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SPELLING-SOUND CONSISTENCY EFFECTS
IN DISYLLABIC WORD NAMING

by

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Submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy

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London, Ontario
February 2001

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Abstract

The present study investigates the role of spelling-sound consistency in naming printed disyllabic words. Participants in Experiment 1 named 1000 monomorphemic six-letter disyllabic words. Spelling-sound consistency measures for 11 orthographic segments were used to predict the naming latencies and error rates on the words. The analyses indicated that the orthographic segment containing the first vowel grapheme and its following consonants, without being limited by the phonological syllable boundary, contributed significantly to the prediction of both latencies and errors. This segment corresponds to Taft's (1992) Body-of the BOSS (BOB). In addition, the vowel grapheme in the second syllable of disyllabic words also contributed significantly to the prediction of naming latencies and error rates. In both cases, higher consistency led to faster naming latencies and fewer errors. The effect of spelling-sound consistency of the BOB was replicated in three factorial experiments. In the first two, BOB consistency affected naming latencies even when the consistency of the initial syllable body was matched. In the third experiment, the consistency of the BOB segment affected the naming of both low-frequency and high-frequency disyllabic words. A final factorial experiment replicated the effect of spelling-sound consistency of the second vowel grapheme. The results indicate that spelling-sound consistency has a widespread effect on word recognition, and that the orthography of disyllabic words is not parsed at syllable boundaries. The pronunciation may be computed for the entire word in parallel.

Keywords: Word recognition, Phonology, Phonological processing, Disyllabic, Polysyllabic, Multisyllabic. Consistency

Acknowledgments

There are many people I would like to thank for helping me through the process of completing this dissertation, and my entire Graduate school career. First, of course, I would like to thank my wife Joanne, for her support through this entire endeavour. Without her, you wouldn't be reading this right now. Of course, I must thank my parents, Denis and Gerry, and my brother Ray, for all of their support, not only in the last few years, but my entire life, encouraging me to follow my dreams.

On to the academic influences... my advisor Debra Jared has been an invaluable aid, pointing out the big picture, where it all fits in. Most importantly, this dissertation would not be the pleasurable read that it is without her help in editing the early, and later, drafts. I am glad to have started my academic research career under the watchful eye of an excellent researcher. I would also like to thank my undergraduate thesis advisor, Rod Barron, for helping me get my focus in Cognitive Psychology, and sending me off into the academic world better prepared for the work to come.

Thanks also to the committee members and faculty who contributed to my education and to this dissertation, in no particular order: Albert Katz, Ken McRae, Peter Denny, Steve Lupker, Christina Gagne, Marc Joanisse, Bob Gardner. I can't think of a better place to have gone through the trials of graduate training.

On a personal note, there are a few graduate students who I learned a lot from, and had a good time with. Thanks go to Erin Knudsen, for putting up with me in the lab, being my friend, and discussing the true nature of the human mind. Only two doors down the hall, George Cree was always willing to discuss the true nature of the human brain, and have a good laugh over a pint. Also of great comfort, Kim Quinn was always prepared to go for a coffee, and that's a good thing. Todd and Anneke, thanks for the evenings out of the house with fellow card-playing enthusiasts.

There are also many other graduate students who contributed to my sanity and my ideas on how the mind/brain works: Penny Pexman, Samar Zebian, Stephen Boisvert,

Leslie Janes, Jen Tomes, Tamsen Taylor, Natalie Kacinik, Monika Stelzl, Caroline Ho, Kym Clow, Paul Shuper, Tom and Karin James.

Finally, thank you to all of the graduate students, faculty, and staff who, over the years, had to deal with Dan.

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Psycholinguistic research has enabled cognitive psychologists to understand many of the processes involved in reading words. The current understanding of word recognition processes, however, has been gained primarily through research conducted with monosyllabic words. Whether the results of these studies generalize to polysyllabic word naming, which in fact make up the majority of words we read, has not yet been explored in much detail. If models of word recognition and naming are to be extended to account for the processing of polysyllabic words, there are many immediate questions that arise. For example, aspects of polysyllabic word recognition that are simply not relevant for processing monosyllabic words include the assignment of stress and the role of the syllable. The likelihood that words contain multiple morphemes, or that a word may be a derivation from another word class, increases as the number of syllables in a word increases. A reader must also determine whether consonants appearing between two vowels should be articulated with the preceding or the following vowel. These additional factors will increase the complexity of current theories and models of word recognition.

A great deal of research on monosyllabic printed word recognition has examined phonological processing, or the conversion of print to sound in the course of naming a word. Recent evidence indicates that this is an important process for activating word meanings, particularly for less familiar words (Jared, Levy, & Rayner, 1999). If a word's phonological representation is a major contributor to activating its meaning, then the factors that influence phonological processing will play an important role in reading comprehension. One of the more influential findings from the literature on phonological processing of monosyllabic words is that spelling-to-sound consistency influences word

naming (Glushko, 1979; Jared, McRae, & Seidenberg, 1990). When the same orthographic pattern (e.g. AVE) can map to different phonological representations or sounds (e.g., GAVE vs. HAVE) rather than a single consistent phonology, there are some associated costs in terms of both naming latency and/or the likelihood of committing an error. In other words, the pronunciation of a target word is influenced by a reader's knowledge of other similarly spelled words, or neighbours. The orthographic neighbourhood that has been found to have a substantial impact for naming monosyllabic words is the set of words that share their word body (i.e. the part of the word after the initial consonant[s]; Treiman, 1986; Treiman & Chafetz, 1987; Peereman & Content, 1997). This raises an important question if the consistency of spelling-sound translations is to be examined with polysyllabic words. Are the relevant neighbours of a polysyllabic word the other polysyllabic words which share the same orthographic pattern after the initial onset or consonant cluster is removed (e.g., MOTHER, BOTHER)? Or, is the processing of polysyllabic words influenced by knowledge of words sharing a 'syllable body', or some other orthographic segment? This is the question addressed in the following series of experiments which are concerned with the phonological processing of disyllabic words.

The most influential theories and computational models of phonological processing and word recognition primarily, or exclusively, address the processing of monosyllabic words (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart & Rastle, 1994; Plaut, McClelland, Seidenberg, & Patterson, 1996; Grainger & Jacobs, 1996; Zorzi, Houghton, & Butterworth). Dual-route theorists have developed a phonological processing mechanism that includes a set of grapheme-phoneme conversion rules which

compute the pronunciation of a word one phoneme at a time (Coltheart & Rastle, 1994; Coltheart et al., 1993). An additional lexical look-up system in the word recognition system is necessary to correctly name exception words such as HAVE. The activation of the correct pronunciation of a word, therefore, is affected by its regularity, or whether it follows the rules. Recently, the dual-route approach has addressed the assignment of stress and vowel pronunciations when reading disyllabic words, although there is no computational extension of the model at present (Rastle & Coltheart, 2000).

Connectionist theorists, on the other hand, see the phonological processing mechanism as one in which readers learn the statistical relationships between spelling and sound, rather than rules. In this type of theory, words are composed of three distributed representations that are interconnected. Each word activates a pattern in a pool of orthographic nodes, a pool of phonological nodes, and a pool of semantic nodes. The system learns the statistical relationships among the pools of nodes through exposure to the language. Words with a similar orthography will have shared orthographic nodes, and the same is true for words with similar phonology or semantics. The computation of the correct pronunciation of a word from its orthography, therefore, is affected by the statistical nature of the spelling-sound translations in that word, or how often the letters map to one pronunciation versus another (Seidenberg & McClelland, 1989; Plaut, et al., 1996). The connectionist approach has not yet been extended to deal with polysyllabic words, although Plaut et al. have stated that, “the most obvious and natural extension [of this approach] is to the reading of polysyllabic words,” (p. 106). For this approach or the dual-route approach to be extended to account for the phonological processing of polysyllabic words, however, more empirical data needs to be gathered concerning the

variables that influence the processing of these words. The goal of the present work is to provide some of this data.

The most basic step up from monosyllabic word naming was taken in this research. Only monomorphemic words were included in these studies, so that effects of morphological characteristics of words were avoided or reduced. All stimuli were disyllabic words, and word length was kept constant at six letters to ensure that a single fixation would be sufficient to encode the stimuli. Factorial studies only included words that were stressed on the first syllable, which is the most frequent stress pattern in English. All of these precautions were taken so that any significant results could be primarily attributed to the processing that takes place in the course of activating phonological representations from orthographic representations.

Before describing the studies, however, there are several empirical findings and observational phenomena in the literature that may help to inform this investigation. First, it is important to be familiar with the effects of consistency that have been established with monosyllabic words, and how these effects have been interpreted within theories of the word recognition system. The sparse literature on spelling-sound consistency in polysyllabic words will also be reviewed. As well, psycholinguistic work on orthographic syllable priming, phonology, and speech production can provide some insights for investigations of the mapping from orthography to phonology. Finally, linguists have laboured intensely to describe the English language, and this has included a considerable amount of work into the nature of the phonological representations of words. Knowledge about the phonological representation of a polysyllabic word can provide some insight into how the translation of print to sound might operate.

Consistency Effects with Monosyllabic Words

The first indication that consistency of the spelling to sound translation might play an important role in word naming appeared in a study by Glushko (1979). Prior to this investigation, a word's pronunciation was largely thought to be derived by a rule system that converted the word's individual letters or graphemes into the corresponding series of phonemes (GPC rules; Coltheart, 1978). Because the English language contains many words that do not adhere to the GPC rules (exception words), an alternate procedure was proposed in which all previously experienced words are stored in a mental lexicon and pronunciations are then looked up in a whole-word fashion. The finding that exception words take longer to name than regular words (which follow the rules) was interpreted as support for the dual-route model (Baron & Strawson, 1976). On this view, the exception words took longer to name because the pronunciation produced by the rule-based procedure (GPC route) disagrees with, and interferes with, the results of the whole-word lookup procedure (lexical route).

If the dual-route model is an accurate description of the system, one would expect that all words which follow the grapheme-to-phoneme conversion rules would be processed in a similar manner, because both the whole-word lookup procedure and the rule system would result in the same pronunciation. Glushko (1979) noted, however, that many 'regular' words are orthographically similar to exception words, and reasoned that this orthographic similarity might affect the processing and naming of those words. In his study, Glushko demonstrated that regular words, such as GAVE, that have exception neighbours, such as HAVE, resulted in longer naming latencies than regular words that have no exception neighbours (e.g., MUST). He concluded that the pronunciation of a

word is influenced by similarly spelled neighbours.

In Glushko's (1979) study, a word's neighbourhood was defined as all the monosyllabic words containing the same orthographic word body, or rime (i.e., the vowel grapheme and the following consonant cluster). A regular-inconsistent word is one which follows the rules, but for which there is an exception neighbour. A regular-consistent word is one whose body is pronounced identically in all other monosyllabic words in which it appears. This same definition was used by many researchers in attempts to replicate the effect, however, while some researchers obtained significant effects of consistency (e.g., Andrews, 1982) others did not (e.g., Stanhope & Parkin, 1987). One relatively stable finding was that consistency effects were present for low-frequency words but more elusive with high-frequency words (e.g., Kay & Bishop, 1987; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; but see Jared, 1997, submitted). The discrepancies between these studies led Jared et al. (1990) to examine the definition and description of orthographic-phonological consistency more closely, in an attempt to resolve the conflicting empirical findings.

A key premise raised by Jared et al. (1990) was that it is the *degree* of consistency that is relevant for processing, and not simply whether or not a word has neighbours with conflicting pronunciations (hereafter referred to as 'enemies'). That is, some inconsistent words have very few and/or very infrequent enemies, while other inconsistent words have many and/or very frequent enemies. The same could be said for the neighbours of a word that share a pronunciation (hereafter referred to as 'friends'); some inconsistent words have many and/or very frequent friends while others have few and/or infrequent friends. Jared et al. (Exp. 1) created a set of matched items that differed in terms of the token

frequency of the words' enemies (high, low). When compared to a control group of matched consistent words, the pattern of results from a naming study indicated that targets with high-frequency enemies produced a significant 18 ms consistency effect while the targets with low-frequency enemies produced a non-significant 6 ms effect. An additional naming experiment which also varied the frequency of the targets' friends (high, low) found that the largest consistency effects are obtained with words that have a high summed frequency of enemies and a low summed frequency of friends. It is interesting to note that most of these items would be classified as exception words according to the GPC rules. No consistency effect was obtained for inconsistent words with a high summed frequency of friends and a low summed frequency of enemies. Words that have a high summed frequency of both friends and enemies, or a low summed frequency of both, produced small effects between the two extremes. The results of this experiment paint a clear picture of the importance of the *degree* of consistency.

A summary of the results obtained by other researchers who examined spelling-sound consistency demonstrated that significant effects of consistency were only obtained when the majority of items included in the experiment had a high frequency of enemies and a low frequency of friends (Jared et al., 1990, Table 5). In fact, the pattern of results for fifteen other experiments fell in line with the results of the Jared et al. study. Significant effects were not obtained when the items in these previous experiments had a low frequency of enemies and a high frequency of friends. For those experiments where the frequency of the friends and of the enemies were low, small non-significant effects were obtained. Experiments with items that had high-frequency friends and enemies produced somewhat larger effects, but not as large as when the frequency of friends was

low. The Jared et al. (1990) study had an important impact on how consistency should be approached. Rather than taking a categorical approach, or considering words to belong to one group or another, the study demonstrated that a continuous view of spelling-sound consistency was more informative.

Jared (1997, submitted) went on to examine the effect of spelling-sound consistency on naming high-frequency words because Jared et al. (1990) had only used low-frequency target words. Studies of spelling-sound *regularity*, rather than consistency, typically found a smaller, or a null, effect with high frequency target words (e.g., Andrews, 1982). Previous studies of consistency effects also typically found null effects (e.g., Kay & Bishop, 1987; Taraban & McClelland, 1987; but cf. Andrews, 1982), but these had not carefully controlled the frequencies of the friends and enemies of the target words. Jared (1997) wanted to determine whether consistency would affect high frequency words, and whether an interaction between frequency and consistency would appear, when both high and low frequency words had a low summed frequency of friends and a high summed frequency of enemies. Spelling-sound consistency affected naming latencies of high-frequency words, and there was no interaction between frequency and consistency. In previous studies, the inconsistent high frequency target words typically had a high summed frequency of friends, and some even had a low summed frequency of enemies, whereas the low-frequency target words were more like the words that produced the largest consistency effect in Jared et al. (1990). This difference in the critical inconsistent words would result in an interaction between frequency and consistency. In another study with even higher frequency words, Jared (submitted) replicated the consistency effect for high frequency words, and again failed to find a frequency by

consistency interaction.

In all of the studies mentioned so far, measures of consistency were based on monosyllabic word neighbours only, ignoring the possible impact of longer words on monosyllabic word recognition. There has, however, been one study that did examine spelling-sound consistency effects in monosyllabic words using measures of consistency that included polysyllabic words as potential neighbours. Treiman, Mullenix, Bijeljac-Babic, and Richmond-Welty (1995) calculated the spelling-sound consistency of various orthographic segments in a set of monosyllabic words that had a CVC structure. The 19,750 words in the computerized version of the *Merriam-Webster Pocket Dictionary*, most of which are polysyllabic, were the database used to calculate the consistency of orthographic segments. The consistency of a particular pronunciation for an orthographic segment was defined as the number of friends divided by the number of all words with the letter pattern. Orthographic segments which are pronounced the same way in all of the words in which they appear would have a value of one (e.g., UST, in MUST, DUST, COMBUST). Orthographic segments that have alternate pronunciations would have values somewhere between zero and one (e.g., AVE, in GAVE, BEHAVE, HAVE, OCTAVE). In essence, this consistency measure is the proportion of similarly pronounced neighbours. Calculations were also made using token counts, but the results of analyses using these measures were quite similar to the analyses using type counts. Spelling-sound consistency was calculated for onsets (C_1), vowels (V), codas (C_2), as well as the word body (VC_2), and the onset – vowel combination (C_1V).

Treiman et al. (1995) first presented an analysis of spelling-sound consistency in the set of CVC monosyllabic words to determine which of the orthographic segments had

the most reliable spelling-to-sound mappings. For each monosyllabic CVC word, the consistency for each of the five segments was calculated as described above. To determine the reliability of an orthographic segment as a class, the mean of the consistency measures for that segment across the set of CVC words was calculated. For example, for the reliability of C_1 graphemes in CVC words, the proportion of consistent neighbours for the C_1 segment in each CVC monosyllabic word was summed and divided by the number of words. A high value on this measure would mean that the pronunciation of that segment is almost always well specified and easy to compute.

The C_1 and C_2 segments in the CVC word set had the most reliable pronunciations when all of the words in the dictionary were considered as potential neighbours of the CVC words. Using token counts, the mean proportions of similarly pronounced neighbours were .95 and .84 respectively. This means that one could almost always be certain of the pronunciation of the consonants in the CVC word set. The C_1 segments, in particular, were pronounced the same way in almost all of the words in which they appeared.

The calculation of reliability for the vowel graphemes in CVC monosyllabic words was a bit more complicated. Because polysyllabic words were included in the database, monosyllabic words' vowel consistencies were calculated twice. In one case, the vowels that appeared in the initial syllable of polysyllabic words were used to calculate consistency, and in the second case, the vowels that appeared in the final syllable in polysyllabic words were used to calculate consistency. Vowels that appeared in syllables in the middle of a polysyllabic word were not considered. The V grapheme segments in CVC monosyllabic words had a low consistency, no matter what vowel

position in polysyllabic words was used to determine the neighbours for calculating consistency (.46 for initial syllable vowels, .47 for final syllable vowels). On average, then, a vowel grapheme in a CVC monosyllabic word is pronounced the same in only about 50% of the other the words in which the grapheme appears.

The C₁V segment (word initial in polysyllabic words) was not consistent in its translation to phonology either (.49). This indicates that the initial consonant in a monosyllabic word does not constrain the pronunciation of the vowel. Only when combined with the C₂ grapheme was the vowel pronunciation somewhat consistent, with the VC₂ segment (final syllable position in polysyllabic words) having a higher average proportion of similar pronunciations (.72) than the vowel graphemes alone, or the vowel combined with the preceding consonant. In other words, the final consonants in a monosyllabic word are more informative regarding the pronunciation of a vowel than the initial consonants. Alternatively, one could view the final consonants in a monosyllabic word as constraining the possible pronunciations of the vowel. Somewhat surprisingly, the vocabulary used to determine the consistency of spelling-sound segments did not affect the measures of consistency. When only the monosyllabic words in the dictionary were considered as possible neighbours, the proportions of consistent pronunciations for the VC₂ and the other orthographic segments were quite similar. The comparison of the various spelling-sound segments in their study supports the assumption in much of the research on spelling-sound consistency that the monosyllabic word body influences phonological processing.

Treiman et al., (1995) then conducted regression analyses on the naming latencies and percentage of errors from two mega-studies, each of which required participants to

name in excess of one thousand words. The five consistency measures (C_1 , V_1 , C_2 , C_1V_1 , V_1C_2) were included as predictors, as well as several other relevant variables, such as printed frequency, initial phoneme, homophony, and interactions between the predictors. Treiman et al. (1995) presented the results of the regression analyses using the consistency measures based on type counts and with only monosyllabic words as potential neighbours. The pattern of results was apparently quite similar when polysyllabic words were also considered as potential neighbours, and when token counts were used rather than type counts. Overall, the regression equations were able to account for a significant proportion of the variance in naming latencies ($R^2 = .38 - .50$). Not surprisingly, the printed frequency of the words contributed significantly to the prediction of naming latencies and error rates in both studies. The consistency of the onset considered alone (C_1), and the consistency of the word body (VC_2), were the best consistency predictors of naming latencies and errors for both of the mega-studies. As mentioned, the previous analysis indicated that the C_2 consonants constrain the pronunciation of the vowel, and these regression results indicate that readers learn this relationship and use it when computing a word's pronunciation. This result also fits well with the findings from factorial studies examining monosyllabic word body consistency effects (e.g., Jared et al., 1990).

The only other consistency predictor which contributed significantly to the multiple regression equations was V consistency, which contributed significantly to the prediction of errors in only one of the mega-studies. The interaction terms between consistency and frequency were not significant for predicting latency in either study. The VC_2 by frequency interaction contributed a significant unique amount of variance in the

prediction of errors in one of the studies. In conjunction with the results of Jared (1997; submitted), this suggests that consistency effects are not limited to low frequency words. Rather, an orthographically similar word with a conflicting pronunciation has an effect on the naming of a target word, regardless of that target word's frequency.

This review of research on monosyllabic word naming begins to set the stage for the investigation of the impact of spelling-sound consistency on disyllabic word naming. It is quite apparent from this work that the 'word body' forms an orthographic segment that is particularly important, likely because it helps to constrain the possible pronunciations of the vowel grapheme (Treiman et al., 1995). With polysyllabic words, therefore, readers may also learn spelling-sound relationships for higher-order orthographic segments. However, it is unclear how many of the consonants following a vowel are useful for constraining the vowel pronunciation. It could be that readers learn the relationship between spelling and sound for segments that are within the same phonological syllable. On the other hand, readers may learn the relationship between spelling and sound for orthographic segments that are larger than a syllable, or that are not limited by syllable boundaries.

There is also the possibility that systematic differences in syllable structure between monosyllabic and polysyllabic words could affect which orthographic segments are influential in word naming. All of the words in Jared's experiments (1997, submitted; Jared et al., 1990) were CVC type words, and this was also true for the test items in Treiman et al.'s analyses (1995). It could be the case that this type of word is where VC₂ or 'word body' consistency exerts its strongest influence. If CV type words (e.g., TRUE) and VC type words (e.g., OUT) had been included in these studies, there may have been a

greater influence of the consistency of individual grapheme-phoneme correspondences, or of the consistency of an onset combined with the following vowel. This is particularly important, because in contrast to the situation with monosyllabic words, few polysyllabic words exclusively contain CVC syllables. An examination of consistency effects in disyllabic words, therefore, may identify orthographic segments other than the word body, or the vowel-plus-following-consonants, whose spelling-sound consistency influences performance in a naming task.

In addition, a question that arises for disyllabic words is whether the position of a segment within a disyllabic word moderates its influence on naming a similar disyllabic word. For example, does the spelling-sound consistency of the vowel or syllable-body in the second syllable of a disyllabic word affect naming as much as the consistency of segments in the first syllable? The effect of spelling-sound consistency for orthographic segments appearing in different positions in polysyllabic words has been examined previously (Jared & Seidenberg, 1990). A review of the findings from that study would help to inform the present study.

Regularity and Consistency Effects in Polysyllabic Word Naming

The first investigation of the phonological processing of polysyllabic words used the syllable as a starting point. For the purposes of their study, Jared and Seidenberg (1990) evaluated a polysyllabic word's regularity and consistency by comparing the pronunciation of each syllable within the word to the syllable's pronunciation when presented in isolation. If the pronunciations of all the syllables in a word were the same in both cases, the word was classified as regular (e.g., CHANNEL). If a word had a syllable that was pronounced differently when presented in isolation, the word was

classified as an exception word (e.g., MANGER). Words were classified as regular-inconsistent if they contained a syllable that was regular in that word, but that was given an exception pronunciation in another word (e.g., DIVINE, compared to RAVINE).

