Word reading and picture naming: Phonological encoding in English language production

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Abstract

In Roelofs' (2004) form preparation study examining processes involved in both word reading and picture naming, he concluded that phonological encoding mechanisms might be shared for the two tasks. Importantly, in his earlier form preparation research Roelofs (1999) argued that phonemic features are not involved during phonological encoding and indeed, most current models of general language production such as Word-form Encoding by Activation and VERification (WEAVER, e.g., Roelofs, 1997a) account for the role of phonemic features once the phonological encoding process has been completed. However, whilst Kinoshita's (2000) re-interpretation of the locus of the masked onset priming effect (MOPE) implies an encoding process for word reading that is similar to that incorporated into WEAVER (e.g., Roelofs, 1997a) and by extension to picture naming, Lukatela, Eaton and Turvey's (2001) results suggest that features may well be involved in the word reading processes. The main purpose of the research undertaken within this thesis was to evaluate phonological encoding for both word reading and picture naming to assess the validity of Roelofs' (2004) claims. This was conducted with the employment of the masked priming paradigm as well as the masked sandwich priming paradigm and by the manipulation of phonemic feature overlap in both the initial and end/coda segment position of primes and monosyllabic targets. From the cumulative results of this research, the notion that encoding mechanisms might be shared between these two tasks could not be ruled out. Importantly, phonemic feature effects were consistently observed across both word reading (with lexical primes) and picture naming. Controversially, these particular findings suggest that conventional thinking is misguided to ignore the role of phonemic features during the phonological encoding process.

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CHAPTER 1: Introduction, outline and models of general language production & word reading

1.1. Introduction

This thesis examines phonological encoding processes that are involved in both single word reading and the naming of pictures of simple objects. The latter is a popular task employed in general language production research which for simplicity hereafter is referred to as the picture naming task. According to some language production theorists (e.g., Levelt, Roelofs & Meyer, 1999; Roelofs, 1992, 1996b, 1997a, 1997b), phonological encoding is a process during which a to-be-named object's word form is constructed. It occurs after the appropriate concept for this item has been selected from the mental lexicon and prior to the generation of articulation.

Although there exists a considerable body of research that has investigated this processing stage in general language production (e.g., Meyer 1990, 1991; Roelofs, 1999, 2004), researchers (e.g., Kinoshita 2000, Kinoshita & Woollams, 2002; Malouf & Kinoshita 2007) are still at the very early stages of examining phonological encoding in word reading. The varying degree of interest in this process between these two domains is reflected in the design of theoretical/computational models that have been developed to account for the processes involved in language production generally and word reading specifically. Consequently and as illustrated in the following sections of this chapter (sections 1.3. and 1.4., respectively), language production models provide an elaborate account of how phonology is constructed whereas word reading models tend

to be primarily focused on mapping orthography onto phonology. However, the fact that research to date has tended to examine word and picture naming separately does not exclude the possibility that similarities exist in the processing of each task. Given that a degree of lexical access is required to accomplish either discipline, an investigation into processes that occur both during and immediately after lexical access whilst manipulating word reading and picture naming within the same experiment has the potential to yield important new information as to the likelihood of common mechanisms.

Importantly, research conducted in Dutch by Roelofs (2004) suggested the possibility of shared phonological encoding mechanisms for both speaking and reading words aloud. In Experiments 1 and 2 Roelofs (2004) employed a form preparation paradigm in which printed words and their corresponding pictures were grouped into four conditions that each consisted of three sets of stimuli per set. In these two studies words and pictures were not mixed within the same set. However, for every set that contained pictures there was a corresponding set that contained the printed names of those pictures. The four conditions were: Begin-homogeneous, End-homogeneous, Begin-heterogeneous and End-heterogeneous. In Experiment 1, the stimuli in Begin-homogeneous sets all shared their initial segment (e.g., bok, boor, bel) whereas in End-homogeneous sets they shared their end segments (e.g., rat, krat, vat). The heterogeneous sets were constructed by taking one stimulus from each of the three corresponding homogeneous sets (e.g., roos, bok, kam – Begin-heterogeneous; peer, rat, clip – End-heterogeneous). Therefore, in Roelofs' (2004) research the same words or pictures were used in both homogeneous and heterogeneous sets thus allowing for more direct comparisons between the two experimental conditions. Participants were required to name words and pictures

presented in separate blocks in which the three stimuli comprising a set were presented five times in random order, with participants' response latencies recorded. The order of block presentation was counterbalanced across participants with a short interval prior to the display of the next block. Experiment 2 was similar to Experiment 1 except that in this study disyllabic words and their corresponding pictures were employed that in Begin-homogeneous sets shared their first syllable (e.g., leraar, lepel, lelie) and in End-homogeneous sets shared their second syllable (e.g., klaver, bever, vijver). Finally, in Experiment 3 the disyllabic words and their corresponding pictures from Experiment 2 were mixed together within the same sets.

From Experiments 1 and 2, Roelofs (2004) demonstrated that both words and pictures in Begin-homogeneous sets were named faster compared to Heterogeneous sets thereby showing a preparation benefit. However, there was no benefit for End-homogeneous sets. These results were therefore consistent with an incremental, rightward phonological encoding process such as that incorporated into the WEAVER general language production model. From Experiment 3, Roelofs (2004) found that even when words and pictures were mixed together within the same sets, the magnitude of observed preparation benefits were similar to those found in the earlier two experiments. As such, Roelofs (2004) concluded that although printed words were named faster than pictures, it is likely that a single serial encoding mechanism is shared for both word reading and picture naming. He thus suggested a possible merging of models of general language production such as WEAVER with models of word reading such as DRC at the segment-to-frame association stage of the phonological encoding process.

Further, because phonemes are represented as abstract entities in WEAVER at this processing stage and are therefore not specified for their features, Roelofs (2004) conclusions were also consistent with the findings from his earlier research (Roelofs, 1999). In his 1999 work which was again conducted in Dutch, Roelofs set out to investigate effects from phonemic feature similarity on spoken word production. To this aim in Experiments 1 and 2 Roelofs (1999) employed the implicit-priming paradigm first introduced by Meyer (1990). In this paradigm, participants had to learn word pairs e.g., kabel-touw (cable-rope). On the presentation of the first word/prompt in a pair they then were required to say the second word/response, with naming latency recorded. Further, in both studies the response words were grouped into four conditions consisting of six sets of three words per set. These conditions were: Segments-homogeneous, Features-homogenous, Segments-heterogeneous and Features-heterogeneous. In Experiment 1 monosyllabic response words in Segments-homogeneous sets shared their initial segment (e.g., touw, teil, thee) whereas in Features-homogeneous sets the initial segment of the response words shared all but one of their phonemic features (e.g., thee, touw, deur – in this example 't' and 'd' share all of their phonemic features except for voicing). Akin to Roelofs' (2004) research the heterogeneous sets were constructed by taking one response word from each corresponding homogeneous set. During Roelofs (1999) Experiment 1 each of the three prompt-response word pairs comprising a set were tested four times in random order within a block. The order with which these blocks were presented was again counterbalanced across participants. The same experimental procedure was used in Experiment 2. However, in this study disyllabic response words were employed that in Segments-homogenous sets shared their first syllable (e.g., degen, demo, deken) whereas in Features-homogeneous sets the shared

first syllable differed by one phonemic feature in the initial segment position (demo, degen, teken).

The results from Experiments 1 and 2 were consistent across the two studies and demonstrated preparation benefits in Segments-homogeneous sets but not in Features-homogeneous sets. However, Roelofs (1999) argued that because in the implicit-priming paradigm participants had to memorise the response words his outcomes could have been due to effects associated with memory retrieval. Consequently, in Experiments 3 and 4 Roelofs (1999) employed the form preparation paradigm described above (Roelofs, 2004). In Experiment 3 therefore, pictures that corresponded to the monosyllabic response words from Experiment 1 were used whereas in Experiment 4 these pictures corresponded to the disyllabic response words from Experiment 2. In both studies pictures were displayed for naming in Segments-Homogeneous, Features-homogeneous and Heterogeneous sets, with response latencies recorded. The findings from Experiments 3 and 4 were in line with the results from Experiments 1 and 2. Since in all of Roelofs' (1999) experiments only benefits from shared segment/s but not from shared phonemic features were observed, the author concluded that his data was consistent with processing at the segment-to-frame association stage of WEAVER and that at this particular stage phonemes are represented as abstract entities and are therefore not specified for their features.

However, as discussed later in this chapter (section 1.4.1.3.), research conducted by Mulatti et al. (2006) and Ashby et al. (2009) all showed effects from phonemic feature similarity in word reading. These findings were thus contrary to both the working assumptions of WEAVER as well as Roelofs' (2004) notion of shared phonological

encoding mechanisms for both word reading and picture naming. Consequently, a simultaneous investigation into the role of phonemic features in both domains could provide important new information concerning how phonology is constructed for each task and thereby either support or invalidate Roelofs' (2004) assertion of shared mechanisms. The experimental work conducted within this thesis was thus designed to address two main research questions namely, what role do phonemic features play in both picture naming and word reading and do shared phonological encoding mechanisms exist for these two domains (Roelofs, 2004)?

1.2. Outline

The current chapter begins by explaining the motivation for conducting research into phonological encoding mechanisms for both word reading and picture naming within the same set of experiments. This is followed by a detailed description of the most influential and relevant models that have been developed to account for the processes involved in each domain. Chapter 2 introduces the masked priming paradigm along with key research that was conducted using this experimental procedure. It concludes that the masked priming paradigm is the most appropriate one to use to assess how phonology is constructed in each of these two tasks. Given that the experimental method employed was similar across the herein reported experiments, to avoid repetitions it is fully described in Chapter 3. The research findings from Experiments 1 to 3 that examined effects from phonemic feature manipulations in the onset position (i.e., the initial consonant) of primes and their corresponding targets are described and evaluated in

Chapter 4 whereas the outcomes from Experiments 4 to 6 in which manipulations related to the coda position (i.e., the final consonant) of these two stimuli are considered in Chapter 5. Chapter 6 reviews the findings from the final two experiments of this thesis (Experiments 7 and 8) that employed the masked sandwich priming paradigm. Finally, in Chapter 7 all the data from this experimental work is considered in great detail in relation to how encoding mechanisms operate separately for each task and also to how some of these processes might be common to both domains. This chapter concludes by suggesting possible lines of future enquires that could contribute further to the current understanding of phonological encoding mechanisms that operate during both word reading and picture naming.

1.3. Models of general language production

1.3.1. Segmental models

1.3.1.1. Dell's (1986) model

According to Dell's (1986) spreading activation model, word production is a product of processes which take place at four hierarchically organised main levels, namely semantic, syntactic, morphological and phonological levels. At the semantic level which is not fully incorporated in the workings of the model, meaning is assigned to what is to be said. The syntactic level specifies to which syntactic category the utterance belongs; whether it is a noun, verb or an adjective. During the morphological level of processing, the utterance is divided into morphemes. A morpheme is the smallest unit of meaning in a word. For example, the word 'boyish' consists of two morphemes; root - 'boy' and

suffix - 'ish'. The phonological level, which 'can be defined as the processes by which the speech sounds that compose a morpheme or string of morphemes are retrieved, ordered, and organized for articulation' (Dell, 1986, pg. 293), is further divided into syllable, syllabic constituent, phoneme and feature levels.

During phonological encoding of a polysyllabic morpheme for example, activation spreads in parallel from the morpheme to its syllables and their constituents. At the beginning of the encoding process the first syllable is activated more strongly than any remaining syllables and is assigned current node status, with the phonemes of this syllable receiving (in parallel) more activation compared to the phonemes constituting other syllables. At the same time a syllable frame is created consisting of ordered slots corresponding to syllable onset (i.e., the initial consonant or consonant cluster), nucleus (i.e., the initial or middle vowel or vowel cluster) and coda (i.e., the final consonant or consonant cluster).

The creation of a syllable frame with its slots for syllable onset, nucleus and coda has a direct implication on how, in Dell's (1986) model, phonemes at the phoneme level are represented. To account for their syllable position, phonemes that can occur in either the onset or coda position are represented twice. For example, the phoneme 't' is represented as 't$_{on}$' for the onset and 't$_{co}$' for the coda position. Thus, the former is activated when 'top' is encoded whilst the latter is activated when 'bat' is encoded. Further, the phoneme level also contains two null elements; one for the onset and one for the coda position. The onset null element is activated when a syllable has no initial consonant as in 'an' whilst the coda null element is activated when a syllable has no final consonant as in 'spa' (Dell, 1986). As such, in Dell's (1986) model 'Onset stands

for either the initial null element, an initial consonant, or an initial consonant cluster; Nucleus stands for a vowel or diphthong; Coda is either the final null element, a final consonant, or a final consonant cluster' (Dell, 1986, pg. 296).

Once phonemes receive activation from the syllable level they then activate (in parallel) their corresponding features (i.e., articulatory gestures such as for example, voiced, nasal, lateral, low, tense) at the feature level. After a while the activation levels of all phonemes are inspected with the most highly activated units selected to fill the slots within the frame of the current syllable. Once selected, the activation levels of these phonemes are set back to zero in what Dell (1986) referred to as post-selection negative feedback. The activation levels of the phonemes which were activated to a lesser extent by the remaining syllables of the polysyllabic morpheme and were therefore not selected to fill the current syllable frame decay over time. A new syllable frame is then created with the next syllable assigned current node status. The process continues until all the syllables have been encoded to form the completed phonological representation. As such, according to the model proposed by Dell (1986), each segment comprising a syllable is activated and then selected in parallel whilst each syllable comprising a morpheme is activated and then selected in a strict rightward serial sequence.

Further, there are two main working assumptions incorporated in Dell's (1986) model. The first assumption postulates that at each level a frame, representing the node marked as current at the higher level, is constructed into which only the most highly activated nodes are inserted. The second assumption relates to the issue of activation. As argued by Dell (1986), during the word production process activation spreads from the higher levels to the lower levels and back up again. This bi-directional spreading activation

means that activation at each level is constantly influenced by the activation at both the level directly above and the level directly below it.

The architecture of Dell's (1986) model and its activation parameters (spreading and decay rates) were specifically designed to account for speech error data. A speech error occurs when instead of the intended utterance an unintended utterance is produced. For example, whilst intending to say 'barn door' a speaker may say 'darn bore'. Since the initial phonemes of the two words switched places, this error can be classified as a phoneme exchange error. As argued by Dell (1986), the occurrence of speech errors such as a phoneme exchange error that in itself reflects the highly interactive nature of the language production process, can successfully be explained with reference to his model.

In Dell's (1986) model, during the production of a two word sequence (e.g., barn door) the morphemes of both words are activated. Due to the model's serial, rightward manner of between utterance processing, the morpheme of the word 'barn' is assigned current node status whilst the morpheme of the second word (door) receives 'anticipatory activation' (Dell, 1986, pg. 296). Next, activation from both morphemes spreads to the syllable level. Since both morphemes are monosyllabic, the syllable 'barn' is assigned current node status and its phonemes receive more activation than the phonemes of the syllable 'door'. However, as the phonemes of both syllables are activated at the same time (albeit to a lesser extent) and they in turn activate their corresponding features which then feedback activation to the phoneme level, there is a lot of 'noise' in the system. Due to this noise, the activation level of some phonemes is altered. Consequently, during the assignment of phonemes into their positions within

the first syllable, the initial phoneme of the second syllable (d) is selected instead of 'b' and is inserted into the onset position of the first syllable resulting in the production of the word 'darn' instead of 'barn'. Next, the activation levels of the selected phonemes are set back to zero. However, as the phoneme 'b' was not selected it remains active. Therefore, it naturally fills the missing onset position of the second syllable.

Further, Dell's (1986) spreading activation model can also provide a feasible explanation for the occurrence of feature exchange errors such as for example, 'glear plue' for 'clear blue' (Dell, 1986). In this example, the featural characteristic (voicing) of the initial phoneme of the second utterance (b - voiced) affected the featural characteristic of the initial phoneme of the first utterance (c - voiceless) and vice versa. This resulted in the selection of the voiced phoneme 'g' instead of the voiceless 'c' in the first word and also the selection of the voiceless 'p' in place of the voiced 'b' in the second word. As such, feature exchange errors are the product of feedback activation from the feature to the phoneme level (Dell, 1986) and can be explained as follows.

During the phoneme selection process (as described in the earlier example) activation from both syllables (clear and blue) spreads to the phoneme and then to the feature level. The activation from the initial phoneme 'c' therefore, activates its corresponding features. Since 'c' and 'g' share all their features but voicing, feedback from the feature level not only supports the activation of the initial phoneme 'c' but also results in the activation of the initial phoneme 'g'. At the same time, the initial phoneme 'b' of the second syllable activates its corresponding features one of which is 'voiced'. As 'g' is also voiced, feedback from the voiced feature increases the activation level of this phoneme. Consequently, 'g' is selected instead of 'c' to fill in the initial position within

the first syllable. Further, reverse logic can be employed to explain the selection of the voiceless phoneme 'p' in place of the voiced 'b' in the initial position of the second syllable. In this case, feedback from the features of the phoneme 'b' activates the phoneme 'p' which also receives activation from the 'voiceless' feature of the initial phoneme 'c' from the first syllable resulting in the production of the word 'plue' instead of 'blue'. Put together, during phonological encoding of a two word sequence, feedback from the feature to the phoneme level can result in the production of 'glear plue' in place of 'clear blue'.

Even though Dell's (1986) model was designed to account for speech errors rather than reaction time data, the results from one classic study undertaken by Meyer (1990) are relevant to the discussion since it was specifically conducted to test whether, as suggested by the model, phonological encoding of successive syllables of an utterance occurs in a serial, rightward manner. In her research, Meyer (1990) ran six experiments in Dutch. In all experiments she employed an implicit-priming paradigm in which participants had to learn word pairs such as touw-kabel (rope-cable), woning-kamer (house-room) and peddel-kano (paddle-canoe). On presentation of the first word in a pair participants were required to say the second word, with naming latency (i.e. the elapse of time between prompt onset and speech onset) recorded. In Experiments 1 to 4 there were five sets of five word pairs in which disyllabic response words were related in form (homogeneous sets) and five sets of five word pairs in which disyllabic response words were unrelated in form (heterogeneous sets). The heterogeneous sets were created by taking one word pair from each of the five homogeneous sets. In homogeneous sets in Experiment 1, response words shared the same stressed first syllable (e.g., kabel, kamer, kano, kater, kalief) whilst in Experiment 2 the unstressed

final syllable was shared (e.g., salto, veto, foto, conto, auto). In Experiment 3 response words in homogeneous sets shared their unstressed first syllable and in Experiment 4 they shared their stressed final syllable. In Experiments 5 two main types of homogeneous sets, each with three sub-sets of three word pairs were created. In the first set (Type 1) tri-syllabic response words shared the same first syllable whereas in the second set (Type 2) they shared the first and second syllable. In both sets, the stress pattern was on the final (third) syllable. Heterogeneous sets for Type 1 and Type 2 sets were created in the same way as in the earlier experiments. Experiment 6 was just a repetition of Experiment 5 but with new stimulus choices.

Meyer (1990) found that independent of word stress pattern naming latencies for homogeneous sets sharing the first syllable were shorter than naming latencies for heterogeneous sets (Experiments 1,3,5 and 6). However, latencies were essentially the same for homogeneous and heterogeneous sets in Experiments 2 and 4 suggesting that a shared final syllable yields no benefit if the initial syllable is not shared. Further, the results from Experiments 5 and 6 showed that compared to Type 1 sets in which response words shared the same first syllable latencies were even shorter when both the first and second syllables were shared (Type 2 sets). This facilitation effect in begin-homogeneous sets became known as the preparation benefit.

Based on these findings, Meyer (1990) concluded that as suggested by Dell's (1986) spreading activation model, phonological encoding must occur along a rightward, serial path, encoding one syllable at the time until the word form is complete. However, in Dell's (1986) model once a syllable frame is filled, the activation levels of the current syllable and the selected corresponding phonemes are set back to zero. Also, in this

model each syllable of an utterance is encoded at 'a constant time span' (Meyer, 1990, pg. 527). Following these principles therefore, Meyer (1990) argued that no facilitation should be observed when words with the same first syllable/syllables are spoken in quick succession. Nonetheless, the above results can be accounted for by the WEAVER (Word-form Encoding by Activation and VERification) computational model of spoken word production (Levelt, Roelofs & Meyer, 1999; Roelofs 1992, 1996b, 1997a, 1997b).

1.3.1.2. WEAVER (Levelt et al., 1999; Roelofs 1992, 1996b, 1997a, 1997b) model

Akin to Dell's (1986) spreading activation model, in WEAVER phonemes are represented as abstract entities from which features are activated at a later level/stage. According to WEAVER, language production occurs in six stages. These stages are: conceptual preparation, lexical selection, morphological encoding, phonological encoding, phonetic encoding and articulation. When presented with an object for naming a speaker first needs to identify what the object is so that the appropriate lexical concept can be activated (conceptual preparation). This lexical concept is then used to select the corresponding lemma (lexical selection). 'A lemma is a memory representation of the syntactic properties of a word' (Roelofs, 1997a, pg. 256). Thus, a lemma specifies whether a word is a noun, a verb or an adjective. During morphological encoding the selected lemma activates its morpheme/s. At the phonological encoding stage that follows, phonemic segments corresponding to a morpheme along with the morpheme's metrical structure are then activated in parallel. A morpheme's metrical structure refers to its number of syllables and the stress pattern across the morpheme. It

is important to highlight at this point that, contrary to Dell's (1986) model in which phonemes are specified for their syllable position, in WEAVER the activated phonemic segments are assigned their place within an activated metrical structure based on their position in the morpheme. For example, the morpheme 'pop' specifies that the activated phonemic segment 'p' should be assigned to the first and then to the third position of the metrical structure. As such, in WEAVER each phonemic segment is not specified for its syllable position and thus, is represented only once (Damian & Dumay, 2009).

Further, in WEAVER, rather than being stored in memory (as in Dell's, 1986, model) a target word's syllable structure is computed on-line (during phonological encoding) by associating a morpheme's segments with the morpheme's metrical structure in what is referred to as the segment-to-frame association process. During this process, segments are assigned their syllable position according to the syllabification rules of the language concerned, in a rightward direction starting with the segment whose link is labeled first (Roelofs, 1997a).

In WEAVER, as soon as the segment-to-frame association process of the first or only syllable of the target word has been completed, phonetic encoding begins. During phonetic encoding the outcome of the phonological encoding stage of processing, namely the abstract phonological syllable/word, is used to access its corresponding articulatory program in the mental syllabary (memory store for learned syllable programs). In agreement with other researchers (e.g., Levelt, 1989, 1992; Levelt & Wheeldon, 1994), Roelofs (1997a) postulated that the articulatory programs for high frequency syllables are stored in the mental syllabary whilst they are computed on-line for low frequency syllables. Further, at the same time the features of each and every

phoneme of the phonological syllable/word as well as the features corresponding to the whole phonological syllable/word are activated, with the former receiving activation in parallel across the word form (Roelofs, 1999). Thus, in WEAVER the inclusion of the phonetic encoding stage of processing allows for a context dependent realization of features. In the final (articulation) stage of spoken word production, the information provided by the articulatory programs (e.g. pitch, duration, and loudness) is used to drive muscular movement during articulation.

Although WEAVER adopts the spreading activation assumptions of Dell (1986), contrary to Dell's (1986) model, in WEAVER there is only unidirectional, feed forward activation from the highest stages of processing to the lower ones. Also in WEAVER, at each stage of the language production process nodes are only selected if they achieve the required activation threshold in conjunction with complying with the production rules of the target nodes at the stage directly above. Thus, their activation is verified prior to selection. Finally, an important feature of WEAVER's segment-to-frame association process is that it incorporates a suspend-resume mechanism. As such, this process can begin even if only the initial segment/s of a morpheme is/are available. In this case the assignment of phonemes into their positions within a given metrical structure will be computed as far as possible and then suspended. When more information becomes available, the segment-to-frame association process can then continue from the point at which it was suspended (Roelofs, 1997a).

This suspend-resume mechanism allows WEAVER to explain the preparation benefit found by Meyer (1990) in homogeneous sets in which the response words to initial prompt words shared their first syllable/ syllables. Consider a homogeneous response

set sharing the first syllable (e.g., kabel, kamer, kano, kater, kalief). Following the first trial the encoder can construct the first syllable, 'ka', of the second response word, at which point the encoding process is suspended. On presentation of the second prompt 'woning' the lemma for 'kamer' is retrieved. At this point the encoder can resume processing and start work on the second syllable, resulting in faster processing times for the second and subsequent response words in the homogeneous set. However, for homogeneous sets sharing the last syllable, although the syllable is known the position of this syllable is to the right of the suspend point. On retrieval of the relevant lemma and then morpheme WEAVER dictates that the encoder has to start work on the initial segment of the word, which by definition for homogeneous sets sharing the last syllable would be different to a prior initial segment remaining within the system from the previous trial. Therefore, the segment-to-frame association process has to start from the beginning resulting, as found by Meyer (1990), in no preparation benefit in this condition.

In addition, WEAVER's suspend-resume mechanism can also account for the results from Meyer's (1991) research. Using the same paradigm as in her previous work (Meyer, 1990), Meyer (1991) set out to establish whether there is a specific order in which syllable constituents are encoded. To accomplish this she conducted eight experiments. In Experiment 1 monosyllabic response words in homogeneous sets shared their onset whereas in Experiment 2 they shared their rhyme (nucleus and coda). In Experiments 3 and 4 disyllabic response words were employed in homogeneous sets which shared the same onset (Experiment 3) or the same rhyme (Experiment 4) of the first syllable. Further, in Experiments 5 and 6 there were two main types of homogeneous sets. In Type 1 disyllabic response words shared the same first syllable

and in Type 2 they shared the first syllable and also the onset of the second syllable. In Experiment 7 on the other hand, stimuli were ordered in three main types of homogenous sets, disyllabic response words in Type 1 shared their onset, in Type 2 they shared the same onset and nucleus whilst in Type 3 the entire first syllable was shared. In Experiment 8 Type 2 and Type 3 sets from Experiment 7 were employed. Finally, in all experiments heterogeneous sets for each corresponding homogeneous set were constructed in the same way as in Meyer (1990).

The results from Meyer's (1991) research can be summarised as follows. Meyer (1991) demonstrated facilitation for both mono and disyllabic words in homogeneous sets in which response words shared the same word onset (Experiments 1, 3 and 7) with even more facilitation observed when disyllabic response words shared the same onset and nucleus of the first syllable (Experiment 7 and 8). Further, Experiments 5, 6, 7 and 8 showed that facilitation increased relative to the amount of initial segments shared. Thus, words sharing the entire first syllable were named faster than words sharing just onset and nucleus with words sharing the first syllable and the onset of the second syllable named fastest of all. However, there was no benefit in both mono (Experiment 2) and disyllabic (Experiment 4) response words from shared rhyme. Therefore, these results indicate that, as incorporated in WEAVER, the segment-to-frame association process of a word starts from the beginning of the word and takes place in a rightward, serial manner encoding one segment at the time and that this process can be suspended and resumed at any time.

Finally, even though WEAVER was not designed to account for speech error data, as argued by Roelofs (1997a) it can successfully do so. However, in contrast to Dell's (1986) model in which speech errors such as the earlier described phoneme and feature exchange errors are due to 'segment selection failure' (Roelofs, 1997a, pg. 270) during phonological encoding, in WEAVER these errors are explained with reference to the phonetic encoding stage of processing. Roelofs (1997a) suggested that phoneme exchange errors (e.g., 'darn bore' for 'barn door') are the consequence of an incorrect syllable program being accessed in the mental syllabary. According to Roelofs (1997a) this can occur because once phonological encoding of the word sequence 'barn door' has been accomplished there is a simultaneous processing of both words at the phonetic encoding stage. Therefore, the phonemes of the phonological word <bɑːn> will activate the syllables <bɑːn>, <dɑːn> as well as other related syllables whereas, at the same time, the phonemes of the phonological word <dɔː(r)> will activate the syllables <dɔː(r)>, <bɔː(r)> and also other related syllables. Since the syllables <dɑːn> and <dɔː(r)> share the same onset phoneme this might result in the selection of a syllable program for <dɑːn> instead of <bɑːn>. The same logic can be applied to explain why the syllable program for <bɔː(r)> might be selected in place of <dɔː(r)>. In reference to feature exchange errors (e.g., 'glear plue' for 'clear blue'), Roelofs (1997a) argued that these errors are due to shared features between phonemes and syllables as according to the modeller, in WEAVER 'Both segments node and syllable program nodes point to their features (i.e. articulatory gestures)' (Roelofs, 1997a, pg. 271).

1.3.2. Feature based model

1.3.2.1. Parallel Distributed Processing (PDP; Dell, Juliano & Govindjee, 1993) model

In contrast to the models described above that advocate the need for abstract phonemes from which features are activated at a later level/stage of the encoding process, in Dell et al.'s (1993) Parallel Distributed Processing (PDP) computational model phonemes are specified for their features. According to this model, at the beginning of single word production a syntactically specified lexical representation/lemma of the word is activated in the input layer. Each segment of this representation/lemma then activates its corresponding features in the output layer with this activation occurring via the hidden units layer and taking place one segment at the time (starting from the first segment of the word). Importantly however, rather than corresponding to specific phonemes, these segments amount to a set of symbols that represent each lemma. Also, in the model the lexical representation/lemma is not specified for its number of syllables and stress pattern.

Although PDP (Dell et al., 1993) is a language production model, in order to conduct its computational processing activation in the input layer is based on the word's orthography. As such, in the model each segment corresponding to a specific lemma is represented as one of the letters of the English alphabet. Therefore, hereafter these segments are referred to as letters. Further, each of the letters used in the words of Dell's et al. (1993) training vocabulary is represented by an arbitrary 5-digit binary

code. For example, the letter 'd' might be coded [0,1,0,0,1] whilst the letter 'i' might be coded [0,1,1,1,0]. Since Dell's et al. (1993) PDP model was only trained on three letter words, there are only fifteen units in the input layer; five for each of the three letters comprising a word. Therefore, using the above codes, at the beginning of the production of a single word such as 'did' for example, the code [0,1,0,0,1,0,1,1,1,0,0,1,0,0,1] is activated in the input layer. Next, activation from the 5-digit code of the first letter (d) spreads to the hidden units layer. In Dell's et al. (1993) model the 20 units of that layer are computational representations of the brain's neurons, which as in humans are defined through practice/training. In addition, due to the fact that these units are connected to each other the activation level of each unit is affected by and also affects the activation levels of its neighbours. Contrary to both Dell's (1986) model and WEAVER in which information about a segment/phoneme is represented within a single unit, in the PDP model (Dell et al., 1993) information about each letter is distributed over all 20 units. Thus, on receiving activation from the first letter's code in the input layer, all hidden units participate in converting its value into the corresponding activation value (between 0 and 1) in the hidden units layer. The employment of a specific activation value (an activation threshold) instructs the network to pass activation to the higher layer only if that value has been generated. This again differs to Dell's (1986) model in which only the more highly activated units are selected however, on this point it is in line with WEAVER.

Once the activation value for the first letter of the input layer has been calculated it is then used to activate (in parallel) its corresponding features at the output layer. The output layer consists of 18 units; one for each phonemic feature of English. Similar to the input layer, at this layer all 18 units are represented as either the number 0 or 1;

where 0 indicates that the unit is switched off whilst 1 shows that it is turned on. Thus, referring to a feature such as voicing for example, the voiced 'd' is assigned the digit '1' whereas the voiceless 't' is represented as '0'. Consequently, in Dell's et al. (1993) model, every letter of the input is represented by an 18-digit binary code of the output. Furthermore, following the activation of the first letter's features in the output layer encoding of the second letter begins. This process continues until all the letters of the input have been encoded. Importantly, the activation level of each unit in Dell's et al. (1993) PDP model is controlled by weighted connections between them. These weighted connections are 'the system's knowledge about how the different types of information are related' (Plaut, McClelland, Seidenberg & Patterson, 1996, pg. 59) which has been acquired through training and can be modified by further experience.

During the training stage, Dell and colleagues (1993) firstly exposed their model to a set of 50 three letter English words. At that point the connections' weights between the three layers were set to random values between -.1 and .1. After all the words of the set were randomly presented to the system a segment by segment comparison of the input with the output for all the words in the training set was conducted. Due to the fact that Dell's et al. (1993) model is a model comprising three layers it was not possible to ascertain the precise proportion of the output error that was caused by the weighted connections activated by the input layer. In a two layer model in contrast, the direct link between the input and output layer means that discrepancies between these two layers can only be the consequence of the weights on their connections. However, in a three layer model such as Dell's et al. (1993) PDP model a third party namely, the hidden units layer, contributes to the discrepancies. As such, a back-propagation (backward

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propagation of errors) learning algorithm was employed to adjust the weights of all connections between each layer.

Back-propagation is basically the repeated adjustment of weights on the connections until a desired outcome is achieved (Rumelhart, Hinton & Williams, 1986). During this process the contribution to the output's error from the hidden units layer first needed to be calculated. This was done to establish what the correct output from the hidden units layer should have been and was achieved by calculating the sum of difference between the required and achieved output. Next, the resulting figure was squared and then divided in half. This calculation provided the estimate of the error rate at the hidden units layer which, when multiplied by both the sum of activation of all the hidden units and the required leaning rate, provided the value by which the weights on the connections between the hidden units and the output layers needed to be adjusted. Also, based on the hidden units layer's error estimate, adjustments to the weights on the connections between the hidden units and the input layers were made in the same way as above. Since in Dell's et al. (1993) model these two layers have an additional, permanently turned on connection which represented a bias/threshold, its weight was also adjusted according to the other weights. Next, the training session was repeated and again any errors at the output layer were back-propagated to the system as described above. This training-reset (learning by practice) process continued until the required output for each input was achieved. When the modelers were satisfied with the system's performance the weighted connections were sealed and the model was ready to be evaluated using the same as well as different inputs.

Finally, in Dell's et al. (1993) model there are two additional working units; internal and external feedback units. The reason for including these units can best be explained with reference to the repeated segments example of the word 'did' provided by Dell et al. (1993). As argued by Dell and colleagues (1993), once the features of the first segment 'd' of the word 'did' are activated at the output layer its activation value is then copied to the external feedback unit whilst at the same time the activation value of the hidden units layer is copied to the internal feedback unit. Thus, these two feedback units serve as buffers for their corresponding layers. As soon as the copying process is completed feedback occurs from both the external and the internal unit to the hidden units layer. The feedback from the external unit informs the hidden units layer that the features for the segment 'd' are selected. However, it does not indicate for which segment 'd' (the initial or the final). Consequently, the hidden units layer does not know whether to continue with the encoding process or stop. The role of the feedback from the internal unit therefore, is to verify the position of the just encoded segment. In this example, feedback from the internal unit verifies that the just encoded segment 'd' is the initial 'd' and by so doing instructs the hidden units layer to begin the encoding process of the second segment (i). Importantly, in Dell's et al. (1993) model once the encoding process of an input has been completed, the activation levels of hidden units are set back to zero whilst the output level is set to the null segment. This information is then copied to the corresponding feedback units. As such, when a new input is presented to the model its processing is unaffected by the remaining activations of the just encoded input.

Akin to Dell's (1986) model, the primary purpose of Dell's et al. (1993) PDP model was to explain the occurrence of speech errors. However, since PDP (Dell et al., 1993) was only trained to produced single words it cannot be employed to generate simple phrases such as for example, 'clear blue'. Consequently, the model's (Dell et al., 1993) ability to generate the earlier mentioned phoneme and feature exchange errors cannot be assessed. Nonetheless, even if PDP (Dell et al., 1993) was modified to produce simple phrases its architecture and working assumptions could not account for those errors. The reason for this is as follows. In Dell's et al. (1993) model an input is processed in a serial rightward manner starting from its first letter. Also, the processing of a subsequent letter of the input can only begin when the processing of the prior letter has been fully completed. Therefore, any effect from a letter other than the one currently being processed is not possible and this is true for all the letters within a single input as well as the letters between two inputs comprising a simple phrase. As such, due to its design the PDP (Dell et al., 1993) computational model cannot physically simulate either phoneme (e.g., 'darn bore' for 'barn door') or feature (e.g., 'glear plue' for 'clear blue') exchange errors.

However, Dell's et al. (1993) model can successfully account for the activation of phonemic features corresponding to a letter that is different to the input's letter. In the model the occurrence of such errors can be explained in two ways. Firstly, the activation of the correct phonemic features might be affected by the model's recent activation/activations that may cause changes on the weights of its connections resulting in a consequential selection error. Secondly, if the letters share some of their phonemic features, their activation parameters are quite similar which makes it possible for the model to activate the incorrect phonemic features for the input's letter. For example, it is

possible for the PDP (Dell et al., 1993) model to activate the phonemic features corresponding to the letter 'p' instead of 'b' as these two letters share all but one of their phonemic features namely, voicing, In fact, based on the PDP (Dell et al., 1993) model's core design, these kinds of errors would be more likely to occur than errors in which the input's letters differed by more than one phonemic feature.

Finally and as argued by the authors, by processing an input in a rightward serial manner and due to its ability to learn from recent experience the PDP (Dell et al., 1993) computational model can successfully simulate the preparation benefit found by Meyer (1990, 1991). According to Dell et al. (1993), the repeated activation of letter/s in homogeneous sets in which response words shared their initial letter/s would have caused changes on the weights of their connections. Thus, after naming the first response word of a homogeneous set the activation of the shared letters would have been faster during the naming of subsequent words. However, since the model processes a given input starting from its first letter and then moves to its second letter and so on, any benefits from shared end letter/s of the response words as shown by Meyer's (1990, 1991) results would have been lost.

1.4. Word reading models

1.4.1. Segmental models

1.4.1.1. Dual Route Cascaded (DRC; Coltheart, Rastle, Perry, Longdon & Ziegler, 2001) model

One of the most frequently cited models in the word reading literature is the Dual Route Cascaded (DRC) computational model of visual word recognition and reading aloud proposed by Coltheart et al. (2001). This model is based on Coltheart's (1978) dual-route framework of reading words aloud. Within the DRC's architecture there are three distinctive processing routes, namely the lexical semantic route, the lexical non-semantic route and the non-lexical, Grapheme-To-Phoneme Convergence (GPC) route. However, since the lexical semantic route is not fully incorporated in the workings of the model, the following description is centred on the two remaining routes. Also, hereafter, the lexical non-semantic route is simply referred to as the lexical route.

When presented with a written word the DRC computational model firstly assesses the written input for visual features (e.g., if a letter has a vertical line and two semicircles to its right; as in the letter B). At this stage of processing there are 14 feature-present and 14 corresponding feature-absent units for each of the eight input positions. For a written word such as BELT for example, the DRC activates the feature-present units in each of the four input positions if the input physically resembles the specific feature-present units. However, if the input is a physical mismatch with the feature-present units, the corresponding feature-absent units are activated. The remaining (empty) four

input positions activate all 14 feature-absent units in each position. As soon as activation at the visual feature level begins information cascades to the letter level and excites all the letters that resemble the activated feature units whilst inhibiting all the letters that do not. This excitatory/inhibitory effect of the visual feature level on the letter level continues until all the letter units of the input are activated. There are 27 letter detectors at the letter level; one for each of the 26 letters of the English alphabet and a blank-letter detector which is activated if all 14 feature-absent units for a specific position are switched on. Within the DRC model, the feature-to-letter activation takes place in parallel across all letter positions and is shared for both the lexical and the non-lexical routes. However, the output of the letter units level is processed separately yet simultaneously by both routes.

During processing through the lexical route there is a bidirectional, excitatory and inhibitory activation between the letter level and the orthographic input lexicon. Each activated letter at the letter level excites all the words in the orthographic lexicon which contain that specific letter in that position and inhibit all the words that do not. As such, using the earlier example BELT, the letter B in the first position excites all the words which contain the letter B in the first position (e.g., BAG, BELT, BALL) and inhibits all the words that do not (e.g., GIRL, DAD, FAN). Importantly, in the DRC model there are 7,981 monosyllabic words (referred to as units) in the orthographic input lexicon.

Further, once a word/unit is activated in the orthographic input lexicon this activation spreads (possibly also via the semantic system) to its corresponding word/unit in the phonological output lexicon. The nature of this activation is also bidirectional but only excitatory in fashion. Since many homophones (words which despite different spelling

and meaning are pronounced the same e.g., pear and pair) exist in the English language there are only 7,131 units in the phonological output lexicon. Next, the activated phonological unit activates the unit's phonemes in the phoneme system. The phoneme system consists of 44 units in each of the eight phoneme positions; one for each of the 43 English phonemes and a blank phoneme. Similar to the blank letter unit, the blank phoneme unit is activated to fill in the empty spaces when an input is shorter than eight characters in length. Importantly, in the DRC model there is only a single phoneme system which is shared by both processing routes. Further, there is bidirectional, excitatory and inhibitory activation between the phonological output lexicon and the phoneme system. Finally, activation within each level of the lexical route occurs in parallel.

Contrary to the lexical route, processing within the non-lexical route takes place in a serial rightward manner. Therefore, on receiving activation from the first letter of the letter level the grapheme-to-phoneme rule system compares the input to all its pre-programmed set of rules (e.g., that the letter 'y' at the beginning of a word corresponds to the phoneme /j/ whilst in the middle of a word it corresponds to the phoneme /ɪ/). When the appropriate rule has been found it is then employed in the activation of the relevant phoneme in the phoneme system. Once the first phoneme has been activated processing of the second letter of the input begins. This process continues until all the letters of the input are converted into their corresponding phonemes. Also, each letter of the letter level becomes available for encoding only after its activation level achieves the specified (17 cycles) threshold. Finally, in contrast to the lexical route there is only excitatory feed-forward activation between each level of the non-lexical route.

