groot & Nas, 1991; Guash et al., 2011; Perea et al., 2008b). The study conducted by Ganushchak et al. (2012) suggests that SMS shortcuts also facilitate processing of associatively related concepts. These authors suggest that due to the brief display of the prime stimuli used in their study (57ms, Experiment 1) it seems unlikely that base-word lexical representations for SMS shortcuts would have time to mediate in this process. In addition this activation would need to occur as rapidly and directly as it does for familiar words in order to produce priming effects that are comparable to words. The theories of spreading activation, feature overlap and the IA model are able to account for these results, however, in order to do so each one would assume that information stored at a lexical level spreads activation to a semantic level or activates a series of overlapping features at a semantic level. The results from Ganushchak et al. therefore support the assumption that SMS shortcuts are added to the lexicon, are able to rapidly access the lexicon and develop direct links with semantic information.

However, various authors have suggested that different experimental tasks will enforce distinct constraints on the visual word recognition system and promote different processes (e.g., Finkbeiner et al., 2004; Johnston & Castles, 2003; Kinoshita & Norris, 2012). For example, a lexical decision task promotes decisions based on the lexical status of stimuli rather than semantic information. It is possible therefore that the outcomes of lexical decision tasks are less influenced by semantic processing compared to lexical processes. In contrast semantic categorisation tasks require a decision to be based on whether or not stimuli are members of a category and as such promote semantic processing. In a review of task dependent effects in masked priming tasks Kinoshita and Norris (2012) state that, in their view, priming effects are based on "the congruence in the information used to make the decision required by the task" (p.6). Implying that responses made in the categorisation task do not rely on response congruence, but semantic information will be retrieved because the task requires a semantic judgement. It therefore seems appropriate to test the conclusions drawn by Ganushchak et al. (2012) using a task that promotes semantic processing. In addition the stimuli used by Ganushchak et al. were associatively related (e.g., *txt-MESSAGE*) and both spreading activation and feature based models predict that these effects can occur at a lexical rather than semantic level (see Bueno & Frenck-Mestre, 2002; Ferrand & New, 2004).

It is therefore possible that the effects observed by Ganushchak et al. are the result of lexical access rather than semantic activation. Furthermore, the Revised Hierarchical Model of bilingual processing (Kroll & Stewart, 1994; Kroll et al., 2010) assumes that until a bilingual becomes proficient they will access semantic information via lexical representations in their L1. Consequently a priming direction from L2-L1 in a lexical decision task, as used by Ganushchak et al. (2012) may again encourage lexical processing rather than semantic processing. Bearing in mind the associations drawn here between SMS shortcuts and second language cognates it is possible that semantic access for SMS shortcuts is mediated via base-word lexical representations whereas associative relationships are mediated at a lexical level. Consequently the current experiment aimed to resolve these questions by using a task that encourages semantic processing rather than lexical decisions.

The conditions employed in the current experiment were similar to those used by Ganushchak et al. (2012). A shortcut condition with primes formed from SMS shortcut stimuli paired with semantically related target words (e.g., *msg-EMAIL*) was employed and compared to equivalent pairs with word primes (e.g., *message-EMAIL*) as well as a baseline measure (e.g., *%%%-EMAIL*). The semantic categorisation task requires exemplars that fit into a pre-designated category and non-exemplars that do not. As SMS shortcuts are drawn from a limited set of words it was impossible to fit them or their target words into specific categories. However, previous research has found that responses to non-exemplars can be facilitated by related primes (Kim & Davis, 2003; Quinn & Kinoshita, 2008) and consequently SMS shortcuts and their related control conditions were used as the negative response (non-exemplars). A number of previous authors have also analysed negative responses in un-primed categorisation tasks (e.g., Carreiras, Perea & Grainger, 1997; Sears, Hino & Lupker, 1999) and Ganushchak et al. (2010b) analysed the 'no' response to SMS shortcuts in an un-primed lexical decision task. In addition, Perea et al. (2010) demonstrated that no differences were found between negative responses to non-words in a lexical decision task and positive responses to the same non-words in a go/no-go task. These results suggest that the basis on which negative 'no' and positive 'yes' decisions are made do not differ. Taken together these findings suggest that the analysis of 'no' responses will not negatively affect the ability of this design to detect effects if they exist.

The exemplar condition was deliberately designed to draw on abstract categories due to the fact that most of the SMS shortcuts and therefore the non-exemplar target words were also mostly abstract. There is evidence that concrete and abstract words exhibit differences in priming tasks and switching between the two can result in a cost for cognitive processing (Kroll & Merves, 1986; Tolentino & Tokowicz, 2009). Schoonbaert et al. (2009) found that priming effects for concrete words in a semantic priming lexical decision task were slightly larger compared to abstract words. However, data from fMRI and

ERP studies suggests that both abstract and concrete words produce cortical activity consistent with the retrieval of semantic information using similar mechanisms (e.g., Friederici et al., 2000). Although there are contradictions in the literature it was felt that keeping all the stimuli relatively abstract would avoid any unanticipated confounds. Thus the categories included abstract concepts such as SOURCE OF ENERGY, TIME and ACADEMIC DISCIPLINE. Exemplar prime-target pairs were formed from target words that matched these categories and paired with semantically related prime words (e.g., *warmth-HEAT*). These items therefore prompted a 'yes' response when presented after the category SOURCE OF ENERGY, in contrast the target words that followed SMS shortcut primes (e.g., *msg-EMAIL*) prompted a 'no' response.

In summary, evidence from lexical decision (Chapter 4), Stroop effects (Chapter 5) and phonological priming tasks (Chapter 6) suggest that SMS shortcuts are processed much like familiar words. The authors of previous research have also concluded that SMS shortcuts are processed like words and may develop lexical representations that correspond to the unique orthography of the shortcut (Ganushchak, et al., 2010a; 2010b; Perea et al. 2009). In addition, it was proposed in Chapter 4 that SMS shortcuts share features with second language cognates and may therefore be assimilated into the lexicon like a cognate word. More recently it has been demonstrated that SMS shortcuts can facilitate processing of associatively related target words suggesting that shortcuts link directly to semantic information (Ganushchak, et al. 2012). It is therefore predicted that in a semantic categorisation task SMS shortcuts and familiar English words will facilitate processing of semantically related target words relative to a baseline condition.

7.2 Method

7.2.1 Participants

40 participants were recruited from Sheffield Hallam University, 21 of whom were undergraduate 1st year psychology students who received course credits for their participation the remainder were postgraduate psychology students or students from other disciplines. The mean age was 25 with a range of 18-60,

including 6 male and 32 female participants all of whom had English as their first language and were naïve of the subject of the study. All participants had no known reading difficulty and had normal or corrected-to-normal vision. Responses to a post-test questionnaire revealed that 44% of the participants sent more than 50 text messages per week, 21% sent 30-50 messages, 26% sent 10-30 messages per week and 9% sent less than 10 messages per week.

7.2.2 Design and materials

7.2.2.1 E-prime task

The experiment employed a masked priming semantic categorisation task in a within-participants experimental design. Target stimuli in the categorisation task were either exemplars that were members of a specified category or non-exemplars that were not. For example *electricity* is an exemplar of the category SOURCE OF ENERGY whereas *message* is not. Exemplars elicited 'YES' responses indicating that they were members of the category, whereas non-exemplars prompted the 'NO' response. Only 'NO' responses were included in the analyses and reaction times to YES and NO responses were not compared.

7.2.2.2 Non-exemplar prime-target pairs.

The materials for the non-exemplar condition were based on a frequency list of SMS shortcuts established via an online questionnaire (see Chapter 2) from which 20 abbreviated SMS shortcuts (e.g., *txt; text, msg; message*), 20 letter-digit SMS shortcuts (e.g., *2day; today, m8; mate*) and 20 phonological approximations (e.g., *wud; would, mite; might*) were selected. SMS shortcuts were presented as the prime stimuli and semantically related words were selected from two online word association databases to form the target stimuli (Science & Technology facilities council in association with the MRC Psycholinguistic Database[23] and 'wordassociation.org'[24]). The most popular semantically related words (first associates) were selected providing they did not contain the same onset or could be considered an associated word. For the purposes of this experiment semantically related words are classified as words

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[23] http://www.eat.rl.ac.uk/
[24] http://wordassociation.org/about/

that share an element of meaning, and associated words are those that commonly co-occur. For example, *bread* and *butter* are associated words that do not share meaning but often occur together whereas semantically related words such as *message* and *EMAIL* share semantic features (See Appendix 7.1 for a full list of prime and target pairs). However, as SMS shortcuts are based on a limited set of words and the options for semantically related targets were restricted some of the items were unavoidably associated as well as semantically related. In total there were 60 SMS shortcut prime-target pairs (e.g., *msg-EMAIL*).

In addition to the SMS shortcut condition a comparison condition with word primes was employed. The word primes were familiar word equivalents of the SMS shortcuts (e.g., *message-EMAIL*) and provided a measure of relatedness. In other words if a priming advantage is observed for related word prime-target pairs it is likely that these words are related. A baseline condition (e.g., *%%%-EMAIL*) was also used to provide a reaction time against which to test any word or shortcut priming effects or inhibition.

As participants who took part in the task were drawn from a different group to the respondents to the online surveys (detailed in Chapter 2), participants taking part in the E-Prime task were tested on their knowledge of SMS shortcuts using a post-test questionnaire. The responses show that comprehension levels were high with each participant correctly identifying an average of 73% of the experimental shortcut stimuli.

7.2.2.3 Categories and exemplar prime-target pairs.

The categories selected were partly inspired by research conducted by Finkbeiner et al. (2004) who used categories such as 'time', 'science' and 'profession' as well as being based on norms developed by Battig & Montague (1969). A total of six categories were used in the current experiment comprising SOURCE OF ENERGY, TIME, ACADEMIC DISCIPLINE, MATHEMATICAL OPERATION, EMOTION and CHEMICAL ELEMENT. The number of items per category varied from 8-11 with a total of 60 items.

The exemplar target stimuli were selected to fit into the above categories and were based on the highest ranking associates from norms developed by Battig & Montague (1969). The semantically related prime stimuli employed with these targets were also selected from Battig & Montague, as well as the two databases mentioned above (see Appendix 7.2 for full list). The exemplars were designed to match the conditions of the non-exemplars with the exception that identity primes were used in the place of SMS shortcut primes. The following three conditions were therefore employed; 1) semantically related prime-target pairs (e.g., *warmth-HEAT*), 2) a baseline condition (e.g., *%%%-HEAT*) and 3) identity primes (e.g., *heat-HEAT*).

7.2.2.4 Block rotations

All experimental trials were combined to make three different versions of the experiment. The three prime conditions were rotated across the three lists for both exemplar and non-exemplar stimuli using a Latin square rotation such that each target appeared once within a list and all priming conditions were represented across the three lists. Each version of the experiment had 60 non-exemplar trials requiring a 'no' response and 60 exemplar trials requiring a 'yes' response, making a total of 120 trials per experimental list. The non-exemplar trials were randomly ordered and combined with the exemplar trials to make an equal number of 'yes' and 'no' responses per category. Each participant experienced an equal number of trials from each of the three experimental conditions without seeing a target item more than once.

All blocks began with a fixation point and an exemplar trial to give the participant time to respond. No more than three trials that required the same response were presented in a row. Prime stimuli with the same onsets, if in the same block, were separated to allow at least 3 trials in between each one. Prime stimuli that could be considered neighbours such as *l8* (*late*) and *m8* (*mate*) were also separated by at least 3 trials in order to control for form priming across trials. The order of the six blocks in each group was randomised using a pseudo Latin square design to create counterbalanced versions of each of the three experimental variations making a total of 18 different versions of the experiment.

7.2.2.5 Questionnaires

Subsequent to completion of the E-prime task participants were asked to fill in two questionnaires. The first questionnaire was designed to gain an understanding of the type of SMS shortcuts participants use and the frequency with which they use them (see chapter 2 for details). The second questionnaire was designed to provide an indication of the associates that each participant would produce to the prime stimuli used in the non-exemplar experimental condition. For example the questionnaire presented participants with a list of the SMS shortcuts that were used as prime stimuli (e.g., *txt, msg, l8r* etc.) and asked them to write down all the words that they could think of that are semantically related to the meaning of the shortcut. Participants were provided with instructions regarding the different relationships that words have, for instance they were given '*salt* and *pepper*' as an example of an associated relationship and '*garden* and *yard*' as an example of a semantic relationship.

7.2.3 Procedure

Participants were tested individually under the same conditions. Participants were instructed that a category name (e.g., SOURCE OF ENERGY) would appear on the monitor in front of them. This would be followed words appearing one at a time that would either be category members or not and they were asked to use a response box to indicate whether they thought the word was a member of that category. The buttons on the response box were clearly labelled, with the 'no' response operated by the left hand and 'yes' response operated by the right hand. Participants were asked to respond as accurately and quickly as possible.

Each participant was initially presented with a practice block of 18 trials. The practice block contained 9 experimental trials ('no' responses) and 9 filler trials ('yes' responses). The practice trials were randomly ordered in exactly the same way as a block of trials within the main experiment and feedback ('correct' or 'incorrect') was provided for the practice block only. On completion of the practice block, providing a considerable number of errors were not made, the researcher checked that the participant was happy with the procedure and started the main experiment. Most participants completed the task, including the practice trials, in less than 10 minutes.