In the first experiment, regularity (regular, exception, regular-inconsistent) and syllable position (first, second) were examined with low-frequency target words. Regular-inconsistent words and exception words took longer to name than their matched regular-consistent words, and exception words took longer to name than regular-inconsistent words. In a second experiment that included a frequency manipulation, the regularity effect was stronger for low-frequency words than it was for high-frequency words, replicating the results of studies using monosyllabic words (e.g., Kay & Bishop, 1987). In their Experiment 2, the size of the regularity effect was larger when the exception appeared in the first syllable compared to when it appeared in the second syllable, and this was particularly true for low-frequency words. One possible explanation for the difference in effect size for the two syllable positions is that phonological representations of polysyllabic words are computed syllable by syllable, and articulation begins once the phonology of the first syllable is computed. However, the third and fourth experiments in Jared and Seidenberg (1990) indicate otherwise.

The third experiment matched pairs of short, medium, and long words for number of letters, but varied the number of syllables (e.g. CRUISE/CROCUS, APPROACH/ ADDITION, COMMISSION/ COMPETITION). If syllables' pronunciations are computed syllable by syllable, then for each word length, words with one more syllable should take longer to name. An effect of the number of syllables was found, but this was only true for low-frequency words. If pronunciations were assigned syllable by syllable,

then the effect should also have been found with high frequency words. In the last experiment, the initial syllable of disyllabic words was presented 250 ms prior to, and above, the second syllable. The expectation was that if polysyllabic words are routinely parsed into syllables in the course of processing, naming latencies should be affected very little as a result of the unusual display. The results of the study, however, demonstrated that naming latencies for exception words were significantly longer than in Experiment 2, in which the words were presented intact, and this increase in naming latencies was similar for both high and low frequency exception words. Importantly, latencies for regular words were unaffected by the change in display, indicating that the procedure did not make reading harder in general. The conclusion was that information outside the syllable could be used in some cases to generate the correct pronunciation of polysyllabic words, particularly exception words.

Overall, these results indicate that the translation of print to sound does not appear to be on a syllable by syllable basis. A remaining question, though, is what factor, if not syllables, was responsible for the effect of number of syllables reported for low frequency words in Experiment 3. Jared and Seidenberg (1990) argued that words with a greater number of syllables had more vowels to process, and that it was the increased number of vowels and their relative spelling-sound inconsistency, that affected naming latencies, not the number of syllables.

Vowel Consistency

What appear to be syllabic effects in Jared and Seidenberg (1990), then, may have another origin, one that considers the generation of vowel pronunciations to have a major influence on naming latencies. A distinguishing characteristic of polysyllabic words in

comparison to monosyllabic words is the presence of multiple vowel graphemes in the longer words. Because these graphemes are often ambiguous as to their pronunciations, it is likely that at least one, if not more, of the vowels would have a low-consistency spelling-sound translation. As the number of vowels increases, then, there will be a corresponding increase in naming latencies and errors, due to the vowels' phonological ambiguity.

Interestingly, Spoehr and Smith (1973) explained effects of the number of syllables in their study by appealing to the Vocalic Centre Group (VCG), which essentially are segments of phonology centred around a vowel pronunciation. From a speech production point of view, the VCG is the "minimal pronunciatonal unit in which most of the articulatory constraints can be fully specified" (Spoehr & Smith, 1973, p. 80). Because a VCG contains only one vocalic element, almost all one-syllable words have one corresponding VCG and two-syllable words have two VCGs, and so on. On this view, the most important step in identifying a written word and producing its phonology is to locate and identify the vowels in the word. Once this is accomplished, the consonant letters are grouped around these vocalic elements, and this will likely result in a match to a word in the mental lexicon. When this research was conducted, it was presumed that a perceptual parsing procedure must be employed, and that this procedure would follow a set of *rules*. Although this approach may no longer be universally accepted, the results of the analyses of tachistoscopic report accuracy in Spoehr and Smith (1973) suggest that vowels' pronunciations play a central role in producing the correct phonology of a word.

Berent and Perfetti (1995) have also suggested that vowels are represented separately from consonants in visual word recognition. Citing several areas of

psycholinguistic research, such as speech production and speech perception, their argument is that "consonant and vowel constituents are derived by two mechanisms that differ in their onset and automaticity," (p. 175). In other words, there is a qualitative difference in their processing. Using a brief priming paradigm (15 ms prime duration, 60 ms target duration), Berent and Perfetti found that primes that preserved the consonants in a target word (e.g., RIKK – RAKE) resulted in faster naming latencies of the target words than primes that preserved the vowel (e.g., RAIB – RAKE). In several other paradigms, they typically found that consonant-preserving primes resulted in better performance than vowel-preserving primes. The generation of consonant pronunciations, therefore, was assumed to be faster and more 'automatic' than the generation of vowel pronunciations.

If Berent and Perfetti (1995) are correct in arguing that vowels' pronunciations take longer to develop than consonants' pronunciations, naming latencies should depend more on the activation of vowel phonemes than on the activation of consonant phonemes. On this view, the *consistency* of those vowel graphemes should play a major role in determining naming latencies. The higher the consistency, the faster they should be activated, and the faster the word should be named. Although Treiman et al.'s (1995) analyses indicated that vowel graphemes have the least consistent pronunciations, the spelling-sound consistency of the vowel did contribute to the prediction of error rates for one mega-study, and the neighbourhood size of the vowel grapheme contributed to the prediction of naming latencies for both mega-studies. It is possible, then, that the consistency of vowel graphemes plays a role in the phonological processing of disyllabic words. The question for this research, then, is what effect, if any, does vowel consistency

have on naming disyllabic words? How does knowledge of the pronunciation of vowels in other similarly spelled words affect the processing of a target word?

Orthographic Representations of Phonological Syllables.

Another possibility is that the consistency of the orthography corresponding to the phonological syllable may help in constraining vowels' pronunciations. For spelling-sound processing, the syllable *body* may be more appropriate, just as the word *body* constrains monosyllabic words' vowel pronunciations. The utility of this orthographic segment would be paramount if polysyllabic words' orthography is parsed at phonological syllable boundaries. This is important, because an orthographic parse would limit the consonants that could be used to constrain vowel pronunciations. For instance, VODKA and PRODUCT would not be processed the same way because the consonant D appears in first syllable in VODKA but in the second syllable in PRODUCE. Although Jared and Seidenberg (1990) argued that polysyllabic words are not parsed into syllables, other evidence suggests that they may be. Experimenters have sought evidence for orthographic syllabic parsing using a number of paradigms, and a review of these studies reveals no clear consensus on this issue.

Illusory conjunctions

Prinzmetal, Treiman, and Rho (1986) examined the nature of orthographic representations of disyllabic words by using brief presentations of target words. Five letter words such as VIRGO and ATLAS were presented for an average of 233 milliseconds to readers. The colour of the medial letter in the words was either the same as the first two letters, or the same as the last two letters. Syllable boundaries of the target words occurred equally often after the second or third letter. Participants in the

study indicated what they thought the colour of the middle letter was. The brief presentation of the stimulus can induce illusory conjunctions in which the colour of the target letter may be mistaken for the colour of the other letters. Prinzmetal et al. hypothesized that the pattern of illusory conjunctions reflects the underlying orthographic structure of the word. If participants were more likely to mistakenly indicate that the target letter was the same colour as the letters in its phonological syllable than the letters from the other syllable, this could be taken as evidence that orthographic representations are parsed along phonological syllable boundaries. Because the task did not require access to meaning or phonology, Prinzmetal et al. felt that the results would primarily reflect the effects of orthographic processing.

In Experiments 1 and 2, participants were more likely to mistake the target letter as being the same colour as the letters in its phonological syllable than to mistakenly indicate that the target letter was the same colour as the letters in the opposing phonological syllable. For example, when the R in VIRGO was the same colour as the VI segment, participants made fewer mistakes than when the R was the same colour as the GO segment. This suggests that the orthographic representations of the target words were parsed into segments that corresponded to the phonological syllable, resulting in readers believing the R was the same colour as the letters in its syllable even when it was not. A subsequent experiment was intended to determine whether these results were due to orthographic redundancy, rather than phonological considerations, because the transitional bigram frequencies of the letters were also lowest at the phonological boundaries. This means that the syllable boundary corresponded to a relatively rarely encountered sequence of letters (e.g., RG in VIRGO, TL in ATLAS). When the

experiment was run controlling for this factor by using a set of words with only one medial consonant (e.g., CAMEL, LAPEL, SEDAN), they found that phonological syllable structure did not affect the pattern of illusory conjunctions. Prinzmetal et al. (1986) concluded that orthographic representations of words do not reflect the corresponding phonological segmentation along syllable boundaries.

Syllable priming

Ferrand, Segui, and Humphreys (1997) used a syllable priming procedure to determine whether orthographic representations are structured according to phonological syllables. They reasoned that if printed words are parsed into syllables, then a brief presentation of a syllable should facilitate subsequent naming of a word that contains the same syllable compared to an unrelated prime syllable. In addition, facilitation would not be expected when primes are either one letter more or one letter less than the syllable. As predicted, facilitation was obtained only when the primes corresponded to the first syllable of clearly syllabifiable words. No facilitation was observed for targets primed by segments corresponding to one letter more than the syllable or one letter less than the syllable. Words with ambisyllabic consonants were facilitated by primes that included the ambisyllabic consonant *and* those that did not (i.e., CAMEL was primed by both CAM and CA). Because there was no significant priming effect when the prime included one letter more than the syllable, the effect was not due to the degree of orthographic overlap, or even phonological overlap. This pattern of facilitation seems to support the notion of a perceptual syllable parse in the course of naming because only those primes that corresponded to the syllable facilitated naming latencies.

A closer look at the target words in the experiment where primes had one letter

more than the phonological syllable reveals that all of the target words were stressed on the second syllable. Although this stress pattern does help in clearly defining the syllable boundary, it also creates a situation in which the phonology of the prime in the syllable + 1 letter condition and the phonology of the target often do not match. For instance, when the prime REP is presented, the vowel phonology which would be produced is not the same as it is in the word REPORT, and the same can be said for REM and REMORSE or REMAIN, and for SAR and SARONG. It is not surprising then, that when one letter more than the syllable was presented, no facilitation was obtained. The same could be said for an earlier experiment where one letter less than the syllable was presented. The pattern of priming obtained by Ferrand et al. (1997), therefore, could in fact be due to phonological overlap between the prime and target. The issue of whether words are explicitly parsed into orthographic syllables that reflect the phonological structure, therefore, is still debatable.

Linguistic Evidence on Syllable Representations

One of the strongest reasons for believing that the orthographic input is parsed into syllables is the intuitive knowledge that speakers have of the phonological structure of English. Evidence for speakers' intuitive knowledge of phonological syllables has been observed in the ability of very young children and illiterate adults to easily and reliably count the number of syllables in a spoken message (Liberman, Shankweiler, Fischer, & Carter, 1974; Morais, Bertelson, Cary, & Alegria, 1986). As far as the reality of syllable sized representations are concerned, research in the area of speech production indicates that syllables are real representational units, and that due to coarticulation constraints they correspond to articulatory motor programs (Levelt & Wheeldon, 1994).

From a connectionist perspective, if syllables play such a prominent role in phonology, it is possible that this structure feeds back to orthographic representations during word recognition. Other aspects of phonology seem to impact the activation of orthographic representations through feedback (Stone, Vanhoy, & Van Orden, 1997; Ziegler, Montant, & Jacobs, 1997; Pexman, Lupker, & Jared, 2001). This feedback, if strong enough, could prompt the development of separate orthographic representations for each syllable. This would, in essence, create an orthographic 'parse' that would mirror the syllabic structure of the word.

In fact, Hammond (1999) proposes that all linguistic *auditory* strings must be exhaustively parsed into syllables. In his prosodic optimality-theoretic approach to the phonology of English, he attempts to uncover constraints on the patterning of phonemes in monomorphemic words¹, as well as the constraints on metrical structure, footing, and sonority of the phonemes. The phonemic constraints dictate what sounds (phonemes) can occur with other sounds and also the permissible ordering of these sounds. These constraints on the ordering of phonemes only apply within syllables, and it is possible that they could have some impact on the computation of phonology from orthography. Using this approach, Hammond was able to demonstrate, for instance, that constraints on the order of phonemes in word onsets almost universally apply to the onset of any syllable within a polysyllabic word (e.g., Affricates cannot occur in complex onsets in words or in the onset of any syllable in a polysyllabic word). The same is true for the constraints concerning the ordering of phonemes at word codas and syllable codas (e.g., the phoneme /h/ cannot occur word finally nor syllable finally). According to Hammond

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¹ Many of the phonological constraints on monomorphemic words do not apply to the division between morphemes in multimorphemic words.

(1999), these constraints are a result of the fact that the sonority of phonemes must rise before the vocalic peak in a syllable, and fall after the vocalic peak. The phonological representation of a polysyllabic word, then, is divided into cohesive syllable segments at some point in processing.

However, some of the additional constraints he proposes would suggest that an orthographic mapping to phonology would need to include information outside the syllable boundaries for efficient computation of the corresponding pronunciation. Hammond (1999) points out that there are many dependencies between the phonological syllables in a word, and these argue against the view that phonological representations of printed words is computed syllable by syllable. First, the independence of phonology is not true for vowels in disyllabic words because one must be stressed, and only one can be stressed. Also, Hammond's (1999) constraints on the ordering of phonemes in syllables takes into account the medial consonants between two vowels in polysyllabic words, regardless of which syllable they may appear in. Almost any ordering of phonemes can occur between vowels, including orderings that would not be allowed either at the beginning or the end of a word. These orderings are allowable because some of the phonemes are assigned to the first syllable as its coda, and the other phonemes are assigned to the second syllable as its onset. This suggests that at some point in the phonological processing of disyllabic words, all of the medial consonants and the surrounding vowels must be available simultaneously. This is necessary in order to know whether to assign a consonant phoneme to one syllable or the other, and to be sure that only one of the vowels is stressed. The abstract orthographic or phonological

representations, then, could be complete patterns for entire words that are then mapped to a concatenated series of articulatory motor programs.

In summary, the evidence from perceptual experiments, such as those conducted by Prinzmetal and his colleagues (Prinzmetal et al., 1986, 1991), indicates that orthographic representations are not parsed into phonological syllables. The linguistic analysis by Hammond (1999) agrees with this, pointing out that although many parts of syllables are independent of the phonological nature of the other syllable in a disyllabic word, there are also many dependencies between syllables. These dependencies suggest that the processing for one syllable must be sensitive to information from the other syllable. On the other hand, the priming experiments by Ferrand et al., (1997) suggest that the orthography of a disyllabic word may be parsed along phonological syllable boundaries, although there are fundamental problems with the primes and stimuli in the study. Given these discrepancies in empirical data concerning syllabic parsing in orthography, the present investigation cannot rule out syllable-body spelling-sound consistency as a factor for phonological processing of disyllabic words. At the same time, because the evidence for syllable based segments is equivocal, the potential influence of alternate orthographic segments on phonological processing must also be examined.

The Surrounding Context in Vowel Production

If vowel pronunciations are typically ambiguous, then how much of the rest of the word is needed to determine the correct pronunciation? The consistency of some larger segment may play an important role in naming disyllabic words by helping to constrain a vowel's pronunciation. The exaggerated effects of regularity in the syllable-by-syllable

study in Jared and Seidenberg (1990, Expt 4) suggest that the information used by readers to disambiguate the pronunciation of an irregularly or inconsistently pronounced vowel was not present when the irregular words were displayed syllable by syllable. Jared and Seidenberg (1990) suggested that perhaps the entire word string was necessary for accurate translation of print to sound. In fact, for the system to be adequate, some other information outside the syllable *must* be used, or the word would never be pronounced correctly.

If naming performance is influenced by the consistency of an orthographic segment that is not restricted by syllable boundaries, an initial hypothesis could be that it is the segment corresponding to the remainder of the word after the initial consonant cluster is stripped off. Neighbours, therefore, would have to share this portion of their orthography (e.g., AGIC for MAGIC, TRAGIC) to influence each other's phonological processing. This is not a likely scenario, however, as most polysyllabic words would have few or no neighbours if this was the case. The next step would be to consider a segment that takes in the consonant grapheme(s) after the syllable boundary. This segment would be just slightly larger than the syllable body. In support of such a segment, it would lead to easier computation of the correct phonology for ambiguous consonants appearing between two vowels. For example, the pronunciation of N as /n/ or /ŋ/ depends on the following consonant in the words DANCER and DANGLE. Additionally, if the word recognition system ignored the phonological syllable boundary there would almost always be a larger consonant context to help in constraining the initial vowel grapheme's pronunciation in a disyllabic word. This is particularly true for words with CV phonological syllables (e.g., GA/LORE, LA/GOON, RE/GRET).

There has, in fact, been some investigation into an orthographic segment that includes consonants from beyond the syllable boundary. The BOSS, or Basic Orthographic Syllable Structure, was first proposed as a unit in lexical access by Taft (1979), and was thought to be the orthographic access code to the mental lexicon. The BOSS was based purely on a word's orthography and was defined as follows:

"Include in the first syllable as many consonants following the first vowel of the word as orthotactic factors will allow without disrupting the morphological structure of that word." (Taft, 1979, p. 24)

The orthotactic factors referred to by Taft specify which combinations of letters can appear at the end of a word (i.e., ND can appear at the end of a word but DN cannot). The initial experiments involving the BOSS unit contrasted the BOSS with the phonologically defined first syllable in a lexical decision task (Taft, 1979). Words were split up at the boundary of either the BOSS or the phonological syllable (e.g. LANT ERN, or LAN TERN) with the expectation that the type of display which corresponded to the unit present in the visual word recognition system would produce faster responses than a display which did not correspond to a unit in the system. In two experiments that contrasted the BOSS and the phonological syllable, the BOSS-divided items produced faster reaction times. Although Taft (1979) argued that this unit was purely visual and that it produced faster reaction times because of its presence in the word recognition system, there is another possible explanation for its utility.

Taft (1979) assumed that a lexical decision was based on information in the visual word recognition system. Under this assumption, he did not control for the phonology of the items (i.e. regular or exception), or whether the additional letter in the BOSS

condition could help constrain the vowel pronunciations. For instance, the item VERBAL would be presented either as VERB AL or VER BAL. The former case includes in the initial letter cluster all the information necessary to unambiguously produce the correct phonology for the vowel. There is not a single word in English that begins with VERB where the vowel or consonants are pronounced differently. However, the phonological syllable division leaves open the possibility that it may be pronounced as in VERIFY or VERY. This same argument can be applied to the divisions of many of the other stimuli used in the experiments, such as MOVIE or VIRTUE or CLIMATE, where the phonological syllable division leaves open many possible pronunciations of the first vowel segment whereas the BOSS allows only one. The advantage of BOSS units over phonological syllable units, therefore, could have resulted from phonological processing as much as direct visual lexical access. The computation of a single coherent phonological representation would have been much easier in the BOSS condition when words were divided so that the correct pronunciation would be immediately generated, rather than in the phonological syllable condition, in which the correct pronunciation would have to compete with incorrect pronunciations. The suggestion that phonology could play a role was recognized in subsequent studies.

Taft's (1992) later research on the BOSS took note of the fact that word naming experiments had identified the word body as an important segment in the production of phonology for monosyllabic words. As in the current investigation, the question to be addressed was what constituted the body of a polysyllabic word. Taft's argument in this series of experiments was that the body-of-the-BOSS (BOB; e.g. EAD in MEADOW) was the important unit for the production of phonology for polysyllabic words. To test

this assumption, Taft (1992) primed a monosyllabic nonword target (e.g. JEAD) in a naming task with a word that either had the same BOB (e.g., MEADOW) or the same onset and vowel (e.g., JEALOUS). The vowel grapheme in JEAD was pronounced more frequently as in the prime when the prime had the same BOB than when the prime had the same onset and vowel. In another experiment in which disyllabic nonwords were used as targets, the dependent variable of interest was the assignment of stress. All primes were words stressed on the second syllable. When the prime word had the same BOB as the target nonword (e.g. LAMENT - CAMULK), stress was more frequently assigned to the second syllable in the target than when the prime word had the same onset plus vowel (e.g. CAVORT - CAMULK). This led Taft to argue that the BOB *and* the BOSS are represented as access codes in the lexicon. More specifically, in an interactive activation network, these access units would intervene between letter or grapheme units and the full wordform units. The BOSS units would mainly be used in morphological processing and access to meaning, and the BOB units would be linked to subword units in the phonological lexicon. The phonology of unknown words or nonwords, such as CAMULK, would be generated by using these latter mappings.

There are many reasons, therefore, for examining the influence of the spelling-sound consistency of orthographic segments that are not limited by phonological syllable boundaries. Linguistic arguments, logical arguments, Jared and Seidenberg's (1990) findings, and results from experiments examining the BOSS and the BOB all suggest that readers may not parse the orthography of a printed word according to its phonological syllables. In the present study, therefore, the spelling-sound consistency of the BOB segment was examined, as this is most similar to the monosyllabic word body while also

including a larger context of consonants than would be present if segments were constrained by syllable boundaries.

The Present Study

In summary, it is essential that word recognition theories are eventually able to explain how people read polysyllabic words, and the studies conducted in this project will help to inform these theories. Research with monosyllabic words has pointed out that the *degree* of consistency of the word body influences naming performance. Empirical work on phonological processing of disyllabic or polysyllabic words, however, (e.g., Jared & Seidenberg, 1990), was conducted before the *degree* of consistency was identified as a key factor for the phonological processing of monosyllabic words. Unless there are some fundamental qualitative differences between the processing of monosyllabic words and the processing of disyllabic words, the relative consistency of some as yet unidentified spelling-sound segment(s) in disyllabic words should have an effect on word naming. The issue, then, is which other similarly spelled words affect the processing of a disyllabic word. How many letters and which letters do words have to share to influence each other's phonological processing? Acquiring this information through the following experiments will provide some key knowledge for the extension of word recognition models and theories of phonological processing beyond monosyllabic words.

Two general approaches have been taken in empirical work on phonological processing: Factorial design studies (e.g. Jared et al., 1990), and regression studies (e.g. Treiman et al., 1995). When stimuli are equated on other relevant variables, a factorial design allows an investigator to confidently assert that the manipulation of the independent variables was responsible for significant effects. Researchers can maximize

the differences between different types of items by choosing those at the extreme ends of the distribution, and by treating a group of items as a homogeneous set, although the items in a group may differ on the variable of interest. For this reason, a much smaller number of critical stimuli can be used in comparison to regression design studies. In order to run a factorial design experiment, however, the factor which is being manipulated must be clearly identified beforehand, and those variables included in the design are usually the only ones that can be tested with the obtained data set.

Unlike factorial design experiments, regression designs may allow the investigator to examine many different variables with a single data set, including variables that are not identified a priori. However, because of the nature of regression studies, a relatively large number of items must usually be employed, since the variance of item means is being correlated with other continuous measures. If a sufficiently large number of items are included, the data set can be used to test many different variables, and to compare the adequacy of each in terms of the percentage of variance accounted for. This design also allows researchers to test the predictive power of a variable after removing the variance in the criterion that is associated with other variables. Compared with factorial design studies, however, the predictor variables should be continuous as opposed to categorical, necessitating the development of an adequate metric of the predictor variable. Given the advantages and disadvantages of each of the factorial and regression designs, some investigators have advocated the use of both (e.g. Treiman et al., 1995). The regression design allows research to be more exploratory in nature, while the factorial design can be used to verify the findings of a regression analysis in a more controlled manner. This combination of methodologies was employed in this project.

Experiment 1

The design of Experiment 1 is quite similar to that employed by Treiman et al. (1995) in their analyses of the results of two mega-studies on monosyllabic word naming. In this experiment, spelling-sound consistency statistics were calculated for a variety of letters and letter clusters that appeared in 1000 disyllabic words, and these consistency statistics were used to predict naming latencies and error rates on those 1000 words. Because this work is the first to examine the issue, it was not known at the outset what the influential spelling-sound segments of a disyllabic word would be, and because there are several different possibilities, the regression method allowed for multiple measures of consistency to be evaluated. The main question, then, was what are the orthographic segments in disyllabic words whose spelling-sound consistency affects naming latencies and errors?