To summarise, in Coltheart et al.'s (2001) DRC model the processing of an input by both the lexical as well as the non-lexical routes involves the direct mapping of the input's orthography/letters onto their corresponding phonemes. However, these phonemes are not specified for their phonemic features. Therefore, akin to Dell's (1986) and WEAVER models, DRC can be categorised as a segmental model. Further, in Coltheart et al.'s (2001) model the workings of the phoneme system are not fully defined. Although the authors suggested that this system might operate in a similar manner to the phonological encoding level/stage of Dell's (1986) and WEAVER models, they do not fully commit themselves to either of these models '... the phonological output of our model, which can be seen as a (highly simplified) version of certain speech-production models such as that of Dell (1986) and Levelt, Roelofs, and Meyer (1999)' (Coltheart et al., 2001, pg. 206). As highlighted in this chapter there are major differences between both models in regards to the phonological encoding level/stage of processing. Firstly, in Dell's (1986) model phonemes are specified for their syllable position and thus, phonemes which can occupy both the onset and coda positions within a syllable are represented as two distinct items. In contrast, each phoneme in WEAVER is represented only once and its syllable position is defined during the segment-to-frame association process. Secondly, in the former model, due to the bidirectional activation between the phoneme and the feature levels during phonological encoding, activated phonemic features directly affect the activation levels of their corresponding phonemes. However, in the latter model which is a feed-forward model, phonemic features are activated only after the phonological encoding process has been completed. Consequently, in WEAVER phonemic features do not affect this stage of processing. As such, these differences in how the phonological encoding

process is accomplished by each model cannot coexist within the same system and thus Coltheart et al. (2001) will have to choose between one or the other.

Furthermore, due to the simultaneous processing of an input from the letter units level by both the lexical and non-lexical routes which as discussed share the same phoneme system, any activation of phonemes at the phoneme system by one of the two routes can be affected by activation from the other route, thereby affecting the resulting speed of processing. Additionally, due to the parallel activation within each level of the lexical route, processing through that route is much faster than through the non-lexical route. This notion of faster processing through the lexical route is supported by the model's ability to generate the correct pronunciation of exception words (words whose pronunciation do not adhere to the general rules of the English language) such as 'pint'; pronounced as /paɪnt/ instead of /pɪnt/. If however, the non-lexical route were faster, during the generation of the pronunciation of the word 'pint' the most common grapheme-to-phoneme correspondence rule for the letter 'i' in the second position would be activated. Therefore, the latter pronunciation would be generated to rhyme with the regular word 'mint'. This so called regularization error was actually found by Coltheart and colleagues (2001) when they switched off the lexical route and thus allowed the slower non-lexical route to exert its effect (Perry, Ziegler & Zorzi, 2007). Based on this, the authors concluded that the longer it takes to read a word the more its pronunciation is influenced by the non-lexical route. Consequently, they argued that in the DRC model high frequency words, which by their very nature are well known and therefore easily recognisable, along with irregular words are encoded in parallel by the lexical route whilst low frequency words are generated letter by letter via the grapheme-to-phoneme rule system of the non-lexical route. Also, according to Coltheart et al.

(2001), the employment of the grapheme-to-phoneme rule system in the non-lexical route allows the DRC model to produce the correct pronunciation of non-words (sequences of letters that may look like real words but have no meaning).

Further support for the architecture and the working assumptions of Coltheart's et al. (2001) model was provided by Rastle and Coltheart's (1999b; Experiment 1) research in which the authors set out to establish whether the position of irregularity within a word would have an effect on the speed of its reading. The position of irregularity simply means that the spelling to sound discrepancy is either in the first (e.g., chief), the second (e.g., pint) or the third (e.g., glow) position of a word. There is an on-going debate in the word reading literature in regards to irregular words. Some researches (e.g., Plaut et al., 1996) argue that words can be irregular but consistent as well as irregular and inconsistent (also referred to as exceptional). This consistency/inconsistency dimension means that as long as the pronunciation of an irregular word is consistent (it rhymes) with the pronunciation of the majority of its orthographic neighbours (e.g., the irregular word 'glow' and its orthographic neighbours 'blow', 'grow', 'flow', 'know', 'low', 'mow', 'row', 'slow', 'stow', 'throw') it can be successfully generated via the grapheme-to-phoneme correspondence rules. However, if a word is irregular and inconsistent/exceptional, the majority or all of the word's orthographic neighbours have pronunciations different to that word (e.g., the irregular word 'pint' and its orthographic neighbours 'dint', 'hint', 'lint', 'mint', 'tint'). Therefore, its correct pronunciation can only be memorised and then called upon during reading. Consequently, the pronunciation of irregular but consistent words is accomplished differently to the pronunciation of irregular and inconsistent/exception words.

Based on this debate, in their research Rastle and Coltheart (1999b; Experiment 1) set out to evaluate the position of the irregularity effect whilst controlling for consistency across the position of irregularity. Therefore, the authors composed three lists of monosyllabic words matched on consistency. All stimuli in list one comprised words in which the spelling to sound irregularity was in the first position of the words. In list two, the irregularity was in the second position and in list three it was in the third position. For their control conditions Rastle and Coltheart (1999b; Experiment 1) matched each irregular word in each list with a regular word of the same letter length, initial phoneme and frequency. Thus, for every target list there was a corresponding control list. Also, in the experiment one hundred and eighty-eight monosyllabic orthographically legal and pronounceable non-words were employed as fillers. During the actual experiment participants had to read all words and non-words displayed to them on a computer screen. The stimuli were presented one by one in a random order. Before the presentation of each stimulus, a fixation bracket was shown for 900ms. The analysis of participants' reaction times for the word stimuli revealed that compared to the corresponding control conditions the first (52ms) and second (9ms) position irregular words took longer to read than the third position irregular words (1ms). These results are consistent with DRC's working assumptions which postulate that at the phoneme level, phonemes activated by the lexical route compete with the phonemes activated by the non-lexical route. Since the former route operates in parallel whereas the latter activates phonemes serially starting from the first letter of the input, the effects of this competition are more apparent if the irregularity is in the first or second position of a word. As suggested by Rastle and Coltheart (1999b; Experiment 1), because of the bidirectional excitatory and inhibitory connections between the phonological output lexicon and the phoneme system, the activation of phonemes by the lexical route needs

time to develop. In the meantime, the first phoneme of the first position irregular word has been activated by the non-lexical route. However, since the non-lexical route activates phonemes via grapheme-to-phoneme correspondence rules, the activated phoneme for the first position irregular word, although consistent with its rules, is incorrect for the input. As such, the activated incorrect phoneme interferes with the activation of the correct phoneme produced by the lexical route resulting in delayed naming of the first position irregular words. Furthermore, when the irregularity is in the second position of a word, the activation of the corresponding phonemes by the lexical route has more time to develop and therefore, the incorrect phoneme activated by the non-lexical route has less effect on the activation of phonemes by the former route. By extension, by the time the non-lexical route has the chance to process the third phoneme of an input there is already an established activation of phonemes by the lexical route. Consequently, the third position irregularity in a word has no effect on the speed of its reading; as found by Rastle and Coltheart (1999b; Experiment 1). As such, the results from Rastle and Coltheart's (1999b; Experiment 1) research provide strong support for the DRC model's serial rightward manner of processing an input by the non-lexical route.

Although the DRC model (Coltheart et al., 2001) can account for most of the data from normal and impaired reading it cannot explain the consistency effect found by Jared (2002; Experiment 1). In her research Jared (2002; Experiment 1) set out to evaluate whether the effects of regularity were dependent on words' consistency. In so doing Jared (2002; Experiment 1) employed low-frequency exception (irregular and inconsistent) words and low-frequency regular-inconsistent words as targets. She divided each target type into two sets. Set one consisted of exception words with a low

summed frequency of friends (words which have similar spelling and their pronunciation rhyme with the exception word) and a high summed frequency of enemies (words which despite similar spelling are pronounced differently to the exception word). In set two on the other hand, exception words had a high summed frequency of friends and a low summed frequency of enemies. The regular-inconsistent words were divided in the same way as the exception words. Next, Jared (2002; Experiment 1) composed four corresponding control sets by matching (on number of variables; e.g., word length, word frequency, number of friends, number of enemies) each word from each of the four target sets with a regular-consistent word. All stimuli were then displayed one by one in a random order on a computer screen. Participants were required to read each word as quickly and as accurately as possible with response time recorded.

The results showed that compared to the corresponding control sets of regular-consistent words, words were read slower in all four target sets. Further, this effect for both target types was largest of all when the targets had a low summed frequency of friends and a high summed frequency of enemies. Since all targets were inconsistent words which varied on their regularity (exception words/irregular and inconsistent verses regular-inconsistent words), Jared (2002; Experiment 1) concluded that rather than being driven by word regularity, this effect was due to body-friends consistency. This effect thus became known as the consistency effect. Consequently, Jared (2002; Experiment 1) argued that because words in the DRC (Coltheart et al., 2001) model are read in the same manner independent of their friends-to-enemies ratio, this model would have difficulty accounting for these findings. In fact, a DRC computer simulation of this data conducted by Jared (2002) confirmed this argument as the DRC (Coltheart et al.,

2001) model failed to replicate Jared's (2002; Experiment 1) findings. However, a model whose architecture and working assumptions can fully account for these results is the Connectionist Dual Processing (CDP+; Perry, Ziegler & Zorzi, 2007) computational model.

1.4.1.2. Connectionist Dual Processing (CDP+; Perry, Ziegler & Zorzi, 2007) model

Akin to the DRC (Coltheart et al., 2001) model, in the CDP+ computational model (Perry et al., 2007) word reading occurs via both lexical and non-lexical routes. Further, in CDP+ (Perry et al., 2007) the feature and letter levels are organised in exactly the same way as in the DRC model (Coltheart et al., 20001) and are again shared by both routes. Therefore, on the presentation of a written input the corresponding feature present or feature absent units are activated in parallel for each letter of the input at the feature detectors level. As in DRC (Coltheart et al., 2001), all 14 feature absent units are switched on in every empty position of an input shorter than eight characters in length. Then, activation spreads to the letter nodes level where the appropriate letters of the input are activated along with null letter units which again fill the empty spaces of a less than eight letter input. Next and consistent with the DRC model (Coltheart et al., 2001), during processing via the lexical route activated letters at the letter units level activate in turn all the words at the orthographic lexicon that share the activated letters in these specific positions and inhibit all the words that do not. Once a word in the orthographic lexicon has been activated it is then used to activate its corresponding entry in the

phonological lexicon. However, in contrast to DRC (Coltheart et al., 2001) there are only excitatory connections between the orthographic and phonological lexicons. Also, unlike in the former model, in CDP+ (Perry et al., 2007) the phonological lexicon does not include null characters that in DRC (Coltheart et al., 2001) are activated when words of less than eight characters are encoded. After the activation of the correct phonological word in the phonological lexicon, this word is then employed to activate its corresponding phonemes at the phoneme nodes level; also referred to by the authors as the phonological output buffer. In line with the DRC model (Coltheart et al., 2001), during processing via the lexical route in CDP+ (Perry et al., 2007) there is a parallel activation of units within each level and there are bidirectional connections between each level. Finally, to account for the contribution of semantics, in Perry's et al. (2007) model the activation of a phonological word at the phonological lexicon level of the lexical route is weighted by the word's phonological frequency. As such, within the lexical route of CDP+ (Perry et al., 2007) higher frequency phonological words are activated faster than lower frequency phonological words.

Furthermore, major differences exist between the DRC (Coltheart et al., 2001) and the CDP+ (Perry et al., 2007) models in regards to the processing of an input by the non-lexical route. Following the activation of an input's letters at the letter nodes level, rather than a letter by letter conversion of the input into its corresponding graphemes processing at the grapheme nodes level (also referred to as the graphemic buffer) of the non-lexical route in the CDP+ (Perry et al., 2007) model involves the mapping of letters directly onto their corresponding complex graphemes. These graphemes can be one to four letters long (e.g., p, ph, str, ough). As argued by the authors, such mapping allows for a context specific activation of each letter of the input. In addition, at the grapheme

nodes level/graphemic buffer each grapheme is specified for its syllable constituents. Consequently, in the graphemic buffer the first three positions are assigned to the input's onset, the fourth position relates to its vowel whereas the remaining four positions correspond to the input's coda. If a given input consists of a single letter grapheme in the onset and/or coda positions, any unfilled spaces are left empty. Therefore, at the graphemic buffer a word such as 'belt' would be coded as 'b-*-*-e-l-t-*-*'; where asterisks represent empty spaces. In addition, in each of the eight graphemic buffer positions there are 96 grapheme nodes. These consist of 26 nodes corresponding to each letter of the English alphabet and 70 complex grapheme nodes which are further divided into 10 onset, 41 vowel and 19 coda grapheme nodes. Therefore, in total there are 768 nodes in the graphemic buffer (i.e., 96 x 8). Although in theory all nodes in the graphemic buffer can become activated at every position (e.g., coda node in the onset position), in practice and due to the nature of the English language only the nodes corresponding to the specific syllable constituent are activated (e.g., coda node in the coda position, onset node in the onset position). As suggested by Perry and colleagues (2007), using all 96 grapheme nodes in every position was only done for simplicity and has no implications for the workings of the model.

Further, contrary to DRC (Coltheart et al., 2001) in which grapheme to phoneme matching is achieved by selecting the appropriate conversion rule, in the CDP+ (Perry et al., 2007) model such matching is accomplished via a two-layer assembly (TLA) network. Except for the absence of the hidden units layer this network operates in a similar manner to Dell et al.'s (1993) three layer model. Therefore, in the TLA network there are direct connections between input and output nodes and each input node is connected to all of the output nodes. In line with Dell et al.'s (1993) model the

relationships between input and output nodes are learned through training and are expressed by changes in the weights/strengths of their connections.

Furthermore, in CDP+ (Perry et al., 2007) the TLA network's input nodes are the fully activated graphemic representations at the graphemic buffer level. Therefore, prior to the processing of an input by the TLA network all the letters activated by the letter nodes level have to be parsed (organised into their syllable constituents) and converted into their corresponding graphemes at the graphemic buffer level. This graphemic parsing starts as soon as the letter in the first position has reached its activation threshold and occurs letter by letter in a left to right manner over a three letter attentional window span. As such, using the example of the word 'match' provided by Perry et al. (2007), at the beginning of the graphemic parsing process the first three letters activate the graphemes 'mat'. Then, the window span moves to the letters 'atc' resulting in the incorrect activation of the grapheme 'c' in the second position of the coda. However, once the window span moves to the letters 'tch' the incorrect activation of the grapheme 'c' would be revised and the correct complex graphemes 'ch' becomes activated. Thus, at the end of the graphemic parsing of the word 'match', the 'm**atch*' representation would be fully activated at the graphemic buffer level. As suggested by Perry and colleagues (2007), this revision process is possible because the incorrect grapheme 'c' is still in the window span when the grapheme 'h' becomes available (tch).

Following the full activation of the relevant graphemes at the graphemic buffer level, activation from each grapheme spreads in parallel via the weighted connections of the TLA network to the phonological output buffer level. The phonological output buffer is

represented by 43 phoneme nodes corresponding to the 96 grapheme nodes in each of the eight positions. Therefore, in total the phonological output buffer consists of 344 phoneme nodes (i.e., 43 x 8). Also, the phonological output buffer is organised in the same way as the graphemic buffer and thus the first three positions are assigned to the input's onset, the fourth to the vowel and the last four positions relate to the input's coda. As such, in CDP+ (Perry et al., 2007) grapheme to phoneme conversion of an input through the non-lexical route adheres to specific syllable constituents. Thus, any knowledge acquired by the TLA network is syllable position specific and cannot be generalised across syllable constituents. In addition, the phonological output buffer in this model is shared by both the lexical and non-lexical routes which means that the output from the lexical route is also specified for its syllable constituents.

Furthermore, akin to Dell et al.'s (1993) model the CDP+'s (Perry et al., 2007) TLA network had to be pre-trained prior to being tested on any data. Since in TLA there are direct connections between inputs and outputs and thus any differences between these two could only be due to the weights on their connections, no back-propagation was required to make the necessary adjustments. Therefore, during the TLA's training a simple gradient descent technique known as the delta rule (Widrow & Hoff, 1960) was applied to calculate the network's error rate which was then employed to modify the weights on its connections. As such, following delta rule (Widrow & Hoff, 1960) principles, Perry and colleagues (2007) first established the error rate for each output by calculating the sum of difference between the required and achieved output. Then they multiplied this sum/error rate by the activation level of the input corresponding to that output. Finally, they used the total from the latter calculation and multiplied it by a learning rate. Importantly, as it was essential for the TLA network to learn the

relationships between inputs and outputs rather than have them imposed by the modeller, the learning rate was set at a very low level (i.e., 0.05). This final total was used to change the weight on that connection. The error calculation and weight adjustment process was then repeated until the TLA network learned to generate the correct output for each input.

To summarise, akin to DRC (Coltheart et al., 2001) therefore, CDP+ (Perry et al., 2007) is a dual processing model of reading in which there is a cascaded activation of each level of the lexical route and a threshold activation of each level of the non-lexical route. In addition, as with the former model CDP+ (Perry et al., 2007) is primarily concerned with the direct mapping of orthography onto abstract phonemes and thus in this model phonemes are also not specified for their phonemic features. However, in contrast to Coltheart et al.'s (2001) model, the phonemic output in Perry et al.'s (2007) model is defined for its syllable constituents. Finally, in line with the DRC (Coltheart et al., 2001) model, in CDP+ (Perry et. al., 2007) the processing of a given input by the lexical route occurs in parallel across its word form whereas the processing of an input by the non-lexical route is conducted in a serial rightward manner.

As mentioned earlier the architecture and working assumptions of the CDP+ (Perry et al., 2007) model can fully account for the outcomes of Jared's (2002; Experiment 1) research in which the author found that inconsistent regular and irregular words were named faster when they had a higher friends-to-enemies ratio (body-friends) compared to a higher enemies-to-friends ratio (body-enemies). In fact, a CDP+ computer simulation in which the same stimuli as those employed in Jared's (2002; Experiment 1) study were used showed an almost identical pattern of results. In contrast to DRC

(Coltheart et al., 2001), CDP+ (Perry et al., 2007) was able to successfully replicate Jared's (2002; Experiment 1) findings for the following reasons. Unlike in the former model, in CDP+ (Perry et al., 2007) the mapping of graphemes onto their corresponding phonemes by the non-lexical route is achieved via the TLA network. This network's knowledge is acquired by learning to recognise similar patterns through exposure to inputs. Therefore, the more the TLA network encounters a specific pattern the stronger its weighted connection to the corresponding output and thus the sooner it can make the correct match. Further, since in CDP+ (Perry et al., 2007) low frequency regular and irregular words are processed via the non-lexical route they are both subjected to the same treatment by the TLA network. Consequently, in the CDP+ (Perry et al., 2007) model the consistency of the body-friends effect is primary driven by a similar pattern being repeated and is independent of whether the word is regular or irregular.

Furthermore, akin to DRC (Coltheart et al., 2001), the CDP+ (Perry et al., 2007) model can successfully simulate the position of irregularity effect found by Rastle and Coltheart (1999b). However, contrary to Rastle and Coltheart (1999b), Perry and colleagues (2007) argued that instead of being due to the serial rightward processing manner of DRC's (Coltheart et al., 2001) non-lexical route, this effect is likely caused by 'a grapheme consistency confound' (Perry et al., 2007, pg. 291). Put simply, in Perry et al.'s (2007) view the first position irregular words employed by Rastle and Coltheart (1999b) might have had on average several more body-enemies (words which in spite of similar spelling are pronounced differently) than friends (words which rhyme) compared to the second position irregular words. Further, the ratio of body friends-to-enemies in the third position irregular words might have been essentially equal hence, there was no position of irregularity effect found in Rastle and Coltheart's (1999b)

research for these stimuli. Finally, as with DRC (Coltheart et al., 2001), the CDP+ (Perry et al., 2007) model is able to successfully simulate most of the data on normal and impaired reading. Importantly, it can read pronounceable non-words almost as well as human participants.

1.4.1.3. Parallel Distributed Processing (PDP; Plaut, McClelland, Seidenberg & Patterson, 1996) model

Another model that can successfully account for all the above described data is the Parallel Distributed Processing (PDP) model of word reading designed by Plaut et al. (1996). Akin to Dell et al.'s (1993) general language production PDP model, this model consists of three main processing levels, namely the orthographic units level, the hidden units level and the phonological units level. However, in contrast to Dell et al.'s (1993) model and in line with Perry et al.'s (2007) TLA network, in Plaut et al.'s (1996) PDP an input's letters/graphemes at the orthographic units level are specified for their syllable constituents (onset, vowel and coda). Also, contrary to both of these models, at the orthographic units level an input's letters/phonemes are processed in parallel. Further, instead of just a single letter/grapheme based representation of an input at the orthographic units level (as in Dell et al.'s, 1993), in Plaut et al.'s (1996) model orthographic units are typified as both single (e.g., p, h, t, c, h) and complex graphemes (e.g., ph, tch). However, contrary to the TLA network (Perry et al., 2007), each syllable position at the input level in this model is only represented by either a single or complex graphemes which correspond to that specific syllable constituent. Therefore, there are only single consonants and consonant clusters corresponding to onsets in the onset

position, vowels and vowel clusters corresponding to vowels in the vowel position and finally consonants and consonant clusters corresponding to codas in the coda position. As a result, there are 105 grapheme units (30 onsets, 27 vowels and 48 codas) at the input layer in Plaut et al.'s (1996) model.

Further, at the beginning of the encoding process the input's letters/graphemes first need to be parsed in to their syllable constituents. This is achieved by identifying the input's vowel or vowel cluster and then assigning the letters/graphemes to its left the onset position and the letters/graphemes to its right coda position. Consequently, this vowel driven graphemic parsing process eliminates the need for assigning a specific number of positions to each syllable constituent and thus there are no empty spaces when shorter words are encoded. Therefore, in contrast to the TLA network (Perry et al., 2007) in which each input is processed as an eight letter/grapheme string regardless of its length, yet in keeping with Dell et al.'s (1993) PDP model, the encoding of each input in Plaut et al.'s (1996) PDP model is based on the input's actual length. Once parsed, each input's grapheme/grapheme cluster activates its corresponding grapheme/grapheme cluster unit within the units related to its syllable position by changing its current activation value from zero to one. Next, activation from each activated grapheme unit spreads to all 100 hidden units at the hidden units level. In the step that follows, activation spreads from all the hidden units to all 61 phonemes units which themselves are not specified for their phonemic features. Akin to the grapheme units, these units are also defined for their syllable position and are represented according to their syllable constituents. As a result, in Plaut et al.'s (1996) model at the phoneme level there are 23 onset phonemes corresponding to the onset position, 14 vowel phonemes corresponding to the vowel position and 24 coda phonemes corresponding to the coda position. Also

and in common with Dell et al.'s (1993) model, there is an additional connection between the hidden and phoneme units that is always in the switched on position and thus serves as bias. Finally, similar to the PDP (Dell et al., 1993) general language production model, the PDP (Plaut et al., 1996) word reading model was pre-trained on monosyllabic words using a back-propagation learning algorithm prior to actual testing. However, the model's training vocabulary was much larger to that of Dell et al.'s (1993) model; 2,897 verses 50 words.

To summarise, the PDP (Plaut et al., 1996) reading model is a single route feed-forward processing model in which a given letter string is encoded in parallel. Since in the model the encoding of an input's letters/graphemes is conducted in a syllable position specific manner, as in CDP+ (Perry et al., 2007) knowledge acquired by the network in relation to a specific syllable position can only be applied to that particular syllable position. Further, akin to both the DRC (Coltheart et al., 2001) and the CDP+ (Perry et al., 2007) models, Plaut and colleagues' (1996) model is primarily concerned with the direct mapping of letters/graphemes onto their corresponding abstract phonemes. Therefore, this model can also be categorised as a segmental model. However, contrary to the general language production PDP (Dell et al., 19993) model the input's letters/graphemes in Plaut et al.'s (1996) PDP model are specified for their syllable constituents and are therefore encoded according to their syllable position.

As previously mentioned, Plaut and colleagues' (1996) PDP model can successfully simulate the results from much of the reading data including both the position of irregularity (Rastle & Coltheart, 1999b) and consistency effects (Jared, 2002). As argued by Plaut et al. (1996) and Perry et al. (2007), rather than being caused by the

position within which the irregularity occurs, the former effect is due to the fact that the first position irregular words have more body-enemies then body-friends whereas there is a smaller difference between these two in the second position irregular words. Finally, there is no difference in the body friends-to-enemies ratio in the third position irregular words. Consequently, this effect is purely due to the word's body consistency which is why it can be successfully replicated by a parallel processing model sensitive to a word's body consistency such as PDP (Plaut et al., 1996).   Regarding the consistency effect found in Jared's (2002) research, as with the TLA network (Perry et al., 2007) the PDP (Plaut et al., 1996) model can account for these results with reference to its ability to learn the relationships between specific inputs' patterns thus, strengthening the weighted connections corresponding to the patterns that are repeated more often than others.

However, neither the PDP model (Plaut et al., 1996) nor the other two (Coltheart et al., 2001 and Perry et al., 2007) word reading models can explain the results from Mulatti, Reynolds and Besner's (2006) research. In Experiment 1, Mulatti and colleagues (2006) compared participants' reading response times in both immediate and delayed reading (when participants were required to read the targets names again after the presentation of a set of brackets) for words from both dense phonological neighbourhoods and sparse phonological neighbourhoods. An analysis of the immediate reading response times showed that words from dense phonological neighbourhoods were read significantly faster than words from sparse phonological neighbourhoods. However, this effect was not found during delayed reading indicating that the locus of this effect is pre-articulatory.   In Experiment 2, Mulatti et al. (2006) again collected participants' response times from both immediate and delayed reading. This time however, they

evaluated density effects from words' orthographic neighbours whilst strictly controlling for phonological neighbourhood density. The authors found that neither immediate nor delayed reading was affected by words' orthographic neighbourhood density when the number of phonological neighbours remained constant. To explain this discrepancy Mulatti et al. (2006) suggested that in the English language words' orthographic and phonological densities are highly correlated. Thus, rather than demonstrating orthographic neighbourhood effects, the earlier data actually reflected effects on word reading caused by phonological neighbourhood density.

Furthermore, the actual DRC and PDP computer simulations conducted by Mulatti and colleagues (2006) showed that both models were unable to replicate the results from Experiment 1 although the DRC model did simulate the null effect of Experiment 2. Contrary to the human data however, the PDP model showed facilitation for words from dense orthographic neighbourhoods from Experiment 2. Additionally, in keeping with the TLA network of the PDP (Plaut et al., 1996) model the learned relationships between inputs and outputs in CDP+ (Perry et al., 2007) are acquired based on the inputs' orthography and thus this model is also unable to account for Mulatti et al.'s (2006) results. As such, if a test of their data were conducted on CDP+ (Perry et al., 2007), it would most likely exhibit similar results to those of PDP's. Consequently, the outcomes from Mulatti et al.'s (2006) research suggest that instead of the mapping of letters/graphemes onto their corresponding phonemes, during reading words are directly processed based on their phonology. Further, to be able to benefit from a word's phonological neighbours a reader must have access to the word's phonemes sounds – phonemic features. Therefore, it is plausible that in reading, phonemes are specified for their phonemic features.

This conclusion is supported by the findings from Ashby, Sanders and Kingston's (2009) Event Related Potentials (ERPs) research in which the authors demonstrated that word reading 'involves the activation of sub-phonemic feature information' (Ashby et al., 2009, pg. 90). In their study, Ashby et al. (2009) asked participants to read single words presented to them on a computer screen whilst their brain activity was recorded. One half of the target words in their research had a voiced final consonant (e.g., fad) and the other half had a voiceless final consonant (e.g., fat). Also, the presentation of each target was preceded by the brief presentation of a masked non-word prime which was either congruent (the final consonants of both target and prime were either voiced or voiceless) or incongruent (if for example the final consonant of the target was voiced, the final consonant of the prime was voiceless) with the target. Ashby et al. (2009) found significant feature-congruency effects which started as early as 80 ms after target onset. Based on these results, Ashby and colleagues (2009) concluded that during word reading there is an automatic activation of phonemic features corresponding to the word's phonemes. As such, to be able to account for Ashby et al.'s (2009) and Mulatti et al.'s (2006) findings, word reading modellers would have to seriously consider the role of phonemic features during this task.

1.5. Conclusions

As illustrated in this chapter, models of general language production have tended to be developed separately from models of word reading. As highlighted, one of the most contentious issues raised by language production modellers involves phoneme representation during the phonological encoding process. Dell (1986) and Roelofs (1997b) postulated that phonemes are not specified for their phonemic features whereas Dell et al., (1993) considered phonemes to be fully defined for their phonemic features during this process. In contrast to language production modellers, word reading researchers mostly agree that during reading phonemes are represented as abstract entities with featural information activated during articulation. Nonetheless, as suggested by the findings of Mulatti et al. (2006) and Ashby et al. (2009), word reading modellers might need to reconsider the role of phonemic features during this task. As such, an investigation into the role of phonemic features in both general language production and word reading has the potential to render important new information concerning the role of features in each task that could make a significant contribution to the current understanding of these two domains. Additionally, this information might also provide fresh evidence that is necessary to either substantiate or refute Roelofs' (2004) assertions of shared phonological encoding mechanisms for both general language production and word reading.

CHAPTER 2: A critical review of masked priming research

2.1. Chapter overview

This chapter begins by introducing the masked priming paradigm which has been frequently employed by researchers wanting to improve their understanding of the cognitive processes involved in word reading. Much of the initial work using this paradigm focused on determining whether masked priming effects are caused by the involvement of episodic memory or whether they reflect automatic and subconsciously driven temporary changes in the cognitive system. Also, researchers wanted to ascertain whether these effects are due to a lexical or sub-lexical level of processing. As argued in this chapter, the empirical evidence suggests that masked priming effects are automatic and subconsciously driven and that they result from a sub-lexical level of processing. That is why they can also be found in word reading studies even when primes and targets share only their onsets.

The masked onset priming effect (MOPE) is then discussed at length. Firstly, it is shown how this onset effect for word reading was first observed by Forster and Davis (1991) who referred to Coltheart's (1978) dual-route framework of word reading when they suggested that this effect lay within the GPC process of the non-lexical route. It is then explained how contrary to Forster and Davis (1991), Kinoshita (2000) re-interpreted this effect as reflecting rightward processing during the segment-to-frame

association stage of phonological encoding, a processing stage that is currently under-specified in word reading models such as DRC. It highlights that since segment-to-frame association is also integral to the WEAVER language production model, Kinoshita's (2000) re-interpretation of the masked onset effect thus implies that similarities might exist between word reading models such as DRC and language production models such as WEAVER at the phonological encoding stage of processing. Importantly and as discussed in Chapter 1, when Roelofs (2004) simultaneously examined both word reading and picture naming using an alternative form-preparation naming task, his observations in fact led him to propose a possible merging of such models at the segment-to-frame association stage of the phonological encoding process.

The final section of this chapter examines the role of phonemic features during word-form encoding. In particular, it discusses the outcomes from a masked priming study conducted by Lukatela et al. (2001) that found effects from featural similarity in the lexical decision task. Such findings however, are incompatible with models of general language production such as WEAVER. In this model phonological encoding involves the insertion of abstract phonemes into a word frame only after which there follows a parallel activation of phonemic features. This parallelism thus implies that as found by Roelofs (1999) there should be no effect from phonemic feature similarity. It is noted however, that whilst Lukatela et al.'s (2001) study examined words using the lexical decision task, Roelofs' (1999) research examined language production using an entirely different paradigm. As such, it highlights the necessity to examine both word reading and picture naming within the same experimental paradigm before firm conclusions as to the notion of shared phonological encoding mechanisms for the two tasks can be drawn.

2.2. Masked priming paradigm

2.2.1. General procedure

A masked priming paradigm is an experimental procedure in which the presentation of a target (the critical response item) is preceded by the very brief presentation of another stimulus (referred to as the prime). The duration of the prime depends on the research question being addressed and generally varies from 20 to 67 ms. Additionally, the prime is usually presented in lower case letters with the target displayed in upper case letters. This is done to reduce visual similarity between the two stimuli. Further, to obscure (mask) the visibility of a prime the experimental procedure usually incorporates the presentation of a forward mask (e.g., a row of hashes - #####) typically shown for a period of time (e.g., 500 ms) prior to the presentation of the prime.

The employment of the masked priming paradigm enables researchers to control for any target related confounds by using the same targets whilst experimentally manipulating the primes which are often presented in at least two conditions namely, a related condition (where the prime is related in some form to the target e.g., semantically - 'dog-CAT' or orthographically – 'can-CAT') and an unrelated/control condition (where prime and target are completely different e.g., 'pin-CAT'). During masked priming studies the presence of the prime is not mentioned to participants. Further, participants are required to respond to targets in a specific way (e.g., to decide whether a letter string is in fact a real word or not – the lexical decision task, or to read aloud a word target –

the reading task) with their reaction times (the time interval between target onset and response onset) recorded across all conditions. Any response time benefit in the related condition relative to the unrelated condition is referred to as a priming effect and is thought to be the result of faster target processing caused by prime-target relatedness. (Forster, Mohan & Hector, 2003). However, although masked priming effects are generally considered to be reliable, the accounts proposed by researchers as to the locus of these effects are often quite different.

2.2.2. The lexical entry opening account of masked priming

Over the past forty years the masked priming paradigm has been frequently employed by researchers interested in developing a better understanding of the cognitive mechanisms involved in written word processing. In contrast to long-term priming in which a prime is displayed for a considerable period of time (e.g., 500 ms) and is then followed by the presentation of intervening items with observed effects thought to be driven by episodic memory trace, masked priming effects are believed to be automatic and subconsciously induced (Bodner & Stalinski, 2008; Forster & Davis, 1984; Forster, Mohan & Hector, 2003; Frost, 1998). As such, they are considered to be due to a temporary change in the cognitive system that is induced by the very brief presentation of the prime.

In support of this subconsciously actuated, short-lived cognitive change view of masked priming, some researchers referred to experimental findings which illustrate that these

effects are insensitive to target words' frequencies and that they tend to disappear if there is a long interval between the presentation of a prime and target. For example, in their masked repetition/identity priming research (where prime and target are the same word e.g., 'cat-CAT'), Forster and Davis (1984; Experiments 1, 5 and 6) found that compared to the corresponding unrelated conditions, lexical decisions were much faster for both high and low frequency word targets in the related conditions with the observed repetition/identity priming effects of a similar magnitude for both target types. Also, in Experiment 6 Forster and Davis (1984) found that displaying another word between the presentation of a prime and target significantly reduces the repetition priming effect (from 35 ms in Experiment 1 to 17 ms in Experiment 6) whereas the presentation of several intervening items eliminates it all together. Consequently, the authors concluded that the repetition/identity priming effects found in their research are short-lived and caused by the time saving property of the prime during lexical entry.

According to Forster and Davis (1984), the brief presentation of an identical prime prior to the presentation of a target in the related condition results in the opening of an entry in the mental lexicon which is specific to that target. Therefore, when the actual target is presented, its entry has already been opened thus its selection takes less time compared to the selection of a target in the unrelated condition where the presentation of a prime has not opened the lexical entry of its corresponding target. Since frequency only affects the speed with which a word's lexical entry can be found but not the time it takes to access the word's specific information (Forster, Mohan & Hector, 2003), Forster and Davis (1984) argued that (as found by them and other researchers e.g., Bodner & Masson, 1997; Ferrand, Grainger & Segui, 1994; Sereno, 1991) both high and low frequency word targets should therefore exhibit similar masked priming effects. The

authors also suggested that if masked priming effects were due to the influence of episodic memory, these effects should have been larger for low frequency word targets than for high frequency word targets. This is because the presentation of a prime in the related condition would have increased the familiarity of the low frequency target to participants thereby accelerating its lexical selection. However, since by definition high frequency words are already familiar, the display of a prime in the related condition should have less effect on the lexical selection process of a high frequency word target.

This word frequency effect was in fact observed by Forster and Davis (1984; Experiment 3). In Experiment 3, Forster and Davis (1984) employed the same stimuli as in Experiment 1. This time however, instead of masked priming they used a long-term priming paradigm which as mentioned earlier is considered to be subject to episodic memory trace. As predicted and in contrast to the results from Experiment 1, they found that compared to the corresponding unrelated conditions lexical decisions were 63 ms faster for low frequency word targets and only 30 ms faster for high frequency word targets. Similar word frequency effects when employing long-term priming were reported by other researchers such as for example, Duchek and Neely (1989). Further, in their research Forster and Davis (1984; Experiment1) also failed to observe masked repetition/identity priming effect for non-word targets. Since only words are represented in the mental lexicon, Forster and Davis (1984; Experiment 1) argued that this null effect for non-word targets is consistent with the lexical account of masked priming and therefore, combined with other findings from their research, provide strong support for the notion that masked repetition/identity priming effects are caused by the prime opening the lexical entry for the related target.

2.2.3. Evidence against the lexical entry opening account of masked priming

However, although Bodner and Masson (1997; Experiment 1) were able to replicate Forster and Davis' (1984; Experiment1) results with both word and non-word targets displayed in upper case letters (e.g., 'WORD', 'PERD'), the outcomes from their follow up studies (Bodner & Masson, 1997; Experiments 2a and 2b) in which high and low frequency word targets and non-word targets were presented in mixed case letters (e.g., 'wOrD', 'pErD) were very different. In Experiment 2a Bodner and Masson (1997) found that consistent with the results from previous research (Forster & Davis, 1984; Experiment 1 and Bodner & Masson, 1997; Experiment1) lexical decisions for both high and low frequency word targets were faster in the related conditions relative to the unrelated conditions. However, although the observed masked repetition/identity priming effects were again of similar magnitude for these two targets types, this time they were considerably larger than in the earlier studies (e.g., 71 ms compared to 45 ms).

Further, contrary to the results from Forster and Davis' (1984; Experiment 1) as well as the outcomes from their own experiment, Bodner and Masson (1997; Experiment 2a) found a 93 ms masked repetition/identity priming effect for non-word targets that were presented in the related condition. Since Bodner and Masson (1997; Experiments 1 and 2a) employed the same stimuli in both experiments with the only difference between the two studies being the format in which the targets were displayed, the authors suggested that the observed discrepancies could only be attributed to differences in which

information provided by the prime was exploited during target processing. Consequently, they postulated that the presentation of targets in mixed case letters in Experiment 2a increased target processing difficulty which thus caused a greater reliance on the prime. However, displaying targets in this way also meant that some of the letters of both primes and targets in the related conditions were always presented in the same case. As there was no masking between these two stimuli, it was therefore possible that instead of a greater reliance on the prime, the outcomes from Experiment 2a might have been caused by an increase in physical similarity between prime and target.

To evaluate this possibility, in Experiment 2b Bodner and Masson (1997) exposed the mixed case letters word and non-word targets from Experiment 2a to non-word primes which in the related conditions shared only their lower case letters with targets (e.g., the prime-target 'phone-pHoNe' from Experiment 2a became 'ptobe-pHoNe' in Experiment 2b). According to the authors, if an increase in physical similarity between primes and targets in the related conditions in Experiment 2a contributed to the observed priming effects for non-word targets as well as increased masked priming effects for word targets, similar effects in these conditions should also be found in Experiment 2b. However, the results from Experiment 2b for both targets types failed to show any significant priming effects. As such, Bodner and Masson (1997; Experiment 2b) argued that these findings clearly illustrate that the shared lower case letters between primes and targets in the related conditions had no effect on the lexical decision task in Experiment 2a thus providing strong support for their hypothesis that these results were due to participants placing a greater reliance on the prime.

As mentioned earlier, this hypothesis is based on the assumption that the extent to which information provided by the prime is exploited is dependent on target processing difficulty. In their final two experiments therefore, Bodner and Masson (1997; Experiments 3 and 4) set out to further evaluate this theory. In Experiment 3 the authors found that lexical decisions to pseudohomophones targets (non-words which sound like real words) were made 38 ms faster in the related relative to the unrelated conditions. This was predicted because as shown by other researchers (e.g., Stone & Van Orden, 1993) pseudohomophones are much more difficult to respond to than other non-words due to their familiarity to actual words. Therefore, the increased difficulty of the non-word targets in Experiment 3 thus appeared to increased participants' reliance on the primes.

In Experiment 4 (Bodner & Masson, 1997) the processing of targets was made easier by employing very high frequency word targets which by definition are much more familiar to participants than other words and thus should reduce the need to adhere to information provided by primes. For non-word targets, Bodner and Masson (1997; Experiment 4) used non-words which consisted only of consonants (e.g., 'RGPRT'). Since these types of targets are very dissimilar to actual words they are therefore much easier to reject during the lexical decision task and consequently should show no priming effects. In line with their predictions, Bodner and Masson (1997; Experiment 4) found only a small (22 ms compared to 71 ms in Experiment 2a) priming effect for word targets and no priming effect whatsoever for non-word targets.

Taken together, the results from Bodner and Masson's (1997) research showed masked priming effects for the more difficult non-word targets (Experiments 2a and 3) and priming effects for word targets which varied according to target processing difficulty (Experiments 1, 2a, 3 and 4). Both of these findings are therefore inconsistent with Forster and Davis' (1984) lexical entry opening account of masked priming effects. Firstly, since non-words are not represented in the mental lexicon, they should not have benefited from the presentation of related primes regardless of their processing difficulty. Secondly, according to Forster and Davis' (1984) account, during masked repetition priming the display of the prime in the related condition opens the word target's specific entry in the mental lexicon. As in this condition the word target's lexical entry is already opened, its processing should have been unaffected by Bodner and Masson's (1997) experimental manipulation. Finally, contrary to Forster and Davis' (1984) argument that masked priming effects are automatic and subconsciously driven, the above results suggest that during masked priming episodic memory trace for the prime is established and can be recruited dependent on target processing difficulty.

However, as discussed Bodner and Masson (1997) also found similar priming effects for both high and low frequency word targets (Experiments 1, 2a and 3). This congruency in the magnitude of priming effects for these two targets types was independent of target processing difficulty (Experiments 2a and 3). Therefore, the word targets' frequency results were consistent with the findings reported by Forster and Davis (1984; Experiment1) and cannot be explained by Bodner and Masson's (1997) account of masked priming effects. According to Bodner and Masson's (1997) explanation, the processing of difficult targets should have caused a greater reliance on the information provided by primes which in turn should have resulted in larger priming

effects for those targets relative to the easier targets. Since by definition low frequency words are more difficult to recognise than high frequency words, following Bodner and Masson's (1997) logic they should therefore have shown larger priming effects compared to the high frequency words. In fact, if as argued by Bodner and Masson (1997) these effects are reflective of the involvement of episodic memory during masked priming experiments, the results for both the high and low frequency words should have been consistent with the findings from Forster and Davis' (1984; Experiment 3) research in which a long-term priming paradigm was employed. As such, the interpretation of mask priming effects provided by Bodner and Masson (1997) can only explain some but not all of their data. Further, their episodic memory account of these effects is not only inconsistent with their results for low frequency word targets but is also contrary to the findings reported by Bodner and Stalinski (2008) whose research is described in the following section.