The visual presentation of each trial proceeded in the following order; fixation point for 500ms, followed by a forward mask for 500ms followed by the prime stimulus for 53ms and a backward mask for 147ms (making a total SOA of 200ms). Following this the target was presented until the participant selected 'YES' or 'NO' as part of the semantic categorisation task. Forward masks consisted of a row of hash marks (#####) backward masks consisted of a row of ampersands of the same length as the forward mask (&&&&&). This procedure was employed in order to avoid the prime becoming visible due to a 'pop out' effect resulting from identical forward and backward masks (see Chapter 3). Due to the fact that primes were sometimes longer than targets both masks were of a uniform length and longer than the longest word. Primes were presented in lower case and targets were presented in upper case, both stimuli were written in Courier New type font, point size 18, in black on a white background. The experiment was controlled using E-Prime experiment presentation software, which was run on a standard PC in an experimental room. The PC was connected to an Ilyama MM904UT CRT monitor with an 85hz refresh rate. Response latencies were recorded via a push button response box. On completion of the E-prime task participants filled in two questionnaires (see above). Most participants completed both questionnaires and the E-Prime task within an hour.

7.2.4 Results

Lexical decision latencies for the non-exemplar stimuli were analysed using SPSS. The data from each participant was subjected to a trim that eliminated any reaction times + or – 2 standard deviations away from participant and item means. Errors were removed from the analysis and no participants lost more than 33% of their data overall or more than 50% of the values from any individual condition. An analysis of the means for each item also revealed that none of the SMS shortcut stimuli lost more than 33% of data overall or more than 50% of the values from any individual condition. One participant was considerably slower than the other participants and produced responses that were up to 3.45 standard deviations away from the mean. This participant was considered an outlier and removed. Just 1% of data was lost due to error and 5% of data was lost from the subjects analysis after the trim making a total of 6%. In addition 3% of data was lost from the items analysis after the trim.

A within participants, 3x (SMS type; Abbreviated, Letter-digit or Phonological) 3x (Prime type; SMS shortcut, Word or Baseline) ANOVA was conducted on the non-exemplar reaction time data but none of the factors (main effects or interactions) reached significance (all *F*'s<1). Inspection of the mean scores (see table 7.1) indicated that prime-target pairs in the Word prime condition (e.g., *message-EMAIL*) did not show any evidence of a semantic priming effect for words based on abbreviated shortcuts and phonological approximations. However, the mean scores for word primes based on letter-digit shortcuts (e.g., *today-NOW*) indicate that primes in this condition may have facilitated responses to targets. In light of these figures responses to the semantic relatedness questionnaire were analysed, the results of which are detailed below.

Table 7.1 Mean reaction times in milliseconds for all prime types in all SMS shortcut conditions (standard deviations in parenthesis)

Prime Type	**Abbreviated (txt)**		**Letter-digit (l8r)**		**Phonological Approximation (wen)**	
	Reaction Time	**% Error**	**Reaction Time**	**% Error**	**Reaction Time**	**% Error**
SMS shortcut (txt/l8r/wen)	766 (176)	0.38	758 (148)	1.52	742 (145)	2.31
Priming effect (compared to baseline)	-3		14		23	
WORD (text/later/when)	770 (143)	0.38	745 (181)	1.92	762 (153)	0.38
Priming effect (compared to baseline)	-7		27		3	
BASELINE (%%%)	763 (158)	2.70	772 (173)	0.75	765 (141)	0.38

7.2.4.1 Semantic Relatedness Questionnaire

The analysis revealed that for this cohort of participants the semantic associates that were paired with abbreviated SMS shortcuts and phonological approximations did not produce high forward association scores (FAS). Previous research has suggested that when brief prime presentations are used, priming advantages will only be elicited from items displaying high FAS (Hutchison et al., 2008).

Hutchison (2003) lists items with a FAS proportion above 20% as strongly associated, above 10% as weakly associated and anything less than 10% is considered to not be associated. Therefore prime-target pairs with FAS proportions lower than 10% were removed. As a result just 5 items remained in both the phonological approximation and the abbreviated SMS shortcut conditions. These findings suggest that the lack of semantic priming seen in the mean scores for these two types of shortcut may be due to low association strengths between the prime and target pairs in these conditions. Consequently the following analysis is based on just the letter-digit shortcuts.

7.2.4.2 Analysis of letter-digit SMS shortcuts

Four prime-target pairs from the letter-digit condition with FAS proportions below 5% were removed (later-SOONER; hate-FEAR; together-WITH and straight-DIRECT). The remaining items had FAS scores above 10% apart from three items that were not removed because they ranked first or second in the responses provided by participants. Additionally one participant who proved to be an extreme outlier was removed. Table 7.2 presents means and standard deviations for the reaction times to non-exemplar targets in each prime type for the letter-digit SMS shortcut condition only. Separate analyses were conducted on the subject (F_1) and item (F_2) means. A repeated measures oneway ANOVA was conducted with reaction time as the dependent variable and prime type (SMS shortcut, Word or Baseline) as a within participants variable. The results of the ANOVA show that there was a significant effect of Prime type ($F_{(1)}(2,76)=3.09$, $p=.051$, $F_{(2)}(2,30)=3.17$, $p=.057$) which was investigated with post hoc *t* tests.

The results of the post hoc analysis show that word primes produced latencies that were significantly faster than baseline primes (t_1(38)2.09, p=.043; t_2(15)2.18, p=.045), whereas reaction times following SMS shortcut primes were no different to baseline (t_1 <1; t_2(15)1.26, p=.225). Additionally word primes produced significantly faster latencies compared to SMS shortcuts in the subjects analysis (t_1(38)=2.11, p=.041), but this contrast was not significant in the items analysis (t_2(15)=1.46, p=.165). An errors analysis produced no significant results.

Table 7.2 Mean reaction times in milliseconds for all prime types in the letter-digit SMS shortcut condition (standard deviations in parenthesis)

Prime Type	Example	Reaction Time (in ms with SD in parenthesis)	Priming effect (compared to baseline)	% Error
SMS shortcut	(l8r)	750 (146)	9 ms	1.42
WORD	(later)	719 (151)	40 ms	1.44
BASELINE	(%%%)	760 (165)		0.94

The results of this analysis demonstrate that latencies for categorical judgements to word targets were faster following related word primes (e.g., *mate-FRIEND*) compared to target words that were preceded by a neutral prime (e.g., *%%%-FRIEND*). However, responses to the same target words preceded by shortcut primes (e.g., *m8-FRIEND*) were no different to those following neutral primes.

7.3 Discussion

The aim of this experiment was to test the ability of SMS shortcuts to directly access semantic information using semantically related target stimuli in a task that encourages semantic processing. Previous research in both monolingual and bilingual studies suggests that responses to target words can be facilitated by semantically related prime stimuli (e.g., Bueno & Frenck-Mestre, 2008; De Groot & Nas, 1991; Quinn & Kinoshita, 2008). In response to this finding various theories have been proposed including those that assume activation can spread between concepts (e.g., Collins & Loftus, 1975) or lexical and semantic levels (Stolz & Besner, 1996) or that feature overlap facilitates semantic processing (e.g., Smith et al., 1974). Thus based on previous research and recent findings that the processing of associated targets can be facilitated by SMS shortcuts (Ganushchak et al., 2012) it was predicted that SMS shortcuts would access semantic information and facilitate responses to semantically related targets. However, although the current experiment demonstrated that when related prime–target pairs were presented as words (e.g., *mate-FRIEND*), a priming advantage was obtained, when the prime stimuli were presented as SMS shortcuts (e.g., *m8-FRIEND*) no facilitation was found. These results suggest that SMS shortcuts may not link directly to semantic information in the same way as familiar words.

In contrast the results from the previous chapters (Chapter 4, 5 & 6) suggest that SMS shortcuts are processed like words and that these items access the lexicon rapidly. The disparity between shortcuts and words found in the current experiment could be an indication that shortcuts do not have unique lexical representations and access the lexicon via base-word representations. In other words, SMS shortcuts may access semantic information via links between L1 and L2 lexical representations as proposed by theories of second language acquisition (e.g., the Revised Hierarchical Model; Kroll et al., 2010). In contrast Ganushchak et al. (2012) concluded that their results provide strong evidence in favour of SMS shortcuts having a specific lexical representation and not requiring mediation via base-word representations.

The discrepancies between this experiment and that of Ganushchak et al. (2012) could be the result of different stimuli and/or methodologies. For instance Ganushchak et al. used associatively related prime and target pairs in a lexical decision task whereas the current experiment used semantically related items in a categorisation task. Based on predictions made by both spreading activation and feature based theories (see Bueno & Frenck-Mestre, 2002; Ferrand & New, 2004) the priming advantages observed by Ganushchak et al. could have been facilitated by connections at a lexical level rather than a semantic level. In addition it is possible that the use of a lexical decision task encouraged lexical processing rather than semantic processing. If this is the case it is possible that semantic processing was encouraged by the stimuli and task used in the current study, which subsequently demonstrated that SMS shortcuts do not develop direct links with semantic information. However, as the findings from Quinn and Kinoshita (2008) show, if the prime and target do not share sufficient semantic overlap a priming effect may not be observed. Thus the lack of priming from SMS shortcuts in the current experiment could be the result of limited semantic networks for SMS shortcuts. In other words it is possible that shortcuts link to a restricted set of features and semantic priming for these items will only be found within a small set of concepts.

In support of this argument the results from the study conducted by Ganushchak et al. (2012) suggest that SMS shortcuts do not access concepts that are more distantly related, whereas familiar words do. As well as testing the relationship between single word primes and associatively related targets (e.g., *msg-TEXT*), Ganushchak et al. included initialisms such as *CU* (*see you*) in their study and also used two different SOAs (57ms & 1000ms). Initialisms were paired with related targets (e.g., *cu-GOODBYE*) that represent the meaning of the phrase and targets that reflect the meaning of their component words (e.g., *cu-LOOK*). Priming effects for the shortcut condition were compared to a word condition where the equivalent word primes were matched to the same targets (e.g. *see you-GOODBYE*). The results showed that for both words and initialisms related prime-target pairs exhibited priming advantages at both SOAs. In contrast component prime-target pairs failed to exhibit any priming advantages at a short SOA, however, at the longer SOA a priming effect emerged for word primes but not initialisms. These results suggest that initialisms only directly access concepts or features relating to the context within which the shortcut is used and unlike familiar words activation does not spread to concepts that are linked to their component parts. It is therefore possible that single word shortcuts also only link to concepts that are directly related and may not trigger activation of concepts outside the specific context within which they are used.

Tagg (2009) suggests that text messages represent a restricted form of language containing a limited set of words that are used with any regularity. The analysis of SMS shortcuts reported in Chapter 2 supports this suggestion, as does the work of previous researchers investigating shortcut use in younger cohorts (Plester & Wood & colleagues, 2008; 2009; 2011). Thus representations for shortcuts and related concepts may appear within a limited context and link to a restricted set of semantic nodes. Theories of spreading activation assume that concepts which are not regularly accessed do not form strong links. Consequently a shortcut such as *msg* that always appears within the context of *text message* may not spread activation to related concepts such as *email* due to the fact that *msg* is not used to refer to an email. In contrast the word *message* would spread activation to concepts relating to emails as well as memos, letters and other forms of message. Likewise feature based models would predict that limited experience with SMS shortcuts may result in these items linking to a restricted set of features. Consequently the features that are activated by SMS shortcuts such as *msg* may not overlap with the features of less directly related concepts such as *email*.

The suggestion that limited experience could result in reduced priming effects is also found in the bilingual literature where it is suggested that this may be caused by impoverished connections to semantic features (e.g., Schoonbaert et al., 2009) or slower processing (e.g., Davis, Kim & Sanchez-Casas, 2003). Schoobaert et al. (2011) suggest that the priming asymmetry found between L1 and L2 cognates may reflect a lack of exposure to the second language resulting in slower processing of L2 words. Consequently it is assumed that lower levels of proficiency may mediate priming effects (e.g., Davis et al., 2010; Dimitropoulou et al., 2011b; Kim et al., 2003). It was suggested in Chapter 4 that the priming asymmetry found in the lexical decision task for SMS shortcuts not only suggests support for the proposal that SMS shortcuts are similar to second language cognates, but also suggests that the cohort who took part in the experiments are unbalanced English-text speak bilinguals. It is likely that most undergraduate students will have been exposed less to SMS shortcuts compared to familiar English words and the participants who took part in the current experiment may also be expected to be unbalanced bilinguals. In a lexical decision task that required these participants to respond to shortcuts rather than familiar words a number of participants failed to accurately identify the more ambiguous abbreviated shortcuts. It could be argued that most university undergraduates will be able to guess the identity of the letter-digit shortcuts (e.g., *l8r*) even if they do not have prior experience with these items. However, abbreviated items such as *wt, nw, hw, nt* (*what, now, how, not*) may be difficult to identify in isolation. Inspection of the accuracy levels for this cohort revealed that 25-58% of participants failed to correctly identify these items. In contrast on average 83% of participants correctly identified the remaining shortcuts. It could therefore be suggested that the participants who took part in this experiment were not proficient English-text speak bilinguals and this may have affected the degree to which SMS shortcuts are able to facilitate processing of semantically related targets.