In the present study, the pool of neighbours for determining the consistency of an orthographic segment in a disyllabic word were the other disyllabic words with the same orthographic segment in the same syllable position. On this view, when a disyllabic word is processed, only other disyllabic words with a similar orthography in the same position would influence performance on the target word. As pointed out earlier, the latter syllables of polysyllabic words tend not to be stressed, and this alters the pronunciation of vowels that appear in the second syllable compared to when they appear in monosyllabic words, or the initial syllables of polysyllabic words. It is unlikely that readers fail to learn this correlation between the position of a vowel grapheme and its likely pronunciation, so considering only disyllabic words should lead to reasonable consistency measures. Even if there is some influence of words where the same segment

appears in a different position, this may not substantially alter consistency statistics calculated using only disyllabic words as potential neighbours. For monosyllabic words, Treiman et al. (1995) found no substantial difference in the predictive power of the consistency measures when they were based only on monosyllabic words compared to when the consistency measures were based on all words. Accordingly, using only disyllabic words to calculate consistency should lead to suitable consistency measures. For these logical reasons, and for computational tractability, this is the approach taken in the current work.

In the present study, then, the consistency of a number of orthographic segments was calculated for each disyllabic target word using all other disyllabic words as potential neighbours. These segments included individual grapheme-phoneme correspondences (e.g., C_1 , V_1 , C_2 , C_3 , V_2 , C_4), orthographic segments that include the vowel grapheme and any consonant(s) prior to the vowel in the same phonological syllable (C_1V_1 , CV_2), orthographic segments that include the vowel grapheme and any consonant(s) after the vowel that are in the same phonological syllable (V_1C_2 , V_2C_4), and the BOB, which includes the first vowel and all following consonants that would constitute legal word endings. Using the consistency of these orthographic segments (i.e., proportion of similarly pronounced orthographically identical segments) as predictors in a multiple regression, as Treiman et al. (1995) did, will allow us to discover which neighbours of disyllabic words most influence performance in a naming task.

Method

Participants

Twenty-nine undergraduate students at the University of Western Ontario

participated in the experiment. Participants volunteered for the study as one method of earning credit in an introductory Psychology class. All participants were native English speakers and had normal or corrected to normal vision.

Apparatus

An Apple MacIntosh LC III computer with a MacIntosh Colour Display monitor was used for this experiment. The computer was interfaced with a model Mk6 button box, developed by MacWhinney, Laxman, and Taylor, to which a Realistic 33-1060 electret condensor microphone was connected. The button box was used to time participants' naming latencies to the nearest millisecond. The application program PsyScope (version 1.0.2; Cohen, MacWhinney, Flatt & Provost, 1993) was used to display stimuli and record participants' naming latencies.

Materials

One thousand disyllabic words were presented to the participants. These words were taken from the CELEX lexical database. There were two constraints on the choice of words. First, the target words had to be monomorphemic (according to the CELEX database). In addition, the target words had to be six letters in length. Any disyllabic word in the database that matched these criteria was included in an initial list. The experimenter went through this list and removed words that first year undergraduate students were unlikely to know. The final list contained 1000 words (see Appendix A for a complete list of the words).

Procedure

Participants in the experiment were tested individually in a session that lasted approximately 55 minutes. Prior to completing the experiment, the participants read and

signed a declaration of informed consent (Appendix B) which outlined the experimental procedure. Upon completion, each participant was given a debriefing form (Appendix C) which outlined the hypotheses tested in the experiment.

Participants were seated in front of the computer and were first presented with written instructions displayed on the computer monitor. These instructions indicated that a series of two syllable words would appear in the centre of the monitor one at a time, and that they were to pronounce the word into the microphone that was in front of them as quickly and accurately as possible. The participants were told that they would be naming 1000 words, and that there would be three breaks during the experiment. When the participant was ready to begin, 10 practice trials followed. During this time, the experimenter adjusted the sensitivity of the microphone in order to ensure that it would pick up the participant's voice, but not be activated due to incidental noises. At the end of the practice trials, the instructions were again displayed on the computer monitor. When the participant was ready to begin the experimental trials, they pressed a button on the button box.

Each individual trial began with a word presented in the middle of the computer monitor in lowercase Chicago 14-point font. This word remained on the screen until the participant voiced a response. The computer began timing the naming latency in milliseconds from the onset of the stimulus. When a response was made, the latency was recorded and the stimulus was removed from the screen. The intertrial interval was 1500 ms. The experimenter recorded participants' incorrect pronunciations by hand. The list of one thousand words was presented in a different random order for each participant. Participants were given a short break after intervals of 250 trials.

Independent Variables

The set of predictor variables used in this regression study is similar to those employed by Treiman et al. (1995). The log frequency of each word, the characteristics of the initial phoneme, and the stress pattern of the word (e.g., first-syllable or second-syllable) served as an initial set of predictors. Ten dummy variables for the initial phoneme were chosen based on Treiman et al.'s (1995) analysis: One for voiced versus unvoiced, four for manner of articulation (nasal, fricative, liquid/semivowel, affricate), and five for place of articulation (bilabial, labiodental, alveolar/alveopalatal, velar, and glottal). Stress pattern was included as a predictor because empirical studies that have included words with the two types of stress patterns have found that trochaic words were named faster than iambic words (e.g., Brown, Lupker, & Colombo, 1994). Characteristics of the initial phoneme and log frequency are not of theoretical interest in the present experiment, but were included to remove variance associated with those variables. This allows for a more accurate estimation of the impact of spelling-sound consistency.

Spelling-sound consistency measures were calculated for each of the following graphemic units and employed as predictors: C_1 , V_1 , C_2 , C_3 , V_2 , C_4 , C_1V_1 , V_1C_2 , BOB, CV_2 , and V_2C_4 . An example of the division of a word into the segments is presented for the word VERTEX in Figure 1. Examples of words with high and low consistency segments are given in Table 1. The identification of orthographic segments is not as simple as for monosyllabic words. For disyllabic words, the identification of V_1C_2 segments was based on the syllable boundary as given by the CELEX database. When V_1C_2 segments were identified, the segment did not need to have a following consonant (i.e., there was no C_2). In these cases ($n=249$), the segment was based on the vowel when

Figure 1. The division of the word VERTEX into orthographic segments for calculating spelling-sound consistency. In addition to the 10 segments shown above, the consistency of the BOB, which is ERT for VERTEX, was also calculated.

Table 1. Examples of high consistency and low consistency words for each orthographic segment.

Segment	High Consistency Word	Low Consistency Word
C ₁	<u>c</u> annon	<u>c</u> ircle
C ₁ V ₁	<u>g</u> ossip	<u>g</u> overn
V ₁	hy <u>p</u> hen	sys <u>y</u> tem
V ₁ C ₂	<u>b</u> arber	<u>w</u> arden
C ₂	cus <u>t</u> om	dis <u>m</u> al
C ₃	ban <u>t</u> er	virt <u>u</u> e
CV ₂	fo <u>s</u> ter	vert <u>e</u> x
V ₂	dom <u>a</u> in	cert <u>a</u> in
V ₂ C ₄	can <u>i</u> ne	fam <u>i</u> ne
BOB	don <u>k</u> ey	mon <u>k</u> ey

Note: Underlined portions of example words denote the orthographic segment that is varied.

it was the terminal grapheme in the first syllable. This segment was not the same as the V_1 segment because it did not include as neighbours any words where the first syllable did indeed have a within-syllable consonant after the vowel. The CV_2 was identified using the C_3 grapheme in most cases, and the second vowel grapheme. Where ambisyllabic consonants were identified as C_2 graphemes the C_2 grapheme was treated as the C_3 solely for the purposes of the calculating CV_2 consistency ($n=128$). The V_2 segment was identified in the same manner as for the initial vowel, except that in this position, there were a number of cases in which a vowel letter would be followed by a consonant, and then the letter E (e.g., RAVINE, VOLUME, CANINE). These cases were considered a single, but discontinuous, vowel grapheme. In this manner, the pronunciation of words containing I_E, for instance, did not affect the consistency measures for I with no following E. These discontinuous vowel graphemes were also used in the identification of CV_2 and V_2C_4 segments. In the case of words ending in a consonant and LE (e.g., MINGLE), the identification of segments was a little more complicated. The initial consonant in the syllable was treated as the C_3 (e.g., the G in MINGLE). The L was treated as the C_4 segment, and the E was the V_2 segment. For the CV_2 , the LE and the preceding consonant were considered the orthographic segment, with potential neighbours being all words that had these letters beginning the second syllable (e.g., GARGLE, NEGLECT, JUGGLER). For the identification of V_2C_4 segments, the LE formed the V_2C_4 orthographic unit ($n=139$), and only words that *ended* in LE could be neighbours. The same procedure was used for words that ended in RE, such as CENTRE and MEAGRE. The various pronunciations for each of the orthographic segments were then identified, and the list of words containing the segment .

was separated into different lists with one for each pronunciation. For the consonant(s) that appeared between two vowels, the phonological correlate could appear in the first syllable or in the second syllable. That is, the consonant phoneme could be articulated as the coda of the first syllable or the onset of the second syllable. These were considered two different pronunciations of the orthographic segment, even if the phoneme was, in fact, the same. This affected the calculation of spelling-sound consistency for C_2 , V_1C_2 , and BOB segments. For example, although the phoneme for the grapheme CK is the same in ROCKET and COCKTAIL, it is articulated with the second vowel in ROCKET, but with the first vowel in COCKTAIL. In this case, this difference would affect the calculation of BOB consistency but not C_2 consistency.

The method for calculating spelling-sound consistency was similar to that used by Treiman et al. (1995). However, rather than calculate a type-based consistency measure and a token-based consistency measure, a single consistency measure was calculated as follows. First, the logarithm of the token count for each word in the database was calculated. For the consistency of a particular pronunciation for an orthographic segment, the log frequencies of all the words in which the segment was pronounced the same were summed.² This sum was then divided by the total of the log frequencies for all words in which the orthographic segment appeared, no matter how it was pronounced. This method yields a value between 0 and 1 for each pronunciation of an orthographic segment, with the total of all pronunciations for a segment being 1.0. A consistent pronunciation, in which all words with the orthographic segment are pronounced the

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² Although the CELEX lexical database is an excellent resource, the given phonology of the entries is the typical British pronunciation. For each of the searches, the word forms identified had to be checked and the pronunciations altered to the Canadian pronunciation as indicated in the Oxford Dictionary of Canadian English.

same, would have a value of 1.0. As an example, the C_1V_1 letter pattern BU has seven possible pronunciations for Canadian speakers. The sum of the logarithm of the token frequencies for each word in which BU is pronounced as in BUGLE is 6.159. This value was then divided by the sum of the logarithm of the token frequencies for all words in which BU appears as a C_1V_1 regardless of the pronunciation (330.065). This particular pronunciation for BU, therefore, has a consistency measure of .0187.

The logarithm of the token frequency for each word was used to calculate consistency measures for two reasons. First, the effect of frequency on word recognition has frequently been characterized as logarithmic. That is, at the low end of the scale a change in frequency has a much greater effect on the processing of a word than a corresponding change in frequency at the high end of the scale. In the data set gathered for this study, for instance, the relationship between frequency and latency is much better characterized in this manner. The correlation between naming latency (in ms) and *raw* frequency is small ($r = -.173$), whereas the correlation between naming latency and *log* frequency is much larger ($r = -.434$), clearly demonstrating the logarithmic relationship between these variables. This is an important change from previous measures of consistency. The use of a logarithmic frequency measure reduces the impact of words with unusually large frequencies on the consistency measures. Previous measures of consistency accomplished this by capping the frequency of a word at 1000 (Jared et al., 1990; Jared, submitted), so that words with frequencies greater than 1000 were simply given the value 1000. Treiman et al. (1995), on the other hand, calculated consistency by two means; one measure used token counts and another used type counts. The token counts underestimated the impact of multiple low frequency words with the same

pronunciation on the consistency measures, and the type-based measures treated a word with a very low frequency the same as a word with a much higher frequency. Using the logarithm of the frequencies of words to calculate consistency is a halfway point between these two extremes.

Identifying the orthographic segments of disyllabic words in this manner means that not all words have a value for all of the segments because the structure of disyllabic words varies. For instance, BELONG has no C_2 segment, and BRANDY has no C_4 segment. This means that in a regression analysis using all consistency measures as predictors, not all of the words' naming latencies would be included in the criterion variable. This is because an item's data point is excluded from an analysis when there is no value for any one of the predictor variables. Only 477 of the 1000 words presented to the participants had a spelling-sound consistency value for all of the orthographic segments. Therefore, the naming latencies and errors for 523 of the 1000 words would not be included in the criterion if all of these predictors were used. For this reason, several regression analyses were run, in which different subsets of the orthographic segments' consistency measures were entered as predictors. In each analysis, then, a different but overlapping subset of the 1000 words' naming latencies or error rates served as the criterion variable.

The data for some of the words were not included in any of the following analyses. Ninety-two words were not included in any of the analyses because the initial phoneme was not a consonant but rather a vowel. These were excluded because the consistency statistics for the initial vowel when preceded by a consonant are likely to be very different from the consistency statistics for words with consonantal onsets. For one

thing, vocalic onsets have a greater tendency to be unstressed. Additionally, the initial-phoneme predictors employed in this study are based on words beginning with a consonant, rather than a vocalic onset. Eight more words were removed because there were no medial consonants between the vowels (e.g., CLIENT), and consistency statistics were not developed for these cases.

Results

Four words were removed from the data set because three or fewer participants named the word correctly. For words that had two possible correct stress patterns ($n=18$), the most frequent stress pattern was treated as correct, and trials from participants responding with the alternate stress patterns were excluded from the data set. Trials in which the naming latency was greater than 1500 milliseconds were not included in the computation of a word's average naming latency. Across all participants, this affected approximately 1.3% of the trials, with the maximum for a single subject being 2.2%. Following Treiman et al. (1995), the logarithm of the mean naming latency for each word was the criterion variable in the first set of analyses, and the square root of the proportion of errors served as the criterion in the second set of analyses. The correlations amongst the set of predictors are presented in Table 2. The results for regression analyses in which all predictors were entered simultaneously are presented prior to results for the set of hierarchical regression analyses.

Multiple Regression On Naming Latencies: Simultaneous Entry of All Predictors

The first analyses on naming latencies and error rates forced all possible predictors into the regression equation, as Treiman et al. (1995) did. Twenty-three predictors were entered in this analysis: 10 initial phoneme dummy variables, 11

Table 2. Correlations between the consistency predictors, frequency and stress pattern.

	C ₁	C ₁ V ₁	V ₁	V ₁ C ₂	C ₂	C ₃	CV ₂	V ₂	V ₂ C ₄	BOB	Freq
Stress	.05	-.12	-.29	-.18	.02	.17	-.07	-.27	-.10	-.23	.04
C ₁		.08	.04	.01	-.05	.03	.06	.03	-.01	-.03	.00
C ₁ V ₁			.67	.25	-.03	-.07	.02	.10	.03	-.01	.02
V ₁				.33	-.02	-.11	.05	.19	.03	.33	-.03
V ₁ C ₂					.59	-.12	.07	.15	.03	.45	.00
C ₂						-.07	.07	.07	.03	.20	-.03
C ₃							.07	-.12	.11	.10	-.05
CV ₂								.59	.36	.15	.03
V ₂									.37	.22	.01
V ₂ C ₄										.11	.04
BOB											.00

Note: Correlations greater than .12 are significant at $p < .001$. Freq = log Frequency.

spelling-sound consistency measures, log frequency, and stress pattern. The regression equation predicting log latency was significant, $F(22, 454) = 14.48, p < .001$. The equation accounted for 41.2% of the variance in the data set (38.4% adjusted). The full set of results for initial phoneme predictors can be found in Appendix D, because they are not of theoretical interest in the present study. Log frequency contributed significantly to the regression equation, with higher frequency words being named faster than lower frequency words. The results for the spelling-sound consistency predictors are presented in Table 3. Of the spelling-sound consistency measures, only BOB consistency and V_2C_4 consistency contributed a significant unique proportion of variance to the regression equation. Two other segments (V_1C_2 and CV_2) were marginally significant predictors. Words with higher consistency measures on these units produced faster latencies than words with lower consistency measures. Stress pattern also contributed significantly to the regression equation, with second syllable stress words producing longer latencies than first syllable stress words.

It is important to note here that the analysis presented above is not technically correct for analyzing repeated measures data. Each word in the data set constitutes a measure to be predicted, and because each measure is not independent (i.e., the naming latencies for the 477 words are coming from the same individuals), the impact of any one predictor may be over- or underestimated (Lorch & Myers, 1990). Lorch and Myers describe a procedure for determining whether a particular predictor is significant in this case. A regression equation should be generated for each individual tested, and then a single sample *t*-test should be conducted on the set of obtained Beta weights to determine whether they are, as a set, significantly different from zero. This procedure was run here

Table 3. Results for multiple regression analysis on naming latencies.

Spelling-sound consistency predictors entered: C_1 , C_2 , C_3 , C_4 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , V_2C_4 , BOB.

Predictor	β	t	p
Log Frequency	-.382	-10.28	<.001
BOB consistency	-.107	-2.52	.012
Stress	.086	2.21	.028
V_2C_4 consistency	-.089	-2.11	.035
CV_2 consistency	-.092	-1.96	.051
V_1C_2 consistency	-.097	-1.90	.058
C_1V_1 consistency	-.083	-1.75	.081
C_3 consistency	.064	1.59	.113
V_2 consistency	-.078	-1.54	.125
C_1 consistency	-.060	-1.43	.152
C_4 consistency	-.050	-1.32	.189
V_1 consistency	.012	0.25	.807
C_2 consistency	.007	0.15	.903

$N= 477$, $R^2=.412$ (.384 adjusted)

and it was found that five predictors contributed significantly to the prediction of naming latencies.: The BOB segment, $t(28) = -2.25$, $p < .05$, the V_1C_2 segment, $t(28) = -5.04$, $p < .01$, and the V_2 segment, $t(28) = -5.92$, $p < .01$, the CV_2 segment, $t(28) = -2.62$, $p < .05$, and the V_2C_4 segment, $t(28) = -4.14$, $p < .01$. Stress did not contribute significantly to naming latencies using this procedure, $t(28) = 1.05$, ns, nor did the consistency of the V_1 segment, $t(28) = -0.84$, ns.

Multiple Regression On Error Rates: Simultaneous Entry of All Predictors

As with the naming latency analysis, twenty-three predictors were entered in this analysis: 10 initial phoneme dummy variables, 11 spelling-sound consistency measures, log frequency, and stress pattern. The regression equation predicting log latency was significant, $F(22, 454) = 8.16$, $p < .001$. The equation accounted for 28.3% of the variance in the data set (24.9% adjusted). The results for initial phoneme predictors can be found in Appendix E. Log frequency contributed significantly to the regression equation, with higher frequency words producing fewer errors than lower frequency words. Stress pattern also contributed significantly to the regression equation, with second-syllable stress words producing more errors than first-syllable stress words. The results for the spelling-sound consistency measures can be found in Table 4. Of the spelling-sound consistency measures, BOB and V_2C_4 consistency contributed significantly to the regression equation. Words with higher consistency measures on these units produced fewer errors than words with lower consistency measures. C_1 consistency also contributed to the regression equation, with words having higher consistency producing *more* errors than words with lower consistency. This result is misleading however. C_1 consistency was uniformly quite high ($> .87$) except for eleven words that

Table 4. Results for multiple regression analysis on error rates.

Spelling-sound consistency predictors entered: C_1 , C_2 , C_3 , C_4 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , V_2C_4 , BOB.

Predictor	β	t	p
Log Frequency	-.233	-5.68	<.001
Stress	.210	4.92	<.001
BOB consistency	-.164	-3.47	.001
C_1 consistency	.144	3.12	.002
V_2C_4 consistency	-.094	-2.01	.045
V_2 consistency	-.097	-1.74	.083
C_3 consistency	.060	1.36	.176
C_4 consistency	-.055	-1.31	.192
CV_2 consistency	-.065	-1.25	.214
C_1V_1 consistency	-.028	-0.53	.597
V_1 consistency	-.019	-0.36	.723
C_2 consistency	.007	0.14	.892
V_1C_2 consistency	-.004	-0.07	.947

$N=477$, $R^2=.283$ (.249 adjusted)

began with the letter C pronounced as /s/ (e.g., CIRCLE), which had a consistency measure of .07. These words, however, had very few errors ($\leq 3\%$), leading to a spurious positive relationship. By eliminating just these eleven words, C_1 consistency does not contribute to the prediction of errors in this analysis. C_1 consistency was also entered in almost all of the following hierarchical regression analyses, but was not included as a significant predictor in any when those eleven words were removed.

The Lorch and Myers (1990) procedure described in the analysis on naming latencies was not run on the error rates. While error rate can be considered a continuous variable when averaged across a set of individuals, the variable is dichotomous for an individual. A participant either named the word correctly or incorrectly, with no values in between. Linear regression analyses cannot, therefore, be run on an individual. Although other types of regression analyses can be run, these analyses do not provide standardized Beta weights. For this reason, only the analyses averaging data over participants were run on error rates.

Hierarchical regression analyses

Entering all predictors as in the above analyses may mask the true impact of many of the predictor variables. Each predictor is tested for the variance that it uniquely contributes to the regression equation. By entering many variables that have no significant impact on naming latencies, the contribution of variables which do have an impact will be underestimated due to shared variance with the other predictors. Therefore, stepwise regression analyses were run to reveal the relative impact of only those variables that actually contribute to the prediction of naming latencies.

As mentioned, the varying structure of disyllabic words meant that several

hierarchical regression analyses were necessary, since many words do not have a value for some of the predictors (e.g., LAGOON has no C_2). The first hierarchical analysis included all of the grapheme-phoneme consistency measures. The only two-syllable words that contain all of these segments are words with a CVC CVC structure ($N = 477$). Six additional analyses were run that entered all possible subsets of the individual grapheme predictors (i.e., C_1, V_1, C_2, C_3, V_2 ; C_1, V_1, C_2, V_2, C_4 ; C_1, V_1, C_3, V_2, C_4 ; C_1, V_1, C_2, V_2 ; C_1, V_1, C_3, V_2 ; C_1, V_1, V_2, C_4). This allows for the determination of the impact of spelling-sound consistency of the orthographic segments on naming words of various structures. Each of these analyses, therefore, predicted naming latencies and errors for a different subset of the 896 words' naming latencies and error rates. The eighth and final analysis entered only C_1, V_1 , and V_2 , as individual predictors, and the larger order segments other than the V_2C_4 , because all of the words in the data file included these segments ($N=896$). Consistent findings across all of the analyses would indicate that a spelling-sound segment is a reliable predictor of naming latencies for all types of disyllabic words.