2.2.4. Episodic memory versus an automatic and subconsciously driven account of masked priming effects

In their research Bodner and Stalinski (2008) set out to establish whether masked repetition priming effects in the lexical decision task would be affected by an additional cognitive load. During their study therefore, they collected participants' response times to word and non-word targets under two cognitive load conditions namely, no load and load conditions. In the no load condition which was consistent with other masked priming research (e.g., Forster & Davis, 1984; Bodner & Masson, 1997; Experiment 1) participants were required to respond to word and non-word targets preceded by the

brief (45 ms) presentation of a prime in either related (where prime and target were the same word or non-word) or unrelated (where prime and target were completely different) sub-conditions. In the load condition by contrast, each trial began with the presentation of an eight-digit number string for 2000 ms. This was followed by a blank screen for 1000 ms, and in line with the no load condition a prime was then shown for 45ms which was immediately followed by the display of a target. The word or non-word target remained on the computer screen until a response was given. Once responded to, the target was replaced by another eight-digit number string with participants required to decide whether this number string was identical or not to the one presented at the beginning of the trial. As such, in the load condition participants performed two tasks which they were instructed to treat with equal importance.

According to Bodner and Stalinski (2008), the purpose of the two tasks in the cognitive load condition was to increase the task demand and by so doing to interfere with any strategic processing of the prime. The authors argued that if masked repetition priming effects are caused by episodic memory trace then they should be reduced or even eliminated in the cognitive load condition. If however, they reflect an automatic and subconscious processing of the prime during masked priming then these effects should be unaffected by their cognitive load experimental manipulation. Nonetheless, Bodner and Stalinski (2008) failed to make separate predictions for the two targets types employed in their study. Yet, given that they used pronounceable non-words displayed in upper case letters, to be consistent with the earlier reported findings (Forster & Davis, 1984, Experiment 1; Bodner & Masson, 1997, Experiment 1) it would be expected that these non-words should exhibit no priming effects in both the no load and load conditions.

In line with the argument just presented, Bodner and Stalinski's (2008) results for the non-word targets failed to show priming effects and were therefore consistent with the findings reported by both Forster and Davis' (1984) as well as Bodner and Masson's (1997). Consequently, they could be explained equally well by either the lexical entry opening account of masked repetition priming (Forster & Davis, 1984) or the perspective that participants place a greater reliance on the prime when target processing difficulty is increased (Bodner & Masson, 1997). As such, they neither support nor dispute the episodic memory based account of masked repetition priming (Bodner & Masson, 1997). Bodner and Stalinski's (2008) word targets' data on the other hand, showed that in both the no load and load conditions word targets were responded to faster in related conditions relative to unrelated conditions. These repetition priming effects were of similar magnitude and thus proved to be unaffected by their cognitive load experimental manipulation. Based on their word targets' results, Bodner and Stalinski (2008) therefore concluded that masked priming effects are in fact automatic and sub-consciously driven.

Further, this automatic and subconsciously driven account of masked priming effects can explain why in post-experimental interviews the majority of participants reported being unaware of the presence of a prime and those who thought they had noticed something prior to the display of targets were unable to explicitly name what they saw (e.g., Bodner & Stalinski, 2008; Forster & Davis, 1984; Grainger & Ferrand, 1996). This account is also consistent with the findings from prime visibility tests in which participants were asked to focus exclusively on identifying the primes and which

explicitly showed that during these tests participants' levels of performance was close to chance (e.g., Forster & Davis, 1984; Grainger & Ferrand, 1996; Schiller, 1998). However, it is important to note at this point that although Bodner and Stalinski's (2008) word targets' findings as well as the outcomes from both post-experimental interviews and prime visibility tests were all in line with Forster and Davis' (1984) notion that masked priming effects reflect subconsciously induced temporary changes in the cognitive system, as discussed earlier Forster and Davis' (1984) lexical entry opening account of these effects cannot explain the difficult non-word targets' priming reported by Bodner and Masson (1997). Since non-words are not represented in the mental lexicon any priming of such targets can only be due to a sub-lexical level of processing. Therefore, the interpretation of masked priming effects provided by Grainger and Ferrand (1996) seems more appropriate to account for these data.

2.2.5. Grainger and Ferrand's (1996) account of masked priming effects

In line with Forster and Davis' (1984) argument, Grainger and Ferrand (1996) also postulated that the effects obtained during masked priming are automatic and subconsciously induced. Contrary to the former authors however, Grainger and Ferrand (1996) suggested that these effects are mediated by both the orthographic and phonological relatedness between a prime and target. Therefore, rather than directly opening a target's specific entry in the mental lexicon, a prime's orthographic and phonological codes in the related condition pre-activate a target's orthographic and phonological codes resulting in faster access to the target's lexical representation in that

condition relative to the unrelated condition. As such, these codes are the proxies for accessing a target's lexical representation. However, prior to their study there was a general lack of masked priming research in the available literature that had attempted to differentiate between effects caused by prime-target relatedness that was either purely orthographic or purely phonological. To test their hypothesis therefore, Grainger and Ferrand (1996) conducted a series of experiments in French that employed a masked form priming paradigm (i.e., when a word or non-word prime differs from the target only by a single letter and /or a single phoneme), the primary aim of which was to establish the exact contribution to masked priming effects separately from both pure orthographic and pure phonological overlap between prime and target. Also, the authors wanted to assess whether any contribution from either or both of these two types of sub-lexical units would be congruent across three different experimental tasks namely, a lexical decision task, a perceptual identification task (in which participants were required to type on a computer keyboard the target word once it had been recognised) and a word reading task.

In Experiment 1 Grainger and Ferrand (1996) used high frequency monosyllabic word targets of four letters in length which were preceded by the brief (43ms) presentation of non-word primes. The primes were also of four letters in length and were organised into three experimental conditions. In the first condition the primes were orthographically unrelated pseudohomophones (they shared their phonology) of the targets (e.g., nair-NERF), in the second condition they were orthographically related pseudohomophones (e.g., nert-NERF) and finally in the third condition they were orthographically related non-homophonic (phonologically unrelated) primes (e.g., nerc-NERF). In all three priming conditions primes and targets shared their initial letter/onset. Finally, the same

stimuli were employed in each experimental task. The results from Experiment 1 (Grainger & Ferrand, 1996) showed masked orthographic and phonological priming effects that were separate and independent of each other in both the lexical decision and perceptual identification tasks. However, no effects were observed from these two sub-lexical units in the word reading task. Consequently, in Experiment 2 the researchers (Grainger & Ferrand, 1996) decided to repeat the word reading task with longer (53 ms) and shorter (29 ms) prime durations. The data from Experiment 2 failed to show any phonological priming effects with both prime durations whilst orthographic priming effects were only observed when the shorter (29 ms) prime duration was employed.

Based on their results so far Grainger and Ferrand (1996) concluded that at least in word recognition tasks such as lexical decision and perceptual identification both shared orthography and shared phonology between prime and target provide separate yet important sources of information necessary to activate a target's lexical representation. They were however, unsure why in the naming task with all three prime durations, they were unable to find any phonological priming effects whereas shared orthography between prime and target yielded facilitation only with the shortest prime exposure. Since the results from the naming task were contrary to the outcomes from the two word recognition tasks, Grainger and Ferrand (1996) decided to investigate these discrepancies further.

In Experiment 3 therefore, the authors set out to establish if the lack of phonological priming effects in the naming task might be attributed to the presence of a shared onset between each of the primes and their target. Consequently, they modified the prime stimuli from Experiment 1 by replacing the onset of each prime in each condition with a

percentage sign (e.g., the prime 'nair' became '%air') whilst keeping target words unchanged. Following this modification, the pseudohomophone primes from Experiment 1 became the word targets' rhymes in Experiment 3. As such, in the first condition in Experiment 3 target words were primed by orthographically unrelated rhymes (e.g., %air-NERF), in the second condition they were primed by orthographically related rhymes (e.g., %ert-NERF) whereas in the third condition targets were primed by orthographically related non-rhymes (e.g., %erc-NERF). Finally, as in Experiment 1, the primes in Experiment 3 for each condition were displayed for 43 ms.

The results from Grainger and Ferrand's (1996) Experiment 3 can be summarised as follows. In the lexical decision task the researchers found both separate and distinct phonological and orthographic priming effects. Further, the magnitude of the phonological priming effect was identical to that obtained in Experiment 1 (45 ms in both experiments). However, the orthographic priming effect in Experiment 3 was much smaller than in Experiment 1 (13 ms compared to 50 ms). According to Grainger and Ferrand (1996) the differences in orthographic priming across these experiments could be attributed to the fact that, following their primes' modifications, in Experiment 3 the primes and targets shared only two out of four letters (e.g., %erc-NERF) whilst in Experiment 1 they shared three out of four letters (e.g., nerc-NERF). Consequently, the authors concluded that in the lexical decision task both phonological and orthographic overlap between prime and target facilitates participants' responses and that these effects are independent of whether or not the two stimuli share their onsets.

In the word reading task on the other hand, the results from Experiment 3 were in striking contrast to those from Experiments 1 and 2. In this task Grainger and Ferrand (1996, Experiment 3) found 28 ms phonological and 7 ms orthographic priming effects. However, only the phonological priming effect was statistically significant. As in the lexical decision task, the authors attributed the lack of a significant priming effect for orthographic overlap to the fact that in this experiment primes and targets shared only two out of four letters. Based on the word reading data collected so far, Grainger and Ferrand (1996) inferred that in this task the shared onset between prime and target 'produces a maximum facilitation effect that prevents more stable form priming effects from emerging' (Grainger & Ferrand, 1996, pg. 637). This is why in Experiments 1 and 2 in which primes and targets in all three conditions shared their onsets, the common shared onset caused a facilitating effect that overshadowed any form priming. However, in Experiment 3 where there was no onset overlap between primes and targets a phonological form priming effect was indeed observed. Grainger and Ferrand's (1996; Experiments 4 and 5) final two experiments therefore, were designed to evaluate this conclusion.

In Experiment 4 Grainger and Ferrand (1996) collected participants' response times to the same word targets used in the earlier experiments. These word targets were again preceded by the brief (43 ms) presentation of non-word primes in three priming conditions. In the first condition primes and targets were both orthographically and phonologically related (e.g., nert-NERF), in the second condition they shared their onsets (e.g., nise-NERF) and finally in the third condition primes were unrelated to targets (e.g., fise-NERF). The results from Experiment 4 showed that relative to the unrelated condition, participants' lexical decisions were faster (49 ms) only in the form

related (shared orthography and phonology) condition. The word reading data showed almost identical form and onset priming effects (30 ms and 29 ms respectively) thus confirming Grainger and Ferrand's (1996) argument that in this task the magnitude of onset priming overshadows any form related priming effects. This is why no such priming was observed in Experiments 1 and 2 where the onset of both prime and target was shared in all conditions. Further, in Experiment 5 in which participants were required to perform only the word reading task, Grainger and Ferrand (1996) found no significant difference between the unrelated (e.g., fise-NERF) and no-letter onset (e.g., %ise-NERF) priming conditions. They also found that relative to these two conditions participants' response times were significantly faster in the shared onset condition (e.g., nise-NERF). Since response times in the unrelated and no-letter onset conditions were very similar, these results indicate that there was no cost to participants' reading aloud word targets in the unrelated condition. As such, the results from Experiment 5 confirmed that the effects obtained from all experiments conducted by Grainer and Ferrand (1996) were in fact facilitory in nature.

All in all, Grainger and Ferrand's (1996) research findings confirmed that in the lexical decision, perceptual identification and naming tasks both orthographic and phonological overlap between primes and targets are important yet separate contributors to masked priming effects. Similar results were also obtained in English (see Rastle & Brysbaert, 2006, for a review) meaning that these outcomes are not only consistent across tasks but also across languages and thus provide strong support for Grainger and Ferrand's (1996) argument that rather then directly opening a target's specific entry in the mental lexicon (Foster & Davis, 1984) masked priming effects are due to a sub-lexical level of processing. Further, in line with the generally accepted view that masked priming

facilitates the naming of targets in the related condition (Forster et al., 2003), Grainger and Ferrand's (1996) data confirmed that the effects found when employing this experimental procedure are in fact facilitatory in nature. Finally, Grainger and Ferrand (1996) also found that in the word reading task a shared onset between prime and target significantly facilitated participants' responses. In fact, the onset effect observed by these authors was so strong (Experiment 4) that it precluded the detection of any effects due to orthographic and/or phonological overlap between primes and targets in all but the onset positions (Experiments 1 and 2). Given that this outcome was not echoed in the lexical decision and perceptual identification tasks, Grainger and Ferrand (1996) concluded that as argued by Forster and Davis (1991), the masked onset priming effect (MOPE) is specific to word reading only and highlights that in this task a word onset plays an important and distinctive role. The masked onset priming effect along with the findings from Forster and Davis' (1991) research are considered in more detail in the following section.

2.2.6. The masked onset priming effect (MOPE)

Forster and Davis (1991) were the first researchers who set out to assess the role of the onset in word reading. In their investigation which was conducted in English, Forster and Davis (1991) used a three-fold masked priming paradigm in which, at the beginning of each trial, a forward mask (a row of six #s) was displayed in the middle of a computer screen for 500ms. This was followed by the presentation of a prime (in

lowercase letters) for 60 ms before the word target was shown (in uppercase letters) for 500ms. During each of Forster and Davis' (1991) experiments, participants were required to read aloud words presented in uppercase letters as quickly and as accurately as possible. Importantly, in addition to the reading/naming task, in Experiment 5 a lexical decision task was also employed. The reason for so doing is explained below. Finally, in all of Foster and Davis' (1991) experiments the participants' response latencies and error scores were the dependent variables.

In Experiment 1 all target words were primed by three types of primes namely, an unrelated (e.g., merry-BREAK), the same onset (e.g., belly-BREAK) and rhyming (e.g., take-BREAK) primes. The authors found that compared to the unrelated condition target words were named 24 ms faster when the same onset was shared between prime and target. However, there was no observed difference between the rhyming and unrelated conditions. Based on these results, Forster and Davis (1991) thus concluded that in masked priming a shared onset between prime and target facilitates word reading. They referred to this facilitation as the masked onset priming effect (MOPE).

To account for the MOPE, Foster and Davis (1991) referred to Coltheart's (1978) dual-route framework of reading words aloud. However, because the architecture and working assumptions of Coltheart et al.'s. (2001) DRC computational model are based on this theoretical framework (as discussed in Chapter 1, section 1.4.1.1.), Forster and Davis' (1991) conclusions can therefore be extended to this model. Forster and Davis (1991) suggested that the locus of the MOPE lies within the sequential rightward GPC processing manner of a given input by the non-lexical route, with the shared initial segment(s) between prime and target (e.g., belly-BREAK in Experiment 1) acting to

facilitate the naming of a word target. In contrast, when the shared segment(s) is positioned later in the word form, the mismatching initial segment between a prime and target induces competition between these segments, the resolution of which holds up the process resulting in no observed facilitation. However, because Forster and Davis (1991) used primes in Experiment 1 that also rhymed with targets (e.g., take-BREAK), the latter part of this explanation could neither be confirmed nor disputed by their findings at that stage.

Forster and Davis' (1991) Experiments 4 to 6 were designed to provide more direct evidence for the argument that the MOPE is caused by serial rightward processing through the non-lexical route. In Experiment 4 the authors used exception word (e.g., PINT) and non-word targets. According to the dual-route theoretical framework (Coltheart, 1978; Coltheart et al., 2001) the correct pronunciation for exception words has to be accessed from memory and thus can only by generated in parallel via the lexical route rather than by letter-to-letter computation via the non-lexical route. As such, Forster and Davis (1991; Experiment 4) postulated that to be consistent with their account for the locus of the MOPE, then relative to controls (e.g., spot-FETE) the naming of exception word targets should not be facilitated by a shared onset between primes and targets (e.g., fish-FETE). By extension, as non-words can only be read letter-by-letter via the non-lexical route, the naming of non-word targets should be faster in the onset condition (e.g., fosk-FENT) compared to the control condition (e.g., jisk- FENT). The results from Experiment 4 were consistent with Forster and Davis' (1991; Experiment 4) predictions and thus showed a MOPE for non-word but not for exception word targets.

Experiment 5 was conducted to assess masked onset priming effects whilst manipulating the strength with which the lexical and non-lexical routes were engaged. This manipulation was achieved by employing both high and low frequency word targets. As argued by the proponents of the dual-route theoretical framework (e.g. Coltheart, 1978; Coltheart et al., 2001), due to their familiarity high frequency words are processed in parallel via the lexical route whereas the unfamiliarity of low frequency words requires letter-by-letter processing via the non-lexical route. Further, in Experiment 5 both high and low frequency word targets were primed by four types of primes namely, identical (e.g., before-BEFORE), different initial letter (e.g., defore-BEFORE), different final letter (e.g., befora-BEFORE) and control (e.g., dranch-BEFORE). The results from this study showed that compared to the corresponding control condition both target types were read significantly faster in the identical condition. They were also read significantly faster in both the initial and final letter different conditions relative to their corresponding control condition. However, for high frequency word targets the difference between the initial and final letter different conditions was not significant (4 ms) whereas for low frequency word targets this difference was highly significant (17 ms). Based on these data Forster and Davis (1991; Experiment 5) thus concluded that when reading aloud word targets in the masked priming paradigm both identity and form priming effects are independent of word frequency. However, consistent with their argument for the locus of the MOPE, a MOPE can only be observed for low frequency words that are processed sequentially via the non-lexical route and not for high frequency words which are processed in parallel by the lexical route.

In Experiment 5 the stimuli for the reading task were then used in a lexical decision task with a different set of participants to those employed in the former task. These participants were required to decide whether a given target was a real word or not by pressing one key for yes and another for no. The data from this part of Experiment 5 showed that both high and low frequency targets were identified as words significantly faster in the identical condition relative to the control condition. They were also labelled as words significantly faster in both the initial and final letter different conditions. These findings were thus consistent with the results from the reading task and therefore demonstrated that in masked priming both identity and form priming effects can be observed regardless of the task employed. However, the lexical decision results showed no facilitation from a shared onset between primes and both high and low frequency word targets. Since deciding whether a given target is a real word or not requires the engagement of the lexical route and also that in the reading task low frequency word targets showed a MOPE whereas in the lexical decision task they did not, Forster and Davis (1991; Experiment 5) postulated that these outcomes provided further confirmation for their argument that the MOPE is due to serial rightward processing in the non-lexical route.

In Experiment 6 that concluded Forster and Davis' (1991) research, the authors employed a go-no-go conditional naming task in which participants were instructed to read aloud a given target only if that target was a real word. In keeping with the lexical decision task of Experiment 5, both word and non-word targets were mixed within the same sets in Experiment 6. By again reasoning that lexical decision task forces the engagement of the lexical route, Forster and Davis (1991; Experiment 6) therefore hypothesised that to be consistent with their argument for the locus of the MOPE, in this

study there should be no observable facilitation from a shared onset between primes and targets. The results from Experiment 6 were in line with Forster and Davis' (1991) predictions and showed no difference in the response latencies between the onset (e.g., belly-BREAK) and control (e.g., merry-BREAK) conditions. Further, the data also showed that targets were read significantly faster in the identical condition (e.g., break-BREAK) compared to controls. The latter findings were thus consistent with the outcomes from Experiment 5 and provided further evidence that identity priming effects can be found regardless of which route is engaged.

Considered together, the results from Forster and Davis' (1991) Experiments 1, 4,5 and 6 provided convincing support for their perspective that the MOPE is caused during serial rightward processing of a word form via the non-lexical route. Further, since this effect was found with some (e.g., low frequency and non-word) but not all (e.g., high frequency and exception) word targets, these outcomes were in line with the dual-route theoretical framework (Coltheart, 1978; Coltheart et al., 2001). Further, as CDP+ (Perry et al., 2007) is also a dual-route model in which akin to the DRC model, the processing of a given input via the lexical route occurs in parallel across its word form whilst that via the non-lexical route takes place in a serial rightward manner, the data from Forster and Davis' (1991) research can also be explained with reference to this model. However, since processing through the PDP (Plaut et al., 1996) word reading model occurs via a single route, this particular model cannot account for the findings reported by Forster and Davis (1991). Furthermore, Forster and Davis' (1991) interpretation of the MOPE as facilitory in nature is consistent with the findings from Grainger and Ferrand's (1996) research in which (as described earlier - section 2.2.5) the authors observed similar response times for word targets named in both the unrelated (e.g., fise-

NERF) and no-letter onset (e.g., %ise-NERF) conditions. In line with Forster and Davis' (1991) results Grainger and Ferrand (1996) also observed that the MOPE is independent of form priming effects and is only found in the word reading task. However, contrary to the former researchers, Grainger and Ferrand (1996) reported a MOPE for high frequency word targets. This latter result was therefore inconsistent with Forster and Davis's (1991) interpretation of the MOPE. As such, Kinoshita's (2000) alternative speech planning/phonological encoding account as to the locus of the MOPE might be more appropriate to explain the above data.

2.2.7. Kinoshita's (2000) re-interpretation of the locus of the MOPE

Kinoshita's (2000) masked priming research was designed to further investigate the locus of the MOPE. She wanted to ascertain whether as argued by Forster and Davis (1991), this effect is in fact caused by serial rightward processing via the non-lexical route (Coltheart, 1978; Coltheart et al., 2001) or whether it occurs after the orthography-to-phonology computation of the non-lexical route or the parallel computation of phonology via the lexical route and takes place at the speech planning/phonological encoding stage that in the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001) is shared by both routes. She thus theorised that processing at this stage might also operate in a sequential manner. To address this research question, Kinoshita (2000) conducted two experiments. In Experiment 1 the author tested non-word targets of three letters in length in both left-to-right and right-to-left overlap sets. In the left-to-right

overlap set non-word targets such as for example SIB, were primed by three types of primes namely, single letter overlap (e.g., suf-SIB), two letters overlap (e.g., sif-SIB) and unrelated (e.g., mof-SIB). There were also three priming conditions employed for the right-to-left overlap set (e.g., mub-SIB in single letter overlap, mib-SIB in two letters overlap and mof-SIB in unrelated). Experiment 1 was therefore designed to assess whether facilitation from a shared letter/s could be obtained independently of the position of overlap between prime and target. If so, this would argue against the sequential nature of the MOPE.

The results from Experiment 1 (Kinoshita, 2000) showed that compared to the unrelated condition, non-word targets were named significantly faster when both prime and target shared their initial letter and also their first two letters. However, the difference between the single letter and two letters overlap conditions was only 3 ms which suggested that this effect was mainly due to the shared initial letter. In the right-to-left overlap set however, there was no benefit to target naming from the shared end letter/s. These outcomes therefore provided support for Forster and Davis' (1991) assertion that the MOPE is caused by serial rightward processing of the word form. However, contrary to the above authors, Kinoshita (2000) argued that the sequential nature of this effect does not automatically mean that the MOPE reflects the working assumptions of the non-lexical route (e.g., DRC, Coltheart et al., 2001). Instead, she suggested that this effect could occur at the speech planning/phonological encoding stage of processing which akin to the non-lexical route might also operate in a serial rightward manner. Kinoshita's (2000) Experiment 2 was conducted to test this hypothesis.

In Experiment 2 Kinoshita (2000) used both simple (e.g., PASTE) and complex (e.g., BLISS) onset targets to evaluate whether the MOPE occurs due to a shared onset or shared initial letter between prime and target. She argued that if this effect is caused by a shared onset then facilitation from a matching initial letter between these two stimuli should only be observed in the simple (e.g., penny-PASTE) but not complex (e.g., bingo-BLISS) onset condition. This is due to the onset in the complex onset condition consisting of a consonant cluster which is thus different to the single consonant onset of the prime. If however, the MOPE is due to a shared initial letter then both conditions should show similar facilitatory effects. Further, according to Kinoshita (2000, Experiment 2), by addressing the question of whether the MOPE is due to a shared onset or just the shared initial letter between a prime and target, she would obtain more direct evidence as to the locus of this effect. This is because in the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001), at the non-lexical level the computation of phonology from orthography takes place letter by letter and thus each letter is represented as a separate unit regardless of whether it belongs to a consonant cluster or not. To be consistent with this working assumption of the non-lexical route therefore, facilitory effects from a shared initial letter between primes and targets should be found in both simple and complex onsets conditions. However, at the speech planning/phonological encoding stage each unit corresponds to the phonological sound such as for example, the onset or coda of a word. Consequently, at this stage only facilitation from a shared onset between primes and targets (simple onset condition) should be observed.

The data from Experiment 2 (Kinoshita, 2000) showed that compared to the control condition (e.g., mummy-PASTE) simple onset targets were named 14 ms faster when

preceded by matching initial letter primes (e.g., penny-PASTE) however, this effect was not found for complex onset targets (e.g., bingo-BLISS). Kinoshita (2000; Experiment 2) thus concluded that the MOPE is actually caused by a shared onset between primes and targets. Since as postulated by the author, in the dual-route framework (e.g., DRC; Coltheart et al., 2001) the onset of a word is represented as a single unit only at the speech planning/phonological encoding stage, the data from Experiment 2 therefore provide strong support for her perspective that the MOPE occurs at this processing stage, which akin to the non-lexical route also operates in a sequential manner. However, as mentioned above, in this theoretical framework the speech planning/phonological encoding stage is shared by both the lexical and non-lexical routes. Consequently and contrary to the data reported by Forster and Davis (1991), a MOPE should also be found for both exception (e.g., 'PINT' – Experiment 4) and high frequency (Experiment 5) word targets. Further, it should also be observed in the go-no-go conditional naming task (Experiment 6).

Kinoshita's follow up masked priming research (Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007) was thus designed to assess the validity of Foster and Davis' (1991) results for these two target types as well as for the go-no-go conditional naming task. As such, in Experiment 1 Kinoshita and Woollams (2002) compared participants' response latencies to both regular and exception word targets that were primed by two types of primes namely, onset related (e.g., fish-FETE) and control (spot-FETE). The results from this study were consistent with Forster and Davis' (1991, Experiment 4) data and showed that relative to corresponding controls, regular word targets were read significantly faster in the onset related condition whereas for exception word targets there was no significant difference between the control and onset related conditions. In

Experiment 2 Kinoshita and Woollams (2002) used the go-no-go conditional naming task employed by Forster and Davis (1991; Experiment 5). In this study the regular and exception word targets from Experiment 1 were mixed randomly with non-words within the same experimental block. Experiment 3 on the other hand, was a repetition of Experiment 1. This time however, rather than being presented for naming in pure blocks the regular and exception word targets from Experiment 1 were mixed randomly within the same experimental block. The data from Experiments 2 and 3 showed that for both regular and exception word targets there was no difference between the onset related and control conditions. The outcomes from Experiment 2 were thus consistent with the go-no-go conditional naming results reported by Forster and Davis (1991; Experiment 6). However, the findings from Experiment 3 were contrary to both the data from Experiment 1 as well as Forster and Davis' (1991, Experiment 4) results.

To explain why in Experiment 3 a MOPE for regular word targets was eliminated, Kinoshita and Woollams (2002) referred to a time criterion phenomenon introduced by Lupker, Brown and Colombo (1997). According to these authors, in the experimental setting participants' verbal responses to given stimuli are affected by the way in which these stimuli are presented. For example, if asked to read easy and difficult words displayed in separate blocks, participants adjust their responses based on the complexity of the items presented within a given block; thereby reading easy words faster than difficult words. However, when easy and difficult words are mixed together within the same experimental block, participants delay their responses to easy words whilst speeding their responses to difficult words. As such, they adopt a new time criterion (deadline) for their verbal responses to these stimuli.

Applying this argument to the data from their research, Kinoshita and Woollams (2002) postulated that the lack of an observed MOPE for regular word targets in Experiment 3 was due to the fact that in this study regular and exception words were mixed together within the same experimental block. Since by definition regular words are easier to read than exception words, in the mixed block in Experiment 3 participants' verbal responses to regular words were thus delayed which in turn meant that any facilitation from the shared onset between primes and regular word targets was simply lost. By extension, Kinoshita and Woollams (2002) also suggested that the time criterion argument could equally well explain the lack of a MOPE in the go-no-go conditional naming task (Experiment 2; Forster and Davis, 1991, Experiment 6). This is because in the conditional naming task both words and non-words were mixed together within the same experimental block making it possible that in this task participants' verbal responses to word targets were delayed due to the presence of the more difficult to read non-word, with the result that a MOPE was not observed.

Although Kinoshita and Woollams' (2002) account for the lack of a MOPE in the go-no-go conditional naming task seams highly plausible, these researchers failed to explain the absence of this effect for exception word targets (Experiment 1; Forster and Davis, 1991, Experiment 4). However, the author of this thesis argues that the latter results could also be explained with reference to the time criterion phenomenon (Lupker et al., 1997). As discussed in Chapter 1 exception words can vary in their degree of difficulty. This is because some of them have more friends (words which have similar spelling and their pronunciation rhymes with the exception word) than enemies (words which despite similar spelling are pronounced differently to the exception word) whilst others have more enemies than friends. It is therefore possible that the former exception

words were easier to read than the latter. Consequently, if mixed together within the same experimental block participants' verbal responses to exception words with higher friends-to-enemies ratio might be delayed whereas their responses to exception words with higher enemies-to-friends ratio might be faster. This again could mean that any benefits from a shared onset between primes and target would be lost. Importantly, although the time criterion argument might well account for the absence of the MOPE for exception words and in the go-no-go conditional naming task (Forster & Davis, 1991, Experiments 4 & 6; Kinoshita & Woollams, 2002, Experiments 1 & 2), it cannot be employed to explain the lack of this effect for high frequency word targets reported by Forster and Davis (1991, Experiment 5). Malouf and Kinoshita's (2007) research was designed to address this issue.

Malouf and Kinoshitas' (2007) research was set up to evaluate whether a MOPE could be found for both high and low frequency word targets. They argued that the absence of this effect for high frequency words reported by Forster and Davis (1991; Experiment 5) might have been caused by the nature of the primes they employed. Specifically, they postulated that because in both the initial (e.g., defore-BEFORE) and final (e.g., befora-BEFORE) letter different conditions there was a significant overlap between the segments of a prime and target (Forster and Davis, 1991; Experiment 5), this form relatedness might have interacted with word frequency with the result that there were no observable effects from a shared onset between these two stimuli for high frequency word targets. To control for any possible interaction therefore, in Experiment 1 Malouf and Kinoshita (2007) used primes that with the exception of the onset position in the onset condition were unrelated in form to both high (e.g., hark-HEAT vs. pork-HEAT) and low frequency (e.g., hark-HEEL vs. pork-HEEL) word targets.

The results from Experiment 1 (Malouf & Kinoshita, 2007) showed a MOPE for both high and low frequency word targets. As such, they were contrary to the data reported by Forster and Davis (1991; Experiment 5) and thus provided strong support for the argument discussed above that the absence of a MOPE for high frequency words in Forster and Davis' (1991) research might have resulted from an interaction between form relatedness and word frequency. However, when in Experiment 2 Malouf and Kinoshita (2007) used primes that were similar to those employed by Forster and Davis (e.g., defore-BEFORE vs befora-BEFORE, 1991; Experiment 5), contrary to the latter authors they once again found a MOPE for both target types. Further, as the magnitude of the observed MOPE was similar for both high and low frequency word targets in Malouf and Kinoshita's studies (2007; Experiments 1 & 2), these authors concluded that word frequency had little to no effect on the processing of these targets. The data from Experiments 1 and 2 therefore, was consistent with Malouf and Kinoshita's (2007) assumption that this effect takes place at the speech planning/phonological encoding stage.

Taken together, Kinoshita's (2000; Kinoshita & Woollams, 2002; Malouf and Kinoshita, 2007) data and interpretation presented above make a convincing case for her explanation for the locus of the MOPE. Importantly, by arguing that this effect occurs at the speech planning/phonological encoding stage of processing which akin to the segment-to-frame association process of the WEAVER (Roelofs, 1997a, 1997b) general language production model operates in a serial rightward manner, she was the first researcher hinting at the possibility of shared phonological encoding mechanisms for these two domains. This argument was thus consistent with that presented by Roelofs

(2004) who as described in Chapter 1 (section 1.1.), observed in his form-preparation research that relative to corresponding heterogeneous sets (e.g., baby, wapen, leraar – Begin-heterogeneous; klaver, varken, bijbel – End-heterogeneous) the naming of both words and pictures was significantly faster in Begin-homogeneous sets (e.g., baby, bezem, beker) but not in End-homogeneous sets (e.g., klaver, bever, vijver). Based on his data, Roelofs (2004) concluded that the results for both target types were consistent with processing akin to that occurring at the segment-to-frame association process of the WEAVER model. Further, as at this processing stage phonemes are not specified for their features, this argument was also in line with the data reported by Roelofs (1999). However, the findings from three masked priming studies discussed below are to a large extent incompatible with the notion of shared phonological encoding mechanisms for both word reading and picture naming for two reasons. Firstly, Schiller (2004, 2008) found some differing results for these two target types. Secondly, Lukatela, Eaton and Turvey (2001) observed that participants' lexical decisions were facilitated when the onset of primes and word targets shared all but one of their phonemic features. Both of these findings are described and evaluated in more detail in the following sections.

2.2.8. Schiller's (2004, 2008) masked priming research

The purpose of Schiller's (2004) research was to examine masked priming effects whilst manipulating both the degree and position of segmental overlap between primes and word targets. In Experiment 1 disyllabic Dutch nouns were primed by five types of primes. These were Begin-related (e.g., %%balans%%-BANAAN), First-syllable (e.g.,

%%ba%%%%%-BANAAN), End-related (e.g., %propaan%%-BANAAN), Second-syllable (%%%%naan%%-BANAAN) and finally Control (e.g., %%%%%%%%-BANAAN). The results from this study showed that relative to the Control condition the reading of word targets was significantly faster in the Begin-related, First-syllable and Second-syllable conditions but not in the End-related condition. As such, in Experiment 1 a shared first syllable between primes and word targets facilitated word reading and this effect was independent of the type of prime employed (first syllable vs. word prime). However, the same was not true for the end overlap priming conditions which showed that facilitation from a shared end segments/syllable between primes and targets could only be observed in the absence of mismatching initial segments between these two stimuli (Second-syllable condition).

Schiller's (2004) Experiment 2 was designed to ascertain whether the facilitation observed in masked priming from a shared segment/s between primes and word targets is position dependent. In this study the word targets were the same as those employed in Experiment 1. This time however, they were primed by the following priming conditions: Begin-related (e.g., %%balans%%-BANAAN), Reversed begin-related (e.g., %%lansba%%-BANAAN), Reversed first-syllable %%%%%ba%%-BANAAN) and Control (e.g., %%%%%%%%-BANAAN). Schiller (2004, Experiment 2) hypothesised that if the facilitation from a shared segment/s between primes and word targets is position dependent, this effect should only be observed in the Begin-related condition. This is because that particular condition represents the only one in which the matching segments of these two stimuli correspond to the same positions within a word form. If however, this effect can be found regardless of whether or not the matching segment/s correspond to the same position/s of these two stimuli,

similar facilitory effects should be observed in the Begin-related, Reversed begin-related and Reversed first-syllable conditions. This is because in all these conditions both primes and targets share an equal amount of segments. The data from Experiment 2 showed that relative to the Control condition word reading was significantly faster in the Begin-related condition whereas there was no difference in response latencies between the Control condition and both the Reversed begin-related and Reversed first-syllable conditions. As such, these results confirmed that in masked priming any facilitation from matching segment/s between primes and targets is position dependent.

In the final experiment of this series Schiller (2004; Experiment 3) used two types of word targets. The first type consisted of words with single consonant onsets (C - onset words) whilst the second consisted of two consonants onsets (CC - onset words). Further, both types of word targets were primed by three types of primes which were First segment (e.g., b%%%%%%-BALLET, b%%%%%%-BROEDER), First two segments (e.g., ba%%%%%-BALLET, br%%%%%-BROEDER) and Control (e.g., %%%%%%%-BALLET, %%%%%%%-BROEDER). Schiller (2004; Experiment 3) found that compared to the Control condition the two target types were read 5 ms faster in the First segment condition and 14 ms faster in the First two segments condition. Importantly though, since in Experiment 3 both target types showed the same facilitory effects and these effects increased with the number of shared segments between primes and targets, Schiller (2004) concluded that in reading in masked priming the facilitation from a matching segment/s between these two stimuli is due to the shared initial segment/s and not the shared onset. Consequently, Schiller's (2004; Experiment 3) findings and conclusions were contrary to those of Kinoshita's (2000; Experiments 1 & 2) for the following reasons. As discussed in the previous section (section 2.2.7.), in her

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Experiment 1 Kinoshita (2000) found virtually no difference between the One letter (e.g., suf-SIB) and Two letters (e.g., sif-SIB) priming conditions whereas in Experiment 2 she observed facilitation from a shared initial letter between primes and targets only for single letter onset (e.g., penny-PASTE) but not for complex (e.g., bingo-BLISS) onset word targets. However, there were some major differences between the studies conducted by each of these authors. For example, Kinoshita's (2000) research was conducted in English and further, in the Control conditions she employed unrelated non-word primes (Experiment 1) and word primes (Experiment 2) whereas Schiller's study was conducted in Dutch with his Control conditions consisting of percentage signs. Therefore, the discrepancies between Kinoshita's (2000; Experiments 1 & 2) and Schiller's (2004; Experiment 4) research could be due to any of these factors.

In his 2008 follow up research that was also conducted in Dutch, Schiller (2008) set out to assess whether as postulated by Forster and Davis (1991), the MOPE occurs during processing via the non-lexical route (Coltheart, 1978; Coltheart et al., 2001; Plaut et al., 1996) or whether it takes place at the speech planning/phonological encoding stage of processing (Kinoshita 2000; Kinoshita and Woollams, 2002; Malouf and Kinoshita, 2007). To this aim the author employed picture targets. Schiller (2008) suggested that since pictures cannot be processed via the non-lexical route, any facilitation from a shared onset between primes and picture targets would therefore have to be due to processing at the speech planning/phonological encoding stage. In this study Schiller (2008) used pictures of simple objects that corresponded to the disyllabic word targets he employed in his earlier research (Schiller, 2004; Experiments 1 & 2). Further, each picture was primed by two main sets of primes namely, Begin-related (e.g., First-segment – %b%%%%%-BANAAN, First-syllable – %ba%%%%-BANAAN,

Whole-word - %beroep%-BANAAN and Control - %%%%%%-BANNAN) and End related (e.g., Last-segment – %%%%%n%-BANAAN, Last-syllable - %%%naan%-BANAAN, Whole-word - %robijn%-BANAAN and Control - %%%%%%-BANAAN. Schiller (2008) found that relative to the Control condition picture naming was facilitated in the First-segment, First-syllable and Last-syllable conditions. However, picture targets were named significantly slower when preceded by Whole-word primes and this interference was observed with both Begin and End related primes. They were also named significantly slower in the Last-segment priming condition but this interfering effect was much smaller than in the other two conditions.

As postulated by Schiller (2008), since in his study First-segment primes facilitated picture naming whereas Last-segment primes did not, these outcomes confirmed that in the former condition a MOPE was observed. Following the argument presented earlier that pictures cannot be named via the non-lexical route, Schiller (2008) suggested that these results thus argued against Forster and Davis' (1991) account for the locus of the MOPE. As such, this part of Schiller's (2008) data seemed to be in line with Kinoshita's (2000; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007) explanation that this effect takes place at the speech planning/phonological encoding stage and occurs in a serial rightward manner akin to the segment-to-frame association process of the WEAVER language production model. This explanation was thus consistent with the results from Roelofs' (2004) research and supported Roelofs' (2004) notion of shared phonological encoding mechanisms for both word reading and picture naming.

However some of Schiller's (2008) picture naming results differed greatly from those obtained in his word reading research (Schiller, 2004). For example, in the Begin-related Whole-word priming condition (e.g., %beroep%-BANAAN) picture naming was inhibited by the brief presentation of the prime whereas in the corresponding priming condition in the word reading task the reading of word targets was facilitated. These discrepancies were therefore contrary to the notion of shared phonology for these two target types. They were also contrary to the data reported by Roelofs (2004) and as such required further investigation. The same was true for the outcomes from Lukatela et al.'s (2001) masked priming research described and evaluated below.

2.2.9. The role of phonemic feature similarity

In their research that employed the lexical decision task Lukatela, Eaton, Lee & Turvey (2001) tested whether the feature description of individual phonemes was important to the word recognition processes. They therefore used a mask-prime-target-mask sequence to investigate if the priming of a word by a rhyming non-word would depend on phonemic feature similarity between the onset of non-word primes and word targets. As an example, the authors considered the onset of the prime ZEA to be one phonemic feature (just a change in voicing) away from the onset of the target SEA whereas the onset of VEA is two features (change in voicing and change in place of articulation) away.

They found that lexical decisions were faster when a word target was primed by a rhyming non-word whose onset differed from the target's onset by just a single

phonemic feature compared to primes whose onset differed by more than one phonemic feature (i.e., lexical decisions were faster for SEA when primed by ZEA compared to VEA). The authors interpreted these results as being consistent with the perspective that in reading phonemes are specified for their features. Therefore, the activation of phonemes for a specific letter string is governed by matching phonemic feature information onto a phoneme (Lukatela et al., 2001). Lukatela et al.'s (2001) findings and conclusions were thus consistent with those of Mulatti et al.'s (2006) and Ashby et al.'s (2009). As discussed in Chapter 1 (section 1.4.1.3.), these researchers also found effects from phonemic feature similarity for word reading. However, effects from phonemic feature similarity are contrary and incompatible with the word reading models evaluated in Chapter 1 (section 1.4.1) according to which during reading the information provided by each letter/grapheme is mapped directly onto its corresponding abstract phoneme and this abstract phoneme is then used to access its corresponding features.