However, recent research using Event Related Potentials has found that individuals who are proficient in 'text speak' access semantics in response to SMS shortcut stimuli (Berger & Coch, 2010). In addition, the patterns of activity found by Berger & Coch (2010) for SMS shortcuts resemble those seen with bilinguals processing a second language. These authors used a paradigm that compares N400 amplitudes for congruent and incongruent sentences to test the extent that SMS shortcuts activate semantic information. The N400 amplitude peaks at around 400ms after stimulus onset and is assumed to provide an index of the difficulty of processing semantic information (Dien, 2009). In the paradigm used by Berger & Coch a sentence was completed with either a congruous or incongruous word, or congruous or incongruous shortcut. The incongruous item is expected to produce larger N400 amplitudes compared to the congruous item due to the extra effort required to process unexpected stimuli. Berger & Coch compared standard English sentences with texts written using shortcuts and found that incongruent text messages produced an N400 effect that was comparable to incongruent standard English sentences. However, the N400 amplitude peaked slightly later and lasted for longer in the shortcut condition, which is a pattern that is also found in second language processing (e.g., Midgely et al., 2009). These findings suggest support for the assumption that links to semantics from a second language (in this case shortcuts) are weaker or take slightly longer to process. The participants in the experiment conducted by Berger & Coch are described by the authors as late bilinguals due to the fact that they did not start texting until after the age of 11. In contrast to the current experiment these participants were considered to be proficient bilinguals based on self-reported experience. However, as there is no standardised test of text speak proficiency it is difficult to know whether or not the participants who took part in Berger and Coch's study were any more proficient than the participants who took part in the experiment reported here. In addition there is evidence to suggest that even beginner bilinguals may be able to form links with semantics from words that have just been learnt (e.g., Duyck & Brysbaert, 2004; Sunderman & Kroll, 2006).

Research conducted to date therefore suggests that semantic information is accessed in response to SMS shortcuts but access for these items is slower compared to familiar words. Consequently the relatively brief SOA used in the current experiment may have precluded semantic priming effects from emerging due to low levels of proficiency and delayed processing. In a comparable study employing a semantic categorisation task and using non-exemplars as the critical stimuli Kim et al. (2003) report that whereas L1-L2 priming was observed L2-L1 priming was not. Kim et al. were restricted in the stimuli that they could use because they were using words in Korean that had been borrowed from English (loan words) and it was not possible to group them into categories. Consequently the experimental stimuli were employed as the non-exemplars and the negative 'no' responses were analysed rather than the 'yes' responses. The stimuli were Korean-English cognate pairs that shared semantics and phonology (e.g. 룸*/rum/* - ROOM) or translation pairs that just shared semantics (e.g., 잠*/tam/* -SLEEP). The results showed a robust priming effect for both cognate and translation primes when the L1 was used as the prime. However, Kim et al., report that when the L2 was used as the prime stimuli no priming effects were found. It is unlikely that the use of the negative response in this task resulted in the lack of priming because effects were found when the priming direction was from L1-L2; consequently these authors suggest that a lack of proficiency may have affected the results.

The current experiment also analysed the non-exemplar trials in a categorisation task and used a priming direction that is analogous to L2-L1 priming. Thus it is possible that had the priming direction been from L1-L2 semantic priming effects would have emerged. However, Quinn & Kinoshita (2008) present an alternative account of semantic priming with non-exemplars in semantic categorisation tasks. As detailed in the introduction these authors found priming advantages for related non-exemplars (e.g., *pistol-RIFLE*) when a broad category (e.g., ANIMAL) was used. However, when they used narrow categories they failed to find a difference between related and category congruent non-exemplars. For example, when the categories had limited numbers of exemplars such as PLANETS, STAR SIGNS or DOG BREEDS non-exemplars with large amounts of feature overlap (e.g., *pistol-RIFLE*) resulted in latencies that were equivalent to category congruent non-exemplar pairs with less semantic overlap (e.g., *boots-RIFLE*). These results suggest that the degree of semantic relatedness between prime and target has no effect on non-exemplar processing when narrow categories are used. Quinn & Kinoshita suggest that semantic priming effects are seen for non-exemplars with broad categories because the lack of a homogenous set of exemplars encourages the system to adopt a less constrained selection process. However, if narrow categories are used it is possible to monitor features that are common to the category rendering semantic similarity between non-exemplar prime and targets irrelevant. Consequently semantic priming advantages that are found for related non-exemplars with large categories are lost when narrow categories are used.

The current experiment employed narrow categories, which may have resulted in the lack of priming advantages from SMS shortcut primes. However, evidence of priming effects for word prime-target pairs is inconsistent with this suggestion, unless these items were affected by category congruency. Category congruency is observed when both the prime and target are either exemplars or non-exemplars of the category and therefore generate the same response (*cf.* Van den Bussche et al., 2009). Thus it is possible that priming effects in semantic categorisation tasks could reflect savings in the time required to make a categorisation response rather than as a result of semantic overlap (see Finkbeiner et al., 2004 for a discussion). In the current experiment due to the use of a neutral prime as the baseline measure it is possible that response congruency could produce a priming effect over and above that observed for targets in the baseline condition. In other words, whereas a response can only be generated on presentation of the target in the baseline condition, in the word condition a response could be prepared on the basis of the prime. Consequently the ability to prepare a response in advance of target presentation may have benefited processing of targets in the word prime condition compared to the baseline condition. However, if the priming effects seen for word pairs reflecting letter-digit shortcuts (e.g., *mate-FRIEND*) were the result of a congruency effect it would be predicted that a similar effect would be seen for all congruent word pairs. However, word primes corresponding to phonological approximations (e.g., *done-FINISHED*) or abbreviated shortcuts (e.g., *message-EMAIL*) did not exhibit priming or category congruency effects. Thus the lack of these effects suggests that category congruency was not a sufficient condition to produce the priming effects seen here.

In summary, evidence that priming advantages, which are assumed to be semantic in nature, can be observed with non-exemplars if the priming direction is from L1-L2 but not L2-L1 (e.g., Kim et al., 2003) suggest that levels of proficiency or lack of exposure to second languages may interact with semantic priming effects. The lack of priming seen here for SMS shortcuts could therefore be the result of lower proficiency with shortcuts compared to familiar words. The evidence that word prime-target pairs produced semantic priming in the current experiment further suggests that semantic priming effects can be obtained with non-exemplar stimuli even when narrow categories are used. Thus the effects seen here do not seem to have been affected by the use of the non-exemplar condition or the narrow categories. Consequently it could be assumed that SMS shortcuts may not directly access semantic information. However, the results from ERP data suggest that SMS shortcuts do access semantics but that access is delayed for these items compared to familiar words. It is therefore possible that slower processing may have resulted in the lack of semantic priming effects seen here. In contrast, Ganushchak et al., (2012) observed priming effects in their study suggesting that shortcuts can access the lexicon rapidly enough to exhibit effects in masked priming experiments with brief prime displays (also see Chapter 4). It is therefore possible that the results observed by Ganushchak et al. were obtained at a lexical level or that shortcuts only exhibit priming effects with associated concepts rather than more distantly related semantic information.

In conclusion the results reported here indicate that non-exemplar word primes facilitate a response to related target words (e.g., *mate-FRIEND*). Hutchison (2003) conducted a regression analysis of prime characteristics that prompt semantic priming and concluded that semantic priming is the result of both association strength and feature overlap. Thus the effect seen here for word pairs could be the result of spreading activation from one concept node to another, the overlap of features in a distributed semantic space or alternatively the result of interactive activation between lexical items and semantic information. In contrast the lack of a semantic priming effect for SMS shortcuts suggests that these items may not directly link to semantics and is inconsistent with the finding that similar stimuli exhibit a semantic priming effect in a lexical decision task (Ganushchak et al., 2012). Methodological differences between this experiment and that of Ganushchak et al. (2012) may account for these differences. More specifically it is likely that the prime-target pairs used in the previous study were highly associated, whereas the current experiment used target words that may not be closely associated with SMS shortcuts.

Consequently the limited context in which shortcuts are used may result in SMS shortcuts having impoverished connections to information that is not closely associated. Furthermore, previous research suggests that L2-L1 priming in both lexical decision tasks and semantic categorisation tasks produces varied results with some researchers finding effects (e.g., De Groot & Nas, 1991; Guash et al., 2011) were others do not (e.g., Davis et al., 2003; Midgley et al., 2009). Thus it is possible that priming effects were observed by Ganushchak et al. due to the highly associative nature of the target words they used and that the results reported here demonstrate that SMS shortcuts do not effectively link to concepts that are more distantly related.

Chapter 8 General Discussion

8.1 Introduction

Three research questions motivated this investigation of the visual recognition of SMS shortcuts: 1) Are SMS shortcuts processed like familiar words? 2) What is the contribution of phonology and orthography to SMS shortcut processing? 3) How are SMS shortcuts integrated with semantic information in the lexicon? It was anticipated that the answers to these questions would not only further current understanding regarding the processing of unusual items such as SMS shortcuts, but also add to the growing body of knowledge concerning visual word recognition. Thus the results reported here contribute to existing knowledge in five ways. Firstly, an extensive survey of undergraduate use of SMS shortcuts provides the first known frequency database for SMS shortcuts within a UK undergraduate demographic. Secondly, the use of SMS shortcuts adds an ecological validity to the research undertaken in this thesis that is often lacking in experimental psycholinguistics where the use of nonwords is common. Thirdly, current knowledge regarding lexical access is expanded following an investigation of the similarities and differences between words and familiar as well as unfamiliar SMS shortcuts. Fourthly, the use of SMS shortcuts based on the orthography or the phonology of a traditional word adds to the current literature exploring orthographic processing and the extent of phonological mediation. In turn this enables a discussion of the capacity of localist and distributed computational models of visual word recognition to account for the data presented here. Finally this thesis presents evidence to support the suggestion that SMS shortcuts are analogous to within language cognates. In the following sections each of the research questions and the contribution made by the results to these areas are explored.

8.2 SMS shortcuts

In much of the psycholinguistic literature nonword stimuli are used because they allow for strict control over the conditions employed in experimental designs. However, the ecological validity of these stimuli could be considered low due to the fact that they are designed by researchers and have not developed from a natural language. Stimuli that are employed in a naturalistic setting and have become standardised through use to the extent that they are routinely recognised by large numbers of users provide a high level of ecological validity. SMS shortcuts offer a form of the written word that fulfils these requirements whilst also presenting visual word information in a unique format that is either orthographically biased (e.g., *txt*) or predisposed towards the phonology of a base-word (e.g., *l8r*). However, in order to ensure the ecological validity of these items it was vital that the familiar SMS shortcut stimuli used here were known by the demographic that took part in the experiments. Therefore the initial aim of this research was to obtain a measure of popular SMS shortcuts from which a set of appropriate stimuli could be developed.

Chapter 2 details the development of two sets of stimuli corresponding to abbreviated and letter-digit shortcuts and an analysis of the frequencies with which these items are used. The results of this analysis demonstrated that both sets of abbreviated and letter-digit shortcuts are used with similar frequency. Furthermore the shortcuts selected as stimuli and used throughout this thesis were the most popular items found in responses to online questionnaires. Consequently the stimuli used within this research were selected from some of the most popular SMS shortcuts to be listed by University undergraduates between 2010 and 2011. As such it is likely that the majority of participants who took part in the experiments reported here were familiar with most of the stimuli. In addition the questionnaire data revealed that the majority of respondents used shortcuts when they were younger but stopped using them around the age of 16 or 17, either because they felt that their use was a little juvenile or because new mobile phone technology made them hard to use. These trends were mirrored amongst the participants who took part in the experiments reported in this thesis[25]; nonetheless the presence of robust priming advantages for SMS shortcuts in lexical decision tasks (Chapter 4) suggests that these items are recognised as readily as familiar words, even if participants have stopped using them.

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[25] It should be noted that only anecdotal evidence is available for the research reported in Chapter 4.

Having developed two sets of SMS shortcut stimuli the subsequent aims of this thesis were to investigate the processing of these items using techniques that are established in the literature. The use of such methodologies, for example the masked priming paradigm, allows for predictions to be made regarding the expected outcomes for words and thus provides a well researched environment within which to test SMS shortcuts. Consequently the first research question to be investigated was whether familiar SMS shortcuts are processed using similar mechanisms to those employed by familiar words in visual word recognition.

8.3 Are SMS shortcuts processed like familiar words?

It is assumed, in localist networks, (e.g., Coltheart et al. 2001; Diependaele et al. 2010) that visually presented words access the lexicon via orthographic and phonological lexical representations that correspond to the unique spelling and sound of a word, allowing for familiar items to be rapidly processed. However, as SMS shortcuts are additional representations of existing words it is possible that they access lexical representations of their base-words rather than developing additional representations corresponding to their unique orthography. Current models of visual word recognition have yet to account for the processing of visually irregular items such as SMS shortcuts and familiar abbreviations. However, previous research using the masked priming paradigm suggests that both abbreviations and prime stimuli based on subsets of the consonants from a word (e.g., *bcln-BALCON*) can access the lexicon (e.g., Brysbaert, et al., 2009; Duñabeitia & Carreiras, 2011; Peressotti & Grainger, 1999). In addition phonological priming studies have presented evidence that prime stimuli reflecting the phonology but not the orthography of a word (e.g., *tekst-TEXT*) can also facilitate target word processing (e.g., Frost, 1998; Hino et al., 2003; Perfetti et al., 1988; Rastle & Brysbaert, 2006). Therefore it was hypothesised that abbreviated SMS shortcuts may be able to access the lexicon via graphemic overlap with base-word lexical representations and letter-digit shortcuts may access lexical representations via the phonological information they convey (Chapter 4).