For each of the eight hierarchical regression analyses on naming latencies and error rates, three blocks of predictors were entered. In the first block, only the initial phoneme characteristics, log frequency, and stress pattern were considered in a stepwise procedure. These variables were considered first so that the variance associated with them would be accounted for before examining the impact of spelling-sound consistency predictors. In the stepwise procedure, however, the only variables that are entered in the equation are the ones that contribute significantly to the prediction of the criterion variable, so not all of the predictors that were considered would be part of the regression

equation at the end of the first block. In the second block, the individual grapheme spelling-sound consistency measures were forced into the regression equation, whether or not they contributed significantly. This would attribute as much variance as possible to the spelling-sound consistency of basic orthographic segments, before examining the impact of larger-order orthographic segments on naming latencies. In the third and final block, all of the larger orthographic segment measures were entered in a stepwise procedure (e.g., C_1V_1 , V_1C_2 , BOB, etc.). In this block, the individual segment consistency measures that were entered on the second block, and stress pattern, were included again, so that if any were not contributing significantly to the regression equation at this point, the stepwise procedure would remove them from the regression equation. After the final block, therefore, only variables that contributed significantly to the prediction of naming latencies or errors would be included in the regression equations. This stands in contrast to the simultaneous entry procedure that includes all variables in the equation, regardless of their actual contribution to the prediction of the criterion measure.

Naming latencies. Eight hierarchical regression analyses were conducted, each entering a different subset of the individual spelling-sound consistency measures. Tables 5 - 12 present the results for each of the regression analyses. The results concerning initial phoneme predictors are presented in Appendix D. The first hierarchical analysis entered all of the spelling sound consistency measures and therefore includes all and only the latencies for the words included in the simultaneous entry analysis presented above. It is, in essence, the stepwise equivalent to that analysis. The final model accounts for

Table 5. Results for hierarchical regression analyses predicting naming latencies.

Spelling-sound consistency predictors entered: C_1 , C_2 , C_3 , C_4 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , V_2C_4 , BOB.

Predictor	β	t	p
Log Frequency	-.391	-10.59	<.001
Stress	.103	2.73	.007
V_2 consistency	-.124	-2.68	.008
BOB consistency	-.107	-2.56	.011
CV_2 consistency	-.104	-2.27	.024
V_1C_2 consistency	-.086	-2.09	.037
C_1V_1 consistency	-.075	-2.00	.046
V_2C_4 consistency ☒	-.075	-1.83	.069
C_4 consistency ☒	-.067	-1.79	.075
C_1 consistency ☒	-.064	-1.60	.110
C_3 consistency ☒	.043	1.10	.272
V_1 consistency ☒	.008	0.164	.869
C_2 consistency ☒	-.006	-0.12	.903

$N = 477$, $R^2 = .370$ (.352 adjusted)

☒ Variable not included in the regression equation.

Table 6. Results for hierarchical regression analyses predicting naming latencies.

Spelling-sound consistency predictors entered: C_1 , C_2 , C_3 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , BOB.

Predictor	β	t	p
Log Frequency	-.411	-11.79	<.001
V_2 consistency	-.194	-5.46	<.001
BOB consistency	-.109	-2.96	.003
V_1 consistency	-.074	-2.09	.037
C_2 consistency	-.075	-2.09	.037
V_1C_2 consistency☒	-.096	-1.962	.050
CV_2 consistency☒	-.086	-1.947	.052
C_3 consistency ☒	.058	1.59	.112
Stress☒	.053	1.48	.140
C_1 consistency ☒	-.053	-1.42	.157
C_1V_1 consistency☒	-.051	-1.162	.246

$N= 519$, $R^2=.393$ (.382 adjusted)

☒Variable not included in the regression equation.

Table 7 . Results for hierarchical regression analyses predicting naming latencies.

Spelling-sound consistency predictors entered: C₁, C₂, C₄, V₁, V₂, C₁V₁, V₁C₂, CV₂, V₂C₄, BOB.

Predictor	β	t	p
Log Frequency	-.431	-13.17	<.001
V ₂ consistency	-.183	-5.52	<.001
BOB consistency	-.182	-5.42	<.001
C ₁ V ₁ consistency	-.105	-3.14	.002
Stress [‡]	.063	1.89	.059
V ₂ C ₄ consistency [‡]	-.066	-1.87	.062
C ₄ consistency [‡]	-.062	-1.85	.064
C ₁ consistency [‡]	-.048	-1.39	.165
V ₁ C ₂ consistency [‡]	-.050	-1.35	.178
CV ₂ consistency [‡]	-.020	-0.49	.627
V ₁ consistency [‡]	-.021	-0.49	.628
C ₂ consistency [‡]	-.011	-0.34	.735

N= 600, R² =.375 (.366 adjusted)

[‡]Variable not included in the regression equation.

Table 8. Results for hierarchical regression analyses predicting naming latencies.

Spelling-sound consistency predictors entered: C_1 , C_3 , C_4 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , V_2C_4 , BOB.

Predictor	β	t	p
Log Frequency	-.417	-14.44	<.001
BOB consistency	-.191	-5.97	<.001
C_4 consistency	-.118	-3.96	<.001
V_2 consistency	-.105	-2.85	.004
CV_2 consistency	-.098	-2.77	.006
V_1 consistency	-.074	-2.34	.020
Stress $\otimes$	.057	1.73	.084
V_2C_4 consistency $\otimes$	-.011	-0.33	.739
C_1 consistency $\otimes$	-.008	-0.25	.802
C_1V_1 consistency $\otimes$	-.006	-0.14	.888
V_1C_2 consistency $\otimes$	.002	0.07	.942
C_3 consistency $\otimes$	.000	0.01	.989

$N=710$, $R^2=.426$ (.417 adjusted)

$\otimes$ Variable not included in the regression equation.

Table 9. Results for hierarchical regression analyses predicting naming latencies.

Spelling-sound consistency predictors entered: C_1 , C_2 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , BOB.

Predictor	β	t	p
Log Frequency	-.433	-13.76	<.001
V_2 consistency	-.169	-5.29	<.001
BOB consistency	-.156	-4.82	<.001
V_1 consistency	-.088	-2.76	.006
C_1V_1 consistency✂	-.075	-1.88	.060
V_1C_2 consistency✂	-.066	-1.83	.068
C_1 consistency ✂	-.049	-1.48	.138
C_2 consistency ✂	-.042	-1.30	.193
Stress✂	.026	0.18	.417
CV_2 consistency✂	.000	-0.00	.997

$N = 647$, $R^2 = .375$ (.367 adjusted)

✂ Variable not included in the regression equation.

Table 10. Results for hierarchical regression analyses predicting naming latencies.

Spelling-sound consistency predictors entered: C_1 , C_3 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , BOB.

Predictor	β	t	p
Log Frequency	-.430	-15.29	<.001
BOB consistency	-.162	-5.25	<.001
V_2 consistency	-.125	-3.49	.001
V_1 consistency	-.086	-2.83	.005
CV_2 consistency	-.090	-2.56	.011
V_1C_2 consistency [‡]	-.040	-1.25	.212
Stress [‡]	.031	0.99	.322
C_1 consistency [‡]	-.028	-0.98	.330
C_3 consistency [‡]	.015	0.52	.601
C_1V_1 consistency [‡]	.004	-0.11	.916

$N = 767$, $R^2 = .408$ (.401 adjusted)

[‡] Variable not included in the regression equation.

Table 11. Results for hierarchical regression analyses predicting naming latencies.

Spelling-sound consistency predictors entered: C_1 , C_4 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , V_2C_4 , BOB.

Predictor	β	t	p
Log Frequency	-.447	-16.69	<.001
BOB consistency	-.190	-6.54	<.001
V_2 consistency	-.152	-5.37	<.001
C_4 consistency	-.109	-3.96	<.001
V_1 consistency	-.081	-2.81	.005
CV_2 consistency☒	-.052	-1.59	.111
Stress☒	.031	1.062	.291
C_1V_1 consistency☒	-.032	-0.84	.399
V_2C_4 consistency☒	-.016	-0.56	.577
V_1C_2 consistency☒	.013	0.42	.676
C_1 consistency☒	-.008	-0.30	.764

$N = 833$, $R^2 = .415$ (.408 adjusted)

☒ Variable not included in the regression equation.

Table 12. Results for hierarchical regression analyses predicting naming latencies.

Spelling-sound consistency predictors entered: C_1 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , BOB.

Predictor	β	t	p
Log Frequency	-.453	-17.73	<.001
V_2 consistency	-.167	-6.20	<.001
BOB consistency	-.163	-5.78	<.001
V_1 consistency	-.094	-3.35	.001
C_1 consistency ☒	-.041	-1.55	.122
CV_2 consistency ☒	-.039	-1.20	.229
V_1C_2 consistency ☒	-.024	-0.82	.414
C_1V_1 consistency ☒	-.018	-0.51	.613
Stress ☒	.010	0.342	.732

$N = 896$, $R^2 = .396$ (.391 adjusted)

☒ Variable not included in the regression equation.

37.0% of the variance in naming latencies (35.2% adjusted), $F(12, 464) = 25.28$, $p < .001$. As presented in Table 5, log frequency and stress are entered in the regression equation.

The consistency of the BOB, V_1C_2 , CV_2 , and C_1V_1 are all entered in this analysis, indicating that they contribute significantly to the prediction of naming latencies. In addition, V_2 consistency was entered as a significant predictor in this analysis. All of these measures were negatively correlated with naming latency, meaning that words with a high consistency measure on these segments would be named faster than words with a low consistency measure. Compared to the simultaneous entry analysis, there are some differences in the spelling-sound consistency measures that are significant. The V_2C_4 is not significant in this analysis, although it was in the simultaneous entry analysis. In addition, the three other larger order segments that were entered in this analysis (V_1C_2 , CV_2 , and C_1V_1) did not contribute significantly in the simultaneous entry analysis, but all three did approach significance in that analysis. Also, V_2 consistency did not contribute a significant proportion of unique variance to the regression equation in the simultaneous entry analysis.

The six analyses in which different subsets of the consistency predictors were entered tended to produce similar results. While many of the words in all six analyses were the same ($N = 477$), each analysis included a subset of words that would not be included in the others (for C_1, C_2, C_3 , $N = 518$, for C_1, C_2, C_4 , $N = 600$, for C_1, C_3, C_4 , $N = 710$; C_1, C_2 , $N = 647$; C_1, C_3 , $N = 768$; C_1, C_4 , $N = 833$). All six analyses resulted in regression equations that were able to predict a significant proportion of the variance in naming latencies, (for $C_1, C_2, C_3 - F(9, 509) = 35.10$, $p < .001$; for $C_1, C_2, C_4 - F(9, 590)$

= 39.35, $p < .001$; for $C_1, C_3, C_4 - F(10, 699) = 51.81, p < .001$; for $C_1, C_2 - F(9, 637) = 42.55, p < .001$; for $C_1, C_3 - F(9, 758) = 57.99, p < .001$; for $C_1, C_4 - F(9, 823) = 64.84, p < .001$). In all of these analyses, stress pattern was initially entered into the regression equation on the first block and was later removed from the equation after the consistency measures were introduced (see Tables 6 - 11). This suggests that much of the variance in naming latencies that stress pattern can account for may be attributable to the effects of spelling-sound consistency. Additionally, in all six analyses, BOB consistency and V_2 consistency contributed significantly to the regression equation, and V_1 consistency was entered in five of the six analyses. Other consistency measures contributed significantly to only one or two of the six analyses (C_2, C_4, C_1V_1, CV_2) or none of the six analyses (C_1, C_3, V_1C_2, V_2C_4).

The final hierarchical regression analysis only entered consistency measures that all of the target words contained and therefore this analysis included the full set of words from which the subsets in the previous analyses were drawn ($N = 896$). This analysis also resulted in a regression equation which accounted for a significant proportion of the variance in naming latencies, $F(8, 887) = 72.77, p < .001$. Only three consistency measures were entered into the regression equation: BOB consistency, V_1 consistency, and V_2 consistency (see Table 12). No larger-order orthographic segments other than the BOB were entered, and C_1 consistency did not contribute significantly to the regression equation.

The Lorch and Myers (1990) procedure for analyzing repeated measures data was run for this final hierarchical analysis as well. Regression equations were again generated for each individual who was tested ($n = 29$), and the distribution of Beta

weights for each predictor was tested against the value of 0. Using this procedure, five segments contributed significantly to the prediction of naming latencies. The Beta for the BOB segment was significantly different from zero, $t(28) = -8.63$, $p < .001$, the V_1C_2 segment, $t(28) = -2.87$, $p < .01$, the V_1 segment, $t(28) = -7.64$, $p < .001$, the C_1V_1 segment, $t(28) = -2.79$, $p < .01$, and the V_2 segment, $t(28) = -9.36$, $p < .001$. The major difference between the results for the Lorch and Myers (1990) analysis and the results using the averaged data is that the consistency of the V_1C_2 segment is significant in the Lorch and Myers (1990) analysis. In contrast to the Lorch and Myers (1990) results for the simultaneous entry analysis presented earlier, the CV_2 is not significant, $t(28) = -1.16$, ns, in this Lorch and Myers (1990) analysis. Again, stress did not contribute significantly to the prediction of naming latencies using this procedure, $t(28) = 0.92$, ns.

Error rates. The eight hierarchical regression analyses were conducted on error rates as well, each entering a different subset of the spelling-sound consistency measures as predictors. The same three-block procedure was used, in which variance associated with stress pattern, frequency, and initial phoneme characteristics was accounted for before estimating the impact of the spelling-sound consistency predictors. Tables 13 - 20 present the results for each of the analyses. As with the analyses of naming latencies, the results concerning initial phoneme predictors are not of theoretical interest here, and are presented in Appendix E. In the following analyses, C_1 consistency was entered as a significant predictor in many of the regression equations, but was not entered when the eleven words in which C was pronounced as /s/ were removed from the data file. The first analysis entered all of the spelling sound consistency measures, and is, therefore, the stepwise equivalent to the simultaneous entry analysis of error rates presented earlier.

Table 13. Results for hierarchical regression analyses predicting error rates.

Spelling-sound consistency predictors entered: C_1 , C_2 , C_3 , C_4 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , V_2C_4 , BOB.

Predictor	β	t	p
Log Frequency	-.222	-5.46	<.001
Stress	.236	5.69	<.001
V_2 consistency	-.213	-5.06	<.001
BOB consistency	-.174	-4.27	<.001
C_1 consistency	.087	2.13	.034
V_2C_4 consistency ☒	-.088	-1.95	.052
C_4 consistency ☒	-.066	-1.59	.113
CV_2 consistency ☒	-.057	-1.13	.258
C_3 consistency ☒	.045	1.07	.284
V_1 consistency ☒	-.041	-0.98	.327
V_1C_2 consistency ☒	-.033	-0.72	.471
C_1V_1 consistency ☒	-.027	-0.66	.509
C_2 consistency ☒	-.008	-0.19	.847

$N=477$, $R^2=.244$ (.234 adjusted)

☒ Variable not included in the regression equation.

Table 14. Results for hierarchical regression analyses predicting error rates.

Spelling-sound consistency predictors entered: C_1 , C_2 , C_3 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , BOB.

Predictor	β	t	p
Log Frequency	-.231	-5.80	<.001
Stress	.197	4.80	<.001
V_2 consistency	-.177	-4.27	<.001
BOB consistency	-.151	-3.74	<.001
C_1 consistency ☒	.066	1.65	.100
V_1C_2 consistency ☒	-.056	-1.24	.215
C_3 consistency ☒	.046	1.12	.265
C_2 consistency ☒	-.042	-1.03	.306
V_1 consistency ☒	-.036	-0.90	.369
CV_2 consistency ☒	-.041	-0.82	.415
C_1V_1 consistency ☒	-.019	-0.47	.637

$N = 519$, $R^2 = .194$ (.187 adjusted)
 ☒ Variable not included in the regression equation.

Table 15. Results for hierarchical regression analyses predicting error rates.

Spelling-sound consistency predictors entered: C_1 , C_2 , C_4 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , V_2C_4 , BOB.

Predictor	β	t	p
Log Frequency	-.274	-7.50	<.001
V_2 consistency	-.170	-4.54	<.001
Stress	.159	4.26	<.001
BOB consistency	-.156	-4.19	<.001
C_1 consistency	.101	2.74	.006
V_1 consistency	-.070	-1.87	.062
C_4 consistency ☒	-.060	-1.60	.111
V_2C_4 consistency ☒	-.063	-1.58	.114
C_2 consistency ☒	.049	1.33	.184
C_1V_1 consistency ☒	-.030	-0.64	.522
V_1C_2 consistency ☒	.011	0.28	.782
CV_2 consistency ☒	.003	0.06	.951

$N=600$, $R^2=.229$ (.218 adjusted)

☒ Variable not included in the regression equation.

Table 16. Results for hierarchical regression analyses predicting error rates.

Spelling-sound consistency predictors entered: C_1 , C_3 , C_4 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , V_2C_4 , BOB.

Predictor	β	t	p
Log Frequency	-.334	-10.36	<.001
CV_2 consistency	-.142	-4.09	<.001
BOB consistency	-.148	-4.07	<.001
C_4 consistency	-.123	-3.71	<.001
C_1 consistency	.104	3.14	.002
Stress	.093	2.64	.008
V_1 consistency	-.084	-2.36	.019
V_2C_4 consistency	-.077	-2.21	.027
V_2 consistency ☒	-.048	-1.11	.269
C_3 consistency ☒	.019	0.57	.569
V_1C_2 consistency ☒	-.010	-0.27	.785
C_1V_1 consistency ☒	.002	0.04	.972

$N=710$, $R^2=.292$ (.279 adjusted)

☒ Variable not included in the regression equation.

Table 17. Results for hierarchical regression analyses predicting error rates.

Spelling-sound consistency predictors entered: C_1 , C_2 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , BOB.

Predictor	β	t	p
Log Frequency	-.268	-7.52	<.001
V_2 consistency	-.155	-4.22	<.001
Stress	.143	3.91	<.001
BOB consistency	-.140	-3.85	<.001
C_1 consistency	.088	2.45	.015
V_1 consistency	-.081	-2.21	.027
C_1V_1 consistency [‡]	-.038	-0.84	.399
C_2 consistency [‡]	.015	0.41	.683
CV_2 consistency [‡]	.008	0.19	.852
V_1C_2 consistency [‡]	-.007	-0.17	.866

$N = 647$, $R^2 = .201$ (.190 adjusted)

[‡] Variable not included in the regression equation.

Table 18. Results for hierarchical regression analyses predicting error rates.

Spelling-sound consistency predictors entered: C_1 , C_3 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , BOB.

Predictor	β	t	p
Log Frequency	-.333	-10.55	<.001
BOB consistency	-.150	-4.32	<.001
V_1 consistency	-.111	-3.26	.001
CV_2 consistency	-.109	-2.77	.006
V_2 consistency	-.107	-2.67	.008
C_1 consistency	.079	2.44	.015
Stress $\text{\textcircled{X}}$	.068	1.90	.058
V_1C_2 consistency $\text{\textcircled{X}}$	-.040	-1.13	.258
C_3 consistency $\text{\textcircled{X}}$	.017	0.50	.615
C_1V_1 consistency $\text{\textcircled{X}}$	-.002	-0.05	.962

$N=767$, $R^2=.253$ (.243 adjusted)

$\text{\textcircled{X}}$ Variable not included in the regression equation.

Table 19. Results for hierarchical regression analyses predicting error rates.

Spelling-sound consistency predictors entered: C_1 , C_4 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , V_2C_4 , BOB.

Predictor	β	t	p
Log Frequency	-.360	-12.11	<.001
BOB consistency	-.159	-4.89	<.001
C_4 consistency	-.112	-3.59	<.001
C_1 consistency	.110	3.58	<.001
V_1 consistency	-.091	-2.79	.005
CV_2 consistency	-.086	-2.34	.019
V_2 consistency	-.078	-1.98	.048
Stress	.064	1.92	.055
V_2C_4 consistency✂	-.059	-1.80	.073
C_1V_1 consistency✂	-.020	-0.48	.635
V_1C_2 consistency✂	.006	0.17	.862

$N = 833$, $R^2 = .281$ (.271 adjusted)

✂ Variable not included in the regression equation.

Table 20. Results for hierarchical regression analyses predicting error rates.

Spelling-sound consistency predictors entered: C_1 , V_1 , V_2 , C_1V_1 , V_1C_2 , CV_2 , BOB.

Predictor	β	t	p
Log Frequency	-.356	-12.14	<.001
V_2 consistency	-.152	-5.03	<.001
BOB consistency	-.158	-5.00	<.001
V_1 consistency	-.114	-3.64	<.001
C_1 consistency	.077	2.58	.010
CV_2 consistency [‡]	-.068	-1.88	.061
Stress [‡]	.045	1.40	.162
V_1C_2 consistency [‡]	-.024	-0.71	.479
C_1V_1 consistency [‡]	-.012	-0.29	.773

$N = 896$, $R^2 = .243$ (.235 adjusted)

[‡]Variable not included in the regression equation.

Because all the predictors were included, the data from only 477 of the 896 words served as the criterion in this analysis. The final model accounted for 24.4% of the variance in error rates (23.4% adjusted), $F(6, 470) = 25.22$, $p < .001$. Log frequency and stress pattern contributed significantly to the regression equation (see Table 13). V_2 consistency was entered as a significant predictor in this analysis, and, as in all regression analyses so far, BOB consistency was a significant predictor in this analysis. BOB consistency was negatively correlated with error rate, meaning that words with a high consistency measure produced fewer errors than words with a low consistency measure. No other larger orthographic segments were entered in this equation (e.g., V_1C_2 , CV_2 , C_1V_1 , V_2C_4). V_2C_4 consistency did not contribute significantly to the prediction of errors in this analysis, although it did in the simultaneous entry analysis presented earlier. The other difference between this analysis and the simultaneous entry analysis was the significant effect of V_2 consistency, which only approached significance in the previous analysis (see Table 4).

The six analyses in which subsets of the consistency predictors were entered tended to produce the same pattern of results. Again, these analyses evaluate the impact of the spelling-sound consistency of the segments on disyllabic words of varying structures, and a different subset of the 896 words served as the criterion variable in each of the analyses. All six analyses were able to predict a significant proportion of the variance in naming latencies, (for $C_1, C_2, C_3 - F(5, 513) = 24.77$, $p < .001$; for $C_1, C_2, C_4 - F(8, 591) = 21.91$, $p < .001$; for $C_1, C_3, C_4 - F(12, 697) = 23.91$, $p < .001$; for $C_1, C_2 - F(8, 638) = 20.00$, $p < .001$; for $C_1, C_3 - F(10, 757) = 25.64$, $p < .001$; and for $C_1, C_4 - F(12, 820) = 26.77$, $p < .001$). Unlike the latency analyses, stress pattern contributed

significantly to five of the six regression equations, even after the consistency measures had been entered (see Tables 14 - 19). In all six analyses, BOB consistency contributed significantly to the regression equation, and V_1 consistency and V_2 consistency were entered in five of the six equations. CV_2 consistency was entered as a significant predictor of error rates in three of the six analyses. C_4 consistency contributed significantly the prediction of errors in two of the four equations in which it was included. Other consistency measures contributed significantly to the regression equation in only one, or none, of the analyses (C_2 , C_3 , C_1V_1 , V_1C_2 , V_2C_4).

The final hierarchical regression analysis included all of the words in the study that had consonant onsets ($N=896$). This analysis also resulted in a regression equation which accounted for a significant proportion of the variance in error rates, $F(9, 886) = 31.54$, $p < .001$. Only four consistency measures were entered into the regression equation: BOB consistency, V_1 consistency, V_2 consistency, and C_1 consistency (see Table 20). Notably, stress pattern did not contribute significantly to the regression equation. No larger order orthographic segment other than the BOB was entered.

Discussion

The results of this study paint a rather clear picture of the importance of spelling-sound consistency for naming disyllabic words. In all of the analyses conducted on naming latencies and on error rates, at least two spelling-sound consistency measures contributed significantly to the regression equation. The spelling-sound consistency of the BOB was always a significant predictor, and the consistency of V_2 was entered as a significant predictor in most of the analyses. These two results suggest that the consistency of smaller individual grapheme segments (V_1 , V_2) and also larger-order

segments (the BOB) influence performance when naming disyllabic words. A discussion of the results for individual spelling-sound segments will precede the discussion of the larger-order orthographic segments, in which vowel and consonant graphemes are combined. It is important to be aware of the degree to which these simple segments contribute to phonological processing in order to correctly estimate the impact of the larger orthographic segments.