Further, the results from Lukatela et al.'s (2001) research were contrary to the findings of Grainger and Ferrand (1996) as well as Forster and Davis (1991) that showed an absence of a MOPE in the lexical decision task. Since in their related conditions both primes and targets shared their onsets and therefore shared all their phonemic features, to be consistent with Lukatela et al.'s (2001) data masked onset priming effects should have been found in both studies which as discussed was not the case. However, it might be possible that in masked priming, effects from phonemic feature similarity on participants' lexical decisions are only observable under specific priming conditions. In Lukatela et al.'s (2001) work targets were primed by rhyming non-words in which the primes only varied from their corresponding targets by the amount of featural overlap in

the onset position. As such, except for the onset position all stimuli employed by Lukatela et al. (2001) shared their remaining segments. In the latter two studies segmental similarity was limited to the onset position of related primes and targets. Consequently, because in the lexical decision task participants are exposed to both word and non-word targets, it could be argued that the combination of these two target types along with the additional mismatching segments induced noise into the process, the resolution of which meant that no onset priming effects were detected in the studies conducted by Grainger and Ferrand (1996) and Forster and Davis (1991). By extension, it is also conceivable that since in the reading task all targets are words, any mismatching segments may well have less of an effect on participants' responses thus allowing masked onset priming effects to be observed (Forster and Davis, 1991; Grainger and Ferrand, 1996).

Importantly, because effects from phonemic feature similarity were found in word reading (Ashby et al., 2009; Mulatti et al., 2006) and the lexical decision task (Lukatela et al., 2001) whereas these effects were not observed in spoken word production (Roelofs, 1999), it is still possible that there are differences in how phonology is constructed during both word reading and picture naming. One of these differences might relate to the way in which phonemes are represented in each task; i.e., in word reading phonemes may be specified for their phonemic features (Ashby et al., 2009; Lukatela et al., 2001; Mulatti et al., 2006) whereas in picture naming they may be represented as abstract entities (Roelofs 1999). If so, this would thus argue against the notion of shared phonological encoding mechanisms for these two target types. However, since the research into effects from phonemic feature similarity in both tasks has been conducted using different paradigms it was important to assess the validity of

these findings by employing the same experimental procedure for both word reading and picture naming. Further, because masked priming effects are thought to be automatic, sub-consciously induced and due to processing at the post-lexical level (Grainger & Ferrand, 1996) and also because in masked priming studies no verbal response to a prime is required, the masked priming experimental procedure was deemed the most appropriate to employ when evaluating pre-articulatory effects of phonemic features.

The research undertaken in this thesis therefore employed the masked priming paradigm to assess the role of phonemic features in both word reading and picture naming. By so doing it attempted to establish whether similarities or differences in how phonemes are represented in each task might support or invalidate the notion of shared phonological encoding mechanisms for both target types (Kinoshita, 2000; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007; Roelofs, 2004). It was anticipated that the data from the series of experiments reported herein and the conclusions drawn would then go some way towards addressing the two research questions raised in the introduction to this thesis namely, what role do phonemic features play in both word reading and picture naming and are phonological encoding mechanisms shared for these two domains (Roelofs, 2004)?

2.3. Conclusions

Kinoshita's (2000; Kinoshita and Woollams, 2002; Malouf and Kinoshita, 2007) investigations into the MOPE led her to conclude that the locus of this effect lies at the speech planning/phonological encoding stage of processing, which akin to the segment-to-frame association process of the WEAVER language production model occurs in a serial rightward manner. This conclusion was thus consistent with that of Roelofs' (2004) who also argued that phonological encoding mechanisms for both word reading and picture naming might well be shared from that stage. Further, because phonemes at the segment-to-frame association stage of WEAVER are represented as abstract entities and are therefore not specified for their features, Roelofs' (1999) observation of preparation benefits for spoken word production in homogeneous sets that fully shared their onsets but not in homogeneous sets in which these onsets shared all but one of their phonemic features was also in line with his 2004 conclusion. In contrast to Roelofs' (2004) findings however, masked priming research conducted by Schiller (2004, 2008) showed conflicting results for word reading and picture naming that depended on the type of prime employed. Importantly, he demonstrated that whilst word reading was facilitated by the brief presentation of word primes in which primes and targets shared their onset, the corresponding priming condition for pictures interfered with target naming. This discrepancy required further investigation. Concerning the role of phonemic features and again in contrast to Roelofs' (1999) data in his language production study, Lukatela et al.(2001) found masked priming effects from featural similarity between the onsets of non-word primes and word targets in the lexical decision task. Lukatela et al.'s (2001) observations suggest that in word reading

phonemic features might play a more distinct role than is currently considered in the word reading models described and evaluated in Chapter 1 (section 1.4.). As discussed throughout this chapter the masked priming paradigm reflects automatic and subconsciously driven temporary changes in the cognitive system (e.g., Grainger and Ferrand, 1996). Importantly, the findings of Lukatela et al. (2001) also suggest that this paradigm is sensitive to manipulations of phonemic feature similarity between primes and targets. Given the discrepancy in results from phonemic feature studies for word reading and language production that were conducted using different paradigms, it was important to assess the validity of these findings using a single experimental paradigm for both tasks. Consequently, the masked priming paradigm was considered to be the most appropriate one to employ to further assess the role of phonemic features in both word reading and picture naming. By so doing, it was anticipated that important new empirical evidence would become available to determine whether features are involved in either task during phonological encoding that could then support or invalidate the notion of shared phonological encoding mechanisms for these two domains (Kinoshita, 2000; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007, Roelofs, 2004).

CHAPTER 3: General method

3.1. Overview

The purpose of this programme of research was to evaluate phonological encoding processes in English for both word reading and picture naming. This was done by manipulating phonemic feature similarity between primes and targets using the masked priming paradigm. A total of eight experiments were conducted. Apart from a few exceptions which are discussed throughout this chapter, the experimental method employed was very similar across these experiments. Therefore, to avoid repetitions this method is described below. To allow for more direct comparisons to Schiller's (2004, 2008) word reading and picture naming results that were described in Chapter 2, the procedure used was in large part consistent with the one he employed. However, where differences occurred these differences and the motivations for them are highlighted and explained in the appropriate sections that follow.

3.2. Participants

Based on Schiller's (2004) observation of a masked priming effect size in word reading from matching single segments between primes and targets that varied between 5 and 10 ms, it was decided to use the lower boundary (5 ms) of this effect size to calculate power. This was done prior to the commencement of the experiment work reported

herein. As discussed in the following section of this chapter, in both the word reading and picture naming tasks of this series of experiments and akin to Schiller's (2004, 2008) research, participants were required to name stimuli that were presented in four separate blocks. However, in Experiment 1 participants were asked to name stimuli from just one of the four blocks. This meant that there were fewer observations per participants in Experiment 1 compared to the other experiments which therefore reduced power in that experiment. Consequently, to increase power the number of participants originally employed in Experiment 1 was doubled. All participants who took part in this research were student volunteers from the University of East London, some of whom participated in exchange for course credit. They were all monolingual native English speakers who had normal or corrected-to-normal vision. None of the participants took part in more than one experiment.

3.3. Design

Even though Schiller (2004, 2008) examined both word reading and picture naming using the same stimuli, he in fact assessed each task in separate studies, with his picture naming research (Schiller, 2008) being a follow-up to his earlier word reading investigation (Schiller, 2004). Given that the purpose of the research undertaken in this thesis was to examine both of these tasks together, it was therefore important to test participants' naming responses to each target type within the same experiment. By so doing, a more accurate assessment as to the interactions between these two tasks and the priming conditions employed could be made. However, to be consistent with Schiller (2004, 2008), in each experiment participants were required to either read aloud words

or name pictures but not to do both. The main aim of this experimental work was to examine naming performance by manipulating phonemic feature similarity between primes and targets. Consequently, the principles used to construct both the Feature priming condition (e.g., zea-SEA – in which the onsets of both primes and targets shared all but one of their phonemic features) as well as the Unrelated priming condition (e.g., vea-SEA – in which these onsets differed by at least two phonemic features) from Lukatela et al.'s (2001) research were used to construct the equivalent conditions in this series of experiments. Further and as discussed in Chapter 2 the two critical priming conditions from Schiller's (2004, 2008) studies (i.e., Identical – e.g., %beroep%-BANAAN - in which the onsets of primes and targets were identical and thus shared all their phonemic features, and Control – e.g., %%%%%%-BANAAN – that consisted of percentage signs) formed the basis for constructing primes in both the equivalent Identical and Control conditions in these experiments. To that extent therefore, the priming conditions employed in this series of experiments were derived by combining those used in both Lukatela et al.'s (2001) and Schiller's (2004, 2008) research. As such, in this research a 2 (Task: word reading vs. picture naming) x 4 (Priming Condition: Identical, Feature, Unrelated or Control) mixed factorial design was used with the Task as a between-participants factor and Priming Condition as a within-participants factor. In all experiments, each target picture or target word was preceded by one of four primes. In Experiments 1, 2, 3 and 7 in which featural similarity in the initial segment position was manipulated, a target word or picture such as BELT in Experiment 2 (in which word primes were used) for example, was preceded by 'bunk' in the Identical, 'punk' in the Feature, 'junk' in the Unrelated and '%%%%' in the Control conditions. Experiments 4, 5, 6, and 8 were designed to evaluate the effects of phonemic feature similarity in the end segment position. Therefore, for a

target word or picture such as BAT in Experiment 5 (that again employed word primes) for example, the primes were 'cot' in the Identical, 'cod' in the Feature, 'con' in the Unrelated and '%%%' in the Control conditions. More information that details exactly how these four priming conditions were constructed for each experiment is provided in the following section (section 3.3.).

Except for Experiment 1 in which due to an oversight participants were shown only one out of four blocks, in the remaining experiments pictures or printed words were presented for naming in 4 separate blocks consisting of six practise stimuli and the targets. Although practise stimuli were not included in Schiller's (2004, 2008) research, it was anticipated that when presented with an experimental block participants might sometimes fail to respond adequately to the first two or three targets, which was in fact observed during the data collection process. Therefore, the inclusion of such stimuli at the beginning of each block insured that valuable data was not lost. Also, to allow for more direct comparisons between the results obtained with each prime type (i.e., single segment, word and non-word – more information on prime types is provided in section 3.3.), it was important to attempt to ensure that the same word and picture targets were used across the initial overlap experiments (Experiments 1 -3) as well as the end overlap experiments (Experiments 4 – 6). However, due to a limitation in prime choices this was not always possible to achieve although best efforts were made. Therefore, the 36 word and picture targets used in Experiment 1 were reduced to 32 in both Experiments 2 and 3. The same was true for the end overlap experiments in which the 28 targets employed in Experiment 4 were reduced to 15 in Experiments 5 and 6. It should be noted that in Experiment 7 the stimuli from Experiment 3 were used whereas Experiment 8 employed the stimuli from Experiment 6. The reason for doing so is

explained in Chapter 6. As such, the number of targets varied across some of these experiments. Further, in all of the experiments participants named either only pictures or only printed words. In every block there was an equal number of targets per priming condition (e.g., for the 36 targets employed in Experiment 1 there were 9 targets per condition). Each target appeared once within a single block and the priming condition for that target was different in each block. If for example, in the first block a target word or picture such as 'BELT' was primed by the Unrelated prime (e.g., junk), in the next block it was primed by the Feature prime (e.g., punk) whereas in the third block the prime was the Identical prime (e.g., bunk) and in the final block it was the Control (e.g., %%%%). Therefore, all targets appeared once in each condition across the experiment. The dependent variables were naming latency and error scores.

3.4. Stimuli

In all eight experiments two target types were used namely, pictures and printed words. Picture stimuli consisted of line drawings of simple objects obtained from the Centre for Research in Language. Word stimuli were the printed names of these objects. During the segment-to-frame association process of WEAVER as soon as the first syllable of a disyllabic input or the single syllable of a monosyllabic input has been encoded, this information then spreads to the phonetic encoding stage at which point the articulatory gestures corresponding to that input are activated. Following this working assumption of WEAVER it could therefore be suggested that the results observed by Schiller (2004, 2008) for his disyllabic word targets and their corresponding pictures might have reflected an interaction between the phonological and phonetic encoding stages of

processing. This is because the second syllable of the word form might still be undergoing processing at the phonological encoding stage whilst the first syllable is being phonetically encoded. Consequently, to control for such a possibility this research employed only monosyllabic word targets. They were all concrete nouns of 3 or 4 characters in length and had regular spelling-to-sound correspondence. The decision to employ regular rather than irregular/exception word targets was based on the outcomes from Forster and Davis' (1991; Experiment 4) as well as Kinoshita and Woollams' (2002; Experiments 1) research who both (as discussed in Chapter 2, sections 2.2.6. and 2.2.7., respectively) found a MOPE only for regular but not exception word targets. Further, since in her study (that was also reviewed in the preceding chapter) Kinoshita (2000; Experiment 2) found facilitation from a shared initial segment between prime and target only for single (e.g., penny-PASTE) but not for complex (e.g., bingo-BLISS) onset word targets whereas in Schiller's (2004; Experiment 3) research this effect was observed with both target types, it was difficult to predict how complex onset word targets would affect the outcomes from this experimental work. As such, the research reported herein employed only single onset word targets. Thus in Experiments 1, 2, 3 and 7 word targets contained only a single-letter consonant onset. To be consistent with the initial overlap experiments, in Experiments 4, 5, 6 and 8 they consisted of a single-letter consonant coda. Both target types were presented in digitized form in the middle of a computer screen, in black on white background. The average target picture size was 2.42 cm wide x 2.25 cm high (area of vision: 2.31° x 2.15° with participants seated 60 cms from the screen). Printed words were presented in size 14 Courier font (visual angle ‹2°).

Schiller (2004, 2008) found a MOPE for both word reading and picture naming with matching single segment onset primes (e.g., %b%%%%%-BANAAN) whereas with word primes that shared their onsets with targets (e.g., %beroep%-BANAAN) he found contrasting effects with the observation of a MOPE for word reading and interference for picture naming. As such, it was important to firstly validate these findings and also to examine more directly how different types of primes might affect naming in these two tasks. Therefore, in this programme of research three main prime types were employed. These were: single segment, word and non-word primes. Further, consistent with the targets, the word and non-word primes had regular spelling-to-sound correspondence. Additionally, akin to the targets in Experiments 1, 2, 3 and 7 they contained only a single-letter consonant onset whereas in Experiments 4, 5, 6 and 8 they consisted of a single-letter consonant coda. They were presented in black on white background in size 14 Courier font (visual angle ‹2°). The primes were generated in the following manner. For the Identical condition and akin to Schiller (2004, 2008), the initial or end segment was identical for both prime and target. For the Feature condition the initial or end segment was matched with the initial or end segment of the target so that they shared all their phonemic features except for voicing. In the Unrelated condition the initial or end segment was mismatched by at least two phonemic features. The choice of segments in both the Feature and Unrelated conditions was closely modelled on those employed by Lukatela et al. (2001) who contrary to Roelofs (1999) used a broader range of voiced-voiceless phoneme pairs (b-p, c-z, d-t, f-v, g-k, s-z versus b-p, d-t, v-f, respectively). The word primes and their targets were semantically unrelated. Again, consistent with Lukatela et al. (2001) the remaining segments of both word and non-word primes in the Identical, Feature and Unrelated conditions were the same across these priming conditions thereby controlling for any confounding variables.

This would thus allow for any effects due to phonemic feature similarity between the corresponding segments of primes and targets to be fully expressed. However, in contrast to Lukatela et al. (2001) these remaining segments were different to the corresponding segments of their targets. This aspect of stimuli choice was adopted from Schiller's (2004, 2008) research to control for any additional effects due to form and/or rhyme priming. Also, each word and non-word prime was constructed to be either 3 or 4 characters in length to match the number of characters of the target. The same was true for the single segment onset and coda primes in which akin to Schiller (2004, 2008), percentage signs were used in the end or initial positions of these primes (i.e., b%%% or %%%b) to ensure that their total number of characters equalled that of their corresponding targets. The Control primes consisted of either 3 or 4 percentage signs. This priming condition was used because it was the same as the main control condition employed by Schiller (2004, 2008). Therefore, its inclusion would allow for direct comparisons between Schiller's (2004, 2008) results and those observed in this experimental work. The complete lists of targets and priming conditions (Identical, Feature and Unrelated) employed in each experiment are included in Appendix. These three priming conditions were controlled across a number of variables that are listed in the Stimuli section of each corresponding experiment. One-Way Independent ANOVAs comparing single segment, word and non-word primes in the Identical, Feature and Unrelated priming conditions on each of the control variables indicated that there were no significant differences, all $ps > .05$.

3.5. Procedure

To comply with the requirements of the British Psychology Society Code of Ethics and Conduct (2009), this research program was approved by the Research Ethics Committee of the University of East London. Also in line with this code, each participant was debriefed about the nature of the experiment. They were informed that they were taking part in an experiment designed to measure their speed when naming well known objects and reading simple words. They were then asked to read the written instructions provided that included details on the issue of consent and their right to withdraw from the experiment at any time. A copy of these written instructions is included in Appendix A. Next, they were asked if they had any questions. If necessary, the examiner verbally clarified any uncertainties. Additionally, participants were reassured that their names would remain confidential and would be stored separately from their data. Finally, they were asked to state their age and were provided with a number under which their data was recorded to aid the withdrawal process if they decided to withdraw from the experiment at a later data.

During each of the experiments participants were randomly assigned to either the word reading or picture naming task. Participants were assessed individually by a single investigator. They were seated approximately 60 cm away from a 17-inch computer monitor. The refresh rate of the computer monitor was 75Hz therefore; one refresh cycle (one tick) was 13.3 ms. In keeping with Schiller (2004, 2008), at the beginning of each trial in Experiments 1 to 6 a fixation cross (+) was displayed in the middle of the screen for 37 ticks (492 ms). Next a forward mask (a row of #'s) was shown for 37 ticks

(492 ms) after which the prime (in lowercase) was displayed for 4 ticks (53 ms). This was followed by a backward mask (a row of #'s) for 1 tick (13 ms). Finally, the target word (in uppercase) or picture was displayed until a naming response was given or 150 ticks (1995 ms) elapsed. When a response was given there was an interval of 75 ticks (998 ms) before the beginning of the next trial.

However, in Experiments 7 and 8 in which the masked sandwich priming paradigm (e.g., Lupker & Davis, 2009) was employed (the reason for using this paradigm is provided in the Introduction to Chapter 6), the experimental procedure was as follows. Each trial began with the display, in the middle of the screen, of a fixation point (+) for 37 ticks (492 ms). Next a forward mask (a row of #'s) was shown for 37 ticks (492 ms) after which the target word (in lowercase) was displayed for 3 ticks (40 ms). Then a backward mask (a row of #'s) was shown for 1 tick (13 ms). After the backward mask the prime (in lowercase) was displayed for 4 ticks (53 ms). This was followed by another backward mask (a row of #'s) for 1 tick (13 ms). Finally, the target word (in uppercase) or picture was displayed until a naming response was given or 150 ticks (1995 ms) elapsed. As in the other experiments, when a response was given there was an interval of 75 ticks (998 ms) before the beginning of the next trial. To reduce flickering on the screen, in all of the experiments reported herein, the forward masks, primes, backward masks and the target words were matched on the number of characters (e.g., ### - bin - ### - BAT). The sequence of experimental trials was controlled by E-Prime software (Schneider, Eschman & Zuccolotto, 2002) with naming latencies recorded via participants speaking into a hand-held microphone connected to a voice key and the software. Prior to collecting data each experiment was pilot tested. Further, in consideration of the suggestion made by Forster and Forster (2003) that E-

Prime might not be reliable because the display of an item using E-Prime can sometimes be delayed by 1 tick (13 ms), in each experiment the software set-up was designed to allow for an assessment of the duration of all the above described items in every trial. This assessment was performed both after a pilot test and following the experiment proper. An evaluation of display timings and durations showed that in all of the experiments the E-Prime software preformed with 100% accuracy in every trial.

As with Schiller (2008), the picture naming task was divided into three stages. In stage one all of the picture targets were displayed individually to participants in the middle of the computer screen with the picture name printed underneath. Participants were instructed to look at the pictures and their printed names. Stage two was a practice trial during which each picture was presented once in a random order with participants asked to name each picture. Any incorrect response was corrected by the experimenter. In the actual experiment (stage 3), in Experiments 2 to 8 participants were required to name stimuli presented in 4 blocks. However, in Experiment 1 each participant was asked to name stimuli presented in just a single block. For Experiments 2 to 8 the order in which the blocks were presented was counterbalanced between-participants. They were then required to name all the pictures in a block as quickly and as accurately as possible. All participants' responses were tape-recorded. Any errors or hesitations were noted by the experimenter. In each block, the six practice stimuli were shown first in random order. They were then followed by the targets which were also presented in random order. Akin to Schiller (2004), the word reading task consisted only of stage 3. In both the picture naming and word reading tasks participants were instructed to focus their attention on the fixation point at all times. The presence of the prime was not mentioned. After the conclusion of each experiment participants were asked if they had

noticed anything unusual during the experiment. This was done to assess the visibility of the primes.

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3.6. Analysis

The naming latencies in milliseconds (ms) and error scores for naming pictures and reading their names in each priming condition were collected from all the participants. The error data was divided in to two categories namely; technical errors and errors. The technical errors included failure of the microphone to pick up a response and triggering the voice key by making unnecessary sounds. The errors included incorrect response, disfluencies and mis-pronunciation of a word. Both the technical errors and errors were eliminated from the latency analyses. Also, only the errors were included in the error analyses, thereby allowing for a more direct assessment of effects that the employed experimental manipulation had on participants' error scores. To reduce the effects of outliers the cut-off procedure adopted by Kinoshita (2000) was used herein to trim the data. The mean reaction time for each participant in each priming condition was calculated and observations more than two standard deviations above and below each mean were trimmed. Because in Schiller's (2004, 2008) research different trimming criteria were used for word reading to those employed in trimming the picture naming data (cut-off point below 300 ms and above 1000 ms, cut-off point below 200 ms and above 900 ms, respectively), it could be suggested that his data treatment might have contributed to the variation of results for these two tasks. Also, considering that picture naming generally takes longer than word reading to accomplish, it was unclear why these cut-off points were so low for pictures and yet so high for words. Consequently, a

decision was made to use Kinoshita's (2000) data trimming method that allowed for the same treatment of both data sets. Finally, if exploratory data analysis revealed the presence of outliers, the results with and without outliers were compared and if similar, the former were reported. The remaining data was analysed by participants (F1) using a 2 x 4 between-participants ANOVA and by items (F2) using a 2 x 4 within-items ANOVA. The alpha level was set at .05. Following the ANOVA analyses and based on the findings from Lukatela et al.'s (2001) and Schiller's (2004, 2008) research, two planned comparisons were conducted. These were between the Identical and Control conditions and also between the Feature and Unrelated conditions. The remaining comparisons were accomplished using pair-wise comparison tests (Bonferroni adjusted).

CHAPTER 4: Masked priming effects when manipulating phonemic features in the initial segment position of monosyllabic words and pictures

4.1. Introduction

The aim of the three experiments (Experiments 1 – 3) reported in this chapter was to evaluate the role of phonemic features in both word reading and picture naming. This was done by employing the masked priming paradigm whilst manipulating featural similarity in the initial/onset position of primes with both word and picture targets. The reasons for doing so were as follows. Kinoshita's (2000; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007) investigation of the MOPE led her to conclude that the locus of this effect lies at the speech planning/phonological encoding stage of processing which akin to the segment-to-frame association process of the WEAVER general language production model operates in a serial rightward manner. Her conclusion thus implied that this processing stage might be shared for both word reading and picture naming. This conclusion was also consistent with that of Roelofs' (2004). Following his observation of preparation benefits for both target types in begin-homogeneous sets (e.g., leraar, lepel, lelie) but not in end-homogeneous sets (e.g., bijbel, label, sabel), Roelofs (2004) postulated that his results were in line with the working assumptions of WEAVER's segment-to-frame association process and were due to sequential rightward processing at that stage. Since in his research the same

effects were observed for both tasks, Roelofs (2004) suggested that phonological encoding mechanisms might therefore be shared between general language production models such as WEAVER and word reading models such as DRC (Coltheart et.al., 2001).

At the segment-to-frame association stage of WEAVER phonemes are represented as abstract entities. As such, they are not specified for their features. Consequently, to be consistent with this model the experimental manipulation of phonemic features during language production tasks would not expect to yield effects. The results of Roelofs (1999) supported this working assumption of WEAVER when he observed in both implicit-priming and form-preparation studies that pictures were named significantly faster in Segments-homogenous sets (e.g., boek, bijl, beer) but not in Features-homogenous sets (e.g., pauw, bijl, boek). Given that this author found preparation benefits when pictures within a given set shared their phonemes in the onset position whereas there was no effect from shared phonemic features, his observations were thus in line with WEAVER. However, masked priming research conducted by Lukatela et al. (2001) showed that in the lexical decision task, participants' lexical decisions were faster when the onsets of primes and word targets shared all but one of their phonemic features (e.g., zea-SEA) relative to when these onsets differed by at least two phonemic features (e.g., vea-SEA). As such, Lukatela et. al.'s (2001) results were consistent with those reported by Ashby et al. (2009) and Mulatti et al. (2006). These researchers thus suggested that phonemes might be defined for their features during word reading. However, a featural account of word reading would not only be contrary to WEAVER, it would also be incompatible with the notion of shared phonological encoding

mechanisms for both word reading and picture naming (Kinoshita, 2000; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007; Roelofs, 2004).

An additional problem for the likelihood of shared phonology for these two domains arose from the outcomes of Schiller's (2004, 2008) masked priming studies. In his research, Schiller (2004, 2008) found that relative to controls (e.g., %%%%%%%-BANAAN) both word and picture targets were named significantly faster when they were primed by related single segment onset primes (e.g., %b%%%%-BANAAN). However, when word primes (e.g., %beroep%-BANAAN) were employed the pattern of observed effects differed across the two tasks, with facilitation found in word reading whereas picture naming was inhibited. The latter finding thus implied that there might be differences in how phonological encoding occurs in each domain.

Finally, because Schiller (2004) found a MOPE in word reading with both single segment and word primes that shared their onsets with targets whereas in picture naming (Schiller, 2008) this effect was only present with single segment primes and not with word primes that in fact caused interference, it was important to assess whether any observed effects would be congruent not only across the two tasks but also with different types of primes. Consequently, in the experiments reported in this chapter three main types of primes were employed. These were: single segment, word and non-word primes (Experiments 1 - 3, respectively).

4.2. Experiment 1 - Single segment onset primes

4.2.1. Introduction

Based on Schiller's (2004, 2008) observation of a MOPE for both word reading and picture naming with single segment onset primes in the Identical condition compared to the Control condition (e.g., %b%%%%%-BANAAN versus %%%%%%%-BANAAN), this research series began by employing similar type primes in Experiment 1. There were two reasons for doing so. Firstly, it was important to ensure that the E-Prime software to be used throughout this research did not have unforeseen errors in its set-up and/or programming and/or functioning that were capable of polluting any collected data. Whilst software malfunctions were thought to be unlikely because as discussed in Chapter 3, each experiment was pilot tested to assess software accuracy prior to running actual trials and also because the timing and duration of the display of all items within an actual trial were to be assessed on post-hoc basis, it was still important to ensure that the data collection process was reliable and able to demonstrate observations consistent with established published research. Given that Schiller's (2004, 2008) findings of a MOPE in the Identical condition above were robust for both word reading and picture naming, a replication of his results would not only serve to validate those particular results but would also provide an assessment as to reliability of the experimental set-up for this research series. Secondly, a replication of Schiller's (2004, 2008) results between the Identical and Control conditions would then provide a baseline from which the presence or absence of effects from phonemic feature similarity

could be compared. In Experiment 1 therefore, both word and picture targets were primed by single segment onset primes.

Consistent with Schiller's (2004, 2008) data when he used single segment onset primes, it was predicted that in Experiment 1 both word and picture targets would be named significantly faster in the Identical condition (e.g., b%%%-BELT) relative to the Control condition (e.g., %%%%-BELT) thereby showing a MOPE. If however, Lukatela et al.'s (2001) argument that word reading is driven by phonemic features is correct, word targets would also be read significantly faster in the Feature condition (e.g., p%%%-BELT) in which the onsets of primes and targets shared all but one of their phonemic features compared to the Unrelated condition (e.g., j%%%-BELT) in which these onsets differed by at least two phonemic features. Finally, since the inclusion of both the Identical and Feature as well as the Unrelated and Control conditions within the same experiment was novel and as Schiller (2004, 2008) was the first researcher to employ single segment primes in the investigation of the MOPE, it remained to be seen whether the other comparisons (i.e., Identical vs. Feature, Identical vs. Unrelated, Feature vs. Control and Unrelated vs. Control) would reveal effects.

4.2.2. Method

The experimental method employed in this experiment adhered largely to that discussed in Chapter 3. In this section therefore only the aspects of the method that were specific to Experiment 1 are described.

4.2.2.1. Participants

One hundred and four participants took part in this experiment. Their mean age was 26.92 and ranged from 18 to 45 years.

4.2.2.2. Design and Stimuli

Each word or picture target (e.g., BELT) was preceded by one of four primes: an Identical (e.g., b%%%), a Feature (e.g., p%%%), an Unrelated (e.g., j%%%) and a Control prime (e.g., %%%%). The experiment consisted of four blocks per target type (word or picture) within which each of the 38 (6 practice + 32 target) stimuli employed was presented only once. Also, within a block there were 8 targets per priming condition (8 x 4 = 32). The priming conditions for each target were varied across blocks so that all targets were eventually exposed to each of the four priming conditions. In all there was a total of 304 trials (38 words x 4 blocks and 38 pictures x 4 blocks) in this experiment with each participants required to name either words or pictures presented in a single block (38 trials). The average written frequency of the word targets was 36.40 per million whereas the average spoken frequency of the picture targets was 15.10 per million. Both of these means were based on the English version of the CELEX database (Baayen, Piepenbrock & Gulikers, 1995). Table 1 displays the means for each control variable of the single segment onset primes (i.e. Identical, Feature and Unrelated). A

complete list of targets and single segment onset primes in the Identical, Feature and Unrelated priming conditions is included in Appendix B.

Table 1

Means for the control variables of the single segment onset primes in the Identical, Feature and Unrelated conditions of Experiment 1.

Control variables	Priming Conditions		
	Identical	Feature	Unrelated
Number of constrained unigrams	44.09	29.49	32.97
Constrained unigrams frequency	105.25	71.89	72.32

Note. The above means are based on the English version of the CELEX (1995) database (Medler & Binder, 2005) and refer to how often a word form is encountered in 1,000,000 presentations of text. Constrained unigram = first letter.

4.2.2.3. Procedure

Post experimental interviews revealed that four participants noticed seeing something before the presentation of the targets but were unable to identify what they had seen.

4.2.3. Results

A total of 4.06% error (0.75% technical errors + 3.31% errors) and 4.84 % trimmed data were removed from the latency analyses. Further, the data from four participants (two in word reading and two in picture naming) consisted of outliers. However, since the pattern of observed results remained the same in the analyses both with and without outliers, the former were reported herein. Mean naming latencies, standard deviations, percentage errors and mean priming effects for both word reading and picture naming in all four priming conditions are displayed in Table 2.

Table 2

Mean Naming Latencies (RT, in Milliseconds), Standard Deviations (SD), Percentage Errors (%E) and Mean Priming Effects (PE, in Milliseconds) for both word reading and picture naming in all four priming conditions for Experiment 1.

	Task							
	Word reading				Picture naming			
Priming condition (example)	RT	SD	%E	PE	RT	SD	%E	PE
Identical (b%%% - BELT)	490.08	58.11	1.0	8	625.11	72.69	3.6	10
Feature (p%%% - BELT)	499.90	61.14	2.2	-2	643.48	88.04	7.2	-8
Unrelated (j%%% - BELT)	498.78	68.72	0.7	-1	636.40	92.68	4.8	-1
Control (%%% - BELT)	497.80	54.62	0.7		635.11	89.78	6.3	

Note. The above means (RT) and standard deviations (SD) are based on the analysis by participants; PE – refers to comparisons to the Control condition as in Schiller's (2004, 2008) research.

For naming latency, the main effect of Task was significant, $F_1(1,102) = 101.03$, MSE $= 19711.80$, $p < .001$, $\eta^2 = .50$; $F_2(1,31) = 617.54$, MSE $= 1977.62$, $p < .001$, $\eta^2 = .95$, as was the main effect of Priming Condition, $F_1(3,306) = 4.32$, MSE $= 847.19$, $p = .005$, $\eta^2 = .04$; $F_2(3,93) = 4.37$, MSE $= 536.36$, $p = .006$, $\eta^2 = .12$. The interaction between Task and Priming Condition was not significant, $F_1(3,306) = .41$, $p > .05$; $F_2(3,93) = .20$, MSE $= 928.34$, $p > .05$. Planned comparisons showed that the response latencies were significantly shorter in the Identical condition compared to the Control condition [$t_1(103) = 2.15$, $p = .034$; $t_2(31) = 2.24$, $p = .033$] whereas there was no significant difference between the Feature and Unrelated conditions; both $ps > .05$. Pairwise comparisons (Bonferroni adjusted) revealed that response latencies were significantly shorter in the Identical condition relative to the Feature condition [$t_1(103) = 14.09$, $p = .004$; $t_2(31) = 14.34$, $p = .012$]. They were also shorter in the Identical condition compared to the Unrelated condition. However, this difference was not statistically significant; both $ps > .05$. Finally, there was no significant difference between the Feature and Control as well as the Unrelated and Control conditions; all $ps > .05$.

The overall error rate in the word reading task was 1.1%. Therefore, only the errors in the picture naming task were analyzed. However, they yielded no significant effects; all $ps > .05$.

4.2.4. Discussion

The results from Experiment 1 showed a significant main effect of Task and Priming Condition. However, the interaction between them was not significant. The response latencies in the Identical condition were shorter than in all the other (i.e., Feature, Unrelated and Control) conditions. However, only the differences between the Identical and Control as well as the Identical and Feature conditions were statistically significant but not between the Identical and Unrelated conditions. Further, there was no significant difference in the response latencies between the Feature and Unrelated, Feature and Control as well as Unrelated and Control conditions. Finally, the error data revealed that even though more errors were made in the picture naming task, these error scores were unaffected by the priming conditions employed.

The response latency outcomes from Experiment 1 were thus consistent with the predictions based on Schiller's (2004, 2008) results when both word and picture targets were primed by related single segment onset primes (e.g., b%%%-BELT). However, since in word reading no significant difference was found between the Feature and Unrelated conditions (e.g., p%%%-BELT vs. j%%%-BELT), these results were contrary to those obtained in the lexical decision task by Lukatela et al. (2001). Whilst at first glance the data from Experiment 1 seemed to be in line with the notion of shared phonological encoding mechanisms for both word reading and picture naming (Kinoshita, 2000; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007; Roelofs, 2004), an alternative explanation that could equally well account for the data is as follows. Because this experiment employed single segment onsets primes which

consistent with the dual-route theoretical framework (e.g., DRC, Coltheart et al., 2001) can only be processed via the non-lexical route, it is possible that in the word reading task the facilitation observed in the Identical condition compared to the Control condition (e.g., b%%%-BELT vs. %%%%-BELT) was due to serial rightward processing of both prime and target via this route. However, since pictures cannot be processed by the non-lexical route (Schiller, 2008), the picture naming data could be accounted for with reference to serial rightward processing at the segment-to-frame association stage of WEAVER. The similarity that exists in processing via the non-lexical route and also during processing at the segment-to-frame association stage (i.e., both processes occur in a sequential manner) could then explain the observed congruency of results for both word reading and picture naming. As such, based on the data from Experiment 1 no firm conclusions regarding the notion of shared phonology for these two domains could be reached.

Further, it was unclear why word and picture targets were named significantly faster in the Identical condition relative to both the Feature and Control conditions but not compared to the Unrelated condition. Numerically, in word reading the differences between the Identical and other conditions were very similar (i.e., 10 ms –Feature, 9 ms – Unrelated, 8 ms – Control conditions). The same was true for the differences between the Identical and both the Unrelated and Control conditions in the picture naming task (i.e, 11 ms and 10 ms, respectively). However, in the latter task picture targets were named 18 ms faster in the Identical condition relative to the Feature condition. It is therefore possible that the observed effect between these two conditions for both target types was primarily driven by the picture naming task. However, because in Experiment 1 there was no significant interaction between target type and priming condition this

possibility could not be confirmed. Importantly and as just mentioned, the largest difference in naming performance across conditions occurred between the Identical and Feature conditions in the picture naming task. This suggests that phonemic feature similarity might in fact interfere with the picture naming process. If so, this would be incompatible with the perspective that these observed effects are caused during processing at the segment-to-frame association stage of WEAVER because in WEAVER at that stage phonemes are not specified for their features. Consequently, it was interesting to examine whether this inhibitory effect would also be observed with word primes that were employed in the following experiment.

4.3. Experiment 2 – Word primes

4.3.1. Introduction

Experiment 2 was conducted as a follow-up to Experiment 1 and was motivated by Schiller's (2004, 2008) contrasting results for word reading and picture naming when he employed word primes that shared their onsets with targets (e.g., %beroep%-BANAAN). In this priming condition Schiller (2004, 2008) found facilitation only in the word reading task whereas the naming of picture targets was in fact inhibited. Consequently, it was important to firstly establish the validity of these findings and secondly, to examine in more detail how word primes affect naming in the masked priming paradigm. Further, even though in Experiment 1 there was no observed effect

for word reading from phonemic feature similarly (i.e., Feature condition versus Unrelated condition e.g., p%%%-BELT vs. j%%%-BELT), it was still plausible that this effect would be found with word primes. This is because in Lukatela et al.'s (2001) research effects from phonemic feature similarity were reported in the lexical decision task, which as argued by Forster and Davis (1991) is a task that engages the lexical route (e.g., DRC, Coltheart et al., 2001). It is therefore logical to assume that the employment of word (i.e., lexical) primes in the reading task would have the same effect. Consequently, in Experiment 2 both word and picture targets were primed by word primes in which the magnitude of phonemic feature overlap between the onsets of primes and targets was manipulated in a similar manner to that in Experiment 1.

To be consistent with the findings from Experiment 1 as well as with Schiller's (2004) word reading results when he employed onset related single segment and word primes, it was predicted that word targets would be named significantly faster in the Identical condition relative to the Control condition (e.g., bunk-BELT vs. %%%-BELT) thus showing a MOPE. In line with the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001) that the MOPE is due to shared phonemes rather than shared features and has previously been observed both with word primes and relative to the unrelated condition (e.g., belly-BREAK vs. merry-BREAK – Forster & Davis, 1991, Experiment 1), it was anticipated that word targets would also be named significantly faster in the Identical condition (e.g., bunk-BELT) compared to both the Feature and Unrelated conditions (e.g., punk-BELT, junk-BELT, respectively) whereas there would be no difference in response latencies between the Feature and Unrelated conditions. Finally, it remained to be seen whether there would be any observed effects between the Unrelated and Control conditions. The absence of such an effect with single segment

onset primes in Experiment 1 in itself did not rule out the possibility that one might be observed with word primes. However, if in reading effects from phonemic feature similarity can be found with word primes that as argued above engage the lexical route, participants' response latencies to word targets should be shorter in both the Identical (in which the onsets of primes and targets shared all their phonemic features) and Feature conditions compared to the Unrelated condition. Also, because the inclusion of the Identical condition distinguished this experiment from Lukatela et al.'s (2001) research, based on his results it was difficult to make a prediction as to whether a difference in response latencies between the Identical and Feature conditions would be found. Akin to Schiller's (2008) results, it was anticipated that relative to the Control condition the naming of picture targets would be inhibited by the brief presentation of word primes in the Identical, Feature and Unrelated conditions. Nonetheless, it remained to be seen whether additional effects between the Identical and Feature, Identical and Unrelated and Feature and Unrelated conditions would be observed.

4.3.2. Method

4.3.2.1. Participants

Forty participants took part in this experiment. Their mean age was 28.58 and ranged from 19 to 55 years.

4.3.2.2. Design and Stimuli

Each target picture or target word (e.g., BELT) was preceded by one of four primes: an Identical (e.g., bunk - BELT), a Feature (e.g., punk - BELT), an Unrelated (e.g., junk – BELT) and a Control prime (e.g., %%%% - BELT). Pictures or printed words were presented for naming in 4 separate blocks consisting of 42 (6 practice + 36 target) stimuli per block that were created for each target type. In every block there were 9 targets per priming condition (9 x 4 = 36) within which each target was shown only once. Also, the priming conditions for each target varied across blocks so that by the conclusion of the experiment each target was exposed to all four priming conditions. As such, in this experiment there was a total of 336 trials (42 words x 4 blocks and 42 pictures x 4 blocks) with each participant required to name either words or pictures presented in four separate blocks (168 trials). The average written frequency of the word targets was 122.37 per million whereas the average spoken frequency of the picture targets was 128.87 per million. Both of these means were based on the English version of the CELEX database (Baayen et al., 1995). Table 3 displays the means for each control variable of the word primes (i.e. Identical, Feature and Unrelated). All of the targets and primes were selected based on the criteria described in Chapter 3 (3.4.). A complete list of targets and word primes in the Identical, Feature and Unrelated priming conditions is included in Appendix C.

Table 3

Means for the control variables of the word primes in the Identical, Feature and Unrelated conditions of Experiment 2.

	Priming Conditions		
Control variables	Identical	Feature	Unrelated
Orthographic frequency	26.88	24.76	25.65
Number of orthographic neighbours	16.50	15.39	15.86
Neighbourhood frequency	83.12	90.56	113.49
Number of constrained unigrams	159.64	155.72	158.54
Constrained unigrams frequency	16516.31	15715.87	15936.51
Number of constrained bigrams	21.96	21.13	21.00
Constrained bigrams frequency	1519.54	1541.90	1854.69

Note. The above means are based on the CELEX (1995) database (Medler & Binder, 2005). Frequency = how often a word form is encountered in 1,000,000 presentations of text; orthographic neighbours = words that differ from each other by only one letter; constrained unigram = first letter; constrained bigram = first two letters.