The experiments conducted in Chapter 4 extended previous investigations of SMS shortcuts (Ganushchak et al., 2010a; 2010b; Perea et al., 2009) by using familiar shortcuts with more (e.g., *txt*) and less (e.g., *l8r*) regular orthography in a masked priming lexical decision task and comparing them to matched unfamiliar items (e.g. *rsk-RISK*; *cre8-CREATE*). The extensive use of the lexical decision task by previous researchers with both word and nonword stimuli has established that related prime stimuli facilitate target word processing. Furthermore, this effect is robust with identical word stimuli but less so with identical nonword stimuli, suggesting that priming effects are the result of lexical activation (see Chapter 3 for a discussion). Thus unfamiliar shortcuts, that are assumed to not have lexical representations, were used in this design to establish the extent that SMS shortcuts are able to rapidly access the lexicon via sub-lexical processes. In much of psycholinguistic research not only are the experimental stimuli unfamiliar nonwords but the control conditions may also introduce unwelcome confounds due to being even less word-like. Consequently the benefit of using unfamiliar shortcuts is that they are perfectly viable as potential shortcuts but just happen to be unfamiliar because a participant is unlikely to use them in a text message. Thus these stimuli are likely to engage the same cognitive systems as familiar stimuli. It was therefore hypothesised that equal priming advantages for both familiar and unfamiliar SMS shortcut stimuli would suggest that SMS shortcuts access representations of their base-words in the lexicon via sub-lexical processes. However, if greater priming advantages were observed for familiar SMS shortcuts compared to unfamiliar items this would support the suggestion that SMS shortcuts are processed like words as well as provide evidence that familiarity is a necessary requirement for rapid lexical access.

Taken as a whole the results from Chapters 4 and 5 suggest that familiar SMS shortcuts are processed like words and produce patterns of data that resemble those exhibited by familiar words. Perhaps one of the most surprising results is the consistent finding that both types of SMS shortcut exhibit comparable priming advantages. However, this suggests that they are both considered equally word-like by the lexical processor. Although the results from the illusory conjunction paradigm reported in Chapter 5 are inconclusive it can be noted that both words and shortcuts exhibited null effects. Furthermore, in a phonological priming paradigm processing of target SMS shortcuts was successfully facilitated by pseudohomophone prime stimuli (e.g., *tekst-TXT*), which is an effect that is also found with familiar words (see Chapter 6). As pointed out by Ganushchak et al. (2012), it might be assumed that SMS shortcuts are added to the lexicon if it is accepted that familiar abbreviations have lexical representation (Brysbaert, et al., 2009; Prinzmetal & Millis-Wright, 1984). Thus the evidence presented here and in previous research (Ganushchak et al., 2010b) suggests that SMS shortcuts are processed like words and a degree of familiarity is required to facilitate rapid lexical access.

Accordingly if SMS shortcuts are word-like they should also be subject to effects that are found for familiar words, such as the relationship between reaction times and frequency. To test this association the SMS shortcut stimuli used here were divided into high and low frequency groups based on the frequency with which they were reported by respondents (see Chapter 2). A measure of un-primed lexical decision latencies for the shortcuts was taken from the baseline condition in the second experiment conducted in Chapter 4 (*%%%-TXT*). In this condition participants were responding to the shortcut rather than the base-word therefore the neutral prime allows for the calculation of mean reaction times to SMS shortcuts in the absence of any prime stimuli. An analysis of these reaction times, comparing high and low frequency shortcuts based on a dichotomous split of the data reveals that high frequency SMS shortcuts are responded to significantly faster (M=745) than low frequency shortcuts (M=826; $t(31)=3.44$, $p=.002$). This relationship was further investigated using a regression analysis incorporating baseline reaction times to SMS shortcuts as the criterion variable with SMS shortcut and base-word frequencies as the predictor variables. This analysis resulted in a significant model ($F(2,33)=3.687$, $p=.036$) that accounted for 13% of the variance in reaction times based on the two types of frequency. However, the unstandardised beta values indicated that only SMS shortcut frequency was a significant predictor of reaction times, with reaction times decreasing by 1.13ms for each increase in reported frequency (β=-1.13, p=.026). This result demonstrates that items with higher frequencies produce faster reaction times and suggests that SMS shortcuts are subject to the effects of frequency in the same way as familiar words. Furthermore the lack of fit from the base-word frequency to the reaction time data suggests that the reaction times found in this experiment are influenced by SMS shortcut frequency rather than base word frequency.

Frequency effects are assumed to emerge at the lexical level (Forster, 1998) thus the finding that lexical decision latencies to SMS shortcuts are related to shortcut frequencies suggests that SMS shortcuts have distinct lexical representations. The presence of lexical representations for SMS shortcuts can explain the priming effects found in Chapter 4, as well as the Stroop effect found for shortcuts in Chapter 5. In addition the suggestion that SMS shortcuts are added to the lexicon provides further support for the proposal that orthographic regularity is not a pre-requisite for lexical access (*cf.* Brysbaert et al., 2009).

8.4 The contribution of phonology and orthography

Previous research is divided between authors who propose a strong phonological view of visual word processing (Brysbaert, 2003; Drieghe & Brysbaert, 2002; Frost, 1998; 2003; Hino et al., 2003; Van Orden, 1990) and those who attribute a dominant role to orthographic processing (Coltheart & Rastle, 1994; Coltheart et al., 2001). From the strong phonological perspective phonological representations, either characterised by localist nodes or patterns of activation across a distributed network, are automatically activated during silent reading and access meaning. However, the Dual Route Cascaded (DRC) model of visual word recognition (Coltheart et al., 2001) assumes that the influence of phonological processing is minimal. According to this view activation of orthographic representations allows familiar items to be rapidly decoded and access meaning. However, more recent models have suggested that neither of the two routes dominate and visual word recognition is achieved via a division of both routes (e.g., Diependaele et al., 2010; Harm & Seidenberg, 2004). In addition research conducted by Rastle and Brysbaert (2006) suggests that phonological processing is active during visual word recognition and the DRC model cannot provide a complete account of behavioural data without substantial adjustments.

SMS shortcuts are of interest in this debate because they are word-like items that have evolved naturally and yet they also have an intrinsic bias towards orthographic or phonological representation. In much of the research investigating the two routes nonword experimental stimuli are used which may encourage processing via one pathway or the other. As a consequence results obtained from unfamiliar stimuli may not reflect processing of familiar items, which puts SMS shortcuts in a unique position due to their familiarity. Using stimuli that are comparable to SMS shortcuts Dimitropoulou et al. (2011b), found that Greeklish prime stimuli which had more orthographic overlap with traditional Greek targets produced larger priming advantages compared to Greeklish primes with less orthographic overlap. These results suggest that increased orthographic overlap between prime and target facilitates target processing. Thus, due to increased orthographic overlap with their base-words familiar abbreviated shortcuts were expected to produce larger priming effects compared to letter-digit shortcuts. However, no differences were observed between the priming advantages for either type of shortcut in lexical decision tasks employing SMS shortcuts as primes or targets (Chapter 4).

The finding that both types of shortcut are equally able to facilitate processing of base-word targets, despite varying degrees of orthographic overlap, does not support the suggestion that priming advantages in lexical decision tasks are governed by orthography (Dimitropoulou et al., 2011a; 2011b). In addition, although there is a hint that the unfamiliar abbreviated shortcuts facilitated responses to target base-words the lack of a reliable effect for these items suggests that orthographic form does not facilitate processing more than phonological overlap. Furthermore, the lack of a priming effect for unfamiliar abbreviated shortcuts contrasts with previous research that has demonstrated priming advantages for primes constructed from the consonants in a word (e.g., *frl-FAROL*; Duñabeitia & Carreiras, 2011; Peressotti & Grainger, 1999). Duñabeitia & Carreiras (2011) suggest that competitive models of visual word recognition (e.g., the IA model of McClelland & Rumelhart, 1981) can account for their data on the assumption that the consonants in the prime stimuli activate orthographic representations matching the consonantal input. Thus it would be expected that unfamiliar abbreviated shortcuts (e.g., *rsk-RISK*) would be able to make use of this route to access the lexicon. However, the data observed in Chapter 4 do not fit this pattern[26]. Johnston & Castles (2003) suggest that lexical decision tasks may promote orthographic processing because the aim of the task is to judge the orthographic familiarity of stimuli. This in turn may lead researchers to overestimate the role of orthography in silent reading. However, if lexical decision latencies benefit from orthographic familiarity abbreviated shortcut primes (whether familiar or unfamiliar) might be expected to facilitate processing more than letter-digit shortcut stimuli and this was not found.

The presence of equally robust priming effects for letter-digit shortcuts indicates that familiar items with reduced orthographic similarity can also facilitate visual word processing. Due to the lack of orthographic overlap between letter-digit shortcuts and their base-words these items share features with cross script cognates. Previous research using cognates with phonological and semantic overlap but limited orthographic similarity, suggests that phonological overlap can facilitate processing (Gollan et al., 1997). However, it is possible that this only occurs when the phonological overlap is identical. Voga & Grainger (2007) demonstrated that cross script Greek-French cognate pairs, which share semantics and phonology but not orthography (e.g., *πιανο-PIANO*), produced larger priming effects compared to translation equivalents that only share semantics (e.g., *δωρο-CADEAU;* meaning *present*). However, when phonology

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[26] This phenomena has recently been investigated by Colin Davis and Jonathon Grainger who found that if the length of the target words used in the lexical decision task are not uniform, priming from the consonants of a word disappears (personal communication May 15th 2012). The target words used in the first experiment reported here were of various lengths and this could explain the discrepancy between this research and previous authors.

was held constant the effects were equal. These results suggest that phonological overlap between the prime and target in the cognate condition facilitated target processing over and above the semantic mediation in the non-cognate condition. In contrast Kim & Davis (2003) presented Korean-English bilinguals with cross script cognate pairs with shared semantics and phonology and did not find evidence of phonological facilitation. Interestingly Dijkstra et al. (2010) recently found evidence that phonological facilitation only occurs for cognate items that are identical, whereas orthographic facilitation is found regardless of whether graphemic overlap is large or small. In an un-primed lexical decision task latencies to English words were facilitated for Dutch-English bilinguals if target words had Dutch cognates that were orthographically and phonologically identical. However, if items differed phonologically no facilitation was seen. In contrast a gradual decline in facilitation was observed for items with decreasing orthographic similarity. It is possible therefore that the lack of phonological facilitation observed in the study conducted by Kim & Davis (2003) was the result of small differences in pronunciation between the Korean and English cognate words. Consequently these results suggest that phonological mediation may be observed for items that share meaning and have identical phonological representations but have limited orthographic overlap. As letter-digit shortcuts and their base-words share meaning and phonology it is possible that the facilitation seen in the lexical decision tasks for these items was mediated by phonological processing.

However, it is equally possible that the priming effects observed for both types of shortcut primes in Chapter 4 were the result of processing at a lexical level. Dual route models of visual word recognition (e.g., DRC: Coltheart et al., 2001) would predict that regardless of whether they are phonological approximations, initialisms, abbreviated or letter-digit shortcuts, once these items become familiar, representations of their orthography would be added to the lexicon. Thus priming effects for both types of shortcut could be facilitated via an orthographic route accessing a unique orthographic representation of each type of shortcut. Alternatively abbreviated shortcuts could be processed via an orthographic route and letter-digit shortcuts via a phonological route. It is also possible that both shortcuts are processed via both routes. However, proponents of a strong phonological theory would propose that both abbreviated and letter-digit shortcuts are processed via phonological mediation. This suggestion was tested in Chapter 6 using a phonological priming task with pseudohomophone primes and shortcut target stimuli (e.g., *tekst-TXT*).

Strong phonological theorists predict that a phonological pathway can assemble phonology rapidly enough to facilitate priming for familiar words and there is evidence from phonological priming studies to support this (e.g., Hino et al., 2003; Perfetti et al., 1988; Rastle & Brysbeart, 2006). However, current models of visual word recognition vary in the degree to which they can account for these findings. For example, the DRC model (Coltheart et al., 2001) struggles to simulate the fast phonological effect whereas the BIAM (Diependaele et al., 2010) has provided a convincing account of this phenomenon. In addition depending on the grapheme-phoneme interface used by each of the models they are able to accommodate visually unusual stimuli such as SMS shortcuts to varying degrees. The non-lexical route of the DRC model has a rigid grapheme to phoneme correspondence (GPC) mechanism that relies on rules and may therefore struggle to process phonologically impoverished items such as abbreviated shortcuts or the digits in letter-digit shortcuts. However, models employing GPC units that learn to connect stimuli with sounds may be able to account for an association between both types of shortcut and the sounds of their base-words (Diependaele et al., 2010; Harm & Seidenberg, 2004). Consequently evidence of phonological mediation for both types of shortcut provides evidence in favour of one of the latter models. The results of the phonological priming experiment (Chapter 6) showed that lexical decision latencies to both types of shortcut were facilitated by the prior presentation of pseudohomophone stimuli. This outcome supports the assumptions of strong phonological theorists and computational models that have less rigid GPC mechanisms (e.g., Diependaele et al., 2010; Harm & Seidenberg, 2004). However, as the BIAM (Diependaele et al., 2010) is the only model to successfully simulate phonological priming effects thus far, it provides the best fit to the data reported here.

In conclusion, despite previous research suggesting that orthographic processing may dominate lexical decision tasks no evidence for this was found, however, evidence of phonological mediation was found for both types of SMS shortcut stimuli. It is therefore possible that the priming effects seen in the lexical decision task (Chapter 4) were mediated by phonology. However, evidence that these stimuli can be processed via phonology does not imply that shortcuts are always processed via this route. Thus it is possible that phonological mediation is found in a phonological priming task for both shortcuts whereas in a lexical decision task processing is divided between the two routes. Nevertheless, these results do suggest that the visual word recognition system is flexible and dynamic enough to learn to associate phonologically impoverished items, such as abbreviated shortcuts, with phonological information. These findings support strong phonological theories of visual word recognition and challenge the assumptions underlying some popular computational models (e.g., the DRC model; Coltheart et al., 2001). Conversely, recent implementations of dual route models may be better able to accommodate the findings reported here (e.g., the BIAM; Diependaele et al., 2010).