Individual Spelling-sound Segments

In the present experiment, the only individual spelling-sound consistency measure that was almost always entered in the regression equations was V_2 consistency. Although it was not entered in the simultaneous entry analyses on naming latencies and errors, V_2 consistency contributed significantly to the regression equation in all eight of the hierarchical regression analyses on latencies and seven of the eight hierarchical analyses on errors. As well, when the Lorch and Myers (1990) procedure was conducted on latency data, V_2 consistency was a significant predictor of naming latencies for the simultaneous entry analysis. These contrasting results for the simultaneous entry analyses indicate that it is important that researchers conducting regression analyses on repeated measures data use the Lorch and Myers (1990) procedure to verify any results from the standard analysis. The results of the analyses presented here indicate that a predictor's contribution to a regression equation can be underestimated if regression analyses are conducted only on group means. In the present case, the contribution of V_2 consistency was underestimated.

The spelling-sound consistency measure for the V_1 segment contributed significantly to the regression equation in six of the eight hierarchical regression analyses

on naming latencies and six of the eight hierarchical regression analyses on error rates. This segment was not a significant predictor in either of the simultaneous entry analyses. The Lorch and Myers (1990) procedure on naming latencies also found that V_1 consistency was not a significant predictor in the simultaneous entry analysis, but was in the final hierarchical analysis. The impact of this segment, therefore, is somewhat questionable. It is likely that the consistency of the V_1 segment is similar to the consistency of the BOB or the V_1C_2 , which include the V_1 segment as its initial grapheme, and therefore may not be included due to shared variance with these larger segments. In combination with the results for the V_2 segment, however, the conclusion can be drawn that the spelling-sound consistency of vowels affected the production of phonology for disyllabic words. These results support the hypothesis made by Jared and Seidenberg (1990) that the computation of vowel pronunciations may be a cause for the syllable length effects reported in their Experiment 3.

The results for the C_4 segment suggest that vowel consistency may not be the only important individual segment in the second syllable of disyllabic words. The consistency of this segment was only considered for entry into the regression equation in four of the eight hierarchical analyses of latencies. In two, the consistency of this segment approached significance (see Tables 5, 7), and in the other two, C_4 consistency contributed significantly to the regression equation (see Tables 8, 11). The same results for the C_4 segment can be seen in the hierarchical regression analyses of error rates. The consistency of the final consonant in disyllabic words, then, may also affect disyllabic word naming, but the effect is not as strong as for the consistency of the V_2 segment.

The results for the V_2 segment, and perhaps the V_1 segment and the C_4 segment as

well, indicate that readers' phonological processing of disyllabic words is affected by the spelling-sound consistency of individual grapheme segments. In particular, vowels' consistencies appear to play a more influential role than do consonants. These three segments alone, however, do not completely explain the impact of spelling-sound consistency on phonological processing. The discussion will now address the impact on naming latencies and error rates of larger orthographic segments that combine consonant and vowel graphemes.

Higher- Order Orthographic Segments

In addition to the simple orthographic segments, the consistency of higher-order orthographic segments also contributed to the prediction of naming latencies and error rates in this experiment. In the simultaneous entry analyses, and in all of the hierarchical regression analyses on naming latencies and error rates, BOB consistency was a significant predictor. It is likely that the BOB is an influential segment in disyllabic word naming because it constrains the possible pronunciations of the initial vowel grapheme and medial consonants. In contrast to the strong influence of the BOB, the consistency of the phonological-syllable defined V_1C_2 segment was significant or marginally significant in only four out of nine regression analyses on naming latencies. In support of the influence of the V_1C_2 segment, however, the Lorch and Myers (1990) procedure identified the consistency of the segment as a significant predictor of naming latencies for the simultaneous entry analysis and for the final hierarchical analysis. In combination with the fact that it approaches significance in the simultaneous entry analysis on averaged data, and that it contributes significantly in the first stepwise analysis, it *may* be an important segment for the phonological processing of disyllabic words. It could be the

case that the V_1C_2 segment constrains the vowel pronunciation only moderately, and to a lesser degree than the BOB segment. On the other hand, V_1C_2 consistency was not significant in any of the regression analyses on error rates. This suggests that this segment may not have a strong effect on disyllabic word naming, in that it doesn't appear to induce a reader to make an error. Experiment 2 examines the relative impact of BOB consistency and V_1C_2 consistency on disyllabic word naming in a factorial design to determine whether both segments do indeed affect performance.

Other higher-order orthographic segments were not consistently entered in the regression equations on naming latencies. The spelling-sound consistency of the V_2C_4 segment, the counterpart of the BOB/ V_1C_2 for the second syllable, was not consistently entered as a predictor in the analyses on naming latencies, although it was entered in the simultaneous entry analysis, and also in the Lorch and Myers (1990) procedure. This segment approached significance in only two of the hierarchical analyses. In the analyses of error rates, the spelling-sound consistency of the V_2C_4 segment contributed significantly to one regression equation. This evidence suggests that the consistency of the V_2C_4 segment has only a weak impact on naming latencies and errors. It is likely the case that the final consonant does not frequently help constrain the pronunciation of the second vowel. The relatively rare occurrences of non-lax vowels in the second syllable may block the phonological processing mechanism from picking up on contingencies between V_2 and C_4 graphemes and their respective pronunciations.

In contrast to the BOB, V_1C_2 , and V_2C_4 segments, the consonant-vowel combination segments (i.e., C_1V_1 , CV_2) did not often contribute to the regression equations in the hierarchical analyses. This is not surprising, because for monosyllabic

words C_1V_1 consistency has not been shown to predict either naming latencies or error rates (Treiman et al., 1995). On the other hand, in English polysyllabic words, there is a far greater proportion of phonological CV syllables than there are for monosyllabic words (approximately 45% of polysyllabic words have at least one CV syllable), so one might expect these segments to have a greater impact on naming these words. In fact, both the C_1V_1 and the CV_2 consistency measures were entered as significant predictors in the first hierarchical regression analysis on naming latencies.

The impact of these segments, however, is considerably less than that for the BOB or the V_2 segment. In the Lorch and Myers (1990) analysis corresponding to the final hierarchical regression analysis, only the CV_2 was identified as a significant predictor. Of the eight hierarchical analyses in which CV_2 consistency was included, it contributed significantly to the regression equation in only two, and approached significance in another two. For the analyses of error rates, CV_2 consistency contributed significantly to only three of the eight equations. The evidence for an influence of C_1V_1 consistency is just as weak. Of the eight hierarchical analyses, it contributed significantly in only one, and approached significance in another two, while not contributing significantly in any of the analyses on error rates. C_1V_1 consistency was significant, however in the Lorch and Myers (1990) analysis corresponding to the final hierarchical analysis on naming latencies. The fact that these spelling-sound segments are not consistently entered in the regression equations suggests that they are not likely to have a substantial impact on the phonological processing of most disyllabic words. It is unlikely that the initial consonant constrains the pronunciation of the following vowel in the same manner as the following consonants in the BOB does. It may be the case that these

segments were occasionally entered in the analyses because the following vowel helps constrain the pronunciation of the preceding consonant when that consonant is a C or a G. Overall, it is clear that there is not a strong influence of these segments on disyllabic word naming performance.

These results concerning the impact of the consistency of various vowel-consonant or consonant-vowel segments indicate that readers' phonological processing is affected by the likelihood that combinations of printed letters will produce one phonological pattern versus another. Quite clearly, the information provided by the BOB plays a role in the phonological processing of disyllabic words. These results also indicate that, for phonological processing, the orthographic representation of a disyllabic word is not parsed into syllable-defined units. If that were the case, the V_1C_2 segment should have been identified as the strongest spelling-sound consistency predictor, because it would correspond to the body of the orthographic segment being mapped to phonology. Likewise, the consistency of the BOB should *not* be a significant predictor, because the word recognition system would not process the BOB as a single orthographic segment. The results from this study point to the opposite conclusion, indicating that, because the BOB is a significant predictor, the word recognition system does not parse polysyllabic words along phonological syllable boundaries.

There is another reason to believe that a word's orthography is not parsed in a strict manner. Experiment 1 indicated that V_1 consistency has an impact on phonological processing. This finding is surprising, since the V_1 segment is contained in the BOB. It is possible, then, that multiple spelling-sound consistency mappings for the same orthographic segments are affecting the naming of disyllabic words. This type of finding

strongly suggests that phonological processing is a matter of a distributed mapping from orthography to phonology. It would be difficult to design a system with a strong parse that can account for effects from different segments that both contain the same letters (i.e., V₁ and BOB).

Stress Pattern Effects

Of additional interest in the present study is the effect of stress pattern. This variable was included in the regression analyses to remove its associated variance because, as mentioned, previous research has found differences in naming latencies for polysyllabic words stressed on the second syllable compared to the first syllable (Colombo, 1992; Colombo & Tabossi, 1992; Brown et al., 1994). Without taking into account spelling-sound consistency, stress pattern was positively correlated with naming latencies in this experiment. However, the pattern of results here suggests that the effect of stress pattern may in fact be due to spelling-sound consistency. When stress is placed on the second syllable, some very low consistency spelling-sound correspondences will be present in the mapping from orthography to phonology. In the analyses of naming latencies, the only instance where stress contributed significantly to the prediction of naming latencies was in the simultaneous entry analysis, but it was not significant in the corresponding Lorch and Myers (1990) analysis, indicating that this may have been a spurious result.

The hierarchical regression analyses that were conducted can shed some light on the hypothesis that stress pattern effects on naming latencies are a matter of spelling-sound consistency. In each of the eight analyses, stress pattern was entered as a significant predictor in the first stepwise block. In seven of these eight analyses, stress

pattern was removed from the prediction equation in the third block, after the measures of consistency had been entered. In most cases, stress pattern was removed as a significant contributor to the regression equation after the consistencies of the individual spelling-sound segments had been forced into the regression equation. It is likely that the effect of stress pattern can be accounted for by V_1 consistency and/or V_2 consistency, because these were the individual segments that contributed significantly to the regression equation in the analyses. The preponderance of evidence, therefore, points to a null effect of stress pattern on the naming latencies of disyllabic words.

Hammond's (1999) linguistic analysis is also consistent with the idea that there could be non-lexical cues to stress provided by orthographic-phonological processing. With the exception of verbs, stress is usually placed on the first syllable in disyllabic words. This could be largely due to a constraint proposed by Hammond that in English, feet are binary (i.e., contain two weight bearing units) and trochaic (i.e., initial stress). Therefore, disyllabic words should have stress on the first syllable, since this would normally satisfy both of these constraints. However, another higher order constraint mandates that stress be placed on the syllable with the greatest weight in terms of moras, and the number of moras in a syllable depends on the particular phonemes in the syllable. It is also necessary to know which syllable a medial consonant belongs to, because all consonants in a syllable onset position contribute no moras, but may contribute one or more as a syllable coda. This makes the determination of stress a somewhat circular procedure, because the moraic value of a medial consonant cannot be known without knowing the pronunciation of the full word, but the pronunciation of the word is assumed to depend on computing the stress pattern. With this in mind, it may be that stress

assignment and phoneme computation are not distinct modular operations, and therefore, activating the phonemes of a disyllabic printed word will substantially influence, or account for, stress assignment.

The effect of stress pattern on the proportion of errors, however, is much more reliable, and apparently cannot be explained by spelling-sound consistency measures. Stress pattern contributed significantly to the regression equation in five of the eight analyses, and approached significance in another two. However, the regression equation in which the fewest consistency measures were entered (C_1 , V_1 , V_2) was the analysis in which stress pattern had the weakest, and non-significant, effect (see Table 20). In conjunction with the results for naming latencies, the fact that stress does not predict the proportion of errors when the greatest number of words are included, and the fewest number of consistency predictors are entered, casts some doubt on its effect on the word recognition system. The effect of stress pattern on error rates could have been exaggerated in these analyses because the majority of the items were stressed on the first syllable, and there were no contextual cues to indicate that second syllable stress would be more likely for some words. When reading a sentence, for example, cues that a word should be a verb would help a reader to produce the correct stress pattern since verbs are more frequently iambic (Kelly & Bock, 1988). Without these cues, the word recognition system may be at a disadvantage when attempting to produce the correct phonology of an iambic item in a standard naming experiment. It is quite clear, though, that when people do produce the correct phonological representation of a disyllabic word, spelling-sound consistency plays a much larger role in determining naming latencies than does the stress pattern of the word.

Factorial Design Experiments

Because this is the first study to examine spelling-sound consistency in disyllabic words, replicating any significant findings from the first experiment with different participants, and using a factorial design, is a warranted additional step. If effects are replicated, the influence of the orthographic segment's consistency on disyllabic word naming and phonological processing would be more clearly established. Verifying the significant findings from the regression study is particularly important for segments that cross syllable boundaries, such as the BOB, because they have not previously been identified as a relevant spelling-sound consistency segment for phonological processing. In addition, while the V_1C_2 may not have been entered in many of the stepwise regression analyses, it was identified as a significant predictor of naming latencies in both of the Lorch and Myers (1990) analyses. Although it is possible that phonological processing is influenced by the spelling-sound consistency of both segments, one might expect that *either* the BOB or the V_1C_2 would be relevant for phonological processing, since they are in many ways similar. Experiments 2a and 2b examine this issue by contrasting the extremes of both segments' consistency distributions.

There are two additional issues that should be immediately examined. First, although the evidence for a frequency by consistency interaction for monosyllabic words has been questioned (Jared, 1997, submitted), there is still the possibility that this interaction may be present in disyllabic words. Jared and Seidenberg (1990) reported a significant frequency and consistency interaction, but the degree of consistency for the high frequency and low frequency words was not controlled. Experiment 3 examined whether there is a frequency by consistency interaction in disyllabic word naming. In

addition, the spelling-sound consistency effects for the second syllable of disyllabic words should be examined. In the present study, the only consistency measure from the second syllable that was identified as affecting naming latencies was the V_2 , so this segment's consistency may have been responsible for the second-syllable consistency effect found by Jared and Seidenberg (1990). Experiment 4 examined the impact of the V_2 segment on naming to verify that this segment's consistency does indeed influence disyllabic word naming.

Experiment 2a: BOB Consistency vs. V_1C_2 Consistency

The regression study paints a clear picture of the importance of the BOB segment's spelling-sound consistency for the phonological processing of disyllabic words. As noted in the discussion of the results, BOB consistency was repeatedly entered into the regression equations on naming latency and error rates. V_1C_2 consistency, on the other hand, was entered in only some of the analyses of naming latency, and not in any of the analyses on error rates. This would suggest that phonological processing is not based on the conversion of a syllable's orthography to the syllable's phonology, but rather that pronunciations of letters in one syllable may be constrained by letters appearing in the other syllable. However, the hypothesis in previous research with disyllabic words is that they are divided into their constituent syllables, and some of the evidence presented in the introduction suggests that this may be the case. To help clarify this issue, and to replicate the findings of the regression study, Experiment 2a contrasts BOB consistency and V_1C_2 consistency directly in a factorial design. This is a strong test of whether disyllabic words are 'parsed' at syllable boundaries, or whether information beyond a syllable boundary influences naming of disyllabic words.

Method

Participants

Thirty undergraduate students at the University of Western Ontario participated in the experiment. None of these participants had completed Experiment 1. Participants volunteered for the study as one method of earning credit in an introductory psychology class. All participants were native English speakers and had normal or corrected to normal vision.

Apparatus and Materials

The same apparatus was used as in Experiment 1. One hundred disyllabic words chosen from the CELEX lexical database were included in this experiment. There were four lists of words. Two lists were matched for the consistency of the V_1C_2 segment, and the consistency of the BOB segment was varied (high, low). In the other two lists, the words were matched for the consistency of the BOB segment, and the consistency of the V_1C_2 segment was varied (high, low). The lists for each segment type were matched on V_1 consistency, V_2 consistency, the number of phonemes, and printed word frequency. Following the suggestion of Kawamoto and his colleagues (Kawamoto, Kello, Jones, & Bame, 1998; Kawamoto, Kello, Higareda, & Vu, 1999), the initial phonemes of the words for simple and complex onsets were also matched (e.g., BEACON – BEAKER, SPIRAL - SPIDER). All words were monomorphemic, six letters in length, and were stressed on the first syllable. The characteristics of these words can be found in Table 21. The full list of words can be found in Appendix F.

Procedure

Participants in the experiment were tested individually, and the testing session

Table 21. Characteristics of the stimuli in Experiment 2a.

Variable	Word Type			
	High BOB	Low BOB	High V_1C_2	Low V_1C_2
CELEX Frequency ^a	149.1	154.8	160.2	146.1
BOB consistency	.806	.353	.762	.756
V_1C_2 consistency	.485	.502	.747	.242
V_1 consistency	.448	.448	.546	.546
V_2 consistency	.646	.687	.730	.761
# of phonemes	5.44	5.52	5.40	5.48

^a Frequencies for individual words are capped at 1000 and are the number of occurrences in 16.5 million tokens. No pairwise comparison on any of the control consistency measures was significant (all p 's >.40).

lasted approximately 10 minutes. Prior to completing the experiment, the participants read and signed a declaration of informed consent (Appendix G) which outlined the experimental procedure. Upon completion, each participant was given a debriefing form (Appendix H) which outlined the hypotheses tested in the experiment.

Participants were seated in front of the computer monitor and were first presented with written instructions displayed on the monitor. These instructions were similar to those presented in Experiment 1, except that participants were informed that 100 experimental trials would follow the practice trials. There were no breaks during this experiment. Individual trials proceeded in the same manner described for Experiment 1 and each participant saw a different random ordering of the stimuli.

Results

For this experiment, naming latencies that exceeded 1200 ms were not included in the analyses. Latencies exceeding this value were very rare and represented a substantial deviation from every subjects mean naming latency. This affected approximately 1.0% of the data. For the analysis treating participants as a random factor (F_1), consistency (high, low) and word type (BOB, V_1C_2) were analyzed as within-participants factors. For the analysis treating items as a random factor (F_2), the same variables were analyzed as between-items factors. The mean naming latencies and error rates by participants are presented in Figure 2.

Of particular interest for this experiment was the interaction between consistency and word type, which was significant by subjects, $F_1(1, 29) = 22.97, p < .001$, and approached significance by items, $F_2(1, 96) = 3.05, p = .084$. To further examine this interaction, tests of the simple main effects of consistency were conducted. The effect of

Figure 2. Mean naming latencies and error rates (in parentheses) for conditions in Experiment 2a.

consistency was significant for words varying in BOB consistency, with high-consistency words being named faster than low-consistency words, $F_1(1, 29) = 32.89$, $p < .001$, $F_2(1, 96) = 4.47$, $p < .05$. The effect of consistency was not significant for words varying in V_1C_2 consistency, $F_1(1, 29) = 2.02$, ns , $F_2 < 1$. The main effect of consistency was significant by participants, $F_1(1, 29) = 8.26$, $p < .01$, but not significant by items, $F_2(1, 96) = 1.55$, $p = .22$.

In the analysis of error rates, a similar pattern emerged. The interaction between consistency and item type was significant by participants, $F_1(1, 29) = 12.19$, $p < .01$, but not by items, $F_2(1, 96) = 1.62$, $p = .21$. In tests of simple main effects, high consistency BOB words produced significantly fewer errors than low consistency BOB words, $F_1(1, 29) = 29.64$, $p < .001$, $F_2(1, 96) = 7.19$, $p < .01$. There was no effect of consistency for V_1C_2 words, F 's < 1 . The main effect of consistency, again, was significant, $F_1(1, 29) = 12.72$, $p < .01$, $F_2(1, 96) = 6.36$, $p < .05$.

Discussion

The results of this experiment support the interpretation of the regression experiment. The spelling-sound consistency of the BOB segment significantly affected readers' ability to name disyllabic words. Low-consistency BOB items produced more errors despite the fact that they also took longer to name. This experiment also demonstrates that the spelling-sound consistency of the phonological-syllable defined V_1C_2 segment does not affect naming latencies or errors. In fact, the pattern of naming latencies and errors would suggest that the consistency of the V_1C_2 segment has an effect in the opposite direction. Low-consistency items produced fewer errors and were faster to name, although not significantly so. The reason for the significant contribution of the

V_1C_2 segment in some of the regression analyses can only be speculated upon. A likely explanation relies on the fact that the V_1C_2 segment and the BOB segment were identical for many of the words in the analyses, but the spelling-sound consistencies were different because the pool of words that contributed to each of the pronunciations for the segments were not the same. The results from this factorial experiment, however, strongly suggest that when readers encounter a disyllabic word, the spelling-sound consistency of the BOB plays a major role in the generation of the phonological representation of the word, whereas the consistency of the V_1C_2 segment does not.

There is, however, one limitation to the experiment. The number of intervening consonants between the two vowel graphemes was not equated across the two BOB lists. The low-consistency BOB condition had significantly fewer intervening letters ($\underline{M}=1.60$) than the high-consistency BOB condition ($\underline{M}=1.96$), $t(48) = 2.25$, $p < .05$. This was not the case for the V_1C_2 conditions (High-consistency, $\underline{M} = 2.24$, Low consistency, $\underline{M} = 2.04$), $t(48) = 1.21$, *ns*. Taft (personal communication, April, 2000) suggested that fewer intervening consonants between vowels could make processing more difficult, regardless of the particular spelling-sound consistency for the segments. For one thing, certain intervening consonants are less constrained when they appear alone (e.g., the C in RACIST, FACIAL, VACANT) than when the same consonants appear with other intervening consonants (e.g., RACCOON, TACKLE, FACTOR). To determine whether the number of intervening consonants between vowels has an effect on word naming, this variable was entered in a regression analysis identical to the final hierarchical regression analysis presented in Experiment 1. The number of intervening consonants contributed significantly to the regression equation, demonstrating that readers may, in fact, use this

information in phonological processing, ($\beta = -.138$, $t(886) = -4.56$, $p < .01$)³. The fewer letters there are between vowel graphemes, the slower people are to name the word. The fact that the spelling-sound consistency of both the BOB and the number of medial consonants contribute a significant unique proportion of the variance to the regression equation indicates that readers pick up on low-level information as well as the particular spelling-sound consistency for an orthographic segment. To determine whether the variation in the number of intervening consonants was actually the cause of the BOB consistency effect in Experiment 2a, Experiment 2b was run, in which the number of intervening letters was matched between the two BOB conditions.

Experiment 2b: BOB consistency vs. V_1C_2 consistency

As with Experiment 2a, participants were required to name four lists of words. Two lists were matched for the consistency of the V_1C_2 segment, and the consistency of the BOB segment was varied (high, low). In the other two lists, the words were matched for the consistency of the BOB segment, and the consistency of the V_1C_2 segment was varied (high, low). Additionally, the number of intervening consonants between the two vowel graphemes was equated.

Method

Participants

Thirty undergraduate students at the University of Western Ontario participated in the experiment, none of whom had participated in previous experiments. Participants volunteered for the study as one method of earning credit in an introductory psychology

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³ All of the regression analyses were re-run with the number of intervening letters entered as a predictor, or considered in a stepwise procedure. This addition to the analyses did not affect the significance of the BOB or V_2 as predictors of naming latencies or percentage of errors.

class. All participants were native English speakers and had normal or corrected to normal vision.