4.3.2.3. Procedure

Post experimental interviews revealed that two participants noticed seeing something before the presentation of the targets but were unsure about what they had seen.

4.3.3. Results

A total of 1.6% error (0.2% technical errors + 1.4% errors) and 5.0% trimmed data were removed from the latency analysis. Also, the data from two participants (one in word reading and one in picture naming) consisted of outliers. However, since the pattern of observed results remained the same when the data was analyzed both with and without outliers, the former were reported herein. Mean naming latencies, standard deviations, percentage errors and mean priming effects for both word reading and picture naming in all four priming conditions are displayed in Table 4.

Table 4

Mean Naming Latencies (RT, in Milliseconds), Standard Deviations (SD), Percentage Errors (%E) and Mean Priming Effects (PE, in Milliseconds) for both word reading and picture naming in all four priming conditions for Experiment 2.

| | Task | | | | | | | |
| | Word reading | | | | Picture naming | | | |
Priming condition (example)	RT	SD	%E	PE	RT	SD	%E	PE
Identical (bunk - BELT)	451.47	37.31	1.1	19	599.37	66.01	2.8	-11
Feature (punk - BELT)	465.47	30.21	1.3	5	608.35	66.04	1.5	-20
Unrelated (junk - BELT)	471.76	34.50	0.6	-1	603.74	64.69	1.4	-16
Control (%%%% - BELT)	470.28	37.10	0.1		588.08	63.56	2.4	

Note. The above means (RT) and standard deviations (SD) are based on the analysis by participants; PE – refers to comparisons to the Control condition as in Schiller's (2004, 2008) research.

For naming latency, the main effect of Task was significant, F1(1,38) = 69.52, MSE = 10507.86, p < .001, η² = .65; F2(1,35) = 1454.97, MSE = 907.49, p < .001, η² = .98, as was the main effect of Priming Condition, F1(3,114) = 10.83, MSE = 133.61, p < .001, η² = .22; F2(3,105) = 8.35, MSE = 313.10, p < .001, η² = . 19. The interaction between the two was also significant, F1(3,114) = 13.35, p < .001, η² = .26; F2(3,105) = 15.28, MSE = 223.61, p < .001, η² = .30.

Separate analysis of Task showed that in the word reading task there was a significant main effect of Priming Condition, F1(3,57) = 31.66, MSE = 54.04, p < .001, η² = .63; F2(3,105) = 21.33, MSE = 143.39, p < .001, η² = .38. Planned comparisons showed that the response latencies were significantly shorter in the Identical condition compared to the Control condition [t1(18) = 7.62, p < .001; t2(35) = 6.70, p < .001]. They were also shorter in the Feature condition relative to the Unrelated condition [t1(18) = 3.24, p = .005; t2(35) = 2.13, p = .040]. Pairwise comparisons (Bonferroni adjusted) showed that the response latencies were significantly shorter in the Identical condition compared to both the Feature [t1(19) = 14.01, p < .001; t2(35) = 13.66, p < .001] and Unrelated [t1(19) = 20.29, p < .001; t2(35) = 20.38, p < .001] conditions. However, there was no difference in the response latencies between the Feature and Control as well as the Unrelated and Control conditions; all ps > .05.

There was also a significant main effect of Priming Condition in the picture naming task, F1(3,57) = 7.11, MSE = 212.28, p < .001, η² = .27; F2(3,105) = 7.56, MSE = 393.32, p < .001, η² = .18. Planned comparisons revealed that relative to the Control condition the response latencies were significantly longer in the Identical condition

[t1(19) = 2.46, p = .024; t2(35) = 2.68, p = .011]. However, there was no significant difference between the Feature and Unrelated conditions; both p > .05. Pairwise comparisons (Bonferroni adjusted) revealed that relative to the Control condition the response latencies were significantly longer in both the Feature [t1(19) = 20.28, p = .002; t2(35) = 21.65, p < .001] and Unrelated [t1(19) = 15.67, p = .041; t2(35) = 15.25, p = .008] conditions. They were also longer in the Feature condition compared to the Identical condition. However, this difference was not statistically significant; both ps > .05. Finally, there was no difference in the response latencies between the Identical and Unrelated conditions; both ps > .05.

The overall error rate in the word reading task was 0.8%. Therefore, only the errors in the picture naming task were analyzed. However, they yielded no significant effects; both ps > .05.

4.3.4. Discussion

The results from Experiment 2 demonstrated an interaction between Task and Priming Condition. Due to this interaction the results for word reading and picture naming were analyzed separately. The analysis for word reading revealed that word targets were read significantly faster in the Identical condition compared to the Feature, Unrelated and Control conditions. They were also read faster in the Feature condition relative to both

the Unrelated and Control conditions however, this effect was significant only between the Feature and Unrelated conditions. Finally, there was no difference in the response latencies between the Unrelated and Control conditions.

In contrast to the word reading results, the picture naming analysis showed that compared to the Control condition targets were named significantly slower in all priming conditions (i.e., Identical, Feature and Unrelated). They were also named slower in the Feature condition compared to the Identical condition although this effect was not statistically significant. Additionally, there was no significant difference in the response latencies between both the Identical and Unrelated and the Feature and Unrelated conditions. Finally, the error data was consistent with the data from Experiment 1 in that relative to the word reading task more errors were made in picture naming. Further, these error scores were unaffected by the priming conditions employed.

Contrary to Experiment 1, facilitating effects from phonemic feature similarity were in fact observed in the word reading task of Experiment 2 (i.e., Feature condition versus the Unrelated condition). This particular finding was in line with Lukatela et al.'s (2001) data and was therefore consistent with the earlier presented argument that masked priming effects from phonemic feature similarity in word reading can only be found when the lexical route is fully engaged (i.e., with the employment of word primes in reading and also in the lexical decision task). Given the finding of an effect from featural similarity, it is important to consider the Identical condition as one in which the onsets of both primes and targets share their entire set of features. By so doing, the word reading results from Experiment 2 that employed word (lexical) primes can be

explained with reference to phonemic features rather than with reference to phoneme overlap. As such, participants' faster response latencies in the Identical condition compared to the Feature condition in which onsets of both primes and targets shared all but one of their phonemic features can be explained by the varying degree of phonemic feature overlap between these two conditions, with reading performance fastest of all in the fully shared featural environment. By extension, it could be argued that the same was true for the significant differences in response latencies between the Identical and Unrelated conditions as well as the Identical and Control conditions. However, it was unclear at this point why there was no significant difference between the Feature and Control conditions even though numerically this difference was very similar to that found between the Feature and Unrelated conditions (i.e., 5 ms and 6 ms, respectively). Finally and in line with Experiment 1, the word reading data from Experiment 2 showed that participants' response latencies in the Unrelated condition were almost identical to those in the Control condition. Given that the former condition employed unrelated word primes (e.g., junk) whereas in the latter condition percentage signs that are not thought to induce inhibitory effects were used (e.g., %%%%), it was thus probable that the presentation of word primes in the Unrelated condition did not cause interfering effects of any sort. Consequently, it can be concluded that above reported word reading results were in fact due to effects that were facilitating in nature rather than interfering.

Regarding the picture naming data from Experiment 2, it was found that in contrast to the outcomes from Experiment 1 picture targets were named significantly slower in all conditions (i.e., Identical, Feature and Unrelated) compared to the Control condition. Since word primes in this experiment interfered with the picture naming process, the results were thus consistent with the predictions that were based on Schiller's (2008)

data. Further, the magnitude of the observed interference from word primes in picture naming was smallest in the Identical condition and largest in the Feature condition. Although this particular effect was not statistically significant, it was suggestive of the possibility that featural similarity in the onset position of both primes and picture targets causes an additional effect that slows down participants' responses even more (Feature condition). If confirmed, this would imply that features are in fact involved during the phonological encoding stage in picture naming. Further, this would be inconsistent with the architecture incorporated into the WEAVER general language production model according to which phonemes are not specified for their features during phonological encoding. Finally, the picture naming data from Experiments 1 and 2 showed that as with the word reading task, it seemed to matter whether a prime was a single segment onset prime or a word prime. In fact, the results in the picture naming task revealed that akin to Schiller's (2008) findings, related single segment onset primes facilitated target naming whereas word primes (whether related or not) actually inhibited this process.

Schiller (2008) made two proposals to account for the interference he observed from word primes in the naming of disyllabic pictures in Dutch. Firstly, he suggested that mismatching segments from the word prime might "inhibit the naming process due to the activation of non-target segments in the phonological output lexicon" (Schiller 2008, pg. 958). The observed slower naming latencies might thus result from competition for selection between these non-target and target segments. Schiller's (2008) second explanation was derived from the Picture-Word Interference (PWI) literature. In the PWI paradigm a distracter word is superimposed onto a picture with participants required to name the picture whilst ignoring the word. According to Schiller (2008) therefore, in masked priming the visually masked word prime presented at a

slightly negative stimulus onset asynchrony of -67ms might act in a similar manner to that of the distracter word in PWI, hence resulting in the observed interference. This is because, during masked priming research the briefly presented word prime might activate its corresponding lemma which could then compete for selection with the picture target's lemma.

However, as highlighted by Damian and Bowers (2009), in PWI research interference tends to be observed only when a distractor word and picture target are semantically related (e.g., dog – CAT) whereas form relatedness between a distractor word and picture target (e.g., can - CAT) tends to result in faster target naming. Since in Schiller's (2008) study and also in the Identical condition in Experiment 2 of this thesis both word primes and picture targets shared their onsets but were semantically unrelated (e.g., bunk-BELT), based on the usual PWI outcomes described above therefore, interference from word primes in the Identical condition should not have been expected. In fact, to be consistent with PWI findings the form relatedness in the onset position would more likely result in facilitation of target naming. Importantly though, in PWI studies to date participants' response latencies to picture targets in the form related condition (e.g., can-CAT) have generally been compared to response latencies in the unrelated condition (e.g., pen-CAT). As such, given that in both conditions distractors are words it is conceivable that in PWI the usual pattern of results may well be representative of less interference in the form related condition compared to the unrelated condition, rather than representing actual facilitation. If so, this would account for why in Experiment 2 there was less interference in the Identical condition (e.g., bunk-BELT) compared to the Unrelated condition (e.g., junk-BELT) and also why word primes interfered with the picture naming process in all conditions relative to the Control condition which itself

consisted of just percentage signs (e.g., %%%%-BELT). Consequently, this possibility required further investigation before firm conclusions as to the cause of this interference could be reached.

4.4. Experiment 3 – Non-word primes

4.4.1. Introduction

The purpose of Experiment 3 was to assess whether the interference from word primes on picture target naming that was observed in both Experiment 2 and Schiller's (2008) research was in fact due to competition for selection between lemmas activated by both a word prime and picture target. To this aim, this experiment employed non-word primes. Given that a non-word by definition does not have a specific lemma, the brief presentation of such a prime should not therefore cause interference in picture naming if the lexical level account provided above is relevant. As such, by employing non-word primes with picture targets it was anticipated that only effects occurring at the post-lexical (phoneme selection) level would be expressed. Additionally, the employment of non-word primes in word reading should assist in validating the conclusions of Experiment 2 that masked priming effects from phonemic feature similarity in the word reading task can only be observed when the lexical route is fully engaged (i.e., with word primes).

In Experiment 3 therefore, both word and picture targets were named following the masked presentation of non-word primes in which the magnitude of phonemic feature overlap between the onsets of primes and targets was manipulated in a similar way to that in Experiments 1 and 2. It was predicted that in this experiment word targets would be named significantly faster in the Identical condition relative to the Control condition, thereby showing a MOPE. Further, since non-word primes can only be processed via the non-lexical route and given that there are a number of studies that demonstrate masked onset priming effects by employing non-word primes with word targets (e.g., Forster and Davis, 1991), it was hypothesized that these targets would also be named significantly faster in the Identical condition compared to both the Feature and Unrelated conditions. Regarding the picture naming data and in line with the perspective that the employment of non-word primes would eliminate any interfering effects that might occur at the lexical level, it was anticipated that picture targets in Experiment 3 would be named significantly faster in the Identical condition relative to both the Unrelated and Control conditions thereby showing a MOPE. However, given the absence of prior research that has examined the masked priming of picture targets with non-word primes, it remained to be seen whether any other effects would be found.

4.4.2. Method

4.4.2.1. Participants

Forty-eight participants took part in this experiment. Their mean age was 25.35 and ranged from 18 to 43.

4.4.2.2. Design and Stimuli

The design was the same as that of Experiment 2. The target words and pictures were also identical to those employed in Experiment 2 and further, the non-word primes were generated and displayed in the same manner as the word primes in Experiment 2. In addition, all the primes were pronounceable non-words that were not homophones or pseudo homophones of existing words. In consideration of Van Heuven, Dijkstra, Grainger and Schriefers' (2001) perspective that in masked priming the shared orthographic neighbours between non-word primes and their corresponding targets interfere with the word reading process, care was taken to ensure that primes and targets did not share orthographic neighbours. However, due to the limitation of choice, 10 of the 36 primes employed in the Identical condition did in fact share one neighbour each with their corresponding targets. Nonetheless, contrary to Van Heuven et al.'s (2001) perspective the analyses both with and without these 10 primes and their corresponding targets showed the same pattern of results. Consequently, the former are reported

herein. A complete list of targets and non-word primes in the Identical, Feature and Unrelated priming conditions is included in Appendix D. Table 5 displays the means for each control variable of the non-word primes.

Table 5

Means for the Control Variables of the non-word primes in the Identical, Feature and Unrelated conditions of Experiment 3.

	Priming Conditions		
Control variables	Identical	Feature	Unrelated
Number of orthographic neighbours	8.31	7.61	7.33
Neighbourhood frequency	73.66	71.68	75.84
Number of constrained unigrams	140.23	136.31	139.13
Constrained unigrams frequency	12389.09	11588.65	11809.29
Number of constrained bigrams	12.65	12.34	12.07
Constrained bigrams frequency	881.16	752.86	1008.30

Note. The above means are based on CELEX, 1995 database (Medler & Binder, 2005). Frequency = how often a word form is encountered in 1,000,000 presentations of text. Constrained unigram = first letter; constrained bigram = first two letters.

4.4.2.3. Procedure

Post experimental interviews revealed that four participants noticed seeing something before the presentation of the targets but were unable to identify what they had seen.

4.4.3. Results

A total of 1.8 % (0.2 % TE + 1.6 % E) of the data was eliminated due to the removal of errors. Also, 5.3% of the data was excluded from the final analyses as it fell outside the 2SDs cut-off value from the mean for each participant. Finally, data from two participants (one in word reading and one in picture naming) consisted of outliers. However, since the analyses both with and without outliers showed the same pattern of results, the former are reported herein. Mean naming latencies, standard deviations, percentage errors and mean priming effects for both word reading and picture naming in all four priming conditions are displayed in Table 6.

Table 6

Mean Naming Latencies (RT, in Milliseconds), Standard Deviations (SD), Percentage

Errors (%E) and Mean Priming Effects (PE, in Milliseconds) for both word reading and

picture naming in all four priming conditions for Experiment 3.

	Task							
	Word reading				Picture naming			
Priming Condition (example)	RT	SD	%E	PE	RT	SD	%E	PE
Identical (bude - BELT)	470.66	59.23	0.1	13	602.33	64.68	2.2	-10
Feature (pude - BELT)	485.22	59.10	1.3	-2	609.05	57.77	2.9	-16
Unrelated (jude - BELT)	489.41	58.02	0.2	-6	606.64	64.03	2.3	-14
Control (%%%% - BELT)	483.25	54.99	0.2		592.69	60.21	3.1	

Note. The above means (RT) and standard deviations (SD) are based on the analysis by participants; PE – refers to comparisons to the Control condition as in Schiller's (2004, 2008) research.

For naming latency, the main effect of Task was significant, $F1(1,46) = 50.05$, MSE =

13936.77, $p < .001$, $\eta^2 = .52$; $F2(1,35) = 1172.37$, MSE = 892.94, $p < .001$, $\eta^2 = .97$, as

was the main effect of Priming Condition, $F1(3,119) = 13.60$, MSE = 148.47, $p < .001$,

$\eta^2 = .23$ (Greenhouse-Geisser); $F2(3,105) = 12.46$, MSE = 172.62, $p < .001$, $\eta^2 = .26$.

The interaction between Task and Priming Condition was also significant, $F1(3,119) =$

8.43, $p < .001$, $\eta^2 = .16$ (Greenhouse-Geisser); $F2(3,105) = 8.46$, MSE = 207.11, $p <$

.001, $\eta^2 = .20$.

Separate analysis of Task showed that in the word reading task there was a significant

main effect of Priming Condition, $F1(3,69) = 13.87$, MSE = 112.66, $p < .001$, $\eta^2 = .38$;

$F2(3,105) = 18.40$, MSE = 113.98, $p < .001$, $\eta^2 = .35$. Planned comparisons showed that

the response latencies were significantly shorter in the Identical condition compared to

the Control [t1(23) = 3.97, p = .001; t2(35) = 5.08, p < .001] condition. However, there was no significant difference between the Feature and Unrelated conditions; both ps > .05. Pairwise comparisons (Bonferroni adjusted) showed that the response latencies were significantly shorter in the Identical condition compared to the Feature [t1(23) = 14.57, p < .001; t2(35) = 14.35, p < .001] and Unrelated [t1(23) = 18.75, p < .001; t2(35) = 17.28, p < .001] conditions. There was however, no significant difference in the response latencies between the Feature and Control as well as the Unrelated and Control conditions; all ps > .05.

There was also a significant main effect of Priming Condition in the picture naming task, F1(3,69) = 8.76, MSE = 142.65, p < .001, η² = .28; F2(3,105) = 6.79, MSE = 265.75, p < .001, η² = .16. Planned comparisons revealed that compared to the Control condition the response latencies were significantly longer in the Identical [t1(23) = 2.29, p = .031; t2(35) = 2.61, p = .013] condition. However, there was no difference in the response latencies between the Feature and Unrelated conditions; both ps > .05. Pairwise comparisons (Bonferroni adjusted) revealed that relative to the Control condition the response latencies were significantly longer in the Feature [t1(23) = 16.36, p = .002; t2(35) = 16.20, p < .001] and Unrelated [t1(23) = 13.95, p = .003; t2(35) = 13.40, p = .007] conditions. They were also longer in the Feature condition compared to the Identical condition. However, this difference was not statistically significant; both ps > .05. Finally, there was no difference in the response latencies between the Identical and Unrelated conditions; both ps > .05.

The overall error rate in the word reading task was 0.5% therefore, akin to Experiments 1 and 2 only the errors in the picture naming task were analysed. They yielded no significant effects; both ps > .05.

4.4.4. Discussion

Akin to Experiment 2, the results from Experiment 3 demonstrated an interaction between Task and Priming Condition. As such, the word reading and picture naming data were analysed separately. As predicted, word reading was significantly faster in the Identical condition compared to all the other conditions (i.e. Feature, Unrelated and Control). Also, there was no significant difference in the response latencies between the Feature and Unrelated, Feature and Control as well as the Unrelated and Control conditions. Therefore, in line with the outcomes from Experiment 1 these results showed facilitation only from full phonemic feature overlap in the initial position (Identical condition) but not when the onsets of non-word primes and word targets shared all their phonemic features except for voicing (Feature condition).

Analyses of the picture naming data from Experiment 3 showed that relative to the Control condition participants took significantly longer to name picture targets in the Identical, Feature and Unrelated conditions. As such, these results echoed those from Experiment 2 and were therefore contrary to the lexical level account for the observed interference from word primes on picture target naming on which the predictions for

this task were based. Since a non-word prime by definition does not have a lemma that could interfere with the selection of a picture target's lemma, the most reasonable explanation for the observed interference from both word and non-word primes on picture naming was that this effect occurred during the phonological encoding stage of processing which as argued by Schiller (2008), was likely caused by competition for selection between the mismatching segments activated by a prime and those activated by a target. Further, akin to Experiment 2, picture targets were also named slower in the Feature condition compared to the Identical condition but this difference was not significant. Finally, the results from the error analysis were consistent with those from Experiments 1 and 2 showing no effects of priming conditions. A more detailed discussion of the data from Experiment 3 and the earlier two experiments is included in the general discussion that follows.

4.5. General Discussion

The word reading results from Experiments 1, 2 and 3 showed that these targets were named significantly faster in the Identical condition relative to both the Feature and Control conditions. They were also named faster in the Identical condition compared to the Unrelated condition. However, this difference was only significant in Experiments 2 and 3 but not in Experiment 1. Given that a MOPE was found in the word reading task, these results were thus consistent with both the predictions of this set of experiments as well as with Schiller's (2004) data on which these predictions were based. Importantly,

the outcomes from Experiment 2 that employed word primes also revealed that participants' response latencies to word targets were significantly faster in the Feature condition relative to the Unrelated condition. This effect was not observed in Experiments 1 and 3 in which single segment onset and non-word primes were used. The finding of a phonemic feature effect in Experiment 2 allows for the faster naming of word targets in the Identical condition to be explained with reference to phonemic features. An alternative way to consider the Identical condition is that it is one in which the onsets of word primes and word targets fully share their phonemic features, rather than one in which these onsets share abstract phonemes. The results reported in Experiment 2 suggest therefore, that when word (i.e., lexical) primes were employed the degree of observed facilitation in word reading was dependent on the varying degree of featural overlap between primes and targets. This would explain why in this experiment participants read word targets significantly faster in the Identical condition compared to the Feature condition in which the onsets of primes and targets shared all but one of their phonemic feature. By extension, this would also account for the facilitation found in the Identical condition relative to both the Unrelated and Control conditions.

Further, the observation that in the word reading task effects from phonemic feature similarity were only observed with word primes but not with both single segment onset and non-word primes that consistent with the dual-route theoretical framework (DRC, Coltheart et. al., 2001; CDP+, Perry et. al., 2007) can only be processed via the non-lexical route, indicates that phonemic feature effects can only be found when the lexical route is fully engaged (i.e., with word primes in reading). According to Forster and Davis (1991), making lexical decisions is also a task that can only be accomplished when the lexical route is fully engaged. As such, the word reading results from

Experiment 2 are fully consistent with Lukatela et al.'s (2001) findings that participants' lexical decisions were faster when the onsets of non-word primes and word targets shared all but one of their phonemic features (e.g., zea-SEA) compared to when these onsets differed by at least two phonemic features (e.g., vea-SEA).

Moreover, the word reading data from Experiments 1 to 3 provide an important contribution to the current understanding of how this process is accomplished. The finding of effects with word primes (Experiment 2) that differed to those observed with both single segment onset and non-word primes (Experiments 1 and 3, respectively) strongly supports the perspective that word reading occurs via two distinct routes (i.e., lexical and non-lexical). These observations are thus consistent with the dual-route theoretical framework (DRC, Coltheart et. al., 2001; CDP+, Perry et. al., 2007). However, they are contrary to the working assumptions of the PDP model (Plaut et al., 1996) according to which the processes underlying word reading operate via a single route. In relation to the dual-route account, the results from Experiment 2 also indicate that the processing of a given input via the lexical route is driven by phonemic features rather than abstract phonemes. Consequently, they suggest that in this route phonemic features might play more important role that is currently considered in both the DRC (Coltheart et al, 2001) and CDP+ (Perry et al., 2007) models. Finally, in all of the word reading experiments reported in this chapter there was no difference in the response latencies between the Unrelated and Control conditions. This confers with Grainger and Ferrand's (1996) conclusions that masked priming effects are facilitating in nature.

The picture naming data revealed a different set of results. In Experiment 1 the naming of picture targets was facilitated by the brief presentation of related single segment

onset primes (i.e., Identical condition) relative to the Feature and Control conditions thus showing a MOPE. These findings were consistent with the word reading results from Experiment 1. In contrast however, the data from Experiments 2 and 3 that used word and non-word primes respectively showed that the masked presentation of these primes inhibited the picture naming process in all conditions (i.e., Identical, Feature and Unrelated) relative to the Control condition. Importantly, across these conditions response latencies were fastest in the Identical condition in which the onsets of primes and targets were identical and slowest of all in the Feature condition in which these onsets shared all but one of their features. As such, these outcomes were not only inconsistent with the picture naming results from Experiment 1 but were also contrary to the word reading data.

Since the results from Experiments 2 and 3 demonstrated that masked priming with both word and non-word primes slows down picture naming, they thus confirmed the similar findings of Schiller (2008) in the naming of disyllabic Dutch picture targets. Further, the finding of interference using non-word primes in Experiment 3 was incompatible with Schiller's (2008) lexical level account that referred to the possibility of interference from competing lemmas akin to that occurring during PWI studies. As discussed in the previous section, this phenomenon might have provided a feasible explanation for the interference from word primes on picture target naming that was observed in Experiment 2 if indeed this interference was a result of factors affecting processing at the lexical level. However, given that by definition a non-word cannot have a lemma, the employment of non-word primes should have eliminated the possibility of a lemma activated by the prime competing for selection with the picture target's lemma. As such, to be consistent with Schiller's (2008) lexical level account,

interference should not have been observed as a consequence of such primes. The finding of interference in Experiment 3 therefore, suggests that Schiller's (2008) sub-lexical level explanation, specifically that picture naming might be inhibited as a result of competition for selection between target and non-target segments at the phonological output lexicon, in fact appears to be in line with the picture naming results reported here.

According to this account (Schiller, 2008), the presentation of the prime in picture naming in Experiments 2 and 3 would have induced noise into the target phoneme selection process that slowed down overall naming latencies. Also, the trend towards the largest interference of all being consistently observed in the Feature condition across these three experiments (Experiments 1 to 3) cannot be ignored and suggests that this noise is increased further when the onset of both a prime and target share all but one of their features. This latter observation thus implies that in picture naming phonemic features may be relevant to the phonological encoding process in a way that is not currently considered in the WEAVER general language production model. As discussed in Chapter 1, in this model phonemic features are activated after the phonological encoding process of a monosyllabic word or the first syllable of a multisyllabic word has been fully completed and takes place at the later, phonetic encoding stage of processing. Also, at this stage the activation of phonemic features occurs in parallel. Consequently, this working assumption of WEAVER cannot explain the presence of an inhibiting effect on target naming performance that is caused by the featural make-up of a phonemic segment that is shared between a prime and its target. Hence, the findings in both Experiments 2 and 3 of additional interference in the Feature condition where picture naming was slowest of all when the onsets of primes and targets shared all but

one of their features suggests that contrary to WEAVER, during phonological encoding phonemes are in fact specified for their features.

WEAVER is classified as a segmental model. However, an alternative segmental model that considers the role of phonemic features that might well be able to account for this observed interference in picture naming is the spreading activation model proposed by Dell (1986 – see Chapter 1 for more details). This model assumes that during the phonological encoding of a monosyllabic morpheme (the smallest unit of meaning in a word e.g., BELT), the syllable corresponding to the morpheme is activated and assigned current node status. Next the syllable's phonemes are activated in parallel whilst at the same time a syllable frame is created. This is then followed by the activation of the features corresponding to these phonemes. Further, according to Dell's (1986) model there are bi-directional connections between each of these processing levels which means that the activation at one level directly influences and is influenced by the activations at both the level directly above and below it. Consequently, it is plausible that as argued by Roelofs (1999), due to the backward spreading of activation from features to segments in Dell (1986), a segment such as /p/ will receive feedback from all but one of the features of the target segment /b/ and thus /p/ will compete for selection along with the target segment /b/. However, a segment such as /j/ shares fewer features with the target segment /b/ compared to /p/ and hence will receive less feedback from that segment resulting in a reduced level of competition between /j/ and /b/. Applying these working assumptions of Dell's (1986) model therefore, it could be suggested that in Experiments 2 and 3 the mismatching phonemes activated by the primes competed for selection with the corresponding phonemes of the picture targets and this competition was supported by the feedback from the feature level that was even

stronger when the onsets of primes and targets shared all but one of their phonemic features.

The final general language production model considered in Chapter 1 that might be relevant to this discussion was Dell et al.'s (1993) PDP model. As previously mentioned, during single word production in PDP (Dell et al., 1993) the word's lemma is first activated in the input layer. Each segment of the lemma then activates its corresponding phonemic features in the output layer. This activation occurs via the hidden units layer and takes place one segment at the time (starting from the first segment of the input). Therefore, in this model a verbal response to a given target is accomplished by the direct activation of phonemic features. However, in Dell et al.'s (1993) PDP model phonemic features are activated as a full, inseparable set corresponding to a specific segment of the input. To be consistent with this model therefore, effects from partial phonemic feature overlap should not have been found (Feature condition). Yet, the results from Experiments 2 and 3 clearly showed interference in this condition. Consequently, akin to WEAVER the outcomes from the picture naming task could not be accounted for within the PDP (Dell et al., 1993) model's architecture. As such, of the general language production models evaluated in Chapter 1, Dell's (1986) model is the only one that is able to account for the picture naming findings of Experiments 1, 2 and 3 reported herein.

A primary reason for conducting these experiments was to establish the likelihood that phonological encoding mechanisms are shared for both word reading and picture naming (Kinoshita, 2000; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007; Roelofs, 2004). There have clearly been differences in the results across these

experiments that were hard to reconcile with the concept of shared encoding mechanisms. As discussed, the persistent observation of interference in picture naming might best be explained with reference to Dell's (1986) model. However, similar inhibiting effects were not observed for word reading. One possible explanation for why both word and non-word targets inhibited picture naming but not word reading is as follows.

In general, picture naming is a more complex task than word reading which is why participants take on average 150 ms longer to produce a verbal response to pictures compared to word targets (see Roelofs, 2003, for discussion). Given that word reading is much faster to accomplish than picture naming, it could be suggested that during the word reading task there is only enough time to process the initial segment of the prime whereas in picture naming the entirety of the prime is fully processed. If this were in fact the case, it would explain why for word reading a MOPE was found in all three experiments and specifically, why in Experiments 2 and 3 no interference from the mismatching end segments between primes and word targets was observed. However, if in contrast to word reading the prime in the picture naming task is fully processed, this could account for the observed differences between the two tasks and in particular for the interference from both word and non-word primes on picture target naming (Experiments 2 and 3).

Finally, the outcomes from Experiments 1, 2 and 3 indicated that phonemic feature similarity between the onsets of a prime and target plays a distinctly different role in word reading compared to picture naming. For word reading the results in the Feature condition in Experiment 2 provided support for the findings of Lukatela et al. (2001)

that featural similarity facilitates word reading. In contrast however, picture naming in Experiments 1, 2 and 3 was slowed down further when the onsets of primes and targets shared all but one of their features. These results implied that phonemic feature similarity between the onset of a prime and target introduces competition into the system that interferes with the picture naming process. Consequently, the data from Experiments 1, 2 and 3 showed that during phonological encoding phonemes appear to be specified for their features. However, phonemic feature similarity in the onset position of primes and targets seemed to have contrary effects on the encoding process of each target type.

Importantly, since in both domains effects from phonemic feature similarity were observed, it was necessary to establish whether these effects were specific to target onsets or whether they would also be observed in the other segments of either word and picture targets such as for example, the coda position (i.e., the final consonant or consonant cluster). As such, this issue and the possibility that the differing results between word reading and picture naming from Experiments 2 and 3 might have been due to the extent to which the prime had been processed in each task needed to be addressed before firm conclusions regarding the herein reported data could be reached. This was done in the following three experiments in which as discussed in the next chapter, phonemic feature similarity in the coda position of primes and both word and picture targets was manipulated.

In conclusion, the results from the masked priming research conducted so far demonstrated facilitation in word reading when both word and non-word primes shared their onsets whereas picture naming was inhibited in the same conditions. This contrast

in findings is suggestive of separate processes and is thus contrary to Kinoshita's (2000; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007) and Roelofs' (2004) assertion that phonological encoding mechanisms might be shared for the two target types. The observation of facilitation found in the Feature condition for word reading when the onsets of word primes and targets shared all but one of their phonemic features (Experiment 2) allowed for the word reading data obtained with the employment of word (lexical) primes to be accounted for with reference to the role of phonemic features. Whilst this interpretation is consistent with Lukatela et al.'s (2001) conclusions, it is incompatible with the influential word reading models described and evaluated in Chapter 1, due to the fact that in these models phonemes are not specified for their features. Similarly, the interference from phonemic feature similarity (Feature condition) observed in picture naming (Experiments 2 and 3) cannot be explained with reference to the WEAVER general language production model that also considers phonemes as abstract entities. However, Dell's (1986) segmental model that incorporates phonemic features within its processing framework can account for the picture naming data. Finally, the interference from word and non-word primes on picture naming might best be explained with reference to Schiller's (2008) post-lexical level account. The fact that this effect was not found in word reading might simply mean that in this task there is only enough time to process the initial segment of the prime whereas in picture naming the whole prime is processed. Consequently, it was necessary to establish whether in both or either the word reading and picture naming tasks, similar effects would be found with other segments (e.g., in the coda position). The aim of the research reported in the following chapter therefore, was to investigate both word reading and picture naming processes further, firstly to address the issues

raised above and secondly, to provide additional validation of the findings observed in

Experiments 1, 2 and 3.

CHAPTER 5: Masked priming effects when manipulating phonemic features in the end/coda segment position of monosyllabic words and pictures

5.1. Introduction

The picture naming data collected so far revealed that picture targets were named significantly faster only with matching single segment onset primes (Identical condition in Experiment 1) but not with word and non-word primes (Experiments 2 and 3, respectively). In fact, these latter two prime types interfered with the picture naming process with this interference occurring regardless of whether onsets between primes and targets were related or not. Given that the same pattern of results was found with both word and non-word primes, consistent with Schiller's (2008) post-lexical level account it was argued that the observed interference was likely due to competition for selection between the mismatching phonemes activated by a prime and the corresponding phonemes activated by its target.

As discussed in Chapter 4, the picture naming results from Experiments 1, 2 and 3 could best be accounted for with reference to the architecture incorporated into Dell's (1986) model. This model explains not only the facilitation that was observed from related single segment onset primes (Identical condition in Experiment 1) but also the interference from both word (Experiment 2) and non-word (Experiment 3) primes.

Based on the working assumptions of Dell's (1986) model it could thus be suggested that following the presentation of a prime, the phonemes and phonemic features corresponding to the prime were activated and remained active within the system whilst the target's phonemes were being processed. Consequently, if an activated phoneme/s of a prime was identical to its corresponding target phoneme/s the selection of the target's phoneme/s was facilitated, with this facilitation resulting in the shorter response latencies that were in fact recorded in the Identical condition in Experiment 1. If however, the prime's phonemes differed to the picture target's phonemes they competed with the latter phonemes for selection. The elapsed time necessary to resolve this competition therefore meant that the naming of picture targets in the Identical, Feature and Unrelated conditions in Experiments 2 and 3 took longer relative to the Control condition that consisted of percentage signs (e.g., %%%%). As such, Schiller's (2008) post-lexical level account for the observed interference from both word and non-word primes (Experiments 2 and 3) was consistent with the working assumptions of Dell's (1986) model.

Further, due to the presence of bidirectional connections between the phoneme and feature levels incorporated within its architecture, Dell's (1986) model can also explain why the magnitude of the observed interference in Experiments 1 to 3 was largest of all in the Feature condition in which the onsets of primes and targets shared all but one of their phonemic features. According to Dell (1986), the degree of feedback increases as the degree of featural overlap between competing phonemes increases. Consistent with this model therefore, due to the almost complete phonemic featural overlap between the onsets of both primes and targets in the Feature condition, feedback from the features activated by the prime's initial phoneme thus meant that the competition for selection in

the initial phoneme position between a prime and its target was at its most intense and thus took the longest to resolve. Yet, in the Unrelated condition in which the onsets of primes and targets differed by at least two phonemic features, there was less competition for selection between the respective phonemes resulting in a smaller magnitude of interference compared to the Feature condition.

Importantly, according to Dell's (1986) model the activation of phonemes that correspond to a given monosyllabic target during the phonological encoding process occurs in parallel. Therefore, by making the assumption that within such a system the pre-activation of the target's onset by the brief presentation of a single segment onset prime that fully shares its onset with the target results in a reduction in the overall time taken to produce a verbal response, it would be logical to argue that similar facilitation should also be observed when single segment primes and targets share a phoneme in the end/coda position. By extension, if mismatching phonemes activated by both word and non-word primes compete for selection with the corresponding phonemes of picture targets, similar interference should also be found regardless of their position within a given word-form. This possibility thus required further investigation.

The word reading results from Experiments 1 to 3 revealed that the naming of word targets was facilitated by both shared onsets between primes and targets (i.e., Identical condition in Experiments 1 and 3) as well as shared phonemic features between these onsets (i.e., Identical and Feature conditions in Experiment 2). Since in this task the outcomes with non-lexical (i.e., single segment onset and non-word) primes differed to those found with lexical (i.e., word) primes, the word reading data collected so far suggested that word reading can be accomplished via two distinct routes and was thus

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consistent with the dual-route theoretical framework (e.g., DRC, Coltheart et al., 2001). However, contrary to this theoretical framework it implied that the processing of a given input by the lexical route occurs via its phonemic features.

Further, to explain why facilitation was observed in word reading whereas picture naming was inhibited by the brief presentation of both word and non-word primes (Experiments 2 and 3, respectively), it was suggested that the contrasting pattern of results between tasks could have reflected the extent to which the primes were processed in each task. Specifically, it was postulated that as word reading is a much faster process to accomplish than picture naming, it is possible that during masked priming in word reading there is only enough time to process the initial/onset segment of a prime whereas in picture naming the whole prime is fully processed. This would also explain why in Schiller's (2004, 2008) masked priming research, null effects were found from shared end segments between word primes and word targets (e.g., %propaan%%-BANAAN) yet in the equivalent priming condition (e.g., %robijn%-BANAAN), picture naming was inhibited. However, this argument is in large part inconsistent with the masked form-priming effects described and evaluated in Chapter 2. As discussed, these form-priming effects are independent of the MOPE and reflect effects due to the remaining phonemes that are shared between primes and word targets (e.g., defore-BEFORE versus dranch-BEFORE – Forster & Davis, 1991, Experiment 5). As such, they suggest that in masked priming in word reading more than just the initial/onset phoneme of a prime is processed. Nonetheless, it still remained an open question as to whether or not in this task the prime is completely processed. Addressing this question therefore, was important to more convincingly account for the

discrepancies between the word reading and picture naming data from Experiments 2 and 3.

Finally, the purpose of the herein reported research was to investigate phonological encoding processes for both word reading and picture naming to either validate or reject Roelofs' (2004) conclusions that these processes are shared for the two tasks. Although some of the data collected so far (Experiments 2 and 3) suggests that differences might exist in how phonology is constructed for each target type, it was deemed to be important to continue further enquiries whilst employing both tasks within the same set of experiments. Such investigations were considered likely to provide additional information relevant to the phonological encoding processes that occur during each task. The aim of Experiments 4 to 6 therefore, was to address the issues discussed above by manipulating phonemic feature similarity in the end/coda position of primes and both word and picture targets whilst employing the three types of primes used in the earlier experiments namely, single segment, word and non-word primes, respectively.

5.2. Experiment 4 - Single segment coda primes

5.2.1. Introduction

In his masked priming research Schiller (2008) found that compared to controls (e.g., %%%%%%%-BANAAN) the naming of picture targets was inhibited by the brief

presentation of related single segment coda primes (e.g., %%%%%n%-BANAAN). This observation was thus contrary to both the picture naming results from Experiment 1 as well as Schiller's (2008) own data which together showed facilitation from related single segment onset primes (e.g., %b%%%%%-BANAAN). Further, since the outcomes from matching single segment coda primes in Schiller's (2008) study differed to those when he employed matching single segment onset primes, at first glance they seemed to be incompatible with the working assumptions of Dell's (1986) model. This is because in this model the activation of phonemes corresponding to a given input occurs in parallel. This parallelism thus implies consistency of results across the two prime types.

However, Dell's (1986) model also assumes that for a multi-syllable input there is a parallel activation of phonemes corresponding to a given syllable but a serial rightward activation of its syllables. Given that in his study Schiller (2008) employed disyllabic picture targets, it is possible that his outcomes with related single segment coda primes reflected effects that occurred during both within and between syllable/s processing. As such, observable effects using primes related in the coda position may well be different with monosyllabic compared to multisyllabic targets and consequently, it remained an open question as to whether or not similar results to Experiment 1 would be obtained with monosyllabic picture targets when related coda primes are used.

Additionally, even though in his picture naming study Schiller (2008) used single segment coda primes, this priming condition was not employed in his word reading research. As discussed in the previous section (section 5.1.) it is plausible that due to its

speeded accomplishment, in word reading there is only enough time to process the initial segment/s of a prime. If confirmed, this could provide an explanation as to why mismatching segments between both word and non-word primes interfered with the picture naming but not with the word reading process. The aim of Experiment 4 therefore, was to assess masked priming effects on the naming of both word and picture targets when phonemic feature similarity in the coda position of single segment coda primes was manipulated. To this end and as in the first three experiments of this thesis, each word and picture target was primed by four types of primes namely, Identical in which the codas of both a prime and its target was identical (e.g., %%t - BAT), Feature in which the codas of both prime and target shared all but one of their phonemic features (e.g., %%d - BAT), Unrelated in which the codas differed by at least two phonemic features (e.g., %%h - BAT) and finally Control that consisted of percentage signs (e.g., %%% - BAT).

To be consistent with the working assumptions of Dell's (1986) model it was predicted that the picture naming results from Experiment 4 would echo those from Experiment 1. It was thus expected that picture targets would be named faster in the Identical condition relative to all the other conditions and that the differences between the Identical and Feature as well as Identical and Control conditions would be statistically significant. However, it remained to be seen whether there would be observable effects in the word reading task.

5.2.2. Method

5.2.2.1. Participants

Forty-eight participants took part in this experiment. Their mean age was 29.35 and ranged from 18 to 50 years.