8.5 How are SMS shortcuts integrated with semantic information?

Throughout this thesis it has been suggested that SMS shortcuts share characteristics with second language cognates (words that share the same root in two languages such as *cat* in English and *gato* in Spanish). This assumption is based on the observation that SMS shortcuts share phonology, meaning and some level of orthography with their base-words. However, unlike cognates that straddle two languages, SMS shortcuts are additional representations of existing words within a language. Previous researchers have drawn similar analogies with comparable stimuli (e.g., Dimitropoulou et al., 2011b) and a recent ERP study suggests that SMS shortcuts exhibit amplitudes that are analogous to those used in second language processing (Berger & Coch, 2010). Due to the parallels that can be drawn between cognates and SMS shortcuts it was hypothesised that shortcuts may be assimilated into the lexicon and linked to semantic information in a way that would be comparable to cross language cognates.

In support of this proposal the results of the lexical decision tasks reported in Chapter 4 suggest that SMS shortcuts exhibit an asymmetry in priming directions that is found in bilingual literature using cognates. In addition, the asymmetry found in lexical decision tasks is more pronounced in less proficient bilinguals (Davis et al., 2010) and can be eliminated if highly proficient bilingual participants are tested (Guasch et al., 2011). Previous studies have found significant priming in both directions (L1-L2 and L2-L1) with Dutch-English bilinguals who are considered 'unbalanced', meaning that they use their L1 considerably more than their L2. However, in line with the findings reported here, a numerically reduced and therefore weaker effect has been found from L2-L1 with unbalanced bilinguals (e.g., Duyck & Warlop, 2009; Schoonbaert et al., 2009). In contrast, Guasch et al. (2011) demonstrated that priming advantages are equal in both priming directions for balanced bilinguals. The finding that priming effects are weaker in lexical decision tasks when SMS shortcuts are used as prime stimuli suggests that not only do shortcuts exhibit similar patterns of priming to cognates, but that the participants who took part in the experiments reported in Chapter 4 are unbalanced English-text speak bilinguals.

In addition, there is evidence that cognates and translation equivalents can facilitate priming of associated words across two or more languages. For example, *author*, used as prime stimuli has been found to facilitate responses to the target word *BOEK*, meaning *book* in Dutch (De Groot & Nas, 1991). More recently similar research has revealed that semantic priming effects are found for proficient bilinguals whether cross language items are related by association (e.g. *author-BOEK*) or semantics (e.g., *horse-DONKEY*) and regardless of the priming direction (Guash et al., 2011; Perea et al., 2008b). These findings suggest that cognate stimuli not only link to semantic information but also to associated concepts in another language. If it is assumed that SMS shortcuts share characteristics with cognates it could be assumed that these items would also link to semantic information and associated concepts presented in traditional English (e.g., *2day-NOW*). Recently Ganushchak et al. (2012) demonstrated that this is the case using shortcut primes with associatively related target words (e.g., *msg-TEXT*) in a semantic priming lexical decision task. Furthermore, Ganushchak et al. interpreted the equivalent priming effects they observed for both shortcuts and words as an indication that SMS shortcuts do not need to access base-word lexical representations to access meaning. In contrast, the results reported in Chapter 7 do not support the conclusion that SMS shortcuts directly access semantic information. Similar stimuli were used in Chapter 7 as Ganushchak et al. (2012) but they were paired with semantically related target words in a semantic categorisation task, as opposed to associatively related words employed in a lexical decision task. A significant semantic priming effect was found for familiar word primes with related targets (e.g., *today-NOW*), but only for words based on letter-digit shortcuts and no semantic priming effects were observed for SMS shortcut primes (e.g., *2day-NOW*). These findings are difficult to reconcile with those of Ganushchak et al. because the semantic categorisation task is assumed to promote semantic processing where the lexical decision task may not. Kinoshita & Norris (2012) suggest that, "masked priming reflects the accumulation of task-specific evidence contributed by the prime" (p.10). Thus if semantic priming effects are observed for SMS shortcuts in a lexical decision task, where the task simply requires a lexical decision, they would be expected in a semantic categorisation task where the decision requires access to semantic information. In addition previous research has found that the usual asymmetry displayed in lexical decision tasks is eliminated in a semantic categorisation task, suggesting that L2-L1 priming is more robust in semantic categorisation tasks (Finkbeiner et al., 2004; Grainger and Frenck-Mestre,1998; Sánchez-Casas et al.,1992).

However, there is a considerable amount of variation in the effects found for both translation (e.g., *plage-BEACH*) and semantic priming (e.g., *author-BOEK*) between two different languages. Davis et al. (2003) report that L2-L1 translation priming was not found in a semantic categorisation task using English-Korean cognate pairs. In addition, Midgley et al. (2009) and Hoshino et al. (2010) failed to find evidence of L2-L1 translation priming using a semantic categorisation task and recording ERP data. In the studies mentioned above, semantic overlap between the prime and target should be optimised due to the fact that translation or cognate equivalents were used that share the same meaning. In contrast semantically related prime-target stimuli (such as those used in Chapter 7) have different meanings and priming effects therefore rely on shared conceptual links between the two stimuli. Consequently if L2-L1 priming in a translation or cognate priming task is not robust it may not be surprising that similar effects are varied for SMS shortcuts. In addition although semantic priming effects have been observed by some authors, comparable effects have not been found in all studies. For example, in a lexical decision task using L2 and L1 stimuli with an associative semantic relationship (e.g., *día–NIGHT*) Basnight-Brown & Altarriba (2007) failed to find an associative semantic priming effect in either priming direction. Thus there may be some circumstances in which L2-L1 priming is not observed for either translation equivalents (cognate or otherwise) or semantically related items in semantic categorisation tasks. Consequently a number of authors have suggested that semantic priming effects may be mediated by proficiency (e.g., Davis et al., 2010; Hoshino et al., 2010; Kroll et al., 2010; Midgley et al., 2009). It is suggested in Chapter 7 that the participants who took part in the current research may not have been proficient users of SMS shortcuts. In addition there is evidence from the asymmetry in priming magnitudes found in lexical decision tasks (Chapter 4) to suggest that the participants who took part in this research were selected from a demographic that may not be proficient users of SMS shortcuts. Although it is not possible to know whether the participants who took part in the study conducted by Ganushchak et al. (2012) were more or less proficient English-text speak bilinguals it is possible that this could explain the discrepancy in results.

Alternatively it is possible that the SMS shortcut primes used in Chapter 7 did not effectively link to the concepts presented as the target stimuli. In other words the shortcut *msg* may not activate semantic features that overlap with those for the target *EMAIL,* whereas, the word *message* may access a richer semantic network that includes features which do overlap. Duyck & Brysbaert (2004) suggest that L2 words link directly with and activate semantic information. In a further development of this work Schoonbaert et al. (2009) suggest that the strength of a priming effect may depend on the number of shared semantic features that are activated between a prime and a target and the strength of lexical-semantic connections. For example, an L1 word (e.g., *boy*) may activate a number of semantic features and have strong connections to those features. In contrast the L2 translation equivalent (e.g., *jongen*; boy) may access fewer features with weaker connections between lexical and semantic levels. Thus if *jongen* is used to prime *girl* a limited number of features will overlap and depending on the richness of the L2 semantic network and the strengths of the connections priming effects may or may not be observed. This proposal resonates with the Senses model proposed by Finkbeiner et al. (2004), which suggests that L2 words link to fewer semantic 'senses' of a word compared to L1 words. For example, for an English-Japanese bilingual the L1 word *black* can relate to a colour, a black market or a financial crash (e.g., black Monday), whereas the Japanese equivalent *kuroi* (meaning black) may only link to the colour sense of the word. In order for semantic priming to be observed between related prime and target stimuli the semantic features activated by the prime need to overlap with the features activated by the target. If a limited number of features are accessed by the prime stimuli it is possible that they would not overlap sufficiently with the target to produce reliable priming effects.

Tagg (2009) suggests that the language used in text messages is limited and formulaic. Thus SMS shortcuts such as *msg* may generally be used in the context of sending 'text messages' (e.g., *txt msg*) and therefore only access concepts relating to text messages. Alternatively following the model described by Schoonbaert et al. (2009) a shortcut such as *msg* may have strong links with features relating to *texts* and *message* but weaker links to semantically related concepts such as *email.* In fact 27% of the participants who took part in the semantic categorisation task reported here (Chapter 7) listed *text* as semantically related to *msg* compared to 15% who listed *email* in a post-test questionnaire. Scrutiny of the post-test norming questionnaire revealed further examples of mismatching prime and target stimuli. For example, the shortcut *in2* was paired with the related target *OUT*, however, the majority of participants listed the word *like,* or related concepts such as *fancy* or *love* (57%) in response to this shortcut, compared to 33% who listed words that correspond to a concept of [going into]. A lack of overlap at the conceptual level for prime and target stimuli could therefore result in reduced or non-existent priming effects for shortcut-word pairs such as, *in2-OUT* or *msg-EMAIL*. In contrast the words *message* or *into* would be expected to rapidly access semantic features relating to all the senses of these words resulting in stronger facilitation between word prime and target pairs. Interestingly, Ganushchak et al. (2012) also used the shortcuts *in2* and *msg* as prime stimuli in a lexical decision task but paired them with the target words *like* and *text*. Thus it is possible that the use of closely associated words in the study conducted by Ganushchak et al. (2012) may have produced a priming effect where the experiment reported in Chapter 7 failed to find an equivalent effect.

A further difference between the two experiments is that Ganushchak et al. (2012) combined abbreviated and letter-digit shortcuts in their analysis, whereas, the analysis reported in Chapter 7 was only conducted on letter-digit shortcuts. Schoonbaert et al. (2009) suggest that L2 cross script cognates may be at a disadvantage compared to same script cognates when used as prime stimuli in a lexical decision task because they cannot benefit from the "well established and fast operating L1 machinery" (p.582). In support of this suggestion, neither Hoshino et al. (2010) nor Kim et al. (2003) report finding an L2-L1 priming effect with cross script prime-target stimuli in a semantic categorisation task. Hoshino et al. (2010) suggest that slower processing of L2 primes due to the different script may have prevented a priming advantage from emerging. Letter-digit shortcuts could be likened to cross script cognates due to their visual irregularity and it is possible that processing of these items was therefore delayed. In addition Ganushchak et al. (2010a) suggest that the digit used in letter-digit shortcuts may initially access a concept relating to the number, which is then rapidly suppressed by the activation of a lexical representation. If this is the case processing for letter-digit shortcuts may have been delayed, or semantic processing inhibited by activation of number concepts.

In conclusion, although the results from the semantic categorisation task conducted here were inconclusive, evidence from previous research suggests that second language cognates and SMS shortcuts link directly to meaning. The results from the semantic lexical decision task conducted by Ganushchak et al. (2012) suggest that SMS shortcuts are not only able to access conceptual representations but also link to associated concepts and facilitate processing of related words. In contrast the findings from Chapter 7 do not support the assumption that SMS shortcuts develop direct links with semantic representations. These results could be interpreted as indicating that the relationship between shortcuts and meaning is mediated by lexical representations of shortcut base-words or that shortcuts have limited semantic networks. Consequently the differences in the outcomes between the current research and that conducted by Ganushchak et al. could be the result of different methodologies and stimuli. In addition the results from previous literature using similar experimental designs and stimuli that are comparable is conflicted, leading Davis et al. (2003) to suggest that "a lack of priming should not be taken as evidence for the lack of a common process between primes and targets" (p.315). Thus the evidence presented here is consistent with the bilingual literature, despite the lack of an effect and supports the suggestion that SMS shortcuts share features with second language cognates and may therefore be assimilated into the lexicon as a within language variant of a cognate.

8.6 Limitations and future directions

8.6.1 Stimuli

An unavoidable limitation to the research presented in this thesis arises from the nature of the SMS stimuli. Although the use of these items provided a high level of ecological validity a certain level of experimental control was lost. For instance the base-words for the two types of shortcut could not be matched on frequency and other psycholinguistic variables, which prevented a direct comparison of these stimuli in the lexical decision task. In addition although the frequencies calculated for the SMS shortcut stimuli suggest that the items employed in the current research are used with equal frequency, the corpus of text messages and self reports from which these figures originate is rather small in comparison to equivalent databases used for familiar words. In addition, due to the restrictions of matching familiar and unfamiliar shortcut stimuli it was difficult to get a good match between the frequencies of the base-words for these items. More specifically the options for creating unfamiliar letter-digit shortcuts were particularly restrictive. As a consequence it is possible that there are differences between the base-words that correspond to the familiar and unfamiliar shortcuts. Reaction time data from the lexical decision task (Chapter 4, experiment 1) suggests that responses to the base-words for the unfamiliar shortcuts were slightly slower than responses to the base-words for familiar shortcuts. However, tests of mean frequencies, neighbourhood densities, imageability and concreteness showed no significant differences.

In addition the length of stimuli is typically kept constant in experimental designs, however, due to the limited number of SMS shortcuts it was impossible to select shortcuts with base-words of the same length. One consequence of this seems to have been that it was more difficult to control the visibility of the prime stimuli (see below), however, the variable lengths of stimuli also seems to have eliminated effects that have been observed in previous research. For instance primes constructed from a subset of consonants in a word have been found to successfully facilitate target word processing in previous research (e.g., *blcn-BALCON*) but this effect was not found with unfamiliar abbreviated shortcuts (e.g., *rsk-RISK*).