Apparatus and Materials

The same apparatus was used as in the previous experiments. One hundred disyllabic words were chosen from the CELEX lexical database. As in Experiment 2a, there were four lists of words in this experiment. In two lists the consistency of the V_1C_2 segment was matched and the BOB segment was varied, and in the other two lists the consistency of the BOB was matched and the consistency of the V_1C_2 segment was varied. In matching the two lists of critical BOB words on number of intervening consonants, severe limitations were placed on the choice of words in order to equate the two lists on V_1C_2 consistency, V_1 consistency, V_2 consistency, the number of phonemes, printed word frequency, and initial phoneme. In this set of items, the constraint on V_2 consistency was relaxed. The high-consistency BOB items had a lower average V_2 consistency ($M = .611$) than the low-consistency BOB items ($M = .726$), although not significantly so, $t(48) = 1.54$, $p = .13$. Importantly, this difference in V_2 consistency can only work against the hypothesis that the spelling-sound consistency of the BOB affects phonological processing, because high consistency V_2 segments led to faster naming latencies in Experiment 1. Again, all words were six letters in length, and were stressed on the first syllable. The characteristics of these words can be found in Table 22. The full list of words can be found in Appendix I.

Procedure

Participants in the experiment were tested individually, and the testing session lasted approximately 10 minutes. Prior to completing the experiment, the participants

Table 22. Characteristics of the stimuli in Experiment 2b.

Variable	High BOB	Low BOB	High V_1C_2	Low V_1C_2
CELEX Frequency ^a	141.9	142.7	151.9	144.9
BOB consistency	.829	.390	.796	.783
V_1C_2 consistency	.518	.517	.749	.230
V_1 consistency	.453	.453	.535	.535
V_2 consistency	.611	.726	.742	.751
# of phonemes	5.44	5.52	5.40	5.48

^a Frequencies for individual words are capped at 1000 and are the number of occurrences in 16.5 million tokens. No pairwise comparison on any of the control consistency measures was significant (all p 's >.15).

read and signed a declaration of informed consent (Appendix G) which outlined the experimental procedure. Upon completion, each participant was given a debriefing form (Appendix H) which outlined the hypotheses tested in the experiment.

Participants were seated in front of the computer monitor and were first presented with written instructions displayed on the computer monitor. These instructions were identical to those presented in Experiment 2a. Individual trials proceeded in the same manner described for Experiment 1. Each participant received a different random ordering of the stimuli.

Results

As in Experiment 2a naming latencies that exceeded 1200 ms were not included in the analyses. This affected approximately 1.6% of the data. For the analysis treating participants as a random factor (E_1), consistency (high, low) and stimulus type (BOB, V_1C_2) were analyzed as within-participants factors. For the analysis treating items as a random factor (E_2), the same variables were analyzed as between-items factors. The mean naming latencies and error rates by participants are presented in Figure 3.

The interaction between consistency and word type was significant by participants, $E_1(1, 29) = 21.82, p < .001$, but not by items, $E_2(1, 96) = 2.16, p = .14$. The effect of BOB consistency was significant in the analysis by participants, $E_1(1, 29) = 24.28, p < .001$, and approached significance in the analysis by items $E_2(1, 96) = 3.12, p = .08$. As expected, high BOB consistency words were named faster than low BOB consistency words. The effect of consistency was not significant for V_1C_2 words, $E_1(1, 29) = 2.63, ns, E_2 < 1$. The main effect of consistency was significant by participants, $E_1(1, 29) = 5.77, p < .05$, but not by items, $E_2(1, 96) = 1.06, ns$.

Figure 3. Mean naming latencies and error rates (in parentheses) for conditions in Experiment 2b.

In the analysis of error rates, there were no significant effects. In particular, there was no indication of an interaction between consistency and item type, $F_s < 1$. Overall, participants in this experiment made fewer errors than did the participants in Experiment 2. The pattern of errors, however, was similar across the two studies. The low-consistency BOB condition (2.9%) produced a higher error rate than the high-consistency BOB condition (1.9%), while the two V_1C_2 conditions produced an equal number of errors (2.1% for both high and low consistency).

Discussion

The results of this experiment also reinforce the interpretation of Experiment 1. The spelling-sound consistency of the BOB segment significantly affected readers' ability to name disyllabic words. Again, the low consistency BOB words took longer to name than the high consistency BOB words. Furthermore, as in Experiment 2a, this experiment demonstrates that the consistency of the phonological-syllable defined V_1C_2 segment does not appear to affect disyllabic word naming.

Together, Experiments 2a and 2b clearly establish the importance of the spelling-sound consistency of the BOB for phonological processing. As suggested earlier, the superiority of the BOB segment over the phonological-syllable defined segment is likely a result of the fact that the extra consonants in the BOB help constrain the pronunciation of the vowel more than the V_1C_2 segment. As pointed out in the discussion of Experiment 2a, the medial consonants also help to constrain each other's possible pronunciations. While these experiments point to the importance of a segment like the BOB, it is not the only possible type of orthographic segment that crosses syllable boundaries. It is limited by the fact that, by definition, the segment must have a legal

word ending. Strings of consonants that would make illegal word endings may be just as helpful for constraining vowel pronunciations and consonant pronunciations as the BOB, however. For example, the BOB for the word PLATFORM would be AT, which has nine possible pronunciations. In the database used for this study, there are five different possible pronunciations of the A (e.g., WATER, PATROL, WHATNOT, STATUS, NATION) and three different pronunciations of the T (PLATFORM, PATIENT, STATUE). If a reader were to consider the medial consonant F from the next syllable as well, however, there is only one possible pronunciation of the AT segment in disyllabic words (i.e., PLATFORM). A segment that included all medial consonants regardless of legality, therefore, would be quite useful in the word recognition system. Whether or not the consonants after the first vowel must correspond to a legal word ending in order to influence naming should be examined in future work.

One difference between Experiments 2a and 2b and the experiments conducted by Jared et al. (1990) concerns the size of the consistency effects. In the present experiments the effect of BOB consistency was 16-20 ms, whereas Jared et al. reported effects as large as 42 ms (Experiment 2). This may be explained by how the words were chosen for the experiments. Jared et al.'s words were manipulated based on the summed token frequency of friends and of enemies. Words with a high frequency of enemies and low frequency of friends produced the largest effect. The present study chose words based on the ratio of the frequency of friends to the frequency of all words containing the orthographic segment was measured. Some words in high and low consistency conditions, therefore, had a low summed frequency of enemies and of friends, or a high summed frequency of enemies and of friends. For instance, LATHER was included as a

low BOB consistency word in Experiment 2a, and the target pronunciation has both a very high summed frequency of friends (649 per million) and of enemies (474 per million). Words of this type produced smaller effects in Jared et al.'s (1990) study than those with a low summed frequency of friends and high summed frequency of enemies. It's possible that relative ratio measure used here does not fully specify the effect of spelling-sound consistency, and a measure taking into account the absolute frequencies of friends and enemies would produce even larger effects, similar in magnitude to those found by Jared et al. (1990).

Experiment 3: No Frequency by Consistency Interaction

As mentioned, there is a considerable amount of evidence that spelling-sound consistency does not affect naming latencies for high-frequency monosyllabic words (e.g., Kay & Bishop, 1987). Additionally, Jared and Seidenberg (1990) found a significant frequency by regularity interaction in their study on polysyllabic word naming. Naming latencies to high frequency disyllabic words, therefore, may not be affected by the spelling-sound consistency of the BOB. On the other hand, three pieces of evidence suggest that spelling-sound consistency does affect the processing of high-frequency monosyllabic words. First, Treiman et al. (1995) found that frequency-by-consistency interaction measures did not predict naming latencies or error rates in their analyses of two mega-studies. Second, Jared (1997) found that spelling sound consistency of the word body affected the naming latencies of high-frequency words when the frequencies of friends and enemies were carefully controlled in the same manner as for low-frequency words that produced consistency effects. Third, Jared (submitted) replicated her earlier result, and again found that high-frequency words were

affected by the spelling-sound consistency of their word-bodies. This more recent evidence suggests that the spelling-sound consistency of the BOB should affect phonological processing of high-frequency disyllabic words as well as low-frequency disyllabic words. However, because frequency-by-consistency interaction measures were not included in the analyses on the data from Experiment 1, the question has not been addressed. A factorial design experiment was conducted to answer this question.

Method

Participants

Thirty-two undergraduate students who had not participated in the previous experiments, completed this experiment. Participants volunteered for the study as one method of earning credit in an introductory psychology class. All participants were native English speakers and had normal or corrected to normal vision.

Apparatus and Materials

This experiment was run on a Power MacIntosh 6100 rather than the LC III used in the previous experiments. The same type of monitor was used to present stimuli. Sixty-four disyllabic words were included in this experiment. These words were chosen from the CELEX lexical database. Thirty-two of these words were low-frequency words, with sixteen having a low BOB consistency, and 16 having a high BOB consistency. The other 32 words were high-frequency words that also varied on BOB consistency. All words were monomorphemic, six letters in length, and stressed on the first syllable. The low consistency BOB words were matched for initial phoneme with the high consistency BOB words. The characteristics of these words can be found in Table 23. The full list of words can be found in Appendix J.

Procedure

Participants in the experiment were tested individually, and the testing session lasted approximately 10 minutes. Prior to completing the experiment, the participants read and signed a declaration of informed consent (Appendix H) which outlined the experimental procedure. Upon completion, each participant was given a debriefing form (Appendix I) which outlined the hypotheses tested in the experiment.

Participants were seated in front of the computer monitor and were first presented with written instructions displayed on the computer monitor. These instructions were identical to those presented in Experiments 2a and 2b, except that participants were informed that they would be presented with 64 words, rather than 100 words. Individual trials proceeded in the same manner as described for Experiment 1. Each participant received a different random ordering of the stimuli.

Results

Naming latencies that exceeded 1200 ms were not included in the analyses. This affected approximately 0.7% of the data. For the analyses treating participants as a random factor (F_1), consistency (high, low) and frequency (high, low) were analyzed as within-participants factors. For the analyses treating items as a random factor (F_2), the same variables were analyzed as between-items factors. The mean naming latencies and error rates by participants are presented in Figure 4.

In the analysis of naming latencies, the main effect of consistency was significant by subjects, $F_1(1, 35) = 30.43$, $p < .0001$, and approached significance by items, $F_2(1, 60) = 2.92$, $p = .09$. High-consistency words were named faster ($M = 524$, $SE = 9.9$) than low consistency words ($M = 540$, $SE = 11.0$). As expected, the main effect of frequency was

Table 23. Characteristics of the stimuli in Experiment 3.

Variable	High Frequency		Low Frequency	
	High BOB	Low BOB	High BOB	Low BOB
CELEX Frequency	1640	1682	68.7	103.8
BOB consistency	.881	.384	.849	.386
V ₁ C ₂ consistency	.536	.516	.488	.480
V ₁ consistency	.501	.430	.473	.497
V ₂ consistency	.732	.593	.641	.731
# of phonemes	5.56	5.44	5.80	5.67

No pairwise comparison on any of the control consistency measures was significant (all p 's > .15).

Figure 4. Mean naming latencies and error rates (in parentheses) for conditions in Experiment 3.

also significant, with high-frequency words named faster ($M = 510$, $SE = 8.1$) than low-frequency words ($M = 554$, $SE = 11.4$), $F_1(1, 35) = 9.15$, $p < .001$, $F_2(1, 60) = 22.12$, $p < .001$. Notably, the interaction between consistency and frequency was not significant, $F_s < 1$.

In the analysis of error rates, high-consistency words produced significantly fewer errors than low-consistency words, $F_1(1, 35) = 8.77$, $p < .01$, $F_2(1, 60) = 8.09$, $p < .01$. The effect of word frequency was also significant, with high-frequency words producing fewer errors than low-frequency words, $F_1(1, 35) = 12.30$, $p < .001$, $F_2(1, 60) = 12.46$, $p < .01$. Again, there was no indication of an interaction between consistency and frequency, $F_s < 1$.

Discussion

The results of this experiment are in agreement with Treiman et al.'s (1995) and Jared's (1997, submitted) results for monosyllabic words. The spelling-sound consistency of the BOB segment significantly affected readers' ability to name disyllabic words regardless of the frequency of the target words. The previous reports of an interaction between frequency and consistency did not match high and low frequency words for the degree of consistency, or the frequencies of friends and enemies (e.g., Kay & Bishop, 1987; Jared & Seidenberg, 1990), whereas Jared's (1997, submitted) studies and this study did. The spelling-sound consistency of the segment, therefore, clearly has a ubiquitous effect on the dynamics of phonological processing. As with monosyllabic words, the consonants that follow the initial vowel in disyllabic words appear to help constrain the pronunciation of the vowel, and this happens regardless of the frequency of the word.

Experiment 4: Spelling-sound consistency in the second syllable

In all of the factorial experiments above, the spelling-sound consistency of the BOB was varied. This segment is relevant for the production of the initial vowel in these words, and also the medial consonants. In the introduction, however, it was suggested that vowel inconsistency may be the cause for the effect of the number of syllables found by Jared and Seidenberg (1990). The results of Experiment 1 supported the hypothesis, finding that V_1 consistency and V_2 consistency affected naming latencies and error rates in many of the analyses. In particular, V_2 consistency appeared to play a very strong role in the dynamics of phonological processing. The veracity of vowel inconsistency explanation, however, is still debatable, because vowel consistencies have not yet been compared in a factorial experiment. Replicating the effect of V_2 consistency in a factorial experiment is important, as this would support the claim that vowels' spelling-sound consistencies are particularly important for naming polysyllabic words.

Method

Participants

Twenty-five undergraduate students at the University of Western Ontario, who had not participated in the previous experiments, participated in this experiment. Participants volunteered for the study as one method of earning credit in an introductory psychology class. All participants were native English speakers and had normal or corrected to normal vision.

Apparatus and Materials

This experiment was run on the same apparatus as in Experiment 3. Fifty disyllabic words chosen from the CELEX lexical database were included in this

experiment. Twenty-five of these words had a low V_2 consistency and the other 25 words had a high V_2 consistency. These two lists of words were matched for initial phoneme, mean BOB consistency, V_2 consistency, V_1C_2 consistency, frequency, and number of phonemes. As in all of the factorial experiments presented, all words were monomorphemic, six letters in length, and were stressed on the first syllable. The characteristics of these words can be found in Table 24. The full list of words can be found in Appendix K.

Procedure

Participants in the experiment were tested individually, and the testing session lasted approximately 10 minutes. Prior to completing the experiment, the participants read and signed a declaration of informed consent (Appendix G) which outlined the experimental procedure. Upon completion, each participant was given a debriefing form (Appendix H) which outlined the hypotheses tested in the experiment.

Participants were seated in front of the computer monitor and were first presented with written instructions displayed on the computer monitor. These instructions were identical to those presented in Experiment 2, except that participants were informed that they would be presented with 50 words, rather than 100. Individual trials proceeded in the same manner as described for Experiment 1. Each participant received a different random ordering of the stimuli.

Results

Naming latencies that exceeded 1200 ms were not included in the analyses. This affected approximately 1.1% of the naming latencies. For the analysis treating participants as a random factor (t_1), consistency (high, low) was analyzed as a within-

Table 24. Characteristics of the stimuli in Experiment 4.

Variable	High V_2	Low V_2
CELEX Frequency ^a	176.8	207.5
BOB consistency	.676	.652
V_1C_2 consistency	.481	.560
V_1 consistency	.424	.435
V_2 consistency	.864	.282
# of phonemes	5.44	5.56

^a Frequencies for individual words are capped at 1000 and are the number of occurrences in 16.5 million tokens. No pairwise comparison on any of the control consistency measures was significant (all p 's > .15).

participants factor. For the analysis treating items as a random factor (t_2), the same variable was analyzed as a between-items factor.

In the analysis of naming latencies, the effect of spelling-sound consistency was significant by participants, $t_1(24) = 4.68$, $p < .001$, and approached significant by items in a one-tailed test, $t_2(48) = 1.35$, $p = .09$. High consistency words were named faster ($M = 547$, $SE = 9.7$) than low-consistency words ($M = 565$, $SE = 10.9$). In the analyses of error rates, the effect of consistency was not significant, $t_1(28) = 1.22$, ns , $t_2(48) = 0.79$, ns . High consistency words produced 3.6% errors ($SE = 0.62$) and low-consistency words produced 2.5% errors ($SE = 0.73$). The difference was mainly attributable to the word REGENT in the high-consistency group, which had a 32% error rate.

Discussion

The results of this study replicate those found in Experiment 1, where V_2 consistency was found to contribute significantly to the prediction of naming latencies and errors in many of the regression analyses. In this experiment, however, V_2 consistency significantly affected naming latencies but did not significantly affect error rates. The size of the effect on naming latencies was numerically similar to the effect produced by the BOB manipulation in Experiments 2a and 2b. The results strongly suggest that the phonological representation of the second syllable of a disyllabic word is computed before articulation of the word is initiated. If this were not the case, then the consistency of an orthographic segment in the later part of a disyllabic word should not have such a strong effect on naming latencies; articulation could begin when the initial phoneme or syllable was activated. This suggests that the entire orthographic representation of a word activates the entire phonological representation of the word,

perhaps in parallel, before a reader begins to name the word.

General Discussion

The results of these experiments can be summed up very briefly. Experiment 1 found that readers are sensitive to the spelling-sound consistency of a number of orthographic segments in disyllabic words (i.e., BOB, V_1 , V_2 , V_1C_2 , V_2C_4). The consistencies of these segments were found to predict naming latencies, and/or the likelihood that an error would be made when naming a word. Greater consistency led to faster naming latencies and fewer errors. Presumably, this effect is due to more efficient, or less noisy, phonological processing. Experiments 2a and 2b established that the consistency of the orthographic segment that includes the first vowel grapheme and the following medial consonants, without being constrained by phonological syllable boundary (i.e. the BOB), has a significant impact on naming latencies and errors. On the other hand, the consistency of the orthographic segment that is constrained by the phonological syllable boundary (V_1C_2) does not affect naming latencies or error rates when the consistency of the BOB is controlled. These factorial experiments settle the issue of which of these two orthographic segments has a greater influence on the naming latencies of disyllabic words. Although the V_1C_2 was, in fact, found to be a significant predictor in some of the regression analyses in Experiment 1, there was no effect of the consistency of this segment in a tightly controlled experiment.

Experiments 3 and 4 examined two other important issues regarding the generality of spelling-sound consistency effects on phonological processing. First, spelling-sound consistency of the BOB was examined as a function of word frequency (Experiment 3). Second, the effect of spelling-sound consistency was examined when the

manipulated orthographic segment appeared in the second syllable of a disyllabic word (Experiment 4). Experiment 3 established the effect of spelling-sound consistency amongst high-frequency disyllabic words, giving greater support to recent evidence indicating that spelling-sound consistency has a universal effect on phonological processing in reading (Treiman et al., 1995; Jared, 1997, submitted). Experiment 4 indicated that manipulations of the spelling-sound consistency of orthographic segments in the second syllable of disyllabic words (V_2) also affect naming latencies. The influence of the consistency of the V_2 segment, rather than the V_2C_4 , may be a result of the fact that the consonant(s) following the V_2 grapheme may not reliably constrain the pronunciation of the vowel. In Experiment 4, the size of the consistency effect for the V_2 segment is of the same magnitude as for manipulations of the spelling-sound consistency of orthographic segments that appear in the initial syllable (BOB), suggesting that the computation of both vowels' pronunciations affect naming latencies to the same degree.

Relation to previous findings with disyllabic words

Jared and Seidenberg (1990)

These findings can now be compared with those in the published literature, and the consistency measures calculated for this study can be used to attempt to account for past data. The closest approximation to the type of investigation conducted here is the study by Jared and Seidenberg (1990). However, they used a rough measure of consistency that, in essence, compared words that had only one pronunciation for their constituent syllables (i.e., regular) with words that had more than one pronunciation for one of their syllables (i.e., regular-inconsistent words and irregular words). In other words, the *degree* of consistency was not measured.

The first experiment from Jared and Seidenberg (1990) may be an ideal test case for the generality of BOB consistency effects. There were eight groups of 20 words each in that experiment. Four groups corresponded to the manipulations in the first syllable position and another four to the second syllable position. For each syllable, there were regular-inconsistent words, exception words, and regular-consistent control words for both of these groups of words. The BOB consistency and V_2 consistency for each of the words in these lists was calculated. The mean naming latencies for each group of words are presented in Table 25, along with the mean BOB consistency and V_2 consistency. The BOB consistency statistics can be used to accurately predict the naming latencies across the eight conditions, $r = -.80$, $F(1, 6) = 10.89$, $p < .01$. In addition, the V_2 consistency statistics are also highly correlated with naming latencies, $r = -.59$, $t(7) = 1.81$, $p = .055$.⁴

The words that took the longest to name, the second syllable exception words, had the lowest BOB consistency. This group of words also had the lowest V_2 consistency. The group of the words with the fastest naming latencies, which was the regular-consistent controls for first syllable regular-inconsistent words, had the highest BOB consistency and the highest V_2 consistency. The only group of words whose mean naming latency is not well predicted is the second syllable regular-inconsistent group, which does not have particularly low BOB consistency or V_2 consistency, but took relatively long to name. The correlation between BOB consistency and naming latency without these words is $-.90$. This analysis, therefore, points out just how relevant the *degree* of consistency is for phonological processing of disyllabic words.

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⁴ A one-tailed was conducted. The hypothesis is specifically that faster naming latencies are correlated with higher consistency.

Table 25. Mean naming latencies and BOB consistency measures for conditions in Jared and Seidenberg (Exp. 1, 1990).

Condition	Latency	BOB consistency	V ₂ consistency
First Syllable			
Exception	617	0.3475	0.7229
Reg. Inc.	595	0.4777	0.6850
Exception control	589	0.6629	0.6860
Reg. Inc. control	581	0.7553	0.7771
Second Syllable			
Exception	638	0.3211	0.3633
Reg. Inc.	619	0.5656	0.6093
Exception control	606	0.4358	0.5177
Reg. Inc. control	585	0.6179	0.5259

Note. Reg.Inc. = regular inconsistent

In Experiment 2 from Jared and Seidenberg (1990) a frequency manipulation (high, low) was crossed with regularity (exception, regular consistent). In that experiment the effect of regularity was much stronger for low-frequency words than for high-frequency words, producing a significant interaction. Experiment 3 from the present study, however, did not find an interaction between frequency and BOB consistency. The interaction in Jared and Seidenberg's (1990) study with high- and low-frequency words may be explained by measuring the actual degree of spelling-sound consistency for their stimuli. The evidence from the present study predicts that where regularity effects were found by Jared and Seidenberg (1990), the consistency of the BOB or V_2 segments should differ substantially between the regular and exception words. The analysis is less robust in this case because there were only 15 words in each group in the study, and a number of these words were trisyllabic rather than disyllabic, or had a vocalic onset rather than consonantal. The measures reported here, therefore, are for only a subset of the stimuli (9-10 of 15 in each group).

Jared and Seidenberg (1990) found that for high-frequency words, there were no significant differences between exception words and regular-consistent control words for either syllable position. For these high-frequency words, the difference in BOB consistency statistics for the regular and exception words (.410 vs. .610) was small and marginally significant, $t(34) = 1.95$, $p = .059$. The difference in BOB consistency between regular words and exceptions is considerably larger for low-frequency words, where Jared and Seidenberg (1990) did find a significant difference in naming latencies between regular and exception words. The consistency measure for regular words is roughly the same (.590) as for high-frequency regular words, but the exceptions are

substantially lower (.281), and this difference is very reliable, $t(40) = 2.94$, $p < .01$. The BOB consistency statistics, therefore, indicate that only where there are significant differences in consistency were there significant differences in the human data.