5.2.2.2. Design and Stimuli

The design was identical to the one employed in Experiments 2 and 3 except that due to a limitation in the number of stimuli choices there were only 272 trials (34 words x 4 blocks plus 34 pictures x 4 blocks). Further, as in the other two experiments each participant was required to name either words or pictures presented in four experimental blocks (136 trials). Thirty-four (6 practice + 28 target) words and their corresponding pictures were employed in this experiment. The average written frequency of the word targets was 46.75 per million whereas the average spoken frequency of the picture targets was 25.71 per million. Both of these means were based on the English version of the CELEX database (Baayen et al., 1995). Akin to Experiments 1, 2 and 3 the primes were organized into four priming conditions namely, Identical (e.g., %%t - BAT), Feature (e.g., %%d - BAT), Unrelated (e.g., %%n - BAT) and Control (e.g., %%% - BAT). Table 7 displays the means for each control variable of the single segment coda

primes (i.e. Identical, Feature and Unrelated). All of the targets and primes were
selected based on the criteria described in Chapter 3 (3.4.). A complete list of targets
and single segment coda primes in the Identical, Feature and Unrelated priming
conditions is included in Appendix E.

Table 7

Means for the control variables of the single segment coda primes in the Identical,
Feature and Unrelated conditions of Experiment 4.

Control variables	Priming Conditions		
	Identical	Feature	Unrelated
Number of constrained unigrams	99.41	46.61	53.85
Constrained unigrams frequency	518.22	249.90	293.25

Note. The above means are based on the English version of the CELEX (1995) database (Medler &
Binder, 2005) and refer to how often a word form is encountered in 1,000,000 presentations of text.
Constrained unigram = last letter.

5.2.2.3. Procedure

Post experimental interviews revealed that one participant noticed seeing something
before the presentation of the targets but was unable to identify what he had seen.

5.2.3. Results

A total of 1.5% error (0.15% technical errors + 1.35% errors) and 5.56 % trimmed data were removed from the latency analyses. Further, the data from five participants (three in word reading and two in picture naming) consisted of outliers. As the results with outliers differed to those without outliers the latter were reported herein. Mean naming latencies, standard deviations, percentage errors and mean priming effects for both word reading and picture naming in all four priming conditions are displayed in Table 8.

Table 8

Mean Naming Latencies (RT, in Milliseconds), Standard Deviations (SD), Percentage Errors (%E) and Mean Priming Effects (PE, in Milliseconds) for both word reading and picture naming in all four priming conditions for Experiment 4.

	Task							
	Word reading				Picture naming			
Priming condition (example)	RT	SD	%E	PE	RT	SD	%E	PE
Identical (%%t - BAT)	482.48	38.04	0.7	6	583.18	38.95	2.1	10
Feature (%%d - BAT)	488.98	39.13	0.9	-1	595.71	40.64	1.3	-3
Unrelated (%%h - BAT)	486.08	36.57	1.0	2	589.95	34.63	1.3	3
Control (%%% - BAT)	488.01	30.64	1.4		592.74	35.04	2.1	

Note. The above means (RT) and standard deviations (SD) are based on the analysis by participants; PE – refers to comparisons to the Control condition as in Schiller's (2004, 2008) research.

For naming latency, the main effect of Task was significant, $F1(1,41) = 92.62$, MSE = 5019.12, $p < .001$, $\eta^2 = .69$; $F2(1,27) = 510.90$, MSE = 1037.28, $p < .001$, $\eta^2 = .95$, as was the main effect of Priming Condition, $F1(3,103) = 5.31$, MSE = 163.16, $p = .003$, η^2

= .16 (Greenhouse-Geisser); F2(2,66) = 3.97, MSE = 320.24, p = .017, η^2 = .13 (Greenhouse-Geisser). The interaction between Task and Priming Condition was not significant, F1(3,103) = .50, p > .05 (Greenhouse-Geisser); F2(3,81) = .50, MSE = 257.49, p > .05. Planned comparisons showed that the response latencies were significantly shorter in the Identical condition compared to Control condition [t1(42) = 3.45, p = .001; t2(27) = 2.78, p = .010]. There was however, no significant difference between the Feature and Unrelated conditions; both ps > .05. Pairwise comparisons (Bonferroni adjusted) showed that response latencies were significantly shorter in the Identical condition compared to the Feature condition [t1(42) = 9.52, p = .005; t2(27) = 9.93, p = .042]. They were also shorter in the Identical condition relative to the Unrelated condition [t1(42) = 5.18, p = .047; t2(27) = 4.22, p > .05] but this difference was only significant by participants. Further, there was no significant difference between the Feature and Control as well as the Unrelated and Control conditions; all ps > .05.

The overall error rate in the word reading task was 1.0%. Therefore, only the errors in the picture naming task were analyzed. However, they yielded no significant effects; both ps > .05.

5.2.4. Discussion

The results from Experiment 4 showed that when primed by single segment coda primes both word and picture targets were named significantly faster in the Identical condition relative to all other conditions (i.e., Feature, Unrelated and Control). It should be noted that the outcomes with outliers were very similar to those without outliers except that in this case the difference between the Identical and Unrelated conditions was not statistically significant. As such, the data from Experiment 4 echoed that from Experiment 1 in which single segment onset primes were employed. Also, akin to Experiment 1 no additional effects were observed. Further, the error data was in line with the error data from Experiments 1, 2 and 3 in that fewer errors were made in the word reading task compared to the picture naming task and in both tasks the error scores were unaffected by the priming conditions employed.

As predicted, the picture naming results from Experiment 4 were in line with those of Experiment 1. Given that in the absence of mismatching phonemes related single segment onset and coda primes both facilitated picture naming, these outcomes appeared to be consistent with the working assumptions of Dell's (1986) model. Specifically, they support the notion that the activation of phonemes corresponding to a given monosyllabic input occurs in parallel across its word-form in a way that is incorporated into this model. However, this parallelism also implies that if mismatching end phonemes between primes and picture targets inhibit the picture naming process (Experiments 2 and 3), the same should be true for mismatching phonemes regardless of their position within a given word-form. This assumption still needed to be tested.

Akin to pictures, word targets in Experiment 4 were also named significantly faster following the brief presentation of related single segment coda primes. Since in this experiment matching single segment coda primes facilitated the word reading process, it could be inferred that in masked priming during word reading the primes are in fact fully processed. Further, in line with the earlier word reading data (Experiments 1 to 3) these results could also be accounted for with reference to the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001) and can be explained as follows. Because single segment coda primes are by definition non-lexical primes, based on the arguments presented in Chapter 4 it could be assumed that following their presentation the non-lexical route was fully engaged. Thus, after the display of a single segment coda prime the non-lexical route began its serial left-to-right processing. As the initial phoneme positions of such a prime consisted of percentage signs, only the phoneme corresponding to its end/coda phoneme was activated and remained active within the system whereas there was no activation of phonemes in the earlier positions. Once the word target was presented the non-lexical route began processing that target, again in a serial rightward manner. The absence of prior activation in the initial phoneme positions meant that the activation of the initial phonemes of the word target occurred at its usual pace. For the final phoneme position of the target the pre-activation of this phoneme following the presentation of a related prime in the Identical condition allowed for its faster selection relative to all the other conditions, resulting in the observed facilitation in this condition. However, although the word reading findings obtained with single segment coda primes were consistent with the workings of the non-lexical route, it remained to be seen if the same would be true when the lexical route is fully engaged.

Considered together, the word reading outcomes from Experiment 4 were consistent with the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001) and suggested that in this task the prime is fully processed. In contrast, the picture naming results were in keeping with the working assumptions of Dell's (1986) model. However, it was important to continue with this line of enquiry to provide further confirmation for the arguments presented above. To this aim, in the following experiment word primes were employed with both word and picture targets whilst akin to Experiment 4 phonemic feature similarity in the end/coda position was manipulated.

5.3. Experiment 5 – Word primes

5.3.1. Introduction

As discussed (section 5.2.4), the results from Experiment 4 showed that the naming of both word and picture targets was significantly faster in the Identical condition relative to all other conditions. Since the two data sets revealed facilitation from related single segment coda primes, these outcomes suggested that in both tasks the primes were fully processed. Therefore, it could not be argued that the interference observed in Experiments 2 and 3 from mismatching segments between primes and picture targets that was not found with word targets was due to the extent to which the primes were processed in each task. Further, given that the picture naming results from Experiment

4 were consistent with those from Experiment 1 that employed single segment onset primes, it was postulated that these findings were in line with the working assumptions of Dell's (1986) model. That is because in this model there is a parallel activation of phonemes corresponding to a given monosyllabic input and it is this parallelism that implies consistency of results from related single segment primes regardless of their position within a word-form. By extension, it could also be assumed that if mismatching end segments between primes and picture targets interfere with the picture naming process (Experiments 2 and 3), the same should be true when the mismatch occurs in the initial segment positions. The latter assumption was tested in this experiment using word primes where the initial segments/phonemes differed to those of their corresponding picture targets and in which, as in Experiment 4, phonemic feature similarity in the end/coda position was manipulated (e.g., cot-BAT – Identical condition).

Additionally, the employment of such primes was expected to provide further insight into phonological encoding processes involved in word reading. As argued, the word reading data collected so far seemed to be consistent with the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001). Specifically, the word reading results from Experiments 1 to 3 implied that in masked priming the observed effects with non-lexical primes (i.e., single segment and non-word – Experiments 1 and 3, respectively) might have reflected processes occurring at the non-lexical route whilst the effects found with lexical primes (i.e., word – Experiment 2) might have been due to processes taking place at the lexical route. Consequently, in Experiments 1 and 3 word targets were read significantly faster only when primes and targets shared their onsets (Identical condition) whereas in Experiment 2 facilitation was observed when the onsets

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of primes and word targets shared both all and all but one of their phonemic features (Identical and Feature conditions, respectively).

Although the word reading results from Experiment 4 that employed single segment coda (non-lexical) primes seemed to be consistent with the working assumptions of the non-lexical route and were thus in line with the argument just presented, it remained to be seen whether the same would be true when the lexical route is fully engaged through the use of word (lexical) primes in Experiment 5 whilst manipulating phonemic feature similarity in the end/coda position. Given that the activation of phonemes corresponding to a given input occurs in parallel both in Dell's (1986) model and at the lexical route of the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001), it was predicted that the word reading and picture naming data from Experiment 5 would echo the outcomes for the corresponding task in Experiment 2 that also employed word primes. As such, in this experiment word targets were predicted to be read significantly faster in the Identical condition compared to all the other conditions (i.e., Feature, Unrelated and Control conditions). They were also expected to be read significantly faster in the Feature condition relative to the Unrelated condition. In contrast, picture naming was anticipated to be inhibited by the brief presentation of word primes in the Identical, Feature and Unrelated conditions and these inhibitory effects were predicted to be statistically significant relative to the Control condition.

5.3.2. Method

5.3.2.1. Participants

Forty-eight participants took part in this experiment. Their mean age was 28.27 and ranged from 19 to 48 years.

5.3.2.2. Design and Stimuli

Again, the design was almost identical to the one employed in Experiments 2, 3 and 4. The only difference related to the total number of trials, which was 176 (22 words x 4 blocks plus 22 pictures x 4 blocks). Also, akin to the other three experiments participants were required to name either words or pictures presented in four separate blocks (88 trials). Twenty-two (6 practice + 16 target) words and their corresponding pictures were employed in this experiment. The average written frequency of the word targets was 77.90 per million whereas the average spoken frequency of the picture targets was 51.39 per million. Both of these means were based on the English version of the CELEX database (Baayen et al., 1995). The word primes were organized into four priming conditions namely, Identical (e.g., cot - BAT), Feature (e.g., cod - BAT), Unrelated (e.g., con - BAT) and Control (e.g., %%% - BAT). Table 9 displays the means for each control variable of the word primes (i.e. Identical, Feature and

Unrelated). All of the targets and primes were selected based on the criteria described in Chapter 3 (3.4.). A complete list of targets and word primes in the Identical, Feature and Unrelated priming conditions is included in Appendix F.

Table 9

Means for the control variables of the word primes in the Identical, Feature and Unrelated conditions of Experiment 5.

	Priming Conditions		
Control variables	Identical	Feature	Unrelated
Orthographic frequency	15.47	14.00	13.97
Number of orthographic neighbours	15.81	13.00	13.31
Neighbourhood frequency	72.67	114.15	82.13

Note. The above means are based on the CELEX (1995) database (Medler & Binder, 2005). Frequency = how often a word form is encountered in 1,000,000 presentations of text; orthographic neighbours = words that differ from each other by only one letter.

5.3.2.3. Procedure

Post experimental interviews revealed that two participants noticed seeing something before the presentation of the targets but were unsure about what they had seen.

5.3.3. Results

A total of 2.2% error (0.5% technical errors + 1.7% errors) and 4.9% trimmed data were removed from the latency analysis. Also, the data from two participants (one in word reading and one in picture naming) consisted of outliers. However, since the pattern of observed results remained the same in the analyses both with and without outliers, the former were reported herein. Mean naming latencies, standard deviations, percentage errors and mean priming effects for both word reading and picture naming in all four priming conditions are displayed in Table 10.

Table 10

Mean Naming Latencies (RT, in Milliseconds), Standard Deviations (SD), Percentage Errors (%E) and Mean Priming Effects (PE, in Milliseconds) for both word reading and picture naming in all four priming conditions for Experiment 5.

	Task							
	Word reading				Picture naming			
Priming condition (example)	RT	SD	%E	PE	RT	SD	%E	PE
Identical (cot – BAT)	498.69	59.81	0.3	-7	613.70	61.86	3.6	-10
Feature (cod – BAT)	506.20	61.04	0.3	-14	617.50	68.76	2.6	-14
Unrelated (con – BAT)	498.36	55.49	0.8	-6	614.74	62.23	2.3	-11
Control (%%% - BAT)	491.97	52.47	0.3		603.71	62.30	3.1	

Note. The above means (RT) and standard deviations (SD) are based on the analysis by participants; PE – refers to comparisons to the Control condition as in Schiller's (2004, 2008) research.

For naming latency, the main effect of Task was significant, $F_1(1,46) = 44.94$, MSE = 13786.28, $p < .001$, $\eta^2 = .49$; $F_2(1,15) = 145.05$, MSE = 2949.46, $p < .001$, $\eta^2 = .91$, as was the main effect of Priming Condition, $F_1(3,138) = 5.15$, MSE = 311.99, $p = .002$, $\eta^2 = .10$; $F_2(3,45) = 6.89$, MSE = 195.37, $p = .001$, $\eta^2 = .32$. The interaction between Task and Priming Condition was not significant, $F_1(3,138) = .24$, $p > .05$; $F_2(3,45) = .50$, MSE = 196.43, $p > .05$. Planned comparisons showed that participants' response latencies were significantly longer in the Identical condition compared to the Control condition [$t_1(47) = 2.27$, $p = .028$; $t_2(15) = 2.28$, $p = .038$]. However, there was no significant difference between the Feature and Unrelated conditions; both $ps > .05$. Pairwise comparisons (Bonferroni adjusted) showed that response latencies were significantly longer in the Feature condition relative to the Control condition [$t_1(47) = 14.01$, $p = .010$; $t_2(15) = 15.63$, $p < .001$]. They were also longer in the Unrelated condition compared to the Control condition as well as in the Feature condition relative to the Identical condition but these differences were not statistically significant; all $ps > .05$. Finally, there was no significant difference between the Identical and Unrelated conditions; both $ps > .05$.

The overall error rate in the word reading task was 0.4%. Therefore, only the errors in the picture naming task were analyzed. However, they yielded no significant effects; both $ps > .05$.

5.3.4. Discussion

The results from Experiment 5 revealed that both word and picture targets were named slower in the Identical, Feature and Unrelated conditions compared to the Control condition. However, only the differences between the Identical and Control as well as the Feature and Control conditions were statistically significant. Considering that in both tasks the differences between the Identical and Control as well as the Unrelated and Control conditions were numerically almost identical, it was unclear why the former difference was statistically significant whereas the latter was not. The error data was consistent with the error data from the previous experiments and showed that although more errors were made in picture naming compared to word reading, neither of these error scores were affected by the priming conditions employed.

The analysis of the word reading data from Experiment 5 yielded surprising results. Interference was observed when reading aloud word targets regardless of whether word primes in the coda position were related with targets or not. These results were inconsistent with both the predictions for this experiment and the word reading data from Experiment 2. As such, they were contrary to the working assumptions of the lexical route of the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001) whose architecture implies consistency of results across Experiments 2 and 5. That is because this architecture incorporates the parallel activation of phonemes corresponding to a given monosyllabic input during the processing of its word-form. Further, the word reading results from Experiment 5 also showed that these targets were named slowest of all in the Feature condition in which the codas of both primes and targets shared all but

one of their phonemic features. Although this effect was not statistically significant relative to both the Identical and Unrelated conditions, its presence provided further support for the argument that in this task, as in picture naming, the prime is fully processed. In Experiment 5 the initial segments/phonemes of word primes were the same across the Identical, Feature and Unrelated conditions whilst phonemic feature similarity in the end/coda position was manipulated. Since the presentation of such primes resulted in the largest of all interference occurring in the Feature condition, it would be logical to conclude that this effect was due to the end/coda phoneme thereby suggesting a full processing of primes. However, this does not explain why in Experiment 2 phonemic feature similarity (Identical and Feature conditions) facilitated word reading whereas in Experiment 5 this similarity seemed to interfere with the word reading process and further, why in the former experiment only facilitation from word primes was observed whilst in the latter experiment such primes inhibited word reading. Consequently, this pattern of interference from word primes on word targets required further investigation before any inferences regarding the word reading data from Experiment 5 could be reached.

As predicted, the naming of picture targets in Experiment 5 was inhibited by the brief presentation of word primes in which phonemic feature similarity in the coda positions of both stimuli was manipulated (Identical, Feature and Unrelated conditions). As such, the picture naming results from Experiment 5 were consistent with the picture naming data from Experiments 2 and 3. Further and in line with the picture naming outcomes from Experiments 1 to 4, in Experiment 5 there was also a trend towards the largest interference of all being observed when all but one of the phonemic features were shared in the coda position (Feature condition) of both word primes and picture targets.

However, before firm conclusion regarding the picture naming data from Experiment 5 could be reached, it was important to establish whether the same pattern of results would be replicated with non-word primes in which, as with the word primes, phonemic feature similarity in the end/coda position between primes and targets was manipulated. This was done in the following experiment.

5.4. Experiment 6 – Non-word primes

5.4.1. Introduction

Experiment 6 was conducted as a follow up to Experiment 5 with its aim two-fold. Firstly and as previously discussed, whilst the word reading results from Experiments 1 to 4 were consistent with the dual-route theoretical framework (e.g., DRC, Coltheart et al., 2001), the word reading outcomes from Experiment 5 were not. Therefore, it was important to continue with this line of investigation to assess whether the employment of non-word primes in which phonemic feature similarity in the end/coda position was manipulated could provide an explanation for this discrepancy. Secondly and with regards to the picture naming task, Experiments 2, 3 and 5 were consistent in revealing interference in picture naming in all conditions relative to controls (i.e., Identical, Feature and Unrelated). However, in Experiments 2 and 3 there was a trend towards this interference being largest of all in the Feature condition in which the onsets of both primes and targets shared all but one of their phonemic features whereas in Experiment

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5 this trend was not observed. Consequently, it was important to continue with this enquiry to establish the precise pattern of effects in picture naming when phonemic feature overlap was varied in the coda position of non-word primes and targets.

Akin to Experiments 4 and 5 therefore, in Experiment 6 phonemic feature similarity in the coda position between primes and both word and picture targets was manipulated. This time however, non-word primes were employed. In keeping with the previous experiments each word and picture target (e.g., BAT) was preceded by the brief presentation of four types of primes namely, Identical (e.g., zut - BAT) in which primes and targets shared their codas, Feature (e.g., zud - BAT) in which the codas of primes and targets shared all but one of their phonemic features, Unrelated (e.g., zun - BAT) in which the codas differed by at least two phonemic features and finally Control (e.g., %%% - BAT) that consisted of percentage signs.

In consideration of the unexpected observation of interference from word primes in the word reading task of Experiment 5 which as discussed, was inconsistent with the outcomes from Experiment 2 and thus contrary to the working assumptions of the lexical route of the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001), it remained to be seen how coda segment related non-word primes would affect the word reading process. However, it was anticipated that the outcomes in the picture naming task would be in line with the findings for the corresponding task in Experiments 2, 3 and 5. As such, it was expected that non-word primes would interfere with the picture naming process in all conditions (i.e., Identical, Feature and Unrelated) relative to the Control condition and that this interference would be largest of all when

the codas of both non-word primes and picture targets shared all but one of their phonemic features (Feature condition).

5.4.2. Method

5.4.2.1. Participants

Forty-eight participants took part in this experiment. Their mean age was 27.17 and ranged from 18 to 50 years.

5.4.2.2. Design and Stimuli

The design was exactly the same as that employed in Experiment 5. The twenty-two (6 practice + 16 target) words and their corresponding pictures used in this experiment were identical to those in Experiment 5. The non-word primes were organized into four priming conditions namely, Identical (e.g., zut - BAT), Feature (e.g., zud - BAT), Unrelated (e.g., zun - BAT) and Control (e.g. %%% - BAT). Table 11 displays the means for each control variable of the non-word primes (i.e., Identical, Feature and Unrelated). Each of the targets and primes were selected based on the criteria described

in Chapter 3. A complete list of targets and non-word primes in the Identical, Feature and Unrelated priming conditions is included in Appendix G.

Table 11

Means for the control variables of the word primes in the Identical, Feature and Unrelated conditions of Experiment 6.

	Priming Conditions		
Control variables	Identical	Feature	Unrelated
Number of orthographic neighbours	10.44	9.88	8.13
Neighbourhood frequency	133.40	140.71	91.76

Note. The above means are based on the CELEX (1995) database (Medler & Binder, 2005). Orthographic neighbours = words that differ from each other by only one letter; Neighbourhood frequency = the average frequency (per million) of the orthographic neighbours.

5.4.2.3. Procedure

Post experimental interviews revealed that two participants noticed seeing something before the presentation of the targets but were unsure about what they had seen.

5.4.3. Results

A total of 2.0% error (0.6% technical errors + 1.4% errors) and 5.2% trimmed data were removed from the latency analysis. Mean naming latencies, standard deviations, percentage errors and mean priming effects for both word reading and picture naming in all four priming conditions are displayed in Table 12.

Table 12

Mean Naming Latencies (RT, in Milliseconds), Standard Deviations (SD), Percentage Errors (%E) and Mean Priming Effects (PE, in Milliseconds) for both word reading and picture naming in all four priming conditions for Experiment 6.

	Task							
	Word reading				Picture naming			
Priming condition (example)	RT	SD	%E	PE	RT	SD	%E	PE
Identical (zut – BAT)	484.17	63.87	0.8	6	594.10	50.00	0.8	-2
Feature (zud – BAT)	487.21	63.99	0.3	3	592.34	50.08	2.6	-1
Unrelated (zun – BAT)	488.51	67.40	0.3	2	593.44	41.11	3.1	-2
Control (%%% - BAT)	490.24	64.36	0.0		591.64	47.27	3.1	

Note. The above means (RT) and standard deviations (SD) are based on the analysis by participants; PE – refers to comparisons to the Control condition as in Schiller's (2004, 2008) research.

For naming latency, the main effect of Task was significant, $F1(1,46) = 43.69$, MSE = 12192.57, $p < .001$, $\eta^2 = .49$; $F2(1,15) = 195.04$, MSE = 1878.43, $p < .001$, $\eta^2 = .93$, whereas the main effect of Priming Condition was not, $F1(3,118) = .17$, MSE = 273.28, $p > .05$ (Greenhouse-Geisser); $F2(2,25) = .10$, MSE = 525.93, $p > .05$, (Greenhouse-

Geisser). Also, the interaction between Task and Priming Condition was not significant, $F_1(3,138) = .63$, $p > .05$; $F_2(3,45) = .44$, $MSE = 257.80$, $p > .05$.

The overall error rate in the word reading task was 0.3%. Therefore, only the errors in the picture naming task were analyzed. They showed that the main effect of Priming Condition was significant by participants but not by items $F_1(3,69) = 2.84$, $MSE = .268$, $p = .044$, $\eta^2 = .11$; $F_2(1,20) = 1.69$, $MSE = 1.53$, $p > .05$, (Greenhouse-Geisser). Planned comparisons of the participants data revealed that significantly fewer errors were made in the Identical condition relative to the Control condition $[t_1(23) = 2.84$, $p = .009]$. However, there was no significant difference in the error scores between the Feature and Unrelated conditions; $p > .05$. Pairwise comparisons (Bonferroni adjusted) showed that there was no difference in the error scores between the Identical and Feature, Identical and Unrelated, Feature and Control as well as the Unrelated and Control conditions; all $ps > .05$.

5.4.4. Discussion

The latency data from Experiment 6 showed that neither word reading nor picture naming were affected by the priming conditions employed. The error scores revealed that fewer errors were made in the word reading task compared to the picture naming task. This was consistent with the error data from all the other experiments. However, contrary to the previous experiments a main effect of priming condition was found in the picture naming task. This effect was significant by participants but not by items. The

participants' error data revealed that significantly fewer errors were made in the Identical condition relative to the Control condition which suggested that at least in this task the final segment of non-word primes had some effect on the picture naming process. These findings along with the results from Experiments 4 and 5 were evaluated in more detail in the general discussion that follows.

5.5. General discussion

Experiments 4, 5 and 6 employed the masked priming paradigm to assess word reading and picture naming when phonemic feature similarity in the coda position of primes and targets was manipulated. However, the outcomes from these experiments were less consistent than those obtained from Experiments 1, 2 and 3 that were designed to assess the effects of phonemic feature overlap in the onset position of these stimuli. In Experiment 4 it was found that when primed by single segment coda primes, both words and pictures were named significantly faster in the Identical condition compared to the Feature and Control conditions. They were also named faster in the Identical condition relative to the Unrelated condition although this difference in naming performance was not statistically significant. In contrast, the masked presentation of word primes in Experiment 5 inhibited the naming process of these two target types with this finding significant in both the Identical and Feature conditions compared to the Control condition. However, even though naming performance was numerically very similar in the Unrelated condition compared to the Identical condition, the slower

naming of targets in the Unrelated condition relative to the Control condition was not significant. Further, in Experiment 5, the observed interference was largest of all when word primes and both word and picture targets shared all but one of their phonemic features (Feature condition). Finally, the latency data from Experiment 6 showed null effects from non-word primes on both target types.

The error scores obtained from Experiments 4 and 5 were consistent with those of Experiments 1, 2 and 3 in that more errors were made in picture naming compared to word reading with the error scores for both tasks unaffected by the priming conditions employed. In Experiment 6 more errors were again made in the picture naming task. This time though and in contrast to the other experiments, significantly fewer errors were made in the Identical condition in which non-word primes and picture targets were related in the coda position relative to the Control condition that consisted of percentage signs. This suggested that at least in the picture naming task of Experiment 6 the final segment of non-word primes had some effect on picture naming. However, it was unclear why this effect was only found with non-word primes related in the coda position and not with any of the other prime types.

The word reading results from Experiments 4 and 6 were both consistent with the notion that in the masked priming of word targets observed effects with non-lexical primes (i.e., single segment and non-word) are due to effects occurring at the non-lexical route that as described earlier operates in a serial rightward manner. Consequently, in the absence of mismatching initial segments/phonemes between primes and word targets facilitation from shared single segment coda primes (Identical condition) was found in Experiment 4. The same argument can also be used to explain

why the presence of mismatching initial segments/phonemes between non-word primes and word targets caused any possible benefits from shared codas (Identical condition) to be simply lost in Experiment 6. Hence, null effects were reported from that experiment. In contrast however, the outcomes from Experiment 5 showed that word primes interfered with the word reading process with this interference appearing to be largest of all when the codas of these two stimuli shared all but one of their phonemic features (Feature condition). These results were contrary to the word reading data from Experiment 2 and thus incompatible with the earlier presented argument that in this paradigm effects found in word reading with the employment of lexical (word) primes are due to the workings of the lexical route. Given that in this route the processing of a given input takes place in parallel across its word-form and that the word reading results from Experiment 2 showed facilitation when all and also all but one of the phonemic features were shared in the onset position of word primes and word targets (Identical and Feature conditions, respectively), it was anticipated that the word reading outcomes from Experiment 5 would reveal similar effects to those in Experiment 2. However, this was not the case. Whilst in both experiments effects from phonemic features were observed (Identical & Feature conditions), at this point it was unclear why word primes in which phonemic feature similarity in the onset position of primes and targets was manipulated resulted in facilitating the naming of word targets whereas word primes in which this manipulation took place in the coda position interfered with the word reading process. Further enquiry was thus required to clarify this issue.

The experimental manipulation of phonemic feature similarity in the end/coda position of primes and picture targets revealed that matching single segment coda primes (Identical condition) facilitated picture naming in Experiment 4 whilst word primes

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interfered with this task (Identical, Feature and Unrelated conditions) in Experiment 5. Further and akin to the earlier experiments (Experiments 1 to 3), the observed interference was largest when all but one of the phonemic features between the codas of word primes and picture targets were shared (Feature condition - Experiments 4 & 5). As such, the results for picture naming from Experiments 4 and 5 can also be accounted for with reference to the architecture incorporated into Dell's (1986) model. As discussed previously, within this model the phonemes corresponding to a given input are activated in parallel and this parallelism thus explains the consistency of results between experiments across each prime type (i.e., Experiment 1 versus Experiment 4, Experiment 2 versus Experiment 5). However, the latency data from Experiment 6 showed null effects from non-word primes on picture naming even though as indicated by the error scores, fewer errors were made in the Identical condition in which the codas of these two stimuli shared the same phoneme. The picture naming data from Experiment 6 were therefore wholly inconsistent with that of Experiment 3 that also employed non-word primes. Consequently, it was unclear why in Experiment 3 non-word primes inhibited picture naming whereas in Experiment 6 they only affected the error scores and had no observable effect on the latency data. The findings from Experiment 6 were thus contrary to all the earlier reported picture naming results (Experiments 1 to 5) and were therefore difficult to explain with reference to Dell's (1986) model. As such, they required further detailed investigation. To this aim and to address the discrepancies observed in the word reading task (Experiment 2 versus Experiment 5), it was decided to employ the masked sandwich priming paradigm (e.g., Lupker & Davis, 2009) in Experiments 7 and 8 to attempt to provide an explanation for the inconsistencies in the data collected so far that are discussed above. The exact

motivation for using the masked sandwich priming paradigm is explained in the Introduction to the following chapter.

CHAPTER 6: Masked sandwich priming effects when manipulating phonemic feature similarity in the initial and end/coda segment positions of non-word primes with both word and picture targets

6.1. Introduction

The final two experiments of this thesis (Experiments 7 and 8) employed the masked sandwich priming paradigm (e.g., Lupker and Davis, 2009). In this paradigm the target itself is displayed (in word form) as an initial prime prior to the presentation of the main prime (e.g., belt-bude-BELT). As discussed in the previous chapter, the majority of the word reading data collected so far was consistent with the dual-route theoretical framework (e.g., DRC, Coltheart et al., 2001) and suggested that in masked priming, effects observed with non-lexical primes (i.e., single segment and non-word primes) occur during processing via the non-lexical route whereas effects found with lexical primes (i.e., word primes) reflect processes that take place through the lexical route. However, contrary to this theoretical framework the outcomes from Experiments 2 and 5 suggested (as argued by Lukatela et al., 2001) that within the lexical route the processing of words is driven by phonemic features. As such, in Experiments 2 and 5 effects were observed with both complete featural overlap and also when all but one of the phonemic features between the corresponding phonemes of word primes and word targets (Identical and Feature conditions) were shared. Nonetheless, at this point it was

unclear why in Experiment 2 the observed effects were facilitating in nature whereas interference was found in Experiment 5. Prior to conducting Experiment 5 it was anticipated that due to the parallel activation of phonemes within the lexical route, observed effects would be consistent across these two experiments regardless of the position of the phoneme within a word-form (onset versus coda position) that was exposed to the experimental manipulation. Consequently, Experiments 7 and 8 were conducted to attempt to tease apart the reasons for this discrepancy in naming performance by directly engaging the lexical route for the subsequent processing of word targets through the use of the masked sandwich priming paradigm. When using this paradigm for word reading, the brief display of the actual target as an initial prime should result in the full engagement of the lexical route because this prime is in itself a lexical item. Given that the subsequent presentation of the non-word main prime and word target occur rapidly thereafter, the prior engagement of the lexical route following the presentation of the initial prime should then force the processing of the main prime and word target through this activated lexical route. As such, effects observed with non-word primes in this masked sandwich priming paradigm should reflect processes occurring at the lexical route and thus have the potential to provide an explanation for the observed discrepancies between the word reading data from Experiment 2 and that of Experiment 5.

The picture naming outcomes reported in Chapters 4 and 5 were consistent with the working assumptions of Dell's (1986) model which incorporates the parallel activation of phonemes corresponding to a given monosyllabic input during the phonological encoding process. That was why regardless of their position within a word-form (onset versus coda position), matching single segment primes (Identical condition) facilitated

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picture naming in Experiments 1 and 4 whereas the presence of mismatching phonemes between both word and non-word primes (Identical, Feature and Unrelated conditions) inhibited this process in Experiments 2, 3 and 5. However, the picture naming results from Experiment 6 that examined coda position manipulations showed null effects from non-word primes. These outcomes were thus contrary to those of Experiment 3 in which non-word primes were also used and therefore could not be accounted for with reference to Dell's (1986) model. Consequently, in Experiments 7 and 8 for picture naming it was decided to employ the masked sandwich priming paradigm to firstly assess if the data collected could provide an explanation for the observed discrepancy between the results from Experiment 3 and those of Experiment 6 and secondly, to more directly test the nature of the interference between both word and non-word primes and picture targets reported in Experiments 2, 3 and 5. Given the likelihood that this interference was due to competition for selection from the mismatching phonemes between the corresponding phonemes of primes and targets, it was logical to assume that the presentation of the actual target prior to the display of a non-word prime should result in the pre-activation of the picture target's phonemes. This pre-activation of the entire set of the target's phonemes should therefore largely reduce if not eliminate the competition between the mismatching phonemes that was observed using the traditional masked priming paradigm. This in turn should then allow for any benefits from the shared phonemes between the main prime and target (Identical condition) to be found. Finally, by varying the degree of featural overlap between respective phonemes, this experimental manipulation might provide further insight into why in Experiments 1 to 5 there was a trend towards the largest interference of all occurring in the Feature condition in which the onsets of primes and picture targets shared all but one of their phonemic features.

In Experiments 7 and 8 therefore, the non-word primes along with the word and picture targets from Experiments 3 and 6 (respectively) were used in the masked sandwich priming paradigm. As such, Experiment 7 examined manipulations in the onset position between primes and targets whilst Experiment 8 examined similar manipulations in the coda position. For word reading, this was done to ascertain whether by forcing the engagement of the lexical route thus reflecting processes occurring through that route it would be possible to tease out an explanation for why facilitation was observed with word primes in Experiment 2 whereas in Experiment 5 these primes interfered with the word reading process. For picture naming, the brief presentation of the actual target in this paradigm should result in the pre-activation of the picture target's phonemes which in turn should allow for any facilitating effects from matching phonemes (and/or features) between a main prime and its target to be fully expressed.

6.2. Experiment 7 - Manipulation of phonemic feature overlap in the onset segment position of non-word primes with both word and picture targets

6.2.1. Introduction

Experiment 7 was designed as a follow up to the masked priming study of Experiment 3 in which the initial segment position of non-word primes and both word and picture

targets was manipulated. Whilst Experiment 7 used exactly the same stimuli as Experiment 3, it contrasted in that it employed the masked sandwich priming paradigm (e.g., Lupker & Davis, 2009) for the experimental manipulation. In line with Experiment 3 the non-word primes were presented in four priming conditions namely, Identical (e.g., belt – bude – BELT), Feature (e.g., belt – pude – BELT), Unrelated (e.g., belt – jude – BELT) and Control (e.g., belt - %%%% -BELT).

With regards to the word reading task and as discussed earlier, the brief display of the actual target as an initial prime was expected to fully engage the lexical route which should then force the processing of both the main prime and word target through this activated route. As such, any masked sandwich priming effects observed with non-word primes in this experiment should therefore reflect processes occurring within the lexical route rather than at the non-lexical route that appeared to be the locus for the observed effects in Experiment 3. Given that in the Control condition the initial prime was the name of the actual word target whereas the main prime consisted purely of percentage signs, the pre-activation of target's name following the presentation of the first prime along with the absence of any additional activations after the display of the second prime was expected to facilitate reading responses in the Control condition. However, in the other three conditions (i.e., Identical, Feature and Unrelated) in which the main prime was a non-word, the activations resulting from the mismatching segments of this prime was expected to introduce noise into the system. Consequently, it was predicted that response latencies to word targets would be faster in the Control condition compared to all other conditions. Further, if the findings from Experiment 2 were correct, specifically that at the lexical route masked priming effects are due to a shared featural environment and are therefore positively correlated with the degree of

phonemic feature overlap between the onsets of primes and targets, by forcing the processing of all stimuli via the lexical route it was predicted that word targets would also be read faster in the Identical condition relative to both the Feature and Unrelated conditions as well as in the Feature condition compared to the Unrelated condition.

Akin to word reading, it was anticipated that picture targets would be named significantly faster in the Control condition relative to the Identical, Feature and Unrelated conditions. This is because consistent with Dell's (1986) model, the presentation of a target's name as an initial prime should pre-activate all the phonemes corresponding to the picture target's phonemes and there should be no additional activity resulting from the display of the main prime that consisted of percentage signs. However, whilst the presentation of the initial prime in the Identical, Feature and Unrelated conditions should again result in the pre-activation of the target's phonemes that could potentially reduce the intensity of competition between the mismatching phonemes of the main prime and picture target, it was difficult to predict at this point whether there would be observable effects due to shared onsets (Identical condition) or shared phonemic features in the onset position (Identical and Feature conditions) between the main primes and their targets.

6.2.2. Method

6.2.2.1. Participants

Forty-eight participants took part in this experiment. Their mean age was 24.08 and ranged from 18 to 44 years.

6.2.2.2. Design

The design was identical to that used in Experiment 3.

6.2.2.3. Stimuli

The word and picture targets as well as the non-word primes were exactly the same as those employed in Experiment 3.

6.2.2.4. Procedure

In this experiment the masked sandwich priming paradigm was employed. As such, the procedure corresponded to that described for this paradigm in Chapter 3.

Post experimental interviews revealed that fifteen participants (seven in word reading and eight in picture naming) noticed seeing something before the presentation of the targets. Further, some of those who were aware of the presence of primes reported seeing words whereas others thought that they could see a row of letters.

6.2.3. Results

A total of 1.4% error (0.4% technical errors + 1.0% errors) and 4.7 % trimmed data were removed from the latency analyses. Further, the data from one participant (in the word reading task) was removed from the analyses due to an experimental error. Finally, the data from four participants (one in word reading and three in picture naming) consisted of outliers. However, since the pattern of observed results remained the same in the analyses both with and without outliers, the former are reported herein. Mean naming latencies, standard deviations, percentage errors and mean priming effects for both word reading and picture naming in all four priming conditions are displayed in Table 13.

Table 13

Mean Naming Latencies (RT, in Milliseconds), Standard Deviations (SD), Percentage

Errors (%E) and Mean Priming Effects (PE, in Milliseconds) for both word reading and

picture naming in all four priming conditions for Experiment 7.

	Task							
	Word reading				Picture naming			
Priming condition (example)	RT	SD	%E	PE	RT	SD	%E	PE
Identical (belt-bude-BELT)	472.52	43.37	0.2	-9	582.33	52.84	1.6	-29
Feature (belt-pude-BELT)	484.52	43.84	0.6	-21	596.23	49.89	2.0	-42
Unrelated (belt-jude-BELT)	489.81	39.89	0.4	-26	601.16	49.89	2.2	-47
Control (belt-%%%-BELT)	463.40	45.97	0.0		553.75	55.53	0.6	

Note. The above means (RT) and standard deviations (SD) are based on the analysis by participants; PE – refers to comparisons to the Control condition as in Schiller's (2004, 2008) research.

For naming latency, the main effect of Task was significant, $F1(1,45) = 59.86$, MSE = 8786.30, $p < .001$, $\eta^2 = .57$; $F2(1,35) = 904.49$, MSE = 905.09, $p < .001$, $\eta^2 = .96$, as was the main effect of Priming Condition, $F1(3,135) = 88.37$, MSE = 143.93, $p < .001$, $\eta^2 = .66$; $F2(2,84) = 72.53$, MSE = 350.91, $p < .001$, $\eta^2 = .67$ (Greenhouse-Geisser). The interaction between the two was also significant, $F1(3,135) = 8.71$, $p < .001$, $\eta^2 = .16$; $F2(3,105) = 8.13$, MSE = 234.23, $p < .001$, $\eta^2 = .19$.

Separate analyses of Task showed that in the word reading task there was a significant main effect of Priming Condition, $F1(3,66) = 34.00$, MSE = 95.72, $p < .001$, $\eta^2 = .61$; $F2(3,105) = 33.83$, MSE = 160.21, $p < .001$, $\eta^2 = .49$. Planned comparisons showed that response latencies were significantly faster in the Control condition compared to the Identical condition [$t1(22) = 3.38$, $p = .003$; $t2(35) = 3.45$, $p < .001$]. They were also

faster in the Feature condition relative to the Unrelated condition [t1(22) = 2.51, p = .020; t2(35) = 1.48, p > .05] however, this effect was significant only by participants but not by items. Pairwise comparisons (Bonferroni adjusted) revealed that response latencies were significantly faster in the Control condition compared to both the Feature [t1(22) = 21.12, p < .001; t2(35) = 22.45, p < .001] and Unrelated [t1(22) = 26.41, p < .001; t2(35) = 26.77, p < .001] conditions. They were also faster in the Identical condition relative to both the Feature [t1(22) = 12.01, p < .001; t2(35) = 13.22, p < .001] and Unrelated [t1(22) = 17.29, p < .001; t2(35) = 17.54, p < .001] conditions.