In the phonological priming task reported in Chapter 6 it is possible that the phonological priming effect observed for familiar shortcuts would also be obtained for unfamiliar items. In the previous lexical decision tasks when base-words were used as prime stimuli and familiar and unfamiliar shortcuts used as targets (e.g., text-TXT; risk-RSK) priming effects were found for both familiar and unfamiliar items, however, they were of a smaller magnitude for the unfamiliar shortcuts. It is therefore possible that a pseudohomophone may also facilitate processing of unfamiliar shortcuts. As an unfamiliar condition was not included in the design of this study, this could be a direction investigated by future research

8.6.2 Baseline measure

As mentioned in Chapter 3 it was suggested that the use of a neutral prime (e.g., %%%) as a baseline measure rather than an unrelated word might underestimate priming effects. In addition it was suggested that this would be preferable to overestimating effects by using an unrelated condition, which may inhibit target processing. The predictions of the IA model were presented in support of this suggestion, however, although the IA model predicts that unrelated word primes (e.g., *pony-ABLE*) inhibit target processing (see chapter 3 for a breakdown) behavioural data suggests that the prime target pair *axle-ABLE* inhibits processing more than the unrelated pair *pony-ABLE* (Davis & Lupker, 2006). Although these findings may seem counter-intuitive Davis & Lupker (2006) demonstrate that a modified IA model can account for these findings by resetting letter level activation between prime and target and adjusting word level inhibition. These authors suggest that the presentation of the prime *axle* accesses word representations for *axle* and *able* via letter level representations that excite connections to both of these words. On presentation of the target *ABLE* the overlap in letters between the prime and target maintains activation of both words but the prime word *axle* strongly inhibits the target word *ABLE* and slows down the processing of this word. Conversely although presentation of the prime *pony* accesses the word *pony*, letter level representations are reset on presentation of the target word *ABLE*. Consequently activation to the word *pony* ceases and is replaced by activation of the target word *ABLE*. Furthermore due to the lack of letter overlap between *pony* and *able* the target word is not inhibited because word level inhibition in this model only occurs between words that have overlapping graphemes (defined as 1 letter the same). Davis & Lupker suggest that these modifications result in reaction times to targets preceded by unrelated primes becoming comparable to un-primed latencies. Consequently it is possible that the use of an unrelated prime does not inhibit target processing sufficiently to inflate priming effects. In addition because perceptual transfer from prime to target is accounted for, unrelated prime stimuli may provide a more accurate reflection of priming advantages. Nevertheless, the baseline measure was instrumental in the current research due to the limitations of the stimuli and the difficulty with matching stimuli to form an unrelated condition.

8.6.3 Masking

Although it was concluded at the end of Chapter 3 that backward pattern masks would not be deleterious to processing or the effects observed here, in some cases the use of a backward mask may have made the prime stimuli more obvious. This effect might be particularly noticeable when the prime and target stimuli are of differing lengths. Finkbeiner et al. (2004) suggest that a 'pop out' effect occurs when backward masks are used due to the two masks forming a perceptually continuous background from which the prime appears to 'pop out'. Although this assumption appears to be based on anecdotal evidence gathered by researchers whilst running masked priming tasks (e.g., Forster et al., 2003; Finkbeiner et al., 2004) rather than empirical evidence, a similar effect was observed in the current research. Participants taking part in the lexical decision tasks detailed in Chapter 4 exhibited very low levels of prime awareness and none of the participants taking part in the phonological priming experiment reported being aware of prime stimuli. However, a number of participants who took part in the semantic categorisation task suggested that they had been able to see the prime and were able to correctly report the prime stimuli. An analysis conducted without these participants produced the same outcomes as the analysis with these participants suggesting that they did not affect the outcomes. However, it is possible that they were able to engage in strategic responses on some trials due to visible prime stimuli. Forster (1998) suggests that under conditions in which a prime stimulus is presented for 60ms following a forward mask and preceding a target "subjects can usually tell that something preceded the target word, but they are quite unable to identify what it was" (p.207). The use of a backward mask in the semantic categorisation task, however, seems to have allowed some participants to be aware of the prime. On reflection and following on from research showing that priming effects are obtained without a backward mask (Monahan et al., 2008; Quinn & Kinoshita, 2008; Wang & Forster, 2010) future research could consider removing this element of the procedure. Alternatively backward masks that are perceptually similar to the prime stimuli could be employed as these masks have been shown to reduce prime awareness (Grainger et al., 2003).

Finally, as pointed out in the introduction the participants who took part in the research reported here are from a demographic that has generally stopped using SMS shortcuts. It was therefore proposed that these participants might be 'unbalanced' English-text speak bilinguals due to lack of current use. Future research could therefore investigate whether similar results to those reported here are observed with a younger cohort, who are currently using SMS shortcuts on a regular basis.

8.7 Final Conclusions

This thesis has presented evidence to suggest that SMS shortcuts have lexical representations that are orthographically distinct from base-word representations and are processed like words. More specifically SMS shortcuts exhibit patterns in behavioural data that are comparable to second language cognates. In addition no advantage for orthographic processing was found for abbreviated shortcuts over letter-digit shortcuts and processing of both types of shortcut was facilitated by phonological information. The findings reported here advance current understanding of the limitations of current computational models to account for the processing of visually unusual items. Furthermore these findings support those of Brysbaert et al. (2009) in suggesting that familiarity rather than orthographic regularity is required for stimuli to achieve rapid lexical access. In addition these results have added to the growing body of knowledge concerning phonological mediation and the level of flexibility exhibited by the lexical processor. Although evidence of direct links with semantic information was not found for SMS shortcuts, as Kinoshita & Norris (2012) suggest "A system performing optimal decisions should obviously make use of all of the information available" (p.5); thus whether processing SMS shortcuts or words, recognition is likely to be the result of information accumulated from all sources, including not only orthographic and phonological, but also morphological, syntactic and semantic information. The research presented here highlights the fact that visual word processing is a dynamic process that is flexible enough to add visually unusual items to the lexicon, allowing for language to be used in ever increasingly creative ways.

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APPENDICES

Appendix 2.1 Text messaging usage Survey - Pilot surveys

Gender:

Age:

Do you use your mobile phone to mostly call, mostly text or both? Please circle one call text both

On average how many text messages do you ***send*** in a week? Please circle one:

never rarely less than 10 10-20 20-30 30-40 40-50 50 or above

On average how many text messages do you ***receive*** in a week? Please circle one:

never rarely less than 10 10-20 20-30 30-40 40-50 50 or above

The following questions concern SMS Shortcuts. An SMS shortcut is defined as a combination of letters, number or other characters used to represent a word:

e.g., pst for post K8 for Kate YGJ for You've got to be joking

In your text messages do you use SMS shortcuts? Please circle one:

Never Rarely Often Always

In the text messages you receive do people make use of shortcuts? Please circle one:

Never Rarely Often Always

Look at the following shortcuts. Please indicate whether you use this shortcut yourself or recognise it from text messages sent to you:

	I use this Shortcut myself (please ✓)	I recognise this shortcut (please ✓)	Please indicate what you think this shortcut means
2day			
2nite			
2moro			
in2			
xlnt			
b4			
4eva			
4get			
gr8			
ez			
L8			
m8			
sum1			
ne1			
nta			
lyk			
msg			
pls			
txt			
fstr			
spk			
nxt			
fwd			
ppl			
tlk			
wknd			
wrk			
gd			
yday			
thx			
prbly			
Bk			

please list any other SMS shortcuts which you frequently use in your text messages.

Appendix 2.2 Pilot surveys frequency list

Full List of SMS shortcuts from pilot surveys.
(** indicates items that were presented in a list to respondents * included in study 5 only).

Item	Shortcut	Meaning	Freq	Item	Shortcut	Meaning	Freq
1	txt**	text	229	34	ez**	easy	15
2	b4**	before	214	35	2	to	15
3	2moro**	tomorrow	211	36	r	are	13
4	2day**	today	202	37	xlnt**	excellent	11
5	2nite**	tonight	197	38	4	for	11
6	msg**	message	186	39	ya	you	9
7	ppl**	people	186	40	l8r	later	8
8	pls**	please	172	41	ur	your/you're	8
9	nxt**	next	169	42	lyk*	like	7
10	wknd**	weekend	155	43	cnt	can't	5
11	bk**	back	147	44	wat	what	5
12	gr8**	great	139	45	hw	how	5
13	gd**	good	139	46	h8	hate	4
14	4get**	forget	135	47	ye	yes	4
15	sum1**	someone	132	48	2moz	tomorrow	4
16	l8**	late	126	49	n	and	4
17	wrk**	work	126	50	plz	please	4
18	m8**	mate	125	51	wt	what	4
19	ne1**	anyone	117	52	soz	sorry	3
20	4eva**	forever	113	53	2mz	tomorrow	3
21	yday**	yesterday	113	54	wot	what	3
22	no1**	no one	111	55	cud	could	3
23	tlk**	talk	107	56	wen	when	3
24	thx**	thanks	101	57	tom	tomorrow	3
25	in2**	into	94	58	lyk	like	3
26	spk**	speak	90	59	myt	might	3
27	fwd**	forward	90	60	y	why	3
28	prbly**	probably	68	61	bak	back	3
29	u	you	64	62	wk	work	3
30	fstr**	faster	22	63	w8	wait	3
31	c	see	18	64	nta**	enter	2
32	luv	love	16	65	bi	bye	2
33	lv	love	16	66	bn	been	2

Appendix 2.2 continued

Item	Shortcut	Meaning	Freq	Item	Shortcut	Meaning	Freq
67	2gether	together	2	100	wud	would	1
68	info	information	2	101	nyt	night	1
69	tomo	tomorrow	2	102	knw	know	1
70	min	minutes	2	103	nt	not	1
71	bin	been	2	104	2dy	today	1
72	every1	everyone	2	105	2nyt	tonight	1
73	2mrw	tomorrow	2	106	wn	when	1
74	ova	over	2	107	wr	we're/where	1
75	sn	soon	2	108	tmo	tomorrow	1
76	whn	when	2	109	myn	mine	1
77	thr	their	2	110	tho	though	1
78	twn	town	2	111	f8	fight (Yorkshire)	1
79	da	the	2	112	2ngt	tonight	1
80	l8a	later	2	113	d8	date	1
81	2mo	tomorrow	2	114	sw	so what	1
82	l8er	later	2	115	trn	turn	1
83	wnt	went	2	116	trd	tried	1
84	tym	time	2	117	cus	because	1
85	jk	like	2	118	jst	just	1
86	wend	weekend	2	119	ryt	right	1
87	tmrw	tomorrow	2	120	thort	thought	1
88	thnx	thanks	2	121	ull	you'll	1
89	sis	sister	2	122	neva	never	1
90	bcos	because	2	123	obv	obviously	1
91	nw	now	2	124	lk	like	1
92	tomoz	tomorrow	2	125	lyt	light	1
93	nite	night	2	126	y'day	yesterday	1
94	myb	maybe	1	127	4got	forgot	1
95	lve	love	1	128	av	have	1
96	tday	today	1	129	fone	phone	1
97	tnite	tonight	1	130	cuz	because	1
98	hlp	help	1	131	2m	tomorrow	1
99	defo	definitely	1	132	ure	you're/your	1

Appendix 2.2 continued

Item	Shortcut	Meaning	Freq	Item	Shortcut	Meaning	Freq
133	ch8	cheat	1	166	qus	question	1
134	hv	have	1	167	hav	have	1
135	bcs	because	1	168	giv	give	1
136	shd	should	1	169	hme	home	1
137	sd	said	1	170	mite	might	1
138	plez	please	1	171	gts	get	1
139	skool	school	1	172	mebe	maybe	1
140	cs	because	1	173	wkend	weekend	1
141	defo	definitely	1	174	neway	anyway	1
142	luk	look	1	175	r8	right/rate	1
143	l8az	later	1	176	4ward	forward	1
144	mayb	maybe	1	177	nd	and	1
145	tmz	tomorrow	1	178	2morrow	tomorrow	1
146	alrt	alright	1	179	nsng		1
147	ltl	little	1	180	lata	later	1
148	2night	tonight	1	181	spose	suppose	1
149	dnt	don't/didn't	1				
150	dat	that	1				
151	den	then	1				
152	pist	pissed	1				
153	ov	over	1				
154	wi	with	1				
155	kwl	cool	1				
156	wkd	wicked	1				
157	ne	any	1				
158	bcoz	because	1				
159	wre	we're/were	1				
160	alr8	alright	1				
161	rite	right	1				
162	beta	better	1				
163	v	very	1				
164	cos	because	1				
165	enuf	enough	1				

Appendix 2.3 Online and post-test SMS shortcut usage survey

Gender:	Age:

Are you Left Handed ❐ Right Handed ❐

Please tick one box to indicate if you use your mobile phone to mostly:

Call ❐ Text ❐ Both ❐

On average how many text messages do you ***send*** in a week?

Please tick one of the following:

None ❐ Less than 10 ❐ 10-20 ❐ 20-30 ❐ 30-40 ❐

40-50 ❐ 50 or above ❐

On average how many text messages do you ***receive*** in a week?

Please tick one of the following:

None ❐ Less than 10 ❐ 10-20 ❐ 20-30 ❐ 30-40 ❐

40-50 ❐ 50 or above ❐

The following questions concern shortcuts that are used in writing text messages on mobile phones. For instance:

[pst] meaning *post* [k8] meaning *Kate*
or [YGJ] meaning *You've got to be joking*

In your text messages do you use texting shortcuts?

Never ❐ Rarely ❐ Sometimes ❐ Often ❐ Always ❐

In the text messages you receive do people use shortcuts?

Never ❐ Rarely ❐ Sometimes ❐ Often ❐ Always ❐

Continued overleaf

Appendix 2.3 continued

In the box below please write down shortcuts that ***you use*** and the word they represent.