In addition to the frequency by consistency interaction, Jared and Seidenberg (1990) also found that for low-frequency words, the exception effect was larger for the first syllable position (80 ms) than the second syllable position (21 ms). Where effect sizes are larger in one condition than another, similar differences should be seen in the average BOB or V_2 consistencies for the groups of words. Like Experiments 2a and 2b from the present study, the consistency statistics for the exception words (i.e., low BOB words) were very low for both syllables (.316 and .310). For the matched regular controls, however, the numbers were quite different (.644 vs. .567). The difference in the BOB consistency was quite large for the first syllable (.328) and significant, $t(24) = 2.71$, $p = .01$. The difference for the second syllable was smaller (.257) and only approached significance, $t(18) = 1.95$, $p = .067$. Again, there is congruency between the results of Jared and Seidenberg (1990) and the consistency measures developed for this study. Where there was a larger difference in naming latencies, there is a larger difference in consistency measures.

Studies of the BOSS

Many previous studies have examined the reality of the BOSS, which contains the BOB, using a lexical decision task (e.g., Taft, 1979, 1987, 1992; Lima & Pollatsek, 1983; Seidenberg, 1987). The very nature of these prior investigations assumes no influence of phonology, and the use of a lexical decision task may dramatically reduce the impact of phonological representations on decision latencies (Jared et al., 1990; Jared, 1997). In

addition, most of these studies employ a priming paradigm, where the target words are compared to themselves in several different conditions (e.g., Lima & Pollatsek, 1983), making an analysis of the results using BOB consistency measures impossible. Some of these studies, however, have used a different approach, in which stimuli are not presented in a standard format. Rather, the words were presented with spaces in different places, either after the BOSS unit or after the phonological syllable boundary (e.g., THUND ER vs. THUN DER). The hypothesis was that the unit corresponding to a lexical access code would speed lexical decision latencies compared to the unit that did not correspond to the access code. If the access code is the BOSS, then this condition should lead to faster decision latencies than the syllable condition. In fact, this effect has been found in many experiments by Taft (1979, 1987).

The non-standard presentation format, however, may also disrupt normal processing, particularly for the orthographic representation of the target words. This may increase the role of phonology in making a lexical decision. If the phonology of the first segment is activated initially, then the BOB consistency of the initial segment (for the correct target pronunciation) would affect decision latencies (e.g., for THUNDER, the BOB consistency of UN vs. the BOB consistency of UND). Experiment 1 of Taft (1987) found that BOSS divided words had faster reaction times (965 ms) than syllable divided words (1015 ms). It turns out that there is also a significant difference in the BOB consistency between the two display conditions. For the BOSS division, the BOB consistency of the correct pronunciation of the orthographic segments (e.g., UND in THUND ER) is .634, and for the syllable division condition, the BOB consistency of the orthographic segments (e.g., UN in THUN DER) is only .280, $t(42) = 3.70$, $p < .001$.

Therefore, any phonological influence on the task will contribute to the difference in decision latencies seen in the human data.

Stress Effects: Rastle & Coltheart (2000)

There is one other recent study that has compared naming latencies on different groups of disyllabic words. In their Experiment 1, Rastle and Coltheart (2000) compared naming latencies for high- and low-frequency words which were divided into 'regular' words that were stressed on the first syllable, and 'irregular' words that were stressed on the second syllable. This was intended as an evaluation of a simple rule that disyllabic words should be stressed on the first syllable, since 83% of disyllabic words have this stress pattern. The results, however, showed no significant stress effect in naming latencies for either high- or low-frequency words. For both high- and low-frequency words, the difference between 'regular' and 'irregular' stressed words was only 3 ms. This is somewhat surprising because Experiment 1 from the present study found that stress pattern affected naming latencies, when BOB consistency was not accounted for. When the BOB consistency of each condition in Rastle and Coltheart is calculated, however, it is apparent that the two groups of words are quite similar. For low frequency words the BOB consistencies are .611 and .516 for regular and irregular stressed words, respectively, $t(43) = 0.92$, ns. For high-frequency words, the means were .670 and .510 respectively, $t(40) = 1.61$, ns. No difference, therefore, would be expected on the naming latencies, given such small and non-significant differences in BOB consistency.

Rastle and Coltheart (2000) did, however, find a difference between regularly and irregularly stressed words in their Experiment 3. Regularity was not based on the simple rule used previously, but instead was determined by a whole *set* of rules, or if-then

statements, which analyze the target word. When the regularity of a word's stress pattern was based on this new algorithm, an interaction between frequency and stress regularity was found. For low-frequency words, regular stress words ($M = 515$) were named faster than those with irregular stress ($M = 543$). For high-frequency words, there was no difference between words with regular ($M=479$) and irregular stress ($M=480$). The BOB consistency measures developed for the present study may account for this interaction. For low-frequency words the regularly stressed words had a BOB consistency of .247 whereas irregularly stressed words had a BOB consistency of .493, $t(44) = 2.78$, $p < .01$. For high-frequency words the mean BOB consistencies were .550 and .680, $t(10) = 0.98$, *ns*. The statistics developed for this study, therefore, would predict the interaction reported by Rastle and Coltheart (2000).

In sum, much of the previous work conducted on disyllabic words can be accounted for by measuring the BOB consistencies of the words employed in the experiments. The contrast between Experiment 3 in the present study and previous reports of a regularity by frequency interaction (Jared & Seidenberg, 1990) can be reconciled by looking to the spelling-sound consistency of the stimuli involved. Experiment 1 and 4 in the present study found substantial effects of spelling-sound consistency for manipulations in the second syllable of disyllabic words, equal to those for the BOB, whereas Jared and Seidenberg (1990) found that the first syllable inconsistencies had a much larger effect in their Experiment 2. Again, this discrepancy can be accounted for by measuring the degree of consistency of the items on the BOB segment. The effect of BOB consistency, therefore, is reliable not only in the present study, but also accounts for data from previously published studies.

Implications for theories of spelling to sound processing.

Dual Route Accounts

As mentioned in the introduction, there are two predominant approaches to phonological processing in the word recognition literature: Dual-route theories, and connectionist theories. Dual-route accounts of phonological processing suggest that there are two mechanisms for producing the phonology of a word from its orthography. The first mechanism relies on a series of grapheme-phoneme conversion (GPC) rules in which the translation of the orthography of a letter or letters to the corresponding phonology is based on the most frequent translation for the grapheme, regardless of the context of letters in which the grapheme appears. The GPC rules, therefore, always provide the ‘regular’ pronunciation. The second mechanism relies on the direct activation of a word’s phonological form from its orthography. A single node corresponding to the word’s orthographic input activates a node for the word’s phonological output. Neither of these mechanisms, nor the two together, can adequately account for the consistency effect for monosyllabic words (Jared, submitted). The model produces a consistency effect for exception words that are high-consistency (e.g., TALK), but Jared did not find the effect in her experiments.

It is difficult to imagine how the dual-route model could account for the present results as well. In particular, the extension to disyllabic words raises an issue with the GPC rules that are applied. These rules are based on monosyllabic words and therefore provide stressed pronunciations. How, then, could the model adequately produce the correct pronunciation for unstressed syllables, of which there will always be one in a disyllabic word? This would mean, in essence, that every word will have at least one

irregular spelling-sound mapping. Rastle and Coltheart (2000) suggested, however, that there is an additional rule system that will mandate where stress should be placed and which vowel should be 'reduced'. In this process there is a considerable amount of checking and double-checking to determine if a word contains certain letter patterns. If a word contains a prefix letter pattern, for instance, an additional procedure is needed to check if the remainder of the word is, in fact, orthographically legal. If it is, then the pronunciation of the prefix is retrieved from the lexicon, and the GPC rules are applied to the remainder of the word, which is stressed. If there is no prefix letter pattern, then the system looks for a suffix letter pattern. If there is one, the same checking and double-checking must occur. In addition, the application of this algorithm changes some of the fundamental assumptions of the model.

A key modification in this new extension is the communication between the non-lexical and lexical routes. In order to function, the non-lexical route must address the lexicon for pronunciations of affixes. In previous descriptions of the dual-route model (Coltheart & Rastle, 1994) there was no communication between the two routes, and the degree to which the model depends on this fact to account for empirical data on monosyllabic words is not known. There is no logical reason to limit communication between the two routes to disyllabic words only, so the effect that these rules would have on monosyllabic words with affix letter patterns must be evaluated. In addition to this, accounts of the GPC route have described it as operating serially, one letter at a time, sending activation to the phoneme output system. To process monomorphemic disyllabic words the entire word must be analyzed by the non-lexical route once to look for letter patterns, and then again to apply the GPC rules. This extra process added to the non-

lexical route would mean that most words would be processed lexically, because that route is assumed to be faster than the GPC route. As a consequence, there should rarely be a regularity effect when naming disyllabic words, or any effect of spelling-sound mapping on performance, particularly for high-frequency words. The present study indicates that such effects do occur, even with high-frequency words. The serial nature of the model's non-lexical route would also make it nearly impossible to produce any effect of V_2 consistency. How the model could overcome these challenges and maintain the serial nature of the non-lexical route is not easy to imagine.

Connectionist Accounts

Connectionist theories, in principle, may have an easier time accounting for the present data. These models learn the statistical relationship between input and output mappings (Seidenberg & McClelland, 1989), and are therefore well suited to account for consistency effects, since consistency effects are based on the statistical probability of competing pronunciations of a given orthographic segment. Importantly, the more similar words are orthographically, the greater the overlap of activation in the orthographic representations, and the more similar phonologically, the greater the overlap of activation in the phonological representations. Therefore, monosyllabic words with the same printed word bodies and the same pronunciations strengthen the connections between the representations. When orthographic segments have multiple pronunciations, the corresponding connections between orthography and phonology are weakened due to crosstalk. Seidenberg and McClelland's (1989) model replicated the consistency effects with monosyllabic words described by Jared (1997, submitted). There was also no interaction between consistency and frequency when the words from Jared's (1997)

Experiment 1 were presented to the model. Plaut et al.'s (1996) model was also able to produce consistency effects for Jared's (1997) high-frequency words, although it also produced a significant interaction between frequency and consistency.

The principles of this model can be applied to the case of disyllabic word naming. First, orthographic segments that increase the consistency of spelling-sound mappings in the language should be learned by the model, so effects of the consistency of the BOB and the V_2 segment should be produced by an extended model. This model can also accommodate findings that inconsistencies in the second syllable have strong effects. Because processing in the connectionist models is parallel, an inconsistency anywhere in a word will affect the coherence of the phonological representation and may delay articulation. More importantly, because of parallel processing, this type of model does not 'parse' words, or unavoidably process parts of words independently from other parts. This means two things. First, large orthographic segments can affect processing regardless of syllable structure or their position in a word. Second, this type of model should also be able to produce multiple effects from the same grapheme, as seen with the BOB and V_1 segment in Experiment 1. The non-linear nature of these models allows for activation from the simple correspondences of a single grapheme (e.g., V_1) and higher order correspondences that depend on activation from multiple graphemes (e.g., BOB).

In principle, then, connectionist accounts are capable of accounting for the data collected in this study. The main difficulty for this account, however, is determining the orthographic and phonological representations for the words. Plaut et al. (1996) employed a scheme that identified graphemes as being the onset, vowel, or coda of a monosyllabic word. It is doubtful that this approach can be directly extended to represent

disyllabic words, however, since the BOB segment frequently includes a coda of the initial syllable and the onset of the second syllable. Other approaches could be employed in which the medial letters are treated as a segment on their own (i.e., onset/ vowel/ middle consonants/ vowel/ coda). This would eliminate the built-in syllabic parse that would result from a simple extension of the Plaut et al. (1996) representations.

Therefore, although connectionist models are well suited to account for the data because of their intrinsic learning of the statistical relationship between spelling and sound, further computational work must be done to produce a working model that will generate the effects described in the present study.

Future Directions

Calculations of Spelling-sound Consistency

The present study used the sum of the logarithm of token frequencies for each pronunciation of an orthographic segment to calculate spelling-sound consistency. Judging by the significant results of this study, this is an adequate way to measure consistency. However, it is not the only way to measure consistency. Treiman et al. (1995) used raw token frequencies to calculate consistency in one case, and type frequencies to calculate consistency in another case. These alternate measures of consistency would most likely produce the same pattern of results as the present study, but this can be empirically tested in future work. More importantly, measuring the absolute frequencies of friends and enemies, as Jared has (1997, submitted; Jared et al., 1990) may provide a more detailed picture of the effects of spelling-sound consistency in disyllabic word naming. Future work should determine whether this is the case. Consistency effects in disyllabic words might be even stronger when the absolute

frequency of friends of the target words is low and the absolute frequency of enemies is high.

Additionally, the present study only calculated consistency for the eleven segments identified prior to the analyses. The present study suggests that one orthographic segment relevant for phonological processing is the initial vowel plus the following consonants. There are many additional segments, however, for which consistency could be calculated, and these may also influence performance in a naming task. This was alluded to in the discussion of Experiment 2b, where the strict BOB definition regarding legal word endings was questioned. Consistency could be calculated a segment that included illegal word endings, and also for even larger orthographic segments. As well, in the present analysis the impact of segments that include the consonants before and after a vowel was not examined. This may be quite relevant for longer polysyllabic words and multi-morphemic words in which the first syllable can act as a very reliable indicator of it's pronunciation (e.g., CON, MID, DIS). The consistency of whole syllables, therefore, could be examined. Because this segment would also be constrained by the syllable boundary, it may, in fact, account for the predictive power of the V_1C_2 segment in Experiment 1.

Spelling-sound Consistency in Other Polysyllabic Words

The present study included only very short monomorphemic disyllabic words as targets, and this choice of words may have affected the outcome of the results. There may be other orthographic segments that play a role in phonological processing which were not identified in the present study. For instance, the C_1V_1 segment may be more important for the processing of multimorphemic words, which were not included as

targets in the present study. Many prefixes correspond to this orthographic segment and so the consistency of this segment in a word may affect processing of these words (e.g., RE, DE, CO). The consistency of the segment may only apply when the letter pattern is itself very frequent, however (Knudsen & Jared, 2000). Since the number of syllables in a word and the number of morphemes are correlated, spelling-sound consistency effects with multimorphemic word targets should be examined when consistency in trisyllabic or longer words is examined.

In addition, words whose onsets are vowels rather than consonants were not included as targets in the present study. In many cases, this indicates that the first syllable is not stressed, or that the vowel will be lax (e.g., A in AMOUNT, E in ELECT). Even more importantly, many of these segments also correspond to prefixes (e.g., UN, AD, AC, IM, IN) and also constitute the V_1C_2 in these words. The inclusion of words whose onsets are vowels may point to the importance of this segment. The impact of the V_1C_2 , may also have been underestimated by using monomorphemic targets only, since many prefixes, and therefore multimorphemic words, begin with vowels.

Future work will also need to consider the spelling-sound consistency dynamics in polysyllabic words that have more than two syllables and which can be processed in a single fixation. How is the pronunciation of a word like BANANA, for instance, computed? Are the segments that play an influential role in naming these words the same as those for disyllabic words (i.e., vowel and following consonants)? In some trisyllabic words, such as BANANA, there are few consonants and, therefore, little information of the type identified by the present study to constrain vowel pronunciations. Based on this, one might expect that the computation of phonology for these words would be

considerably slowed, but this also needs to be tested empirically.

Stress Effects

The analysis of Experiment 1 also raises issues about stress effects and where they arise in reading printed words. The present experiment suggested that these effects may be secondary to the low-consistency mappings of graphemes to phonemes that appear in second-syllable stressed words. However, the computation of the correct pronunciation of a disyllabic word may also take into account the general phonological constraint that only one syllable in a monomorphemic disyllabic word can be stressed. This constraint is independent of the reading system. The interaction between the activation of phonemes from orthography and general phonological constraints can now be examined in greater detail.

Another immediate step to take in examining stress effects in disyllabic words would be to determine whether letter patterns mark stress independently of the particular phonemes to which they map. For example the letter pattern UTE, as a V_2C_4 , is low consistency for all pronunciations (DILUTE, COMMUTE, MINUTE), but would be a high consistency mapping to second-syllable stress because both DILUTE type words and COMMUTE type words are primarily stressed on that syllable. Other similar segments are evenly split between the number of pronunciations, and also between the opposing stress patterns (e.g., URE). Determining whether some type of stress mapping is taking place simultaneously with the activation of particular phonemes would be an interesting and important question to address.

Conclusions

The present study has established that spelling-sound consistency effects are not

limited to the monosyllabic word body. The consistencies of the BOB and V_2 orthographic segments influenced the naming of disyllabic words in Experiment 1, and this was replicated in factorial experiments. The present study also indicates that spelling-sound consistency affects high-frequency words. These results indicate that spelling-sound consistency is a universal factor in phonological processing, and affects the naming of words of any length and frequency. These effects of consistency appear arise because the influential segments constrain the pronunciation of vowel graphemes in words. In addition, there is evidence to suggest that readers do not parse disyllabic words. The simultaneous mapping to phonology of smaller orthographic segments and larger orthographic segments that contain the smaller ones appears to occur. These findings are very important for the development of word recognition theories and computational models of phonological processing, indicating that these models should not parse the orthographic input, and must be sensitive to the statistical nature of the particular language's spelling to sound mappings.

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Appendix A

Stimuli used in Experiment 1.

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aboard	appeal	babble	battle
aboard	appear	baboon	bauble
accent	append	backup	bazaar
accord	arcane	badger	beagle
accost	around	baffle	beaten
accrue	arrest	ballad	bedlam
accuse	arrive	ballet	beetle
active	aspect	ballot	before
addict	assail	balsam	beggar
advice	assent	bamboo	behind
affair	assert	bandit	belief
afraid	assess	banner	bellow
allure	assist	bantam	bereft
almond	asthma	banter	better
ambush	astute	barley	beyond
anchor	attach	barrel	biceps
anneal	attack	barter	billet
answer	attire	basalt	billow
anthem	auburn	basket	bishop
antics	autumn	batter	bistro

bitter	bungle	canuck	cervix
blazon	bunker	canvas	chalet
boggle	burden	canyon	chapel
bonnet	bureau	carafe	cherry
boogie	burgle	carbon	cherub
border	burlap	careen	chilli
borrow	burrow	career	chisel
bother	bustle	caress	chorus
bottle	butter	carpal	cipher
bottom	button	carpet	circle
brandy	cachet	carrot	circus
bridle	cackle	cartel	cirrus
broken	cactus	carton	citrus
bronco	cajole	cashew	clever
bubble	callus	castle	cliche
bucket	campus	cattle	client
buckle	cancel	caucus	climax
budget	cancer	cavort	closet
buffer	candle	cellar	cobalt
buffet	canine	cement	cobble
bullet	canker	ensor	cocoon
bumble	cannon	census	coddle
bundle	canter	centre	coffee

coffin	cotton	cymbal	detail
collar	cougar	daemon	device
collie	couple	damage	devout
colour	coupon	damask	diesel
column	cousin	damsel	digest
combat	covert	dangle	dilute
comics	cradle	dawdle	dimple
common	cravat	dazzle	direct
compel	crayon	deacon	discus
condom	create	debate	dismay
condor	credit	deceit	dither
consul	creole	decide	divide
convex	cretin	decree	divine
convey	crisis	defeat	docket
convoy	crocus	defect	doctor
copper	cuckoo	degree	dollop
cordon	cuddle	deluge	domain
corner	cudgel	demand	donkey
corpus	cumber	dental	doodle
corral	curdle	desert	double
corset	curfew	design	dragon
cortex	curtsy	desire	drivel
cosmos	custom	despot	duffel

duplex	expert	fidget	fossil
efface	export	figure	fracas
effect	facial	fillet	fresco
effort	factor	filter	frigid
either	faeces	finger	frolic
emblem	faggot	finish	fuddle
empire	falcon	finite	fumble
employ	fallow	fiscal	fungus
encore	famine	flimsy	funnel
engine	father	flower	furor
enough	fathom	flurry	furrow
entail	faucet	foetus	future
enzyme	favour	foible	gadget
escape	feeble	follow	gaggle
escort	feline	foment	gallon
esprit	fellow	fondle	gallop
esteem	female	fondue	galore
ethics	fennel	forage	galosh
eunuch	ferret	forbid	gambit
except	fetish	forest	gamble
excess	fetter	forget	garage
excuse	fickle	format	garble
exempt	fiddle	former	garden

gargle	gratis	hassle	horrid
garlic	gravel	hazard	horror
garner	grotto	heaven	hostel
gasket	grovel	heckle	hubbub
gather	guffaw	helmet	huddle
gaucho	guinea	herald	humane
geisha	guitar	hermit	humble
genius	gullet	herpes	humour
gentle	gurgle	hiccup	hunger
ghetto	gutter	hijack	hurdle
gibbon	guzzle	hither	hurrah
gibbon	haggis	hobble	hurray
ginger	haggle	hobnob	hurtle
girdle	hallow	hockey	hustle
gluten	hammer	holdup	hybrid
gobble	handle	holler	hyphen
goblin	hangar	hollow	ignite
goggle	hangup	honour	ignore
gorgon	hansom	hoodoo	illuminate
gospel	happen	hookah	immune
gossip	harass	hooray	impact
gothic	harlot	hoover	import
govern	harrow	hornet	incest

incise	jungle	legume	mantle
income	junior	lentil	manure
infest	kelvin	lesser	maraud
insect	kennel	lesson	marble
insert	kernel	letter	margin
insult	kettle	liaise	marine
intact	kidnap	lichen	market
intent	kindle	liquid	marmot
invite	kitten	liquor	maroon
jabber	kowtow	listen	marrow
jagged	labour	litter	martyr
jaguar	ladder	little	marvel
jangle	lading	lockup	mascot
jargon	lagoon	locust	master
jersey	lament	lumber	matric
jetsam	larynx	lustre	matrix
jiggle	lather	maggot	matron
jingle	latter	magnet	matter
jockey	laurel	maiden	mature
jostle	layoff	malign	mayhem
juggle	leaven	mammal	meadow
jujube	legend	mangle	meagre
jumble	legion	mantel	meddle

mellow	mother	native	oblige
menace	motion	natter	oblong
mescal	motive	nectar	occult
method	motley	needle	octave
middle	muddle	nephew	opaque
mildew	muesli	nether	orange
mingle	muffin	neuter	orchid
minnow	muffle	nibble	ordain
minute	mumble	nickel	ordeal
mirror	murder	nimble	ordure
missus	murmur	nipple	orgasm
mobile	muscle	noodle	orphan
modern	musket	nordic	outfit
modest	mussel	normal	outlaw
molest	mussel	notice	paddle
molten	mutter	nougat	palace
moment	mutton	nozzle	palais
monkey	muzzle	nuance	palate
morass	myrtle	nudist	pallet
morose	mystic	nugget	pallor
morsel	napalm	number	pampas
mortal	napkin	nympho	pamper
mortar	narrow	object	pander

parade	permit	pocket	psycho
parcel	person	pogrom	public
pardon	petrol	poison	pucker
parent	phobic	polish	puddle
paring	phoney	polite	pulpit
parish	picket	pollen	pundit
parley	pickle	pommel	purple
parole	picnic	pompom	pursue
parrot	pidgin	ponder	purvey
parson	pigeon	poodle	puzzle
pastel	pilfer	poplar	python
pastor	pillar	potent	quarry
pastry	pillow	powder	quaver
patent	pimple	precis	quiver
pathos	pirate	presto	rabbit
patrol	pisces	pretty	rabble
patter	pistil	prison	rabies
pebble	pistol	profit	racist
pellet	piston	proper	racket
pelvis	planet	proton	raffle
pencil	plasma	proven	raisin
people	plexus	pseudo	ramble
pepper	plural	psyche	random

rankle	remand	ripple	satrap
ransom	remark	robust	savage
rascal	renege	rocket	savour
rather	repair	rodent	scampi
ration	repeal	rotund	scarab
rattan	repeat	rouble	schema
rattle	report	rubber	scurry
ravine	repose	rubble	scurvy
razzle	repute	ruffle	season
reason	rescue	rumble	secede
rebuff	result	rumour	second
rebuke	retail	rumple	secret
recess	retain	rumpus	sector
reckon	retire	rustic	secure
recoil	retort	rustle	sedate
record	return	saddle	seesaw
refuse	revise	saline	seldom
regard	revoke	salmon	select
regent	revolt	saloon	senate
regret	reward	salute	senior
reject	rhesus	sample	sequel
relief	ribbon	sandal	sequin
relish	riddle	sashay	serene

sermon	snivel	stucco	talent
settle	soccer	stupid	tampon
severe	social	stupor	tandem
shadow	solace	stymie	tangle
shiver	solder	suckle	target
shoddy	solemn	sudden	tariff
shovel	sombre	sulpha	tarmac
shower	sorbet	sultan	tartar
sickle	sorrow	summer	tassel
signal	speedo	summon	tattle
silent	spider	sundae	tattoo
silver	spiral	sundry	tavern
simmer	spirit	supple	teeter
simper	stable	supply	temper
simple	stamen	surrey	temple
single	stanza	survey	tenant
siphon	staple	swivel	tender
sizzle	static	symbol	tendon
skewer	statue	syntax	tennis
skivvy	status	system	terror
slalom	steady	tackle	tether
sliver	stifle	tailor	thorax
slogan	stigma	talcum	ticket

tickle	trojan	vermin	warble
timbre	trowel	versus	warden
tingle	tumble	vertex	weapon
tinker	tumour	vessel	weasel
tinkle	tumult	vestal	weevil
tinsel	tunnel	vested	welter
tissue	turban	victim	whinny
titter	turbot	viking	wiggle
toddle	turnip	virgin	wigwam
toffee	turtle	virtue	willow
toggle	twilit	volley	window
toilet	tycoon	volume	winter
totter	ulster	voodoo	wizard
toucan	umpire	vortex	wobble
toupee	urchin	voyage	wombat
tousle	utmost	waddle	wonder
trauma	valise	waffle	yankee
travel	vandal	wallet	yellow
treble	vassal	wallop	yonder
tremor	vector	wallow	zenith
tribal	velvet	walrus	zephyr
trifle	veneer	wangle	zigzag
triple	verbal	wanton	zircon

Appendix B

Consent form for Experiment 1.