There was also a significant main effect of Priming Condition in the picture naming task, F1(3,69) = 57.25, MSE = 190.04, p < .001, η^2 = .71; F2(3,105) = 47.51, MSE = 355.13, p < .001, η^2 = .58. Planned comparisons showed that response latencies were significantly faster in the Control condition compared to the Identical condition [t1(23) = 7.16, p < .001; t2(35) = 5.35, p < .001]. However, there was no significant difference in the response latencies between the Feature and Unrelated conditions, both ps > .05. Pairwise comparisons (Bonferroni adjusted) revealed that response latencies were significantly faster in the Control condition relative to both the Feature [t1(23) = 42.48, p < .001; t2(35) = 44.04, p < .001] and Unrelated [t1(23) = 47.40, p < .001; t2(35) = 47.49, p < .001] conditions. They were also faster in the Identical condition relative to both the Feature [t1(23) = 13.91, p = .003; t2(35) = 15.74, p < .001] and Unrelated [t1(23) = 18.83, p < .001; t2(35) = 19.19, p < .001] conditions.

The overall error rate in the word reading task was 0.3%. Therefore, only the errors in the picture naming task were analysed. They showed a significant main effect of Priming Condition, F1(2,51) = 3.29, MSE = .661, p = .041, η^2 = .13 (Greenhouse-

Geisser); $F_2(3,105) = 2.97$, MSE = .358, p = .035, η^2 = .08. Planned comparisons revealed that less errors were made in the Control condition relative to the Identical condition [$t_1(23) = 2.84$, p = .009; $t_2(35) = 1.66$, p > .05] although this effect was only significant by participants but not by items. There was however, no significant difference in error scores between the Feature and Unrelated conditions, both ps > .05. Pairwise comparisons (Bonferroni adjusted) showed that significantly fewer errors were made in the Control condition relative to the Unrelated condition [$t_1(23) = .58$, p = .021; $t_2(35) = .39$, p > .05]; with this effect again significant only by participants but not by items. Finally, there was no significant difference in the error scores between the Control and Feature, Identical and Feature as well as the Identical and Unrelated conditions; all ps > .05.

6.2.4. Discussion

The results from Experiment 7 demonstrated an interaction between Task and Priming Condition. Due to this interaction the data for word reading and picture naming were analysed separately. These analyses revealed that word targets were read significantly faster in the Control condition relative to all other conditions (i.e., Identical, Feature and Unrelated). They were also read significantly faster in the Identical condition compared to both the Feature and Unrelated conditions. Response latencies were also shorter in the Feature condition relative to the Unrelated condition. However, this difference was significant only by participants but not by items. The picture naming data showed

similar effects to those found in word reading except that the magnitude of the differences in naming latencies between the Control condition and all other conditions (i.e., Identical, Feature and Unrelated) was larger in this task compared to word reading. Additionally and in contrast to word reading, there was no significant difference in response latencies to picture targets between the Feature and Unrelated conditions. It is this contrast that can thus account for the significant interaction found between these two tasks. Finally, akin to the previous experiments fewer errors were made in word reading compared to picture naming. The analysis of the error scores from the picture naming task showed that more errors were made in the Identical, Feature and Unrelated conditions relative to the Control condition. However, the difference between the Control and the Feature conditions was not significant whereas the differences between the Control condition and both the Identical and Unrelated conditions were significant by participants but not by items.

As predicted, the results from Experiment 7 showed that the naming of both word and picture targets was significantly faster in the Control condition relative to all other conditions (i.e., Identical, Feature and Unrelated conditions). In the Control condition the display of the actual target's name as an initial prime was followed by the brief presentation of percentage signs as the main prime (e.g., belt - %%%% - BELT) whereas in the other three conditions the main prime consisted of a non-word in which phonemic feature similarity in the onset position of both the non-word prime and its target was manipulated (e.g., belt-jude-BELT – Unrelated condition). It could therefore be concluded that consistent with the arguments presented earlier for word reading, the display of the target's name as the initial prime engaged the lexical route and thus resulted in the pre-activation of the actual word target at that route. Given that in the

Control condition the word target was already pre-activated and further, that there were no additional activations within the system resulting from the presentation of the main prime that consisted of percentage signs, target naming thus required less time compared to all other conditions in which the display of both lexical and non-lexical primes might have induced noise into the system that needed to be resolved prior to target naming.

During the picture naming task and in line with Dell's (1986) model, the presentation of target's name as the initial prime resulted in the pre-activation (in parallel) of all the picture target's phonemes at the phoneme level. This, combined with the absence of any additional activations in the Control condition following the display of percentage signs as the main prime meant faster target naming in that condition relative to the other conditions in which the second prime was a non-word. This is because in the Identical, Feature and Unrelated conditions the mismatching phonemes activated by non-word primes would have competed for selection with the corresponding picture target's phonemes and thus either reduced or possibly even eliminated any facilitating effects that were introduced by the initial prime. This also explains why for the picture naming task, fewer errors were made in the Control condition compared to all other conditions.

Further, the word reading data from Experiment 7 also revealed that word targets were read significantly faster in the Identical condition relative to both the Feature and Unrelated conditions. They were also read significantly faster in the Feature condition compared to the Unrelated condition. In contrast to Experiment 3, this latter observation thus showed phonemic feature effects and was therefore consistent with the predictions for this experiment and also with the results of Experiment 2 that used word primes.

Since in Experiments 3 and 7 the same stimuli were employed with the only difference being that in Experiment 7 the actual target was displayed as an initial prime prior to the presentation of the non-word prime, it could be concluded that in Experiment 7 the brief presentation of the target as an initial prime did in fact engage the lexical route and thus the observations reflected effects occurring at that route. Consequently, the word reading data from Experiment 7 provided further empirical support for the argument presented in the previous two chapters that in the traditional masked priming paradigm, effects on word targets from non-lexical primes (i.e., single segment and non-word primes) are due to processes taking place through the non-lexical route whereas those with lexical primes (i.e., word primes) occur at the lexical route.

Similarly to the word reading task, picture targets in Experiment 7 were named significantly faster in the Identical condition relative to both the Feature and Unrelated conditions. However, even though naming latencies were faster in the Feature condition compared to the Unrelated condition, unlike with word reading the difference between these two conditions was not significant. This contrasted with the outcomes from Experiment 3 in which non-word primes in the Identical, Feature and Unrelated conditions interfered with the picture naming process with this interference being largest of all when the onsets of primes and targets shared all but one of their phonemic features (Feature condition). However, this discrepancy between the results from Experiments 3 and 7 can still be accommodated within the workings of Dell's (1986) model and can be explained as follows. After the display of the target's name as the initial prime during picture naming in Experiment 7 the phonemes corresponding to the picture target's phonemes were activated (in parallel) at the phoneme level and remained active within the system. Then the non-word prime was presented. Since in

both the Feature and Unrelated conditions all of the phonemes corresponding to this prime differed to the relevant picture target's phonemes, they competed for selection with the target's phonemes. The same was true for the Identical condition in which except for the onset position that was common for each of the initial prime, main prime and the target, the remaining phonemes of the non-word prime differed to and thus competed with the relevant picture target's phonemes for selection. However, in the onset position in the Identical condition the non-word prime's phoneme would have been pre-activated following the display of the initial prime. This pre-activation then acted to reinforced the facilitating effects from the shared segment in this position between the non-word prime and the target itself, with the result of clear facilitation in the Identical condition relative to both the Feature and Unrelated conditions.

In Experiment 3 and as discussed earlier, an almost fully shared featural environment between the initial phoneme of a prime and picture target induced the greatest amount of competition within the system with the result that naming latencies were slowest of all in the Feature condition. However, this finding was not replicated in Experiment 7 where if anything there was a trend towards faster target naming in the Feature condition compared to the Unrelated condition. This discrepancy in results can be explained with reference to differences in the paradigms employed. Specifically, in the Feature condition of Experiment 7 the picture target's onset was already pre-activated as a consequence of the presentation of the initial prime. Referring to Dell's (1986) model, the bi-directional connections between the phoneme and feature levels would then have to apply to both the representations of the initial prime and non-word prime and also to the representations of the non-word prime and picture target. For the Feature condition therefore, in the onset position feedback between the pre-activated phoneme

and features of the initial prime (i.e., the target's phoneme and features) and the non-word prime together with feedback between the non-word prime and the target itself appeared to act to eliminate the presence of additional interference from featural similarity that was found in the same condition in Experiment 3. It may even be that the combination of feedback between the activated phonemes and features in the initial segment position of the three separate stimuli that are presented during the masked sandwich priming paradigm results in reducing the level of competition within the system when the degree of featural overlap between the main prime and target is increased. If so, this would account for the trend towards faster target naming in the Feature condition compared to the Unrelated condition in Experiment 7 that was suggested by the data.

Finally, even though the picture naming results from Experiment 7 seemed to be compatible with the working assumptions of Dell's (1986) model and also that the word reading data from this experiment appeared to be in line with the dual-route theoretical framework (e.g., Coltheart et al., 2001), it is important to note that there was a substantial difference between the Control condition in Experiment 7 and those employed in the other experiments. In this condition of Experiment 7 the actual target's name was presented as the initial prime prior to the display of percentage signs as the main prime. However, in all the previous experiments the Control prime was simply a string of percentage signs. As such, it was difficult to ascertain whether in both tasks the above reported masked sandwich priming effects were representative of facilitation or whether they were simply due to less interference occurring in both the Identical and Feature conditions compared to the Unrelated condition. Consequently, for the final masked sandwich priming experiment that completed the experimental work undertaken

within this thesis it was decided to modify the Control condition to be one that was more consistent with Experiments 1 to 6.

6.3. Experiment 8 – Manipulation of phonemic feature overlap in the coda segment position of non-word primes with both word and picture targets

6.3.1. Introduction

As discussed in the introduction to this chapter, Experiment 8 was conducted as a follow up to Experiment 6 that examined manipulations in the coda position of non-word primes and targets. Consequently, the masked sandwich priming procedure (e.g., Lupker and Davis, 2009) was employed in conjunction with the same non-word primes and both the word and picture targets from Experiment 6. As mentioned in the previous section, the display of the target's name as the initial prime in the Control condition of Experiment 7 had disadvantages. Specifically, based on the data collected from this experiment it was not possible to draw firm conclusions as to whether the observed effects for each task in the Identical and Feature conditions were due to facilitation from shared onsets and/or their phonemic features or whether they were simply a reflection of less interference within the system resulting from the presentation of these primes

compared to the primes used in the Unrelated condition. As such, in order to produce neutral effects in the Control condition to ascertain more directly whether the observed effects were facilitating or inhibiting a decision was made for this condition in Experiment 8 to be changed to one that was similar to those employed in Experiments 1 to 6.   Consequently, in the Control condition of Experiment 8 the initial prime consisted of a row of '&' symbols rather than the target name itself whilst the main prime remained unchanged as a row of percentage signs.   In line with the previous experiments therefore, in Experiment 8 there were four priming conditions namely, Identical (e.g., bat – zut –BAT), Feature (e.g., bat – zud – BAT), Unrelated (e.g., bat – zun – BAT) and Control (e.g., &&& - %%% - BAT).

As discussed, the word reading data from Experiment 7 was consistent with the argument presented earlier that in masked sandwich priming the brief display of the actual target as an initial prime fully engages the lexical route and thus reflects effects that occur at that route. That was why the results of Experiment 7 echoed those from Experiment 2 that employed word primes and showed phonemic feature effects in the onset position of non-word primes and word targets (Feature versus Unrelated conditions) even though the main prime was a non-lexical item.   As such, it was anticipated that the same would also be true in Experiment 8 in which the non-word primes and word targets from Experiment 6 were used in the masked sandwich priming paradigm. However, given that the observed effects in Experiment 2 were facilitating in nature (and most probably in Experiment 7 too) whereas in Experiment 5 these effects were interpreted as interference, it was difficult to predict whether the word reading results from Experiment 8 would be consistent with the former or the latter findings. Either way, it was expected that the word reading data collected from Experiment 8

should provide an explanation for this discrepancy and thus contribute greatly to the discussion.

Regarding the picture naming results from Experiment 7, it was argued that these outcomes were compatible with the working assumptions of Dell's (1986) model and that was why picture targets were named significantly faster in the Control condition relative to all other conditions as well as in the Identical condition compared to both the Feature and Unrelated conditions. It was also suggested that the combination of feedback between the activated phonemes and features in the initial segment position of the three separate stimuli presented during masked sandwich priming appears to act in a way that reduces the level of competition within the system when the degree of featural overlap between the main prime and target is increased. This explanation would account for the trend towards faster target naming in the Feature condition compared to the Unrelated condition in Experiment 7 that was contrary to the outcome between those conditions in Experiment 3. Importantly however, the picture naming data from Experiment 6 could not be accounted for with reference to Dell's (1986) model in that this data showed null effects from coda position manipulations. Consequently, it remained to be seen whether the employment of the same non-word primes and picture targets from that experiment within the masked sandwich priming paradigm would yield effects.

6.3.2. Method

6.3.2.1. Participants

Forty-eight participants took part in this experiment. Their mean age was 22.75 and ranged from 18 to 45 years.

6.3.2.2. Design

The design was identical to that used in Experiment 6.

6.3.2.3. Stimuli

The word and picture targets as well as the non-word primes were exactly the same as those employed in Experiment 6.

6.3.2.4. Procedure

The procedure was exactly the same as that used in Experiment 7. Post experimental interviews revealed that sixteen participants (nine in word reading and seven in picture naming) noticed seeing something before the presentation of the targets. Further, some of those who were aware of the presence of primes reported seeing the actual target's name whereas others thought that they could see either words or a row of letters.

6.3.3. Results

A total of 2.4% error (0.6% technical errors + 1.8% errors) and 5.4 % trimmed data were removed from the latency analyses. Further, the data from one participant (in the picture naming task) consisted of outliers. However, since the pattern of observed results remained the same in the analyses both with and without outliers, the former are reported herein. Mean naming latencies, standard deviations, percentage errors and mean priming effects for both word reading and picture naming in all four priming conditions are displayed in Table 14.

Table 14

Mean Naming Latencies (RT, in Milliseconds), Standard Deviations (SD), Percentage
Errors (%E) and Mean Priming Effects (PE, in Milliseconds) for both word reading and
picture naming in all four priming conditions for Experiment 8.

	Task							
	Word reading				Picture naming			
Priming condition (example)	RT	SD	%E	PE	RT	SD	%E	PE
Identical (bat-zut-BAT)	486.86	43.77	0.3	-10	613.61	66.74	3.6	-11
Feature (bat-zud-BAT)	488.16	39.33	0.0	-11	614.09	66.41	3.1	-12
Unrelated (bat-zun-BAT)	489.80	41.02	0.8	-13	618.87	55.60	2.9	-17
Control (&&&-%%%-BAT)	476.97	38.96	0.5		602.21	44.89	3.4	

Note. The above means (RT) and standard deviations (SD) are based on the analysis by participants; PE –
refers to comparisons to the Control condition as in Schiller's (2004, 2008) research.

For naming latency, the main effect of Task was significant, $F1(1,46) = 80.96$, MSE =
9524.18, $p < .001$, $\eta^2 = .64$; $F2(1,15) = 274.95$, MSE = 1918.65, $p < .001$, $\eta^2 = .95$, as
was the main effect of Priming Condition, $F1(3,138) = 7.44$, MSE = 264.12, $p < .001$, η^2
$= .14$; $F2(3,45) = 8.98$, MSE = 158.54, $p = .001$, $\eta^2 = .37$. The interaction between Task
and Priming Condition was not significant, $F1(3,138) = .13$, $p > .05$; $F2(3,45) = .14$,
MSE = 313.33, $p > .05$. Planned comparisons showed that relative to the Control
condition response latencies were significantly longer in the Identical condition [$t1(47)$
$= 3.04$, $p = .004$; $t2(15) = 3.23$, $p = .006$]. However, there was no significant difference
in the response latencies between the Feature and Unrelated conditions; both $ps > .05$.
Pairwise comparisons (Bonferroni adjusted) showed that relative to the Control
condition response latencies were significantly longer in both the Feature [$t1(47) =$

11.53, p = .033; t2(15) = 12.75, p = .006] and Unrelated [t1(47) = 14.74, p < .001; t2(15) = 14.96, p = .003] conditions. There was however, no significant difference in the response latencies between the Identical and Feature as well as the Identical and Unrelated conditions; all ps > .05.

The overall error rate in the word reading task was 0.4%. Therefore, only the errors in the picture naming task were analysed. However, they yielded no significant effects; both ps > .05.

6.3.4. Discussion

The latency data from Experiment 8 showed that both word and picture targets were named significantly faster in the Control condition compared to all other conditions (i.e., Identical, Feature and Unrelated). No further effects were found. These results were thus inconsistent with those from Experiment 6 that employed the same non-word primes and both word and picture targets. They were however, similar to the findings from Experiment 5 in which word primes were used. Further, akin to the previous experiments more errors were made in picture naming compared to word reading. However, the analyses of the error data from the picture naming task revealed that error scores were unaffected by the priming conditions employed. All of the findings from Experiment 8 are discussed in more detail in the general discussion that follows.

6.4. General discussion

Based on the masked priming data for word reading from Experiments 1 to 6, it was argued that observed effects with non-lexical primes (i.e., single segment and non-word primes) are due to processes occurring through the non-lexical route whereas lexical primes (i.e., word primes) engage the lexical route and thus reflect effects taking place via that route. It was also postulated that at the non-lexical route effects are caused by shared phonemes between primes and targets (Identical condition in Experiments 1, 3, 4, 6) whilst at the lexical route they are driven by a shared featural environment between the relevant phonemes of these two stimuli (Identical and Feature conditions in Experiments 2 and 5). Further, although the first part of this argument was consistent with the dual-route theoretical framework (e.g., Coltheart et al., 2001) the observation of phonemic feature effects was not. This is because according to the dual-route theoretical framework, phonemes at both the lexical and non-lexical routes are represented as abstract entities and therefore not specified for their features. Consequently, it was important to validate these findings. To this aim, in Experiments 7 and 8 the non-word primes and word targets from Experiments 3 and 6 (respectively) were used in the masked sandwich priming paradigm. During this experimental procedure the actual target is presented as an initial (word) prime prior to the display of the main (in this case non-word) prime. The brief display of the target's name as the initial prime was expected to fully engage the lexical route and thus show effects occurring at that route. By so doing, it was anticipated that the word reading data from Experiments 7 and 8 would reveal phonemic feature effects and possibly provide an

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explanation for why these effects were facilitating in Experiment 2 whereas in Experiment 5 interference was observed.

As predicted, the results from Experiment 7 revealed that word targets were read significantly faster in the Identical condition relative to both the Feature and Unrelated conditions as well as in the Feature condition compared to the Unrelated condition. They thus showed phonemic feature effects that were consistent with the data from Experiment 2 that used word primes but were contrary to the outcomes from Experiment 3 that employed the same non-word primes and word targets as Experiment 7. The Control condition of Experiment 7 consisted of the display of the actual target as an initial prime prior to the presentation of percentage signs as the main prime. Given the strong facilitating effects caused by this sequence of prime presentation in the Control condition, it was hard to draw a baseline from which to compare additional effects that occurred in this experiment. As such, it was difficult to know whether the observed effects in both the Identical and Feature conditions compared to the Unrelated condition were representative of facilitation or simply of less interference within the system with those conditions. Nonetheless, a visual inspection of the means in the Identical, Feature and Unrelated conditions across Experiments 7 and 3 revealed that these means were very similar (e.g., 489.81 ms versus 489.41 ms − Unrelated condition in Experiments 7 and 3, respectively). This suggested that akin to Experiment 2, the phonemic feature effects observed in Experiment 7 were facilitating in nature.

In contrast, word targets in Experiment 8 were read significantly slower in the Identical, Feature and Unrelated conditions relative to the Control condition, which in this experiment was designed to provide a more neutral baseline and to be similar to the

controls employed in Experiments 1 to 6 (i.e. &&& - %%% - BAT). These results were again contrary to those from Experiment 6 in which the same non-word primes and word targets were used however, they were consistent with the outcomes from Experiment 5 that employed word primes. As such, the word reading data from both Experiments 7 and 8 provided a direct validation of the argument that in masked priming observed effects during word reading with lexical primes (i.e., word primes) are due to processes occurring at the lexical route. However, it was still unclear why in Experiments 2 and 7 facilitation was found whereas in Experiments 5 and 8 the observed effects were inhibitory in nature.

Even though the picture naming data from Experiments 1 to 5 seemed to be consistent with the working assumptions of Dell's (1986) model, the findings of null effects across all conditions in Experiment 6 were not. This is because in line with the findings from Experiments 2, 3 and 5, it was anticipated that in Experiment 6 the mismatching phonemes activated by the non-word prime would compete for selection with the corresponding phonemes of the picture target resulting in slower target naming in the Identical, Feature and Unrelated conditions relative to Controls. Since the picture naming results from Experiment 6 were inconsistent with those predictions, they somewhat undermined the competing phonemes account for interference in picture naming that was presented in the previous two chapters. Consequently, it was decided to employ the masked sandwich priming paradigm in Experiments 7 and 8 to attempt to tease apart an explanation for this discrepancy in naming performance. Given that in the masked sandwich priming paradigm the picture target's name is displayed as the initial prime prior to the presentation of the main prime, it was anticipated that the employment of this experimental procedure in Experiments 7 and 8 to the non-word

primes and picture targets from Experiments 3 and 6 (respectively) might act to either reduce or even completely eliminate the competitive effects caused by the mismatching phonemes activated by a non-word primes and its target. If so, this should then allow for any resulting benefits from the shared phonemes and/or features between the relevant phonemes of these two stimuli to be observed. The picture naming results from Experiment 7 went some way towards confirming this hypothesis in that picture targets were named significantly faster in the Identical condition relative to both the Feature and Unrelated conditions. They were also suggestive of a trend towards facilitation in the Feature condition compared to the Unrelated condition that was contrary to the finding of Experiment 3 in which there was a trend towards interference between those conditions. This discrepancy in the Feature condition between the two experiments was accounted for with reference to Dell's (1986) model along with the order of stimuli presentation within each paradigm. In traditional masked priming it seems that feedback and hence the level of competition within the system is at its most intense when the phoneme in the onset position of a prime shares all but one of its features with the phoneme in the onset position of a target. However, when three stimuli are presented in quick succession during masked sandwich priming, the bi-directional connections between the phoneme and feature levels incorporated into Dell (1986) have to apply to both the representations of the initial prime and non-word prime and also to the representations of the non-word prime and picture target. It is likely therefore, that the combination of feedback between the activated phonemes and features of these three stimuli (bearing in mind that the first of these stimuli is the printed name of the last) results in reducing the level in the onset position of competition within the system when the degree of featural overlap between the main prime and target is increased.

Further, akin to the word reading task the display of the picture target's name in the Control condition of Experiment 7 meant that it was difficult to conclude whether the observed effects in the Identical condition was due to facilitation or just less interference within the system in that condition relative to the Feature and Unrelated conditions. Nonetheless, given the finding in Experiment 7 of a significant difference in the response latencies between the Identical and both the Feature and Unrelated conditions, it could be suggested that the brief display of the target's name as the initial prime did in fact result in the pre-activation of the target's phonemes. This in turn likely acted to reduce the interfering effects caused by the mismatching phonemes activated by the non-word prime and the corresponding phonemes of the picture target allowing for the benefits from the shared phoneme in the onset position between the main prime and target (Identical condition) to be observed.

Further, although the picture naming outcomes from Experiment 7 were in line with the predictions for this experiment, the results from Experiment 8 were not. In Experiment 8 picture targets were named significantly slower in each of the Identical, Feature and Unrelated conditions compared to the Control condition (e.g., &&& - %%% - BAT). This was after the Control condition was amended from that employed in Experiment 7 to one that was more like the Control conditions used in the earlier experiments (e.g., %%% - BAT - in Experiment 6). Similarly to Experiment 8, the results for picture naming from Experiment 6 showed effects that were also inconsistent with the preceding experiments. Importantly, because Experiment 8 used the same non-word primes and picture targets as Experiment 6, it could be concluded that the outcomes from both Experiments 6 and 8 were subject to additional effects caused by the stimuli employed.

All in all, the word reading results from Experiments 7 and 8 were in line with those for the corresponding task in Experiments 2 and 5 respectively and thus confirmed the argument presented within this thesis that in word reading, masked priming effects with lexical primes (i.e., word primes) are due to processes occurring at the lexical route. However, it was still unclear why facilitating effects were found in Experiments 2 and 7 whereas in Experiments 5 and 8 the observed effects were inhibitory in nature. Further, although the picture naming data from Experiment 7 were consistent with the working assumptions of Dell's (1986) model, the outcomes from Experiment 8 were not. Given that in the latter experiment the non-word primes and picture targets from Experiment 6 were used, and also that the data from Experiment 6 was again inconsistent with Dell's (1986) model, it could be postulated that these differences were due to some specific aspects of the stimuli employed. All of the discrepancies discussed above are addressed fully in the following concluding chapter of this thesis.

CHAPTER 7: Aims revisited, summary of findings, future directions and conclusions

7.1. Chapter outline

The main purpose of this thesis was to answer the question: 'Are there shared phonological encoding mechanisms for both word reading and picture naming?' This chapter begins with a short review of the key literature that provided inspiration and motivation for conducting the experimental work undertaken to attempt to answer the above question. This is followed by a brief summary of the data that was collected from Experiments 1 to 8. The word reading results from Experiments 1 to 8 are then considered at length with reference to the dual-route theoretical framework (e.g., DRC; Coltheart et al., 2001) after which the outcomes for picture naming are discussed in relation to the working assumptions of Dell's (1986) general language production model. Next, the likelihood that shared phonological encoding mechanisms exist for these two target types is examined and suggestions are made as to how this research could be expanded upon in the future.

7.2. Aims revisited

The purpose of the herein reported research was to investigate phonological encoding mechanisms for both word reading and picture naming. This experimental work was inspired by the form-preparation study conducted by Roelofs (2004) who found that

relative to corresponding heterogeneous sets the naming of both words and pictures was facilitated in begin-homogeneous sets (e.g., bok, boor, bel versus roos, bok, kam) but not in end-homogeneous sets (e.g., rat, krat, vat versus peer, rat, clip). Based on these results Roelofs (2004) argued that phonological encoding processes for both word reading and picture naming operate in a serial rightward manner consistent with the working assumptions of WEAVER's (e.g., Roelofs, 1997a) segment-to-frame association process. Given his finding of similar outcomes when he mixed both words and pictures within the same sets, Roelofs (2004) concluded that phonological encoding mechanisms might be shared for the two tasks and proposed a possible merging of models of general language production such as WEAVER (e.g., Roelofs, 1997a) with word reading models such as DRC (Coltheart et al., 2001) at the segment-to-frame association stage. Additionally, Roelofs (1999) observed preparation benefits when pictures were presented for naming in sets that fully shared their onsets (e.g., bami, bajes, balie) but not when onsets shared all but one of their phonemic features (e.g., bajes, bami, paling). He thus concluded that the findings from that study were also consistent with WEAVER's (e.g., Roelofs, 1997a) segment-to-frame association process because during this process in WEAVER (e.g., Roelofs, 1997a) phonemes are represented as abstract entities and therefore not specified for their features. Consequently and as illustrated by Roleofs' (1999, 2004) data, preparation benefits can only be observed when the items within a given set fully share their onsets.

In separate masked priming research that was designed to investigate the locus of the MOPE for word reading Kinoshita (2000; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007) accounted for her results with reference to the DRC (Coltheart et al., 2001) model. She postulated that the MOPE occurs after the emergence of word's

representation from either the lexical or non-lexical route and results from rightward processing during segment-to-frame association in a manner similar to that incorporated into WEAVER (e.g., Roelofs, 1997a). As such, her conclusions were fully compatible with Roelofs' (2004) assertions of shared encoding mechanisms for both word reading and picture naming.

However, in masked priming research conducted by Lukatela et al. (2001), it was found that participants' lexical decisions were faster when the onsets of non-word primes and word targets shared all but one of their phonemic features (e.g., zea-SEA) compared to when these onsets differed by at least two phonemic features (e.g., vea-SEA). These phonemic feature effects for words were therefore incompatible with the working assumptions of WEAVER's (e.g., Roelofs, 1997a) segment-to-frame association process according to which, phonemic feature effects should not be observed. They were also contrary to the findings of null effects from featural similarity for picture naming from Roelofs' (1999) and as such, they were suggestive of differences in phonological encoding mechanisms for both word reading and picture naming. Additional difficulties for the notion of shared encoding mechanisms were introduced by the findings of Schiller's (2004, 2008) two masked priming studies that reported contrasting results for word reading and picture naming. Schiller (2004, 2008) observed that compared to controls (e.g., %%%%%%%%% - BANAAN), word reading was facilitated by the brief presentation of word primes related in the onset position with targets (e.g., %%balans%% - BANAAN - Schiller, 2004) whereas interference was found in the same condition for picture naming (e.g., %beroep% - BANAAN - Schiller, 2008). These outcomes were again suggestive of separate phonological encoding processes and did not fit with Roelofs' (2004) results that showed similar preparation

benefits across the two tasks. Consequently, the discrepancy between Roelofs' (2004) and Schiller's (2004, 2008) studies along with the findings of phonemic feature effects for words (Lukatela et al., 2001) but not for pictures (Roelofs, 1999) needed to be addressed. To this aim, it was decided to employ the masked priming paradigm in the research work undertaken as part of this thesis to conduct a detailed examination of the role of phonemic features in each task and by so doing, to determine with more confidence the existence or not of shared phonological encoding mechanisms for both word reading and picture naming.

7.3. Summary of findings

7.3.1. Experiments 1 to 3

Experiments 1 to 3 were designed to evaluate masked priming effects when manipulating phonemic features in the onset (initial) segment position between primes and both monosyllabic word and corresponding picture targets. In each experiment the same four priming conditions were used. These were the Identical condition in which a prime and target shared their initial segment, the Feature condition where the initial segment of both prime and target shared all their features but voicing, the Unrelated condition in which the initial segment of a prime and target differed by at least two phonemic features and finally, the Control that consisted of percentage signs. For the

target word or picture 'BELT' in Experiment 1 for example, these priming conditions were thus 'b%%%', 'p%%%', 'j%%%' and '%%%%' respectively. The main difference between these experiments related to the type of prime employed. In Experiment 1 the primes were single segment onset primes, Experiment 2 used word primes and Experiment 3 employed non-word primes.

The word reading data from Experiments 1 to 3 revealed that word targets were named faster when primes and targets shared their onset (Identical condition). In Experiment 1 this effect was significant relative to both the Feature and Control conditions whereas in Experiments 2 and 3 it was significant compared to all three conditions (i.e., Feature, Unrelated and Control). An additional observation was that word targets were read significantly faster in the Feature condition compared to the Unrelated condition. However, this phonemic feature effect was only found when word primes (Experiment 2) were employed and not with either single segment onset (Experiment 1) or non-word (Experiment 3) primes. Akin to the word reading task, picture naming was also facilitated by the brief presentation of matching single segment onset primes (Identical condition in Experiment 1) with this effect significant relative to both the Feature and Control conditions. However, compared to the Control condition the naming of picture targets was significantly slower when targets were primed by both word (Experiment 2) and non-word (Experiment 3) primes. Further, with both prime types this inhibitory effect was largest of all in the Feature condition in which the initial segment of both prime and target shared all their phonemic features but voicing.

7.3.2. Experiments 4 to 6

The aim of Experiments 4 to 6 was to examine masked priming effects when manipulating phonemic features in the coda (end) segment position. In keeping with the earlier experiments, monosyllabic word and corresponding picture targets were presented for naming in four priming conditions namely, Identical, Feature, Unrelated and Control. These priming conditions were designed in a similar manner to those in Experiments 1 to 3 with the only difference being that phonemic feature similarity was manipulated in the coda segment position. Also, in line with the earlier experiments, this research employed single segment (Experiment 4), word (Experiment 5) and non-word (Experiment 6) primes.

The data from Experiments 4 to 6 showed a similar pattern of results for both word reading and picture naming. In Experiment 4 it was found that relative to the Feature, Unrelated and Control conditions both target types were named significantly faster in the Identical condition where primes and targets shared their codas. However, in Experiment 5 word primes inhibited both word and picture naming with this effect significant in the Identical and Feature conditions compared to the Control condition. Finally, the latency data from Experiment 6 that employed non-word primes showed null effects for both tasks even though in picture naming fewer errors were made in the Identical condition relative to all other conditions.

7.3.3. Experiments 7 and 8

The final two experiments (Experiments 7 and 8) used the masked sandwich priming paradigm (e.g., Lupker & Davis, 2009). This paradigm is similar to the traditional masked priming procedure except that during masked sandwich priming the target is briefly presented in a written form as an initial prime prior to the presentation of the main prime (e.g., belt – bude - BELT). As such, the display of each target is preceded by the brief presentation of two primes. Experiment 7 employed the same word and picture targets and non-word primes that were used in Experiment 3 whilst the stimuli employed in Experiment 8 were identical to those of Experiment 6.

The results from Experiment 7 showed that both word and picture targets were named significantly faster in the Control condition compared to the Identical, Feature and Unrelated conditions. They were also named significantly faster in the Identical condition relative to both the Feature and Unrelated conditions. However, whilst the data from this experiment showed largely similar effects across tasks, a difference in the pattern of results was that word targets were named significantly faster in the Feature condition compared to the Unrelated condition thus demonstrating a phonemic feature effect. This effect was not observed for picture naming. Finally, as with Experiment 7 the data from Experiment 8 showed that both target types were named significantly faster in the Control condition relative to the Identical, Feature and Unrelated conditions.

However, the control condition of Experiment 8 differed to that used in Experiment 7. In Experiment 7 the Control condition consisted of the target's name presented as the initial prime prior to the display of percentage signs as the main prime. Consequently, it was likely that in this condition of Experiment 7 the activation of the target's phonemes resulting from the display of its name as the initial prime in conjunction with the absence of mismatching phonemes due to the lack of additional activations within the system following the presentation of percentage signs as the main prime allowed for faster target naming in that condition relative to all other conditions. This was because in each of the remaining conditions in which the main prime was a non-word, activations from the mismatching phonemes of the main prime would have induced noise into the system that likely reduced or even eliminated any benefits from the initial prime. This can explain why in the picture naming task of Experiment 7 fewer errors were made in the Control condition compared to the Identical, Feature and Unrelated conditions. As such, the employment of this type of Control made it difficult to draw a baseline from which to compare additional effects that were observed in the other conditions. Consequently, in Experiment 8 the Control condition was amended to be more similar to that employed in the earlier experiments so that it would produce neutral effects. Rather than the display of the target's name therefore, the initial prime in the Control condition of Experiment 8 was changed to a row of '&' signs. An overview of the priming effects observed in the latency data (by participants) in both word reading and picture naming across Experiments 1 to 8 is included in Table 15 that follows.

Table 15

An overview of the priming effects observed in the latency data (by participants) in both word reading and picture naming across Experiments 1 to 8.

	Exp. 1	Exp. 2		Exp. 3		Exp. 4	Exp. 5	Exp. 6	Exp. 7		Exp. 8
Conditions Compared	W * P	W	P	W	P	W * P	W * P	W * P	W	P	W * P
ID v FT	<	<	>	<	>	<	x	x	<	<	x
ID v UN	<	<	>	<	>	<	x	x	<	<	x
ID v CO	<	<	>	<	>	<	>	x	>	>	>
FT v UN	x	<	x	x	x	x	x	x	<	x	x
FT v CO	x	x	x	x	x	x	>	x	>	>	>
UN v CO	x	x	x	x	x	x	>	x	>	>	>

Note. W – word reading; P – picture naming; * - no interaction; ID – Identical condition; FT – Feature condition; UN – Unrelated condition; CO – Control condition; < - named faster in the first condition relative to the second condition; > - named slower in the first condition relative to the second condition; x – no effect.

7.4. The data from Experiments 1 to 8 and phonological encoding.

7.4.1. The word reading data from Experiments 1 to 8 and phonological encoding.

The results from the herein reported research clearly showed that regardless of the type of prime employed (i.e., single segment, word or non-word), the reading of word targets was facilitated when primes and targets shared their onsets (Identical condition in Experiments 1, 2 and 3). Facilitation was also found when the onsets of word primes and word targets shared all but one of their phonemic features (Feature condition in Experiment 2). However, this effect was not found in the same condition with either single segment (Experiment 1) or non-word (Experiment 3) primes. Further, when the same non-word primes and word targets from Experiment 3 were used in the masked sandwich priming paradigm employed in Experiment 7 (in which the word target was presented as an initial prime prior to the display of the non-word prime), facilitating effects from both full (Identical condition) and all but one (Feature condition) phonemic feature overlap between the onsets of non-word primes and word targets were observed.

As discussed in the previous chapters, the data from the above experiments (Experiments 1, 2, 3 and 7) therefore suggest that for single word reading in both masked priming and masked sandwich priming, the nature of the observed effects is dependent on the type of prime employed. It was argued that lexical primes (i.e., word primes) fully engage the lexical route and thus show effects occurring at that route. In contrast, the effects found with non-lexical primes (i.e., single segment and non-word

primes) are due to processes taking place at the non-lexical route. It was also postulated that at the lexical route, any observed effects are due to phonemic feature similarity between the initial phonemes of primes and targets (Identical and Feature conditions in Experiments 2 & 7) whereas at the non-lexical route effects only occur when there is full phonemic feature overlap between the initial phonemes of these two stimuli (Identical condition in Experiments 1 & 3). This argument was validated by the results from Experiment 7 in which the lexical route was experimentally engaged through the employment of the masked sandwich priming paradigm with the non-word primes and word targets from Experiment 3.

However, even though Lukatela et al. (2001) observed phonemic feature similarity effects in their masked priming research that employed non-word primes and at first glance their results appear to be contrary to the argument presented above, a consideration of the task employed by these authors provides a logical explanation for this discrepancy. In Lukatela et al.'s (2001) research participants were engaged in the lexical decision task. They were therefore asked to decide whether a given target was a word or non-word. Since the processes underlying the making of such a decision cannot be accomplished without prior access to lexical knowledge (and therefore, the activation of the lexical route), the nature of the lexical decision task thus automatically engages the lexical route regardless of the type of prime employed. Based on the results from Lukatela et al.'s (2001) research as well as the word reading data from Experiments 1, 2, 3 and 7 it can therefore be concluded that in masked priming the effects observed in the lexical decision task occur during processing at the lexical route and are independent of the type of prime employed whereas in the word reading task in which access to lexical knowledge is not always necessary, effects found with lexical (i.e., word) primes

are due to the workings of the lexical route whilst those observed with non-lexical (i.e., single segment and non-word) primes reflect processes occurring at the non-lexical route.

The notion of two routes of targets' processing (i.e., lexical and non-lexical) during masked priming in word reading is consistent with the dual-route theoretical framework incorporated in the DRC (Coltheart et al., 2001) model. According to this model and as described in Chapter 1, during reading there is a separate yet simultaneous processing of a given input by both the lexical and non-lexical routes. Within the lexical route, each letter/phoneme of an input excites all the words in the system which contain that specific letter/phoneme in that position. This excitatory process takes place in parallel across the input's word form. In contrast to the lexical route, processing within the non-lexical route occurs in a serial rightward manner. As such, on receiving activation from the first letter of an input its corresponding phoneme is activated after which the processing of the second letter of the input begins. This process continues until all the letters of a given input are converted into their corresponding phonemes. The direct mapping of orthography to phonology thus takes place through both routes. However, it must be noted that in DRC as it currently stands, phonemes are not specified for their features in either of these two routes. Finally, the representation that emerges first from either route then enters the phonemic buffer prior to further processing.

It is important to consider how the word reading data from Experiments 1, 2, 3 and 7 contribute to the discussion regarding the locus of the MOPE. As mentioned throughout this thesis, Kinoshita (2000) argued that the MOPE occurs after the processing of a given input through either the lexical or non-lexical routes of the DRC model and takes

place at the phonemic buffer level. She suggested that at this level the information provided by either of these routes is processed in a serial, rightward manner similar to the segment-to-frame association process incorporated into the WEAVER (e.g., Roelofs, 1997a) general language production model. According to Kinoshita (2000), it is at this stage that residual representations of the prime impact on target processing. However, since in DRC both routes share the phonemic buffer level, for this argument to be plausible the nature of the observed effects should be independent of the type of prime employed. Yet, the outcomes from Experiments 2 and 7 that employed lexical (i.e., word) primes showed facilitation from both full (Identical condition) and all but one (Feature condition) phonemic feature similarity between the onsets of primes and targets. In contrast, in Experiments 1 and 3 that employed non-lexical (i.e., single segment and non-word) primes, facilitation was only observed from full (Identical condition) phonemic feature overlap between these two stimuli. Consequently, the word reading results from Experiments 1, 2, 3 and 7 are contrary to Kinoshita's (2000) explanation for the locus of the MOPE. Rather, these results can be accounted for more appropriately by postulating that this effect takes place prior to the phonemic buffer level and occurs during processing through either the lexical or non-lexical route.

Further and as mentioned above, in the DRC (Coltheat et al., 2001) model phonemes are currently represented as abstract entities. They are thus not specified for their phonemic features. To be consistent with the working assumptions of this model therefore, no effects from phonemic feature similarity should have been observed (Feature condition in Experiments 2 and 7). Also, in line with the DRC model it should be assumed that the herein reported facilitation from shared onsets between primes and targets (Identical condition in Experiments 1, 2, 3 and 7) was due to shared abstract phonemes rather than

full phonemic feature overlap. However, according to the DRC model the information that emerges first from either the lexical or non-lexical route is then processed at the phonemic buffer level that is shared by both routes. The presence of a shared phonemic buffer level thus implies consistency of output from either of these routes into the phonemic buffer. Consequently, if at the non-lexical route phonemes are not specified for their features, the same should be true for the lexical route. Yet, the results from Experiments 2 and 7 clearly showed effects due to phonemic feature similarity between the onsets of primes and targets (Feature condition) that can only occur during processing via the lexical route. As such, it is reasonable to postulate that representations that emerge from the lexical route are in fact fully defined for their features prior to entering the phonemic buffer rather than being something that consists of a string of phonemes that themselves are represented as abstract entities. Based on the principle of a shared phonemic buffer therefore, if the output from the lexical route is defined for its features then it must also be the case that phonemes selected via the non-lexical route are also defined for their features. Consequently, using this line of reasoning it can be concluded that the MOPE found in the Identical condition in Experiments 1, 2, 3 and 7 was due to full phonemic feature overlap between the onsets of primes and targets. However, this last point would not be valid if it could be argued that there are separate phonemic buffers for each route. In such a case it might be possible that at the non-lexical route the MOPE is caused by shared abstract phonemes in the onset position between primes and targets whereas at the lexical route this effect results from a shared featural environment between the onsets of these two stimuli.