SHORTCUT	**MEANING**

Have you ever changed the amount of text message shortcuts you use? For instance has there been a time in your life when you have used more or less shortcuts than you do now?

If you have changed usage what is the reason for the change?

Are you on contract or pay as you go?

Continued overleaf

Appendix 2.3 continued

Please indicate which shortcut is the correct one for the following words by ticking the appropriate box. (Some shortcuts may have more than one way of being written down, please indicate which you think is the most common representation).

When	wen	☐	whn	☐	w3n	☐
Tomorrow	2moro	☐	moroz	☐	tomo	☐
Them	zem	☐	thm	☐	th3m	☐
Rate	rait	☐	rt	☐	r8	☐
Weekend	wknd	☐	weeknd	☐	wkend	☐
Tonight	tnght	☐	2nite	☐	tnite	☐
Traffic	traffc	☐	Tffic	☐	Trffc	☐
Forces	4ces	☐	frcs	☐	frces	☐
Message	mssg	☐	msg	☐	msage	☐
Today	tdy	☐	tday	☐	2day	☐
Explain	expln	☐	xpln	☐	xplain	☐
Reform	rfrm	☐	refrm	☐	re4m	☐
Text	txt	☐	tex	☐	t3ks	☐
Before	bfr	☐	be4	☐	b4	☐
Boys	boiz	☐	Bys	☐	byz	☐

Appendix 2.3 continued

Formula	frmla	☐	4mla	☐	4mula	☐
Speak	spk	☐	sk	☐	sp3k	☐
Late	lte	☐	l8	☐	la3t	☐
Stand	stnd	☐	st&	☐	Std	☐
Forced	4cd	☐	frcd	☐	4ced	☐
Please	pleez	☐	pls	☐	plse	☐
Later	ltr	☐	l8a	☐	l8r	☐
Garden	grdn	☐	gardn	☐	grden	☐
Estate	est8	☐	estt	☐	s-tate	☐
Talk	tk	☐	tlk	☐	tak	☐
Hate	ht	☐	hte	☐	h8	☐
Risk	r1sk	☐	rsk	☐	rk	☐
Straight	strate	☐	strght	☐	str8	☐
What	wht	☐	wt	☐	wat	☐
Mate	m8	☐	mt	☐	mte	☐
Which	wich	☐	whch	☐	whi	☐

Appendix 2.3 continued

Statement	st8ment	☐	stmnt	☐	statemnt	☐
Love	lov	☐	lve	☐	lv	☐
Great	grt	☐	gr8	☐	g8	☐
Light	lyht	☐	lht	☐	lght	☐
Foreign	4eign	☐	4ain	☐	frgn	☐
Yesterday	ystrdy	☐	yestrdy	☐	yday	☐
Forward	4wrd	☐	frwrd	☐	4ward	☐
Sometimes	sometms	☐	stimes	☐	sumtimes	☐
Oxford	ox4d	☐	xfrd	☐	oxfrd	☐
Probably	prbly	☐	probly	☐	prbably	☐
Forget	4gt	☐	frgt	☐	4get	☐
Question	questn	☐	qustn	☐	qstion	☐
Therefore	thrfr	☐	there4	☐	therefr	☐
Work	wk	☐	w3rk	☐	wrk	☐
Wait	wt	☐	w8	☐	wate	☐
Over	ova	☐	vr	☐	ovr	☐

Appendix 2.3 continued

Formal	4ml	☐	frml	☐	4mal	☐
Next	nt	☐	nxt	☐	nkst	☐
Together	2gether	☐	2gthr	☐	tgthr	☐
High	hgh	☐	hi	☐	hih	☐
Private	prv8	☐	priv8	☐	prvt	☐
Good	gd	☐	gud	☐	g00d	☐
Date	dt	☐	dte	☐	d8	☐
Still	stl	☐	stll	☐	stil	☐
Former	frmr	☐	4mr	☐	4mer	☐
Back	bck	☐	bk	☐	bak	☐
Forever	frvr	☐	4vr	☐	4eva	☐
Down	dn	☐	daun	☐	dwn	☐
Create	cre8	☐	cr8	☐	crte	☐
How	hau	☐	hw	☐	h0w	☐
Everyone	every1	☐	evry1	☐	evryn	☐
Like	lk	☐	lyk	☐	lik	☐

Appendix 2.3 continued

State	stt	☐	stait	☐	st8	☐
People	ppl	☐	pple	☐	peepl	☐
Someone	smn	☐	smeone	☐	sum1	☐
Between	betwn	☐	btwn	☐	btween	☐
Onto	ont	☐	on2	☐	nto	☐
Town	tn	☐	ta1	☐	twn	☐
Into	n2	☐	nto	☐	in2	☐
Half	haf	☐	hlf	☐	hal	☐
Towards	2wrds	☐	2wards	☐	twrds	☐

Thank you.

Appendix 2.4 Self-produced frequency list.

List of SMS shortcuts with frequency count of 10 or above listed by respondents.
From all online and post test surveys (total respondents 709).

Item	Shortcut	Meaning	Freq	Item	Shortcut	Meaning	Freq
1	u	you	412	34	nite	night	51
2	lol	laugh out loud	369	35	cu	see you	50
3	2	two/to/too	219	36	wot	what	48
4	r	are	140	37	luv	love	46
5	txt	text	132	38	nxt	next	46
6	4	for	117	39	wtf	what the fuck	44
7	ur	your or you're	113	40	cba	cant be arsed	43
8	omg	oh my god	110	41	cos	because	43
9	m8	mate	108	42	tho	though	43
10	b4	before	104	43	wuu2	what you up to?	43
11	c	see	96	44	fb	facebook	41
12	l8r	later	92	45	dnt	dont	40
13	lmao	laughing my arse off	89	46	lv	love	40
14	2nite	tonight	85	47	plz	please	38
15	2day	today	84	48	goin	going	37
16	pls	please	84	49	ly	love you	35
17	bk	back	81	50	ya	you	35
18	gd	good	78	51	atm	at the moment	34
19	b	be	77	52	probs	problems	34
20	brb	be right back	77	53	thx	thanks	34
21	2moro	tomorrow	76	54	wud	would	34
22	msg	message	76	55	gud	good	33
23	l8	late	71	56	kk	ok	33
24	tbh	to be honest	70	57	jst	just	31
25	gr8	great	66	58	rofl	rolling on the floor laughing	31
26	k	okay	66	59	yday	yesterday	31
27	btw	by the way	63	60	cnt	Cant	30
28	y	why	61	61	h8	hate	30
29	n	and	60	62	wat	what	30
30	ppl	people	58	63	@	at	29
31	2moz	tomorrow	56	64	bout	about	28
32	wen	when	56	65	yh	yeah	28
33	cya	see you	51	66	nt	not	27

Appendix 2.4 continued

Item	Shortcut	Meaning	Freq	Item	Shortcut	Meaning	Freq
67	wk	week	27	101	uni	university	17
68	gonna	going to	26	102	cn	can	16
69	TY	thank you	26	103	frm	from	16
70	wrk	work	26	104	np	no problems	16
71	coz	because	24	105	thnx	thanks	16
72	no	know	24	106	tht	that	16
73	tbf	to be fair	23	107	tlk	talk	16
74	wkend	weekend	23	108	cuz	because	15
75	ye	yes	23	109	guna	going to	15
76	defo	definitely	22	110	lyk	like	15
77	w8	wait	22	111	or8	alright	15
78	bt	but	21	112	shud	should	15
79	hav	have	21	113	ttyl	talk to you later	15
80	ru	are you	21	114	yeh	yes	15
81	sum	some	21	115	:)	happy	14
82	tb	text back	21	116	2morrow	tomorrow	14
83	wknd	weekend	21	117	bday	birthday	14
84	av	have	20	118	g2g	got to go	14
85	hw	how	20	119	gt	got	14
86	lol	lots of love	19	120	knw	know	14
87	pmsl	pissing myself laughing	19	121	nd	and	14
88	rite	right	19	122	ta	thanks	14
89	spk	speak	19	123	til	until	14
90	wanna	want to	19	124	wubu2	what've you been up to	14
91	asap	As Soon As Possible	18	125	duno	Don't know	13
92	cum	come	18	126	lmfao	laughing my fucking ass off	13
93	mite	might	18	127	min	minutes	13
94	prob	probably	18	128	nyt	night	13
95	soz	sorry	18	129	sum1	someone	13
96	4get	forget	17	130	v	very	13
97	cud	could	17	131	wt	what	13
98	fml	fuck my life	17	132	2mz	tomorrow	12
99	nw	now	17	133	2nyt	tonight	12
100	thanx	thanks	17	134	4ward	forward	12

Appendix 2.4 continued

Item	Shortcut	Meaning	Freq	Item	Shortcut	Meaning	Freq
135	bbe	baby	12	171	mayb	maybe	10
136	doin	doing	12	172	mins	minutes	10
137	dun	done	12	173	Nvm	nevermind	10
138	ftw	for the win	12	174	thn	then	10
139	obv	obviously	12	175	tmro	tomorrow	10
140	tnite	tonight	12	176	tmrw	tomorrow	10
141	2mo	tomorrow	11	177	Tom	tomorrow	10
142	2mrw	tomorrow	11	178	tonite	tonight	10
143	da	the	11	179	tym	time	10
144	def	definitely	11	180	urs	yours	10
145	dint	didn't	11	156	w/e	whatever	11
146	gna	going to	11	157	wit	with	11
147	hun	honey	11	158	yr	your/you are	11
148	idk	I don't know	11	159	2dy	today	10
149	kwl	cool	11	160	2night	tonight	10
150	l8a	later	11	161	4eva	forever	10
151	l8er	later	11	162	alr8	alright	10
152	r8	Barnsley pronunciation right	11	163	bak	back	10
153	tday	today	11	164	deffo	definitely	10
154	th	the	11	165	dm	doesnt matter	10
155	tx	thanks	11	166	dw	Don't worry	10
156	w/e	whatever	11	167	ere	here	10
157	wit	with	11	168	ffs	for fucks sake	10
158	yr	your/you are	11	169	gona	going to	10
159	2dy	today	10	170	ltr	later	10
160	2night	tonight	10	171	mayb	maybe	10
161	4eva	forever	10	172	mins	minutes	10
162	alr8	alright	10	173	Nvm	nevermind	10
163	bak	back	10	174	thn	then	10
164	deffo	definitely	10	175	tmro	tomorrow	10
165	dm	doesn't matter	10	176	tmrw	tomorrow	10
166	dw	don't worry	10	177	Tom	tomorrow	10
167	ere	here	10	178	tonite	tonight	10
168	ffs	for fucks sake	10	179	tym	time	10
169	gona	going to	10	180	urs	yours	10
170	ltr	later	10				

Appendix 2.5 Genuine usage frequency list

List of SMS shortcuts extracted from genuine text messages with frequency of 3 or above. From all online and post-test surveys (total respondents 309).

Item	Shortcut	Meaning	Freq	Item	Shortcut	Meaning	Freq
1	u	you	231	36	wanna	want to	11
2	:)	smile	126	37	aw	aw	10
3	lol	laugh out loud	78	38	hows	how is	10
4	im	I'm	64	39	hun	honey	10
5	r	are	43	40	nt	not	10
6	2	to	41	41	t	to/the	10
7	haha	laughing	34	42	doin	doing	9
8	yeah	yes	32	43	gd	good	9
9	uni	University	30	44	gud	good	9
10	c	see	29	45	hav	have	9
11	its	It's	24	46	jus	just	9
12	4	for	23	47	thats	that's	9
13	dont	don't	23	48	yep	yes	9
14	ill	I'll	22	49	cya	see you	8
15	ur	your/ you're	22	50	gt	got	8
16	ya	you	21	51	probs	problem	8
17	b	be	20	52	wat	what	8
18	hey	hello	20	53	your	you're	8
19	gonna	going to	18	54	:-)	smile	7
20	:(	unhappy	17	55	2moro	tomorrow	7
21	il	I'll	17	56	bout	about	7
22	:P	tongue out	16	57	ive	I've	7
23	n	and	16	58	nxt	next	7
24	wen	when	14	59	tho	though	7
25	yeh	yes	14	60	till	unitl	7
26	@	at	13	61	wot	what	7
27	hiya	hi there	13	62	wuu2	what you up to?	7
28	:D	grinning	12	63	;)	smile	6
29	mins	minutes	12	64	ahh	ahh	6
30	til	until	12	65	aww	aww	6
31	bk	back	11	66	btw	by the way	6
32	cant	can't	11	67	jst	just	6
33	goin	going	11	68	lmao	laughing my arse off	6
34	no	know	11	69	nw	now	6
35	txt	text	11	70	ta	thanks	6