Consent Form: Pronouncing Words

The aim of this study is to understand the cognitive processes involved in generating the pronunciations of words. In this study you will be required to pronounce a series of words presented one at a time on a computer monitor into a microphone. You will be asked to name each word aloud as quickly and accurately as you can. The time it takes to pronounce each word will be recorded by the computer. The entire session is expected to last approximately one hour, and you will receive one experimental credit for your participation in this study.

There are no known physical or psychological risks associated with this research and no discomfort to you is expected during this session. You may terminate the session at any time without loss of promised credit. Information about your particular performance will be kept strictly confidential. You will be informed about the experimental hypotheses upon completion of the experiment.

I have read the above statement and consent to participate in this experiment

---

Signature

Date

Appendix C

Debriefing form for Experiment 1.

The purpose of this study was to uncover some of the processes that are involved in pronouncing words with two or more syllables. Although research into word naming has established a number of factors as relevant in determining how long it will take to pronounce a word, most of this research has been conducted with monosyllabic words. We were particularly interested in how people translate the *spelling* of a word into its *pronunciation*. With one syllable words, it has been established that the consistency of the spelling to sound translation is important in determining how long it will take to name a word (Jared, McRae, & Seidenberg, 1990). Words such as GAVE contain an inconsistent letter pattern (AVE), since there are other words with the same letter pattern that are pronounced differently, such as HAVE. These words take longer to name than words that contain letter patterns that are consistent, such as UST in MUST.

With longer multi-syllabic words, the consistency of letter to sound translations is not the same as it is in one syllable words, and very few studies have examined this process (Jared & Seidenberg, 1990). One question is whether readers use separate resources for each syllable in a longer word when it is translated to a pronunciation. This could be the case since there are letter patterns which are pronounced differently in longer words than they are in one syllable words. For instance, INE is pronounced as in FINE and DINE in shorter words, but is sometimes pronounced differently in longer words (e.g. MARINE, EXAMINE). The present study will take a closer look at this aspect of word naming, by comparing the results of this study to several different measures of the consistency of spelling to sound translation to determine which is the best measure of consistency for longer words.

Jared, D. & Seidenberg, M. S. (1990). Naming multisyllabic words. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 16, 92-105.

Appendix D

Results for initial phoneme predictors for regression analyses of naming latencies.

Phoneme predictors corresponding to analysis presented in Table 3.

Variable	β	t	p
Voicing	-.067	-1.32	.189
Glottal	-.256	-5.29	<.001
Fricative	.246	3.37	.001
Labiodental	-.136	-2.65	.008
Liquid	-.209	-4.28	<.001
Bilabial	-.044	-0.85	.397
Alveolar/alveopalatal ☒	N/A		
Velar	-.036	-0.71	.480
Affricate	.015	0.367	.714
Nasal	-.043	-0.98	.330

☒ Variable excluded due to tolerance limitation for collinearity.

Phoneme predictors corresponding to analysis presented in Table 5.

Variable	β	t	p
Voicing	-.094	-2.19	.029
Glottal	-.270	-5.86	<.001
Fricative	.297	5.16	<.001
Labiodental	-.160	-3.32	.001
Liquid	-.196	-4.87	<.001
Bilabial✂	-.038	-0.92	.359
Alveolar/alveopalatal ✂	.033	0.727	.468
Velar✂	.013	0.309	.758
Affricate✂	.032	0.859	.391
Nasal✂	-.056	-1.33	.184

✂ Variable not included in the final regression equation.

Phoneme predictors corresponding to analysis presented in Table 6.

Variable	β	t	p
Voicing	-.122	-2.98	.003
Glottal	-.274	-6.52	<.001
Fricative	.324	6.13	<.001
Labiodental	-.173	-3.88	<.001
Liquid	-.179	-4.72	<.001
Bilabial✕	-.030	-0.77	.443
Alveolar/alveopalatal ✕	.015	0.343	.732
Velar✕	.021	0.549	.583
Affricate✕	.051	1.43	.154
Nasal✕	-.033	-0.81	.418

✕ Variable not included in the final regression equation.

Phoneme predictors corresponding to analysis presented in Table 7.

Variable	β	t	p
Voicing	-.128	-3.30	.001
Glottal	-.254	-6.14	<.001
Fricative	.274	5.35	<.001
Labiodental	-.140	-3.27	.001
Liquid	-.154	-4.25	<.001
Bilabial✂	-.053	-1.44	.150
Alveolar/alveopalatal ✂	.064	1.55	.122
Velar✂	.000	0.01	.991
Affricate✂	.045	1.34	.180
Nasal✂	-.060	-1.59	.111

✂ Variable not included in the final regression equation.

Phoneme predictors corresponding to analysis presented in Table 8.

Variable	β	t	p
Voicing	-.150	-4.34	<.001
Glottal	-.173	-5.46	<.001
Fricative	.159	4.61	<.001
Labiodental✂	-.021	-0.576	.565
Liquid	-.136	-4.25	<.001
Bilabial✂	-.005	-0.16	.871
Alveolar/alveopalatal ✂	.036	1.13	.260
Velar✂	-.030	-0.91	.362
Affricate✂	.034	1.15	.252
Nasal✂	-.047	-1.40	.161

✂ Variable not included in the final regression equation.

Phoneme predictors corresponding to analysis presented in Table 9.

Variable	β	t	p
Voicing	-.127	-3.38	.001
Glottal	-.252	-6.59	<.001
Fricative	.293	6.18	<.001
Labiodental	-.153	-3.83	<.001
Liquid	-.163	-4.71	<.001
Bilabial✂	-.059	-1.69	.092
Alveolar/alveopalatal ✂	.047	1.17	.242
Velar✂	.025	0.73	.463
Affricate✂	.049	1.51	.131
Nasal✂	-.051	-1.41	.159

✂Variable not included in the final regression equation.

Phoneme predictors corresponding to analysis presented in Table 10.

Variable	β	t	p
Voicing	-.147	-4.36	<.001
Glottal	-.185	-6.05	<.001
Fricative	.178	5.31	<.001
Labiodental✂	-.062	-1.77	.077
Liquid	-.135	-4.35	<.001
Bilabial✂	-.013	-0.43	.670
Alveolar/alveopalatal ✂	.039	1.25	.212
Velar✂	.003	0.10	.921
Affricate✂	.032	1.13	.258
Nasal✂	-.049	-1.52	.129

✂Variable not included in the final regression equation.

Phoneme predictors corresponding to analysis presented in Table 11.

Variable	β	t	p
Voicing	-.157	-4.84	<.001
Glottal	-.167	-5.63	<.001
Fricative	.149	4.62	<.001
Labiodental✂	-.036	-1.04	.297
Liquid	-.126	-4.23	<.001
Bilabial✂	-.019	-0.61	.536
Alveolar/alveopalatal ✂	.051	1.72	.086
Velar✂	-.025	-0.85	.396
Affricate✂	.033	1.21	.225
Nasal✂	-.055	-1.80	.073

✂ Variable not included in the final regression equation.

Phoneme predictors corresponding to analysis presented in Table 12.

Variable	β	t	p
Voicing	-.148	-4.69	<.001
Glottal	-.175	-6.14	<.001
Fricative	.161	5.12	<.001
Labiodental✂	-.065	-1.99	.047
Liquid	-.132	-4.54	<.001
Bilabial✂	-.030	-1.02	.310
Alveolar/alveopalatal ✂	.046	1.60	.111
Velar✂	.014	0.49	.622
Affricate✂	.032	1.20	.231
Nasal✂	-.061	-2.04	.042

✂ Variable not included in the final regression equation.

Appendix E

Results for initial phoneme predictors in regression analyses of error rates.

Phoneme predictors corresponding to analysis presented in Table 4.

Variable	β	t	p
Voicing	-.033	-0.59	.557
Glottal	-.203	-3.80	<.001
Fricative	.229	2.84	.005
Labiodental	-.193	-3.41	.001
Liquid	-.003	-0.06	.950
Bilabial	-.069	-1.19	.236
Alveolar/alveopalatal ☞	.N/A		
Velar	-.074	-1.30	.193
Affricate	-.003	-0.07	.946
Nasal	-.054	-1.11	.268

☞ Variable excluded due to tolerance limitation for collinearity.

Phoneme predictors corresponding to analysis presented in Table 13.

Variable	β	t	p
Voicing✂	-.079	-1.93	.054
Glottal✂	-.007	-0.17	.866
Fricative✂	.072	1.76	.080
Labiodental✂	-.002	-0.06	.952
Liquid✂	-.003	-0.06	.950
Bilabial✂	.007	0.15	.878
Alveolar/alveopalatal	.144	3.52	<.001
Velar✂	.000	-0.01	.993
Affricate✂	-.044	-1.05	.296
Nasal✂	-.077	-1.90	.059

✂ Variable not included in the regression equation.

Phoneme predictors corresponding to analysis presented in Table 14.

Variable	β	t	p
Voicing✕	-.043	-1.01	.315
Glottal✕	-.041	-1.03	.303
Fricative✕	.051	1.24	.216
Labiodental✕	-.039	-0.99	.325
Liquid✕	.046	1.15	.253
Bilabial✕	-.027	-0.64	.525
Alveolar/alveopalatal ✕	.100	2.51	.012
Velar✕	-.041	-1.01	.311
Affricate✕	-.047	-1.18	.238
Nasal	-.079	-2.00	.047

✕ Variable not included in the regression equation.

Phoneme predictors corresponding to analysis presented in Table 15.

Variable	β	t	p
Voicing	-.096	-2.63	.009
Glottal✂	-.055	-1.42	.156
Fricative✂	.053	1.31	.191
Labiodental✂	.008	0.21	.832
Liquid✂	.017	0.41	.684
Bilabial✂	.037	0.82	.415
Alveolar/alveopalatal	.173	4.70	<.001
Velar✂	-.001	-0.04	.970
Affricate✂	-.027	-0.71	.477
Nasal✂	-.057	-1.44	.150

✂Variable not included in the regression equation.

Phoneme predictors corresponding to analysis presented in Table 16.

Variable	β	t	p
Voicing	-.097	-2.51	.012
Glottal	-.126	-3.56	<.001
Fricative	.135	3.48	.001
Labiodental [✕]	-.106	-2.54	.011
Liquid	.088	2.45	.014
Bilabial [✕]	-.026	-0.71	.480
Alveolar/alveopalatal [✕]	.092	2.56	.011
Velar [✕]	-.031	-0.85	.397
Affricate [✕]	-.009	-0.28	.777
Nasal [✕]	-.005	-0.13	.896

[✕] Variable not included in the regression equation.

Phoneme predictors corresponding to analysis presented in Table 17.

Variable	β	t	p
Voicing✂	-.061	-1.58	.114
Glottal✂	-.039	-1.07	.286
Fricative✂	.060	1.62	.105
Labiodental✂	-.006	-0.15	.881
Liquid✂	-.016	-0.43	.667
Bilabial✂	.016	0.36	.719
Alveolar/alveopalatal	.137	3.82	<.001
Velar✂	.020	0.50	.617
Affricate✂	-.060	-1.62	.107
Nasal	-.086	-2.41	.016

✂ Variable not included in the regression equation.

Phoneme predictors corresponding to analysis presented in Table 18.

Variable	β	t	p
Voicing	-.097	-2.56	.011
Glottal	-.123	-3.55	<.001
Fricative	.106	2.81	.005
Labiodental [ⓧ]	-.108	-2.70	.007
Liquid	.089	2.55	.011
Bilabial [ⓧ]	-.029	-0.81	.421
Alveolar/alveopalatal [ⓧ]	.072	2.04	.042
Velar [ⓧ]	.005	0.14	.886
Affricate [ⓧ]	-.034	-1.06	.291
Nasal [ⓧ]	-.023	-0.62	.534

[ⓧ]Variable not included in the regression equation.

Phoneme predictors corresponding to analysis presented in Table 19.

Variable	β	t	p
Voicing	-.085	-2.50	.013
Glottal	-.095	-2.81	.005
Fricative	.099	2.70	.007
Labiodental [‡]	-.065	-1.46	.144
Liquid [‡]	.041	1.16	.245
Bilabial [‡]	.033	0.83	.409
Alveolar/alveopalatal	.122	3.92	<.001
Velar [‡]	.002	0.05	.959
Affricate [‡]	-.030	-0.96	.337
Nasal [‡]	-.022	-0.69	.493

[‡]Variable not included in the regression equation.

Phoneme predictors corresponding to analysis presented in Table 20.

Variable	β	t	p
Voicing	-.073	-2.20	.028
Glottal	-.094	-2.86	.004
Fricative	.078	2.17	.030
Labiodental✂	-.076	-1.77	.077
Liquid✂	.050	1.43	.153
Bilabial✂	.004	0.10	.924
Alveolar/alveopalatal	.100	3.26	.001
Velar✂	.038	1.08	.283
Affricate✂	-.048	-1.58	.114
Nasal✂	-.043	-1.36	.174

✂ Variable not included in the regression equation.

Appendix F

Stimuli used in experiment 2a.

High BOB consistency	Low BOB consistency	High VIC2 consistency	Low VIC2 consistency
beacon	beaker	bamboo	banner
cherry	cherub	bumble	bunker
cosmos	common	burlap	burrow
dimple	discus	cashew	canyon
filter	finish	column	combat
format	foster	tender	tennis
garble	gargle	damsel	damage
gadget	gather	sudden	summer
hammer	hazard	fidget	fiddle
hiccup	hither	fumble	funnel
hockey	hostel	ticket	tinsel
jacket	jaguar	goblin	gothic
ladder	lather	cattle	cannon
manage	mangle	huddle	hunger
marvel	margin	jabber	jagged
minge	mildew	juggle	jungle
motive	motion	kettle	kennel
pardon	parcel	mussel	musket
parrot	parish	pebble	pelvis

High BOB consistency	Low BOB consistency	High VIC2 consistency	Low VIC2 consistency
random	ransom	picnic	pigeon
reckon	relish	pillar	pilfer
sandal	savage	tumble	tunnel
spider	spiral	ribbon	riddle
stable	stamen	talent	tangle
tandem	tavern	trifle	tribal

Appendix G

Consent form for Experiments 2a, 2b, 3, 4.

The aim of this study is to understand the cognitive processes involved in reading. In this session, you will be asked to do three tasks. In the first task, you will be asked to fill out a brief information sheet regarding your education and language experience. In the second task, you will be presented with words one at a time on a computer screen and asked to name them as quickly and accurately as you can. In the third task, you will be presented with a string of letters and asked to decide whether each string is a word or not. You will indicate this by pressing a yes or no button as quickly and accurately as you can. The computer will record your answers as well as the time that it takes you to respond to each item. The entire session is expected to last about 45 minutes and you will receive one experimental credit for each hour or part hour that you participate in the study.

There are no known physical or psychological risks associated with this research. You have the right to terminate the session at any time without loss of credit. Information about your performance will be kept strictly confidential. The only information that will be released are average reading times and scores across all participants in the experiment.

You will receive written feedback about the experimental hypotheses upon completion of the study. If you have any questions or concerns now, please ask the experimenter to answer them for you. You are welcome to contact Erin Knudsen or Dan Chateau in SSC 7222 if you have any further questions or if you want to find out the results of the study.

I have read the above statement and agree to participate in the study.

(signature)

(date)

Appendix H

Debriefing form for Experiments 2a, 2b, 3, 4.

The purpose of the first study was to uncover some of the processes that are involved in pronouncing words with two or more syllables. With one syllable words, it has been established that the consistency of the spelling to sound translation is important in determining how long it will take to name a word (Jared, McRae, & Seidenberg, 1990). Words such as GAVE contain an inconsistent letter pattern (AVE), since there are other words with the same letter pattern that are pronounced differently, such as HAVE. These words take longer to name than words that contain letter patterns that are consistent, such as UST in MUST. With longer multi-syllabic words, the consistency of letter to sound translations is not the same as it is in one syllable words, and very few studies have examined this process. One question is whether readers use separate resources for each syllable in a longer word when it is translated to a pronunciation. This could be the case since there are letter patterns which are pronounced differently in longer words than they are in one syllable words. For instance, INE is pronounced as in FINE and DINE in shorter words, but is sometimes pronounced differently in longer words (e.g. MARINE, EXAMINE). The present study will take a closer look at this aspect of word naming, by comparing the results of this study to several different measures of the consistency of spelling to sound translation to determine which is the best measure of consistency for longer words.

Thank you for participating in this study. For more information, please contact Erin Knudsen (Graduate Student) in SSC7222, Dan Chateau (Graduate Student) in SSC 7222 or Dr. Debra Jared in SSC 6304 (679-211 ext. 4631).

For further information, you might be interested in the following:

Jared, D., McRae, K., & Seidenberg, M.S. (1990). The basis of consistency effects in word naming. *Journal of Memory and Language*, 29, 687-715.

Jared, D. & Seidenberg, M. S. (1990). Naming multisyllabic words. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 16, 92-105.

Appendix I

Stimuli used in experiment 2b.

High BOB consistency	Low BOB consistency	High VIC2 consistency	Low VIC2 consistency
beacon	beaker	bamboo	banner
pillar	picnic	bumble	bunker
cosmos	common	burlap	burrow
dazzle	dangle	cashew	canyon
filter	fiscal	cattle	cannon
format	foster	column	combat
garble	gargle	damsel	damage
gadget	gather	doctor	donkey
hamper	hazard	fidget	fiddle
hiccup	hither	fumble	funnel
hockey	hostel	goblin	gothic
corpus	corset	huddle	hunger
ladder	lather	jabber	jagged
manage	mangle	juggle	jungle
marvel	margin	kettle	kennel
mingle	mildew	mussel	musket
motive	motion	pebble	pelvis
pardon	parcel	gambit	gasket
cellar	censor	ramble	rankle

High BOB consistency	Low BOB consistency	High V1C2 consistency	Low V1C2 consistency
random	ransom	ribbon	riddle
reckon	rescue	talent	tangle
rocket	roster	tender	tennis
spider	spiral	ticket	tinsel
stable	staple	trifle	tribal
tendon	tether	tumble	tunnel

Appendix J

Stimuli used in Experiment 3.

High Frequency Words		Low Frequency Words	
High BOB consistency	Low BOB consistency	High BOB consistency	Low BOB consistency
coffee	common	cosmos	column
corner	couple	corpus	corset
dinner	danger	dazzle	dangle
doctor	damage	dimple	dither
finger	figure	filter	fiscal
former	fellow	format	foster
happen	heaven	hamper	hazard
market	modest	marvel	margin
matter	master	mingle	mildew
middle	modern	motive	mangle
pardon	palace	pillar	picnic
sector	season	spider	spiral
seldom	second	stable	staple
simple	social	sandal	savage
terror	target	tendon	tether
winter	window	wombat	wobble

Appendix K

Stimuli used in Experiment 4.

Low V2 consistency	High V2 consistency
bishop	bitter
burlap	burden
button	butter
cannon	cancel
census	centre
cortex	comics
curfew	cherry
follow	forest
fungus	funnel
future	flower
horror	hostel
liquid	liquor
mascot	magnet
menace	motion
mutton	muster
palate	pamper
proton	potent
recess	regent

Low V2 consistency	High V2 consistency
rescue	retail
rumpus	rustle
sundae	sultan
zircon	zenith
talcum	tandem
vertex	vermin
volume	volley

Appendix L

Copy of ethics approval for research with human participants.

March 22, 1999

M E M O R A N D U M

To: Dan Chateau
 From: Jim Olson on behalf of the Ethics and Subject Pool Committee
 Re: Ethical review of "Pronouncing Words"
 Protocol # 99 03 02

STATUS

- ☒ Approved
- ☐ Approved conditional to making changes listed below
 (please file changes with your application to use the subject pool with Helen Harris in Rm. 7304)
- ☐ Please make the changes listed below and resubmit for review

SIGN-UP POSTER

- ☐ Briefly describe the task required of subjects
- ☐ Do not "hype" the advertising of your study
- ☐ Use 10cpi or 12cpi, with standard letter size, for description
- ☐ Other (see attached sheet)

INFORMED CONSENT SHEET

- ☐ Briefly describe the task the subjects are agreeing to perform
- ☐ Promise that the data will be kept confidential and used for research purposes only
- ☐ Promise that audio and/or video tapes will be erased, in part or entirely, at the subjects' wishes at any time
- ☐ State how many credits the subjects will receive for participation
- ☐ State that subjects may terminate the experiment at any time without loss of promised credit(s)
- ☐ State that there are no known risks to participation or state the risks
- ☐ State that subjects will receive written feedback at the end of the session or study and/or that subjects have had an opportunity to ask questions about the study
- ☐ Other (see attached sheet)

WRITTEN FEEDBACK

- ☐ Elaborate your feedback
- ☐ Rewrite your feedback at a level that is understandable to a Psychology 020/023 student
- ☐ Add a few references at the end and/or your name and how you can be reached
- ☐ Other (see attached sheet)

OTHER ☐ See attached comments

c. D. Jared