The results from these experiments also suggest that the nature of the prime plays an important role in determining the route through which word targets are processed during

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the reading of mono-syllabic words in the masked priming paradigm. The finding of lexical effects with lexical primes and non-lexical effects with non-lexical primes suggests that the initial processing of the prime engages one of the two routes through which the target is then processed. Specifically, the engagement of the lexical route caused by the prior presentation of a word (lexical) prime causes target processing to occur via the lexical route. In contrast, single segment and non-word (non-lexical) primes can only be processed via the non-lexical route and the engagement of this route then causes the target to be processed via the same route.

Applying the above argument, the results from Experiments 1, 2, 3 and 7 can be explained in the following manner. After the presentation of the single segment and non-word (non-lexical) primes in Experiments 1 and 3 respectively, target words were then processed via the non-lexical route that according to the DRC model operates in the serial rightward manner. The facilitation observed in the Identical condition was thus caused by the pre-activation of the target's onset that resulted from the presentation of a prime related to the target in the onset position. This in turn meant that word targets were read faster in the Identical condition relative to all other conditions in which the onsets of primes and targets were unrelated. However, as this is a non-lexical process there were no observed effects when the onsets of primes and targets shared all but one of their phonemic features (Feature condition). In Experiment 2, following the display of the word (lexical) prime, target processing took place in parallel via the lexical route. Within this route representations activated by the prime corresponding to the shared featural environment in the initial segment position between a prime and target (both full and all but one feature overlap) facilitated target selection. As such, in Experiment 2 a MOPE was observed in both the Identical and Feature conditions. Even though non-

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word primes were employed in the masked sandwich priming paradigm of Experiment 7, the presentation of the target word (a lexical prime) as the initial prime prior to the presentation of the non-word prime engaged the lexical route and consequently forced the processing of both the main (non-word) prime and target to take place through that route. The result of this was that facilitation was also observed in both the Identical and Feature conditions due to the shared featural environment in the onset position in these conditions.

Additional support for this argument was provided by the word reading data from Experiments 4, 5, 6 and 8. As discussed, these experiments were designed to evaluate effects from phonemic feature similarity in the coda (end) segment/phoneme position of both primes and targets. It was found that full phonemic feature overlap in the coda segment/phoneme position between single segment primes and word targets (Identical condition in Experiment 4) facilitated word reading. However, in Experiment 6 that employed non-word primes, the obtained data showed null effects. In contrast, when in Experiment 8 the stimuli from Experiment 6 were used in the masked sandwich priming paradigm the reading of word targets was inhibited by the brief presentation of non-word primes (Identical, Feature and Unrelated conditions). Similar inhibitory effects were also found in Experiment 5 that employed word primes. This time however, only the effects from full (Identical condition) and all but one (Feature condition) phonemic feature similarity were statistically significant whilst the interference found in the Unrelated condition was not.

The word reading data from Experiments 4, 5, 6 and 8 can also be explained within the amended dual route framework using the arguments presented above. In Experiment 4

that employed single segment coda primes, after the presentation of the prime only the phoneme corresponding to the prime in the coda segment position would have been activated prior to target processing. Consequently, during the processing of a word target there would have been no active phonemes within the system in the initial segment positions to interfere with the serial, rightward activation and then selection of the target's corresponding phonemes, thus allowing for any benefit from the shared coda phoneme between the prime and target (Identical condition) to be observed. However, since only effects from full phonemic feature overlap (Identical condition) can be found at the non-lexical route, consistent with this argument no facilitation from all but one phonemic feature similarity (Feature condition) was obtained in Experiment 4. In Experiment 6 in contrast, the unrelated initial phonemes activated by the brief presentation of the non-word prime likely interfered with the serial, rightward activation and then selection of the word target's initial phonemes. This interference would have meant that by the time the initial phonemes of the target were activated, any facilitation from the shared coda segment/phoneme between a non-word prime and word target (Identical condition) was simply lost. Further, due to the fact that for each target the initial phonemes of the non-word primes were kept constant across conditions (Identical, Feature and Unrelated), it could be assumed that any interference caused by the initial phonemes of the non-word primes was the same in each condition hence, null effects were observed in all three conditions.

Further, as postulated by Coltheart et al. (2001), in the DRC model the processing of a given input via the lexical route takes place in parallel across its word form; with each abstract letter/phoneme of the input simultaneously exciting all the words in the system which contain that specific letter/phoneme in that position. This parallelism thus implies

that within this route any observed effects should be consistent regardless of the position of overlap between the corresponding phonemes of primes and targets. Yet, the word reading results from Experiment 5 that employed word (lexical) primes showed inhibitory effects whereas in Experiments 2 and 7, facilitation from both full (Identical condition) and all but one (Feature condition) phonemic feature similarity was found. Although (as already argued) the outcomes from the latter two experiments strongly suggest that within the lexical route any observed effects are due to phonemic feature similarity between the corresponding phonemes of primes and targets, this does not explain why the word primes in Experiment 5 inhibited the reading of word targets. Further, when in Experiment 8 the same stimuli from Experiment 6 were employed with the masked sandwich priming paradigm, the presentation of the target word (lexical prime) as an initial prime engaged the lexical route meaning that the main (non-word) prime and target processing continued via this route. As such, the same processes that affected naming performance in Experiment 5 caused similar inhibiting effects in Experiment 8 with interference observed across all three conditions (i.e., Identical, Feature and Unrelated conditions). Given that the results from Experiment 8 provided a direct validation of the findings from Experiment 5, the interference observed in both experiments seems to be a reliable finding and thus required an explanation. To account for this interference it could be suggested that within the lexical route, representations that arise from the shared coda segment between a prime and target are insufficient to aid the target selection process. In contrast, the representations that arise from the earlier mismatching segments between these two stimuli compete for selection and therefore interfere with target processing resulting in the observed interference. However, this explanation automatically assigns a more important role to the initial segment position and by so doing undermines one of the principle assumptions of the workings of the

lexical route within the DRC (Coltheart et al., 2001) model that phonemes corresponding to a given input are activated in parallel.

A possible compromise that could be applied to the assumption of parallel activation within the lexical route is that whilst activations do occur in parallel across a monosyllabic word-form, it is plausible that the onset is activated as a separate unit whilst both the vowel and coda (that together constitute the rhyme) are processed together and are therefore activated as a second separate unit. This would then provide a feasible explanation for the interference observed in Experiments 5 and 8. In these experiments phonemic feature similarity in the coda position of primes and targets was manipulated whilst the vowels of primes (i.e., the primes in Experiment 5 and the main primes in Experiment 8) differed to those of the targets. By considering the rhyme as a separate and discrete unit in itself therefore, the rhymes of the primes in each of the Identical, Feature and Unrelated conditions were thus mismatched with the rhymes of the targets even though the phonemes in the coda position were shared in the Identical condition and shared all but one of their features in the Feature condition. As such, the mismatched rhymes introduced noise into the system that resulted in a similar level of interference being observed in all conditions relative to Controls. By way of contrast, in Experiments 2 and 7 the phonemic feature manipulation occurred in the onset position that as argued in this amended lexical route, would be activated in parallel as its own separate and discrete unit. Consequently, in these two experiments the shared featural environment in the onset position facilitated word reading in both the Identical and Feature conditions. However, this argument of parallel yet separate processing of the onset and rhyme within the lexical route still needs to be empirically tested.

Taken together, the word reading results from Experiments 1 – 8 showed that in the naming of monosyllabic word targets using both the masked priming and masked sandwich priming paradigms, the construction of phonology for a given input appears to depend on the type of prime used. Specifically, the presentation of lexical primes seemed to direct processing through the lexical route whereas non-lexical primes caused this process to occur via the non-lexical route. These findings were thus consistent with the working assumptions of the DRC (Coltheart et al., 2001) model. The key difference in the observed effects involved the role of phonemic feature similarity. The engagement of the lexical route led to effects due to phonemic feature similarity between the corresponding phonemes of primes and targets whereas when processing took place through the non-lexical route, only effects from shared phonemes between the corresponding phonemes of these two stimuli could be found. Importantly, the findings of effects due to phonemic feature similarity are fully in line with those reported by Lukatela et al. (2001). They are however, contrary to the strict workings of the DRC (Coltheart et al., 2001) model as it currently stands in which at each route phonemes are not specified for their features. Finally, the results from Experiments 2 and 7 along with those from Experiments 5 and 8 suggest that at the lexical route the nature of the observed masked priming effects depends on the position of the phoneme exposed to the experimental manipulation, with phonemic feature manipulation in the onset position of primes and targets facilitating word reading (Identical and Feature conditions in Experiments 2 & 7) whereas a similar manipulation in the coda position of these two stimuli caused interference (Identical, Feature and Unrelated conditions in Experiments 5 & 8). This discrepancy of effects was explained by arguing that it is possible that at the lexical route there is a parallel yet separate activation of the onset and rhyme. However, this hypothesis still needs to be tested.

7.4.2. The picture naming data from Experiments 1 to 8 and phonological encoding.

Akin to word reading, Experiments 1, 2, 3 and 7 of the picture naming research were designed to evaluate effects from phonemic feature similarity in the onset position of primes and targets. They showed that matching single segment primes facilitated picture naming (Identical condition in Experiment 1) however, the brief presentation of word primes in Experiment 2 caused interference (Identical, Feature and Unrelated conditions). Further, this interfering effect was largest of all when the onsets of primes and targets shared all but one of their phonemic features (Feature condition).

The outcomes from Experiment 2 were suggestive of interference during the lemma selection process (Schiller, 2008). It was argued earlier that the presentation of a word prime activated the prime's lemma which then competed and thus interfered with the activation and selection of the picture target's lemma. To test this theory, non-word primes were employed with the same picture stimuli in Experiment 3. Since non-word primes do not have lemmas, no specific lemma should in theory be activated following their display. It was therefore postulated that the employment of non-word primes should eliminate any lemma level effects that might have occurred during Experiment 2 thus allowing for effects from the later (i.e. phonological encoding) level to be fully expressed. Consequently, it was predicted that akin to the data from Experiment 1, the results from Experiment 3 should show facilitation from shared onsets between primes and targets (Identical condition). However, the results from Experiment 3 were similar to those from Experiment 2 with interference observed from non-word primes on the

naming of picture targets in all conditions. This effect was again largest of all in the Feature condition. Since a trend towards larger interference in the Feature condition was observed in both Experiments 2 and 3, these findings should not be dismissed.

The most likely interpretation of these observations of interference in Experiments 2 and 3 was therefore that these effects occurred during phonological encoding and were due to competition for selection between the mismatching phonemes of a prime and its target (Schiller, 2008). The validity of this argument was evaluated in Experiment 7 in which the stimuli from Experiment 3 were used in the masked sandwich priming paradigm. In this paradigm the written name of the picture target is displayed as an initial prime prior to the presentation of the main prime. As such, it was hypothesized that the pre-activation of all of the target's phonemes by the initial prime should reduce/eliminate any interference caused by the mismatching phonemes of the main prime allowing for any facilitating effects from shared phonemes and/or features to be fully expressed. The data from Experiment 7 confirmed this hypothesis.

As explained in the general discussion to Chapter 4, the picture naming results from Experiments 2 and 3 were inconsistent with some of the working assumptions of the WEAVER (e.g., Roelofs, 1997a) general language production model. According to this model, the phonological encoding stage begins with the activation of both the abstract phonemes corresponding to a given input and its metrical structure that refers to the number of syllables and stress pattern across the input. Next, the activated abstract phonemes are inserted into the metrical structure in a process referred to as segment-to-frame association. In WEAVER (e.g., Roelofs, 1997a), the segment-to-frame association process starts with the first phoneme of an input and continues until all the

phonemes of that input have been inserted into the structure. A further rule of this model is that for each input the segment-to-frame association process has to start from the beginning. Therefore, whilst it is possible to observe a preparation benefit (e.g., Roelofs, 2004) if there are matching phonemes in the initial segment/s position, the model does not allow for interference caused by a mismatch between the corresponding phonemes of primes and targets in any segment position. Also, within the architecture incorporated into WEAVER (e.g., Roelofs, 1997a) phonemes are not specified for their phonemic features during the phonological encoding stage. As such, there should be no effects from phonemic feature similarity (Feature condition) between the corresponding phonemes of primes and targets. However, the results from Experiments 2 and 3 clearly showed interference from both word and non-word primes on the naming of picture targets that was largest of all in the Feature condition in which the onsets of primes and targets shared all but one of their phonemic features. Consequently, the data from these two experiments cannot be accounted for with reference to WEAVER (e.g., Roelofs, 1997a).

However, the outcomes from Experiments 2 and 3 are in line with the working assumptions of Dell's (1986) general language production model. As discussed in Chapter 1, this model assumes that during the phonological encoding of a monosyllabic morpheme (the smallest unit of meaning in a word e.g., BELT), the syllable corresponding to the morpheme is activated and assigned current node status. Next the syllable's phonemes are activated whilst at the same time a syllable frame is created. This is followed by the activation of the features corresponding to these phonemes. Further, according to Dell's (1986) model there are bi-directional connections between each of these processing levels which means that the activation at one level directly

influences and is influenced by the activations at both the level directly above and below it. Consequently and as argued by Roelofs (1999), due to the backward spreading of activation from features to segments in Dell (1986), a segment such as /p/ will receive feedback from all but one of the features of the target segment /b/ and thus /p/ will compete for selection along with the target segment /b/. However, a segment such as /j/ shares fewer features with the target segment /b/ compared to /p/ and hence will receive less feedback from that segment resulting in a reduced level of competition between /j/ and /b/.

Additionally, in Dell's (1986) model only the activation levels of selected phonemes are set back to zero whereas the activation levels of unselected phonemes are left to decay over time. Since during masked priming no verbal response to a prime is required, it could thus be inferred that in this paradigm the phonemes activated by the prime are not selected and thus remain active within the system whilst the phonemes of a given target are being processed. By applying the principles underlying the workings of Dell's (1986) model, the masked priming effects observed in the picture naming task in Experiments 2 and 3 could therefore be explained in the following manner. In Experiments 2 and 3 phonemic feature similarity in the onset position of a prime and target was manipulated whilst the remaining phonemes of the prime were kept constant across each of the Identical, Feature and Unrelated conditions. Aside from the onset position, these remaining phonemes were all different to the corresponding phonemes of the target (e.g., prime - bude; target – BELT – Identical condition in Experiment 3) As such, following the brief presentation of a word or non-word prime the phonemes corresponding to the prime for each syllable/word position were activated and remained active within the system before decaying over time. Consequently, when a picture target

was then displayed for naming all the mismatching phonemes activated by the prime competed with the target's phonemes for selection with this competition taking time to resolve. This explanation can thus account for why in Experiments 2 and 3 picture targets were named significantly slower in all conditions compared to the Control condition that consisted purely of percentage signs (e.g., %%%%) with this interference being independent of whether or not a prime and target shared their onset (Identical condition).

Furthermore, the largest interference of all was observed in the Feature condition and this can also be explained using the working assumptions of Dell's (1986) model. It could therefore be argued that during picture naming the phonemes activated by the picture target's phonemes activated their corresponding features, which in turn caused feedback to the features of the other phonemes within the system. According to Dell (1986), this feedback increases in line with the number of shared features between competing phonemes and is therefore at its greatest when all but one of the corresponding features are shared, such as was the case in the Feature condition between a prime and target pair (e.g., pude – BELT). In this example therefore, the initial phoneme /p/ of the prime would have received stronger feedback from the features of the target's initial phoneme /b/ compared to the initial phoneme /j/ of the corresponding prime in the Unrelated condition (e.g., jude – BELT) that shared fewer features with the target. The phoneme /p/ in the Feature condition would thus have competed more strongly for selection compared to the phoneme /j/ in the Unrelated condition and it is this increased level of competition for selection between the phonemes /p/ and /b/ that resulted in the largest interference of all occurring in the Feature condition.

In contrast, for the Identical condition (e.g., bude - BELT) where all the features of the initial phoneme of both the prime and target were the same, feedback between the features of these like for like phonemes would have acted to facilitate the selection of the target phoneme /b/. In the absence of other mismatching phonemes from other segment positions, this would also mean that full phonemic feature overlap in the onset position of primes and targets should have facilitated the picture naming process. This perspective was supported by the fact that facilitation was found in the Identical condition in Experiment 1 in which picture targets were primed by related single segment onsets primes. It was also validated by the data from Experiment 7 in which, as argued earlier, the presentation of the target's written name as an initial prime prior to the display of the non-word prime reduced the interfering effect from the mismatching phonemes between the main prime and picture target. Consequently, in Experiment 7 facilitation from shared onsets (Identical condition) between primes and targets was found.

However, in Experiment 7 there was also a trend towards facilitation in the Feature condition relative to the Unrelated condition. This effect was again accounted for with reference to Dell's (1986) model by arguing that it was caused by the interaction between the three stimuli presented during the masked sandwich priming procedure. Specifically, it was postulated that in the Feature condition of Experiment 7 the picture target's onset was already pre-activated as a consequence of the presentation of the initial prime. The bi-directional connections between the phoneme and feature levels would then have to apply to both the representations of the initial prime and non-word prime and also to the representations of the non-word prime and picture target. For the

Feature condition therefore, in the onset position feedback between the pre-activated phoneme and features of the initial prime (i.e., the target's phoneme and features) and the non-word prime together with feedback between the non-word prime and the target itself appeared to act to eliminate the presence of additional interference from featural similarity that was found in the same condition in Experiment 3. It may even be that the combination of feedback between the activated phonemes and features in the initial segment position of the three separate stimuli that are presented during the masked sandwich priming paradigm results in reducing the level of competition within the system when the degree of featural overlap between the main prime and target is increased. If so, this would account for the trend towards faster target naming in the Feature condition compared to the Unrelated condition in Experiment 7 that was suggested by the data.

However, a working assumption of Dell's (1986) model is that at each level the processing of a monosyllabic input occurs in parallel across that input. Based on this assumption therefore, it was hypothesized that the results from Experiments 4, 5, 6 and 8 that were designed to evaluate effects from phonemic feature similarity in the end/coda phoneme position should be similar to the outcomes from the corresponding Experiments 1, 2, 3 and 7. Whilst the results demonstrated that this was true for Experiments 4 and 5, it was however, not the case for Experiments 6 and 8. As reported, akin to the data from Experiment 1, the results from Experiment 4 showed facilitation from matching single segment coda primes (Identical condition). Also, in line with the outcomes from Experiment 2 word primes inhibited the naming of picture targets (Identical, Feature and Unrelated conditions) in Experiment 5.

However, although non-word primes interfered with picture naming in Experiment 3, the employment of non-word primes in Experiment 6 yielded null effects in the latency data whilst the error scores showed that fewer errors were made in the Identical condition relative to all other conditions. It could therefore be assumed that the results from that experiment might have reflected some speed-accuracy trade-off. Further, the data using the masked sandwich priming paradigm from Experiment 8 showed inhibitory effects in the Identical, Feature and Unrelated conditions whereas facilitation was observed in Experiment 7 from shared phonemes between primes and targets in the onset position (Identical condition). Since the same stimuli were used in both Experiments 6 and 8 and also that it was the results from these two experiments that were inconsistent with the findings from each of the other experiments that comprised this research, it might be that these two particular outcomes reflected some additional effects caused by the specific stimuli employed in Experiments 6 and 8. Perhaps, these results might have been influenced by the choice of either/both primes and/or targets. Addressing these anomalies in future research could therefore provide further insight into the phonological encoding process of a picture name.

To sum up, the picture naming data from Experiments 1, 2, 3, 4, 5 and 7 were consistent with the working assumptions of Dell's (1986) general language production model. They thus provide evidence to suggest that the phonological encoding process that occurs during picture naming takes place in parallel across the word form. As such, regardless of the position of overlap, shared phonemes between the corresponding phonemes of primes and targets facilitated picture naming. Additionally, any mismatching phonemes activated by the brief presentation of a prime interfered with the activation/selection process of the corresponding target's phonemes; with this

interference being largest of all when these phonemes shared all but one of their phonemic features (Feature condition, Experiments 1, 2, 3, 4, 5 and 7). However, the picture naming results from Experiments 6 and 8 were inconsistent with this theoretical framework and might have been reflective of some additional effects caused by the stimuli choice that requires further investigation.

7.5. The notion of shared phonological encoding mechanisms for both word reading and picture naming

The results from the research undertaken in this thesis were strongly suggestive of phonemic features being involved during the phonological encoding process that takes place in picture naming. Additionally, the findings for word reading were accounted for with reference to the DRC (Coltheart et al., 2001) model and showed that the observations with lexical primes (i.e., word primes) appear to be due to processes occurring at the lexical route, with these effects resulting from a shared featural environment between primes and targets. Given that picture naming is a task that can only be accomplished with lexical access, it is therefore plausible that a processing route akin to the lexical route of the DRC (Coltheart et al., 2001) model might be shared for both word reading (with lexical primes) and picture naming with phonological encoding occurring through this route during the two tasks. If so, this would eliminate the need for separate storage in the mental lexicon for each domain. However, the picture naming data from Experiments 1 to 8 were in large part consistent with the

working assumptions of Dell's (1986) model. Consequently, for the above to be true it would have to be argued that the lexical route operates in a manner similar to that incorporated in this model. This in turn would have to account for the word reading results observed with lexical primes (Experiments 2, 5, 7 & 8) and explain why some of these outcomes differed to those reported in the picture naming task (Experiment 2). Before attempting to do so, it is important to note that word reading is a much faster process to accomplish than picture naming. As such, these discrepancies might be due to the speed of processing during each task. Specifically, because in Dell's (1986) model there are bi-directional connections between the syllable, phoneme and feature levels, it is possible that these differences reflect the degree of feedback between these levels that might vary according to the speed taken to accomplish the task employed.

Consider the data from Experiment 5 that manipulated phonemic feature similarity in the coda position of word primes and targets. These results showed that the brief presentation of word primes interfered with the naming of both word and picture targets. As discussed, the interference in the picture naming task was accounted for by arguing that that this effect was caused by competition for selection between the mismatching phonemes activated by the primes and the corresponding phonemes of their targets. Since similar interference was observed in word reading, the same account to explain that interference can easily be extended to word reading. Further, competition for selection can also explain the outcomes from Experiment 7. In this experiment the two target types were named significantly faster in the Identical condition relative to both the Feature and Unrelated conditions. It was postulated that in Experiment 7 the display of the target's name as the initial prime reduced the competitive effects from the mismatching phonemes between the main prime and the target, thus allowing

facilitation from the shared phonemes between these two stimuli to be observed. However, the results from Experiment 7 also showed that word reading was significantly faster in the Feature condition compared to the Unrelated condition whereas in picture naming there was only a trend towards facilitation between the same conditions. The fact that this effect was significant in word reading but not in picture naming might therefore be due to word reading being a faster task to accomplish than picture naming. For pictures, this slower processing might have allowed the activated representations of the target's name that resulted from the display of the initial prime to have somewhat decayed before target processing. Hence, in picture naming it was only possible to observe a trend towards facilitation between the Feature and Unrelated conditions.

Even though the word reading data from Experiment 8 was consistent with that for the corresponding task in Experiment 5 and showed interference from primes on word reading, the former findings cannot be accounted for with reference to Dell's (1986) model. This is because in line with the outcomes from Experiment 7, the display of the target's name as the initial prime should have reduced the competitive effects caused by the mismatching phonemes activated by the main prime and its target and thus should have allowed for the facilitating effects from the shared phonemes between these two stimuli to be observed. However, because this did not happen and since similar results to word reading were also observed in picture naming in Experiment 8, it was argued that the inapplicability of these findings to the working assumptions of Dell's (1986) model might be due the to stimuli choice for that experiment. If so, this would also explain why the picture naming outcomes from Experiment 6 that employed the same non-word primes and targets as Experiment 8 were also incompatible with this model.

Finally, the results from Experiment 2 showed contrasting effects across the two tasks with facilitation observed in word reading and interference found in picture naming. Although the latter results were consistent with the workings of Dell' s (1986) model, the facilitation found in both the Identical and Feature conditions in the word reading task was not. Further, because the observation of a MOPE in word reading is a widely accepted phenomenon, these results cannot be easily dismissed and thus imply that the word reading outcomes from Experiment 2 are reliable. However, these particular results are clearly not compatible with the workings of Dell's (1986) model. This in turn suggests that if both words and pictures are processed via a lexical route akin to that incorporated in this model, then there might be differences in how phonology is constructed for each target type through such a route. One such difference could be that although in both tasks there is a parallel activation of phonemes corresponding to a given input, it might be that in picture naming each phoneme is activated separately whereas in word reading the onset is activated as one unit whilst the rhyme (vowel and coda) is activated as another separate and discrete unit. This possibility thus requires further investigation to ascertain which, if any of the working assumptions of Dell's (1986) model might be shared between both word reading and picture naming.

7.6. Future research

The previous section explored the notion of shared phonological encoding mechanisms for both word reading and picture naming that was the main focus of the experimental work undertaken in this thesis. It was suggested that due to picture naming being a task that can only be accomplished via lexical access and also because in word reading effects observed with lexical primes (i.e., word primes) are thought to result from processes occurring at the lexical route of a dual-route framework such as that incorporated in the DRC (Coltheat et al., 2001) model, it might be possible that a single lexical processing route is thus shared for both tasks. This suggestion seemed logical for the following two reasons. Firstly, it would eliminate the need for separate lexical storage for each domain. Secondly, most of the picture naming and word reading (with word primes) data in fact showed consistent results across the two tasks with phonemic feature effects observed with both target types. Importantly, the interpretation of these results suggested that phonemic feature effects are reflective of lexical route processing.

However, given that the majority of the picture naming results were consistent with Dell's (1986) model, for a single shared lexical route to be operative it would have to be argued that processing through such a route operates in the manner similar to that model. Consequently, the word reading outcomes with word primes (Experiments 2, 5, 7, 8) would also have to be accounted for with reference to Dell's (1986) model. This was possible for the word reading data from Experiments 5, 7 and 8 but not from Experiment 2. In the latter experiment word reading was significantly faster in the Identical condition relative to the Feature, Unrelated and Control conditions as well as

in the Feature condition compared to the Unrelated condition. These particular results were thus contrary to those for picture naming in Experiment 2 and were therefore incompatible with the workings of Dell's (1986) model. This is because according to Dell's (1986) model the mismatching phonemes activated by word primes should compete for selection with the corresponding targets' phonemes resulting in longer target naming in the Identical, Feature and Unrelated conditions relative to the Control condition in which the primes consisted of percentage signs. The discrepancy between the word reading and picture naming outcomes from Experiment 2 thus suggested that there might be differences in how phonology is constructed for each task. One possible difference might be that even though there is a parallel activation of phonemes corresponding to a given input in both domains, there may well be a variation in how these phonemes are activated. Specifically, it may be that in word reading the onset is activated as one unit whereas the rhyme (vowel and coda together) may be activated as a separate and discrete unit. In pictures, it may be that each phoneme is activated separately. If confirmed, this would mean that the interference observed in word reading in Experiments 5 and 8 was due to the rhyme being processed as a single unit that resulted in competition for selection between the mismatching rhymes of primes and the corresponding rhymes of word targets even though the codas of these stimuli shared their phonemic features in both the Identical and Feature conditions. However, this argument still needs to be empirically tested.

One possible line of inquiry could be to manipulate phonemic feature similarity in the coda position of rhyme primes with both word and picture targets during masked sandwich priming whilst maintaining constancy in the vowel position between primes and targets. Based on the arguments presented herein, the display of the target's name

as the initial prime in word reading should force the processing of the rhyme prime (non-lexical prime) and target via the lexical route. If as suggested above, the lexical route is then engaged and the rhyme is activated as a separate and discrete unit, the shared vowel between the main prime and word target would not be expected to interfere with the processing of the coda and should thus allow facilitating effects from shared phonemic features in the coda position (Identical and Feature conditions) to be observed. At the same time, the picture naming results from such a study could provide an explanation for why the masked sandwich priming data for pictures from Experiment 8 that manipulated phonemic feature similarity in the coda position of non-word primes and picture targets was contrary to the predictions for that experiment and therefore incompatible with Dell's (1986) model.

Further, even though the word reading data from Experiment 2 seemed to be inconsistent with the notion of shared phonological encoding mechanisms for both word reading and picture naming and could not be accounted for with reference to Dell's (1986) model, it is still plausible that some aspects of that model might be applicable to word reading. Given that in Dell's (1986) model there are three main processing levels namely, the syllable, the phoneme and the feature levels, research focused on addressing these levels individually during both word reading and picture naming has the potential to reveal which if any of these levels are common for the two tasks and by so doing, provide further valuable insight into phonological encoding mechanisms for each domain.

Finally, the experimental work reported within this thesis was designed to assess phonological encoding mechanisms for both word reading and picture naming. To this

aim monosyllabic words and their corresponding pictures were employed in both the masked priming and masked sandwich priming paradigms. As such, it must be noted that the conclusions reached can only be applied to monosyllabic targets and these two very similar experimental procedures. Consequently, a validation of the herein reported findings using a different experimental paradigm and/or multi-syllabic words and pictures would enhance the applicability of these conclusions more generally to the phonological encoding processes that occur during each task.

7.7. Conclusions

The main purpose of the research reported within this thesis was to evaluate phonological encoding for both word reading and picture naming to assess the validity of Roelofs' (2004) conclusions that encoding mechanisms might be shared for the two tasks. This was conducted with the employment of the masked priming paradigm as well as the masked sandwich priming paradigm and by the manipulation of phonemic feature overlap in both the initial and end segment position of primes and monosyllabic targets. Most current models of general language production such as WEAVER (e.g., Roelofs, 1997a) account for the role of phonemic features once the phonological encoding process has been completed. However, whilst Kinoshita's (2000) re-interpretation of the locus of the MOPE implies an encoding process for word reading that is similar to that incorporated into WEAVER (e.g., Roelofs, 1997a) and by extension to picture naming, Lukatela et al.'s (2001) results suggest that features are

actually involved in the word reading processes. As such, the manipulation of phonemic features was considered the most appropriate way to address both the research question above and also to gain further insight into the precise processes that occur for each task. The results across the set of experiments reported in this thesis were consistent in demonstrating that features are in fact involved in both tasks. Specifically, the results for word reading fit within a revised version of the DRC (Coltheart et al., 2001) model that accounts for the role of phonemic features within the lexical route. In particular, it was shown that word reading was facilitated when all but one of the features in the onset position between a prime and its target were shared. Further, the observed effects from featural similarity were explained with reference to processing at the lexical route and were fully supportive of the findings of Lukatela et al. (2001). The results for picture naming were incompatible with the architecture incorporated into WEAVER (e.g., Roelofs, 1997a) and fit more appropriately within the working assumptions of Dell's (1986) general language production model that involves phonemic features during a phonological encoding process that takes place in parallel across a word form. Addressing the issue of shared phonological encoding mechanisms for both word reading and picture naming, the possibility that these two tasks might be processed via a single lexical route such as that incorporated into the dual-route framework was suggested. From a strategic perspective, this would make sense in that it would eliminate the requirement for separate lexical storage. However, to be so, this lexical route would need to operate in a manner similar to Dell's (1986) model and thus the word reading data with lexical primes would also have to be compatible with that model. This was true for some but not all of the results obtained in the word reading task. Consequently, future research should address this discrepancy whilst also evaluating which if any aspects of Dell's (1986) model might be applicable to both

domains. Such an enquiry could contribute greatly to the current understanding of phonological encoding processes that occur during each task.

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Appendix A – an example of a consent form and participants' instructions

UNIVERSITY OF EAST LONDON

Consent to Participate in an Experimental Programme Involving the Use of Human Participants

Single word reading and object naming:
Phonological encoding in English language production.

I have read the information leaflet relating to the above programme of research in which I have been asked to participate and have been given a copy to keep. The nature and the purposes of the research have been explained to me, and I have had the opportunity to discuss the details and ask questions about this information. I understand what is being proposed and the procedures in which I will be involved have been explained to me.

I understand that my involvement in this study, and particular data from this research, will remain strictly confidential. Only the researcher involved in the study and the project supervisor will have access to the data. It has been explained to me what will happen to the data once the experimental programme has been completed.

I hereby fully and freely consent to participate in the study which has been fully explained to me.

Having given this consent I understand that I have the right to withdraw from the programme at any time without disadvantage to myself and without being obliged to give any reason.

Participant's name (BLOCK CAPITALS): …………………………………...………

Participant's signature: …………………………………...………

Investigator's name: …………………………………...…

Investigator's signature: …………………………………...…

Date: …………………………………...

UNIVERSITY OF EAST LONDON

Stratford Campus

Romford Road

London E15 4LZ

University Research Ethics Committee

If you have any queries regarding the conduct of the programme in which you are being asked to participate please contact the Secretary of the University Research Ethics Committee: Ms D Dada, Administrative Officer for Research, Graduate School, University of East London, Docklands Campus. London E16 2RD (telephone 0208 223 2976, e-mail d.dada@uel.ac.uk)

The Principal Investigator

Anna O'Reilly
University of East London, Stratford Campus
Romfrod Road, London E15 4LZ
(tel: 0208 223 4592, mobile: 07884313384, e-mail a.oreilly@uel.ac.uk)

Consent to Participate in a Research Study

The purpose of this letter is to provide you with the information that you need to consider in deciding whether to participate in this study.

Project Title

Single word reading and object naming:
Phonological encoding in English language production.

Project Description

The purpose of the study is to examine processes involved in single word reading/object naming (the precise details will be provided with each study).

Confidentiality of the Data

All experimental data will be recorded electronically and stored on a compact disc. After completing the experiment, each participant will be provided with a number under which their data will be stored to aid the withdrawal process if any participant decides to withdraw at a later stage. Only the researcher and the researcher's supervisors will have access to the data unless the research findings are published.

Location

This study will be conducted at the University of East London's Stratford campus.

Disclaimer

You are not obliged to take part in this study, and are free to withdraw at any time during the tests. Should you choose to withdraw from the programme you may do so without disadvantage to yourself and without any obligation to give a reason.

I N S T R U C T I O N S

**Single word reading and object naming:
Phonological encoding in English language production.**

Dear Participant

Welcome and thank you for agreeing to take part in this research which has been designed to examine the processes involved in single word reading/ object naming.

The experiment should take less than 30 minutes. During the study you will be asked to name sets of words/ pictures presented to you on a computer screen. Please try to name the words/ pictures as quickly and as accurately as possible while avoiding making unnecessary sounds that could trigger the voice key.

If you make a mistake or fail to recognise a word/ object before the next one is presented, please do not attempt to correct your response. When the next word/ object is presented please continue with the naming process.

If you have any questions or if you are unsure of what is expected of you please do not hesitate to ask the researcher.

Before proceeding with the research please sign the consent form provided.

Please remember that you have the right to withdraw from the study at any time and are NOT required to provide an explanation for doing so. If you decide to withdraw from the study at a later date please contact the researcher Anna O'Reilly on 0208 223 4592, 07884313384 or a.oreilly@uel.ac.uk, providing the number assigned to your data which is…………… to aid in this process.

You are not required to provide any personal details other than your age. Your data will be treated as confidential and will be analysed as part of a larger database.

The researcher will be grateful for any comments you may have regarding this study or its procedures and there will be time allocated after the experiment for doing so.

To find out more about the outcome of the study please contact the researcher Anna O'Reilly in ……………… on the above numbers.

And finally, please retain these instructions for future reference.

Once again, thank you for your time and contribution.

Appendix B – Stimuli used in Experiment 1

Target	Identical	Feature	Unrelated
BELL	b%%%	p%%%	z%%%
BELT	b%%%	p%%%	z%%%
BIRD	b%%%	p%%%	z%%%
BOAT	b%%%	p%%%	z%%%
BONE	b%%%	p%%%	s%%%
BOOT	b%%%	p%%%	s%%%
CAGE	c%%%	g%%%	l%%%
CAKE	c%%%	g%%%	l%%%
CANE	c%%%	g%%%	l%%%
COAT	c%%%	g%%%	l%%%
CORK	c%%%	g%%%	l%%%
CORN	c%%%	g%%%	l%%%
DEER	d%%%	t%%%	v%%%
DESK	d%%%	t%%%	v%%%
DIME	d%%%	t%%%	v%%%
DOLL	d%%%	t%%%	n%%%
DUCK	d%%%	t%%%	v%%%
FORK	f%%%	v%%%	m%%%
GIRL	g%%%	k%%%	m%%%
GOAT	g%%%	k%%%	p%%%
KING	k%%%	g%%%	l%%%
KITE	k%%%	g%%%	l%%%

PIPE	p%%%	b%%%	n%%%
POOL	p%%%	b%%%	n%%%
SAFE	s%%%	z%%%	d%%%
SEAL	s%%%	z%%%	l%%%
SINK	s%%%	z%%%	y%%%
SOCK	s%%%	z%%%	h%%%
TAIL	t%%%	d%%%	y%%%
TANK	t%%%	d%%%	y%%%
TENT	t%%%	d%%%	y%%%
VEST	v%%%	f%%%	t%%%

Appendix C – Stimuli used in Experiment 2

Target	Identical	Feature	Unrelated
BAT	bin	pin	sin
BED	bay	pay	jay
BOX	bee	pee	zee
BUS	bad	pad	sad
CAN	cod	god	sod
CAR	cob	gob	sob
CAT	coo	goo	loo
CUP	cad	gad	lad
DOG	dip	tip	nip
FAN	fie	vie	hie
FOX	fat	vat	mat
GUN	gab	cab	lab
PEN	pug	bug	jug
PIG	par	bar	jar
SAW	sen	zen	hen
SUN	sip	zip	dip
TIE	tab	dab	jab
BELL	buck	puck	suck
BELT	bunk	punk	junk
BIRD	bump	pump	sump
BONE	beat	peat	seat

BOOT	bang	pang	sang
CAKE	cold	gold	sold
DESK	dine	tine	nine
DUCK	dale	tale	vale
FOOT	fine	vine	mine
FORK	fast	vast	mast
GIRL	gore	core	yore
GOAT	gage	cage	sage
KITE	kale	gale	sale
PIPE	pail	bail	sail
SINK	seal	zeal	heal
SOCK	sing	zing	ling
TANK	tune	dune	june
TENT	tame	dame	name
VEST	vile	file	mile

Appendix D – Stimuli used in Experiments 3 & 7

Target	Identical	Feature	Unrelated
BAT	bof	pof	sof
BED	bav	pav	jav
BELL	bive	pive	sive
BELT	bude	pude	jude
BIRD	bazz	pazz	sazz
BONE	beft	peft	seft
BOOT	bife	pife	sife
BOX	bem	pem	zem
BUS	boz	poz	soz
CAKE	coid	goid	soid
CAN	cug	gug	sug
CAR	cuz	guz	suz
CAT	cux	gux	lux
CUP	com	gom	lom
DESK	doop	toop	noop
DOG	dur	tur	nur
DUCK	dabe	tabe	vabe
FAN	fup	vup	hup
FOOT	fige	vige	mige
FORK	fasp	vasp	masp
FOX	fut	vut	mut

GIRL	gobe	cobe	yobe
GOAT	guge	cuge	suge
GUN	gaj	caj	laj
KITE	kaun	gaun	saun
PEN	piv	biv	jiv
PIG	pez	bez	jez
PIPE	parl	barl	sarl
SAW	sev	zev	hev
SINK	salc	zalc	halc
SOCK	sirm	zirm	lirm
SUN	ses	zes	des
TANK	tume	dume	jume
TENT	tilk	dilk	nilk
TIE	tep	dep	jep
VEST	viln	filn	miln

Appendix E – Stimuli used in Experiment 4

Target	Identical	Feature	Unrelated
BAG	%%g	%%k	%%l
BAT	%%t	%%d	%%h
BED	%%d	%%t	%%n
BOOT	%%%t	%%%d	%%%y
BUG	%%g	%%k	%%m
BUS	%%s	%%z	%%v
CAT	%%t	%%d	%%y
CRAB	%%%b	%%%p	%%%n
CUP	%%p	%%b	%%j
DOG	%%g	%%k	%%p
FLAG	%%%g	%%%k	%%%m
FOOT	%%%t	%%%d	%%%h
FROG	%%%g	%%%k	%%%l
GOAT	%%%t	%%%d	%%%n
HAT	%%t	%%d	%%n
HOOF	%%%f	%%%v	%%%r
HOOK	%%%k	%%%g	%%%p
LEAF	%%%f	%%%v	%%%r
LEG	%%g	%%k	%%m
LOG	%%g	%%k	%%p
MAP	%%p	%%b	%%s

MOP	%%p	%%b	%%n
NET	%%t	%%d	%%h
PIG	%%g	%%k	%%m
PLUG	%%%g	%%%k	%%%m
ROAD	%%%d	%%%t	%%%y
ROOF	%%%f	%%%v	%%%h
RUG	%%g	%%k	%%l

Appendix F – Stimuli used in Experiment 5

Target	Identical	Feature	Unrelated
BAG	dog	doc	don
LOG	sag	sac	sap
BED	fad	fat	fan
CUP	rip	rib	rim
TOP	cap	cab	cam
MOP	tap	tab	tan
BAT	cot	cod	con
HAT	kit	kid	kin
NET	pat	pad	pal
BOAT	skit	skid	skin
CRIB	slab	slap	slam
COAT	slit	slid	slim
FOOT	beat	bead	bean
ROAD	quid	quit	quin
HOOK	flak	flag	flap
MAP	nip	nib	nil

Appendix G – Stimuli used in Experiments 6 & 8

Target	Identical	Feature	Unrelated
BAG	vog	voc	vop
LOG	zag	zak	zam
BED	vod	vot	von
CUP	lep	leb	lem
TOP	vap	vab	vam
MOP	lup	lub	lum
BAT	zut	zud	zun
HAT	fot	fod	fon
NET	zat	zad	zal
BOAT	clet	cled	clen
CRIB	fleb	flep	flen
COAT	veet	veed	veen
FOOT	zait	zaid	zain
ROAD	cred	cret	cren
HOOK	zeek	zeeg	zeem
MAP	zop	zob	zol