Appendix 2.5 continued

Item	Shortcut	Meaning	Freq	Item	Shortcut	Meaning	Freq
71	th	the	6	108	wil	will	4
72	asap	as soon as possible	5	109	wk	work	4
73	av	have	5	110	wnt	want	4
74	cba	can't be arsed	5	111	fri	friday	3
75	coz	because	5	112	:-(	unhappy	3
76	defo	definitely	5	113	1	one	3
77	dunno	I don't know	5	114	2moz	tomorrow	3
78	fb	facebook	5	115	2night	tonight	3
79	hmmm	hmmm	5	116	2nite	tonight	3
80	kk	ok	5	117	agn	again	3
81	msg	message	5	118	atm	at the moment	3
82	nah	no	5	119	cn	can	3
83	nite	night	5	120	comin	coming	3
84	pls	please	5	121	cud	could	3
85	whats	what's	5	122	cum	come	3
86	workin	working	5	123	didnt	didn't	3
87	wrk	work	5	124	eve	evening	3
88	yh	yes	5	125	frm	from	3
89	sat	saturday	4	126	gr8	great	3
90	2day	today	4	127	havent	haven't	3
91	al	I'll	4	128	hme	home	3
92	cos	because	4	129	hv	have	3
93	cu	see you	4	130	hw	how	3
94	cuz	because	4	131	iv	I've	3
95	dnt	don't/didn't	4	132	k	ok	3
96	gona	going to	4	133	lv	love	3
97	gotta	got to	4	134	m8	mate	3
98	ha	laughing	4	135	mayb	maybe	3
99	hr	hour	4	136	morn	morning	3
100	l8r	later	4	137	nd	and	3
101	min	minute	4	138	okies	ok	3
102	okay	ok	4	139	ome	home	3
103	ooo	ooo	4	140	ooh	ooh	3
104	sum	some	4	141	pic	picture	3
105	tbh	to be honest	4	142	ps	please	3
106	urs	yours	4	143	sed	said	3
107	were	we are	4	144	thx	thanks	3

Appendix 2.5 *continued*

Item	Shortcut	Meaning	Freq
145	tonite	tonight	3
146	tym	time	3
147	v	very	3
148	wer	were/where	3
149	wheres	where is	3
150	wont	won't	3
151	yea	yes	3
152	yer	yes	3

Appendix 4.1 Experimental stimuli Experiment 1

Abbreviated SMS shortcut set					
Familiar SMS shortcuts		Unfamiliar SMS shortcuts		Fillers	
Prime	Target	Prime	Target	Prime	Target
whn	WHEN	thm	THEM	vhn	VHAN
wknd	WEEKEND	crrct	CORRECT	hdlt	HAIDALT
msg	MESSAGE	mng	MEANING	ywd	YOWD
txt	TEXT	bys	BOYS	zrk	ZORK
spk	SPEAK	cvl	CIVIL	zsk	ZISK
pls	PLEASE	cpl	COUPLE	qz	QUEZ
tlk	TALK	rsk	RISK	jq	JUQUE
wt	WHAT	sm	SOME	yft	YOFT
lv	LOVE	gm	GAME	zf	ZOOF
yday	YESTERDAY	stimes	SOMETIMES	rxt	RUXT
prbly	PROBABLY	qustn	QUESTION	yf	YOFE
wrk	WORK	ovr	OVER	fh	FOGH
nxt	NEXT	hgh	HIGH	kfl	KEEFLE
gd	GOOD	stl	STILL	snt	SANT
bk	BACK	dn	DOWN	kft	KAFT
hw	HOW	wy	WAY		
ppl	PEOPLE	shld	SHOULD		
twn	TOWN	hlf	HALF		

Appendix 4.1 continued

Letter-digit SMS shortcut set

Familiar SMS shortcuts		Unfamiliar SMS shortcuts		Fillers	
Prime	**Target**	**Prime**	**Target**	**Prime**	**Target**
d8	DATE	r8	RATE	p8	PATE
m8	MATE	f8	FATE	j8	JATE
4eva	FOREVER	4bid	FORBID	4ora	FORORER
h8	HATE	g8	GATE	ju1	JUWUN
4get	FORGET	pl8	PLATE	z8	ZATE
2nite	TONIGHT	est8	ESTATE	4mit	FORMIT
w8	WAIT	str8	STRAIGHT	2jagt	TOJAGHT
2moro	TOMORROW	oper8	OPERATE	th8	THATE
b4	BEFORE	4eign	FOREIGN	2mitha	TOMITHER
4ward	FORWARD	1da	WONDER	c4	CEFORE
evry1	EVERYONE	there4	THEREFORE	4tion	FORTION
L8	LATE	4m	FORM	t8	TATE
sum1	SOMEONE	priv8	PRIVATE	ru1	RUWON
2day	TODAY	4mer	FORMER	2loy	TULOY
l8r	LATER	cre8	CREATE	em2	EMTO
gr8	GREAT	st8	STATE		
in2	INTO	on2	ONTO		
2gether	TOGETHER	2wards	TOWARDS		

Appendix 4.2 Experimental stimuli Experiment 2

Abbreviated SMS shortcut set

Familiar SMS shortcuts		Unfamiliar SMS shortcuts		Fillers	
Prime	Target	Prime	Target	Prime	Target
when	whn	them	thm	nhuw	nhw
weekend	wknd	traffic	trffc	dunwaak	dnwk
message	msg	explain	xpln	saggem	sgm
text	txt	boys	bys	xett	xtt
speak	spk	stand	stnd	kpeas	kps
please	pls	garden	grdn	pseale	psl
talk	tlk	risk	rsk	lakt	lkt
what	wt	which	whch	tahw	tw
love	lv	light	lght	vafa	vf
yesterday	yday	sometimes	stimes	diftaryay	dyay
probably	prbly	question	qustn	yelbirpa	ylbrp
work	wrk	over	ovr	ruwk	rwk
next	nxt	high	hgh	xont	xnt
good	gd	still	stll	daque	dq
back	bk	down	dwn	kunb	kb
how	hw	like	lyk		
people	ppl	between	btwn		
town	twn	half	hlf		

Appendix 4.2 continued

Letter-digit SMS shortcut set					
Familiar SMS shortcuts		**Unfamiliar SMS shortcuts**		**Fillers**	
Prime	**Target**	**Prime**	**Target**	**Prime**	**Target**
date	d8	statement	st8ment	oromto	orom2
mate	m8	estate	est8	tetoin	te2in
forever	4eva	former	4mer	yatod	ya2d
hate	h8	foreign	4eign	forbe	4b
forget	4get	formal	4mal	aitel	8l
tonight	2nite	create	cre8	raitel	r8l
wait	w8	formula	4mula	aith	8h
tomorrow	2moro	forces	4ces	aitm	8m
before	b4	state	st8	aitger	8gr
forward	4ward	oxford	ox4d	phorwrad	4wrad
everyone	evry1	forced	4ced	tegfor	teg4
late	L8	straight	str8	aitew	8w
someone	sum1	towards	2wards	tohegter	2hegter
today	2day	rate	r8	aitde	8d
later	l8r	reform	re4m	efora	ve4a
great	gr8	therefore	there4		
into	in2	private	priv8		
together	2gether	onto	on2		

Appendix 5.1 Stimuli list

base word	Shortcut	Word	Nonword
s stimuli			
speak	spk	son	kps
just	jst	use	sjt
please	pls	gas	psl
w stimuli			
work	wrk	win	rkw
town	twn	own	wtn
know	knw	now	nwk
filler			
from	frm	for	fmr

Appendix 5.2 Example of colour rotations

	Stimuli	colour of 1st letter	colour of 2nd letter	colour of 3rd letter
	12x different colour rotations			
1	SPK	red	purple	green
2	SPK	brown	red	purple
3	SPK	green	brown	red
4	SPK	purple	green	brown
5	SPK	red	brown	green
6	SPK	brown	green	purple
7	SPK	green	purple	red
8	SPK	purple	red	brown
9	SPK	red	green	brown
10	SPK	brown	purple	green
11	SPK	green	red	purple
12	SPK	purple	brown	red
	2 same colours target letter in odd colour			
13	SPK	red	purple	purple
14	SPK	purple	red	red
	2 same colours target letter 1 of the 2 same colours			
15	SPK	red	red	purple
16	SPK	green	green	brown
17	SPK	brown	brown	green
18	SPK	purple	purple	red

Appendix 5.3 Type of error

	Type of Error	Proportion of all errors
1	Conjunction error	26.94
2	Reported letter & colour from different letter in display	1.11
3	Initially reported wrong colour but corrected to right colour	24.17
4	Initially reported wrong letter but corrected to right letter	12.22
5	Initially reported 2 colours but corrected to right letter and colour	1.39
6	Reported letter & colour from different letter in display but correct to right letter & colour	0.83
7	Don't know	14.17
8	Initially reported 2 letters but corrected to right letter and colour	1.39
9	Initially reported letter & colour not present but corrected	0.28
10	Reported letter & colour from different letter in display but corrected	0.28
11	Colour reported before letter but correct letter and colour	4.72
12	Reported non present target letter	1.67
13	Initially reported nothing but corrected to right letter & colour	1.11
14	Speech error	5.83
15	Two target letters reported not corrected	1.11
16	Letter only reported	1.11
17	Initially reported non present target letter then corrected	0.28
18	Missing data	1.67

Appendix 6.1 Experimental stimuli

Abbreviated SMS shortcut set.

Item	Pseudohomophone	Graphemic control	SMS shortcut target	Fillers
1	tecst	taect	txt	nhw
2	mesij	miseg	msg	dunwaak
3	pleiz	plaif	pls	%%%
4	baque	bafte	bk	xtt
5	peepul	pupeel	ppl	kpeas
6	nekst	netsk	nxt	%%%
7	yestadeigh	yastedauth	yday	tn
8	noht	nolt	nt	tahw
9	werc	warc	wrk	%%
10	weikened	weykined	wknd	dyya
11	speec	spaet	spk	kutl
12	hau	heo	hw	%%%
13	tawque	talsue	tlk	xnt
14	woht	wuft	wt	vanu
15	toun	tion	twn	%%
16	uen	aen	whn	nkw
17	nau	nia	nw	lapoep
18	noe	nio	knw	%%%

Appendix 6.1 continued

Phonological SMS shortcut set.

	Pseudohomophone	Graphemic control	SMS shortcut Target	Fillers
19	mait	maut	m8	oromto
20	beefoar	beufoir	b4	%%%%
21	laeta	laute	l8r	ya2d
22	tudae	tidao	2day	forbe
23	tumoroe	timoroi	2moro	%%
24	laet	laot	l8	r8l
25	tunait	tiniit	2nite	aith
26	grait	graot	gr8	%%
27	hayt	haut	h8	8gr
28	weyt	wiut	w8	forwada
29	phorwawd	phrowamd	4ward	%%%%
30	phorevur	phroevit	4eva	8w
31	phorget	phrogit	4get	tohegter
32	tugeva	togexa	2getha	%%
33	phourgott	phoergoth	4got	ve4a
34	deit	duot	d8	onevrey
35	eintu	uinti	in2	%%%
36	evriwun	evroson	every1	i2n

Appendix 7.1 Non-exemplar (experimental) stimuli

Abbreviated shortcut set		Letter-digit shortcut set		Phonological shortcut set	
Shortcut Prime	**Semantic Target**	**Shortcut Prime**	**Semantic Target**	**Shortcut Prime**	**Semantic Target**
txt	PHONE	m8	FRIEND	nite	DARK
gd	BAD	b4	AFTER	tho	EVEN
msg	EMAIL	l8r	SOONER	cos	REASON
pls	BEG	2day	NOW	thx	GRATEFUL
bk	FRONT	2moro	DAY	wud	IF
ppl	CROWD	l8	EARLY	rite	LEFT
lv	MARRIAGE	2nite	EVENING	sum	MANY
nxt	THEN	gr8	FANTASTIC	mite	PERHAPS
yday	PAST	h8	FEAR	cum	GO
nt	YES	w8	STOP	kwl	AWESOME
wrk	PLAY	4ward	BACK	lyk	SIMILAR
jst	ONLY	4eva	ALWAYS	cud	PERHAPS
wknd	HOLIDAY	4get	REMEMBER	dun	FINISHED
bt	HOWEVER	2getha	WITH	eva	FOR
spk	HEAR	sum1	PERSON	ova	UNDER
hw	WHY	4got	MEMORY	shud	OUGHT
tlk	LISTEN	d8	CALENDAR	wer	ARE
wt	QUESTION	in2	OUT	neva	SOMETIMES
twn	COUNTRY	str8	DIRECT	sed	WORD
whn	TIME	every1	ALL	uva	SAME

Appendix 7.2 Exemplar (non-experimental) stimuli

Source of Energy	
Prime	Target
warmth	HEAT
planets	SOLAR
wind	TURBINE
pump	HYDRAULIC
current	ELECTRICITY
pressure	STEAM
fusion	ATOM
reactor	NUCLEAR

Time	
Prime	Target
twelve	NOON
term	SEMESTER
twelve	MIDDAY
morning	AFTERNOON
dusk	EVENING
instant	MINUTE
month	YEAR
hour	MILLISECOND
fleeting	MOMENT
lifetime	ETERNITY
horizon	SUNSET

Academic Discipline	
Prime	Target
experiment	CHEMISTRY
quantum	PHYSICS
mind	PSYCHOLOGY
cells	BIOLOGY
court	LAW
probability	STATISTICS
sums	MATHEMATICS
ethics	PHILOSOPHY
discovery	SCIENCE
money	ECONOMICS
technology	ENGINEERING

Mathematical Operation	
Prime	Target
calculation	ADDITION
solve	EQUATION
reasoning	LOGIC
portion	DIVISION
geometry	ALGEBRA
times	MULTIPLICATION
minus	SUBTRACTION
rate	PERCENTAGES
compound	FORMULA
circle	PI
decimal	FRACTION

Emotion	
Prime	Target
greed	ENVY
bliss	HAPPINESS
pleasure	DELIGHT
adventure	EXCITEMENT
covet	JEALOUSY
indifference	APATHY
rage	ANGER
glee	JOY
wish	HOPE
unexpected	SURPRISE

Chemical Element	
Prime	Target
balloon	HELIUM
bronze	COPPER
steel	IRON
thermometer	MERCURY
diamond	CARBON
bones	CALCIUM
graphite	LEAD
tin	ALUMINIUM
silver	GOLD
radioactive	URANIUM