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A resolution test chart featuring several groups of horizontal and vertical lines of varying thicknesses. Each group is accompanied by a numerical value indicating the resolution. The values include 1.0, 1.1, 1.25, 1.4, 1.6, 1.8, 2.0, 2.2, 2.5, 2.8, 3.2, 3.6, 4.0, 4.5, 5.0, and 5.6. The chart is used to measure the resolving power of an imaging system.

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**Disrupting Holistic Word Recognition:
Evidence for Word-Specific Visual Patterns**

by

Donna Chernecki

**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of**

Master of Arts

Department of Psychology

**Carleton University
Ottawa, Ontario
12 May, 1992
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Disrupting Holistic Word Recognition:
Evidence for Word-Specific Visual Patterns

submitted by Donna Chernecki, B.A.
in partial fulfilment of the requirements for
the degree of Master of Arts

Thesis supervisor

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Carleton University
14 May, 1992

Abstract

Three experiments were conducted to examine the role of word-specific visual patterns (WSVPs) in visual word recognition. In Experiments 1 and 3, case alternation was used as a manipulation to distort the feature-based pattern of words and eliminate WSVP facilitation such that processing would be forced from the word level to the letter level. The results supported the WSVP facilitation hypothesis: Case alternation slowed naming of high-frequency exception words more than naming of high-frequency regular words. An additional consideration was whether case alternation affects encoding processes or processes involved in lexical access. In Experiment 2, stimulus quality was varied as it has been shown to affect encoding processes. The effects from Experiments 1 and 3 were in contrast to those from Experiment 2; stimulus quality was additive with frequency and regularity. The conclusion is drawn that WSVPs provide facilitation in recognizing familiar words.

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I would also like to dedicate this thesis to my parents, for their years of love, support, and faith in my ability and for helping me to realize my potential.

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Disrupting Holistic Word Recognition:

Evidence for Word-Specific Visual Patterns

Reading is a skill that is often taken for granted and assumed to be achieved 'naturally' by those who are able to read. A layperson's account of the reading process may include a simple description of "looking at the words" and "knowing what they mean." On closer examination, however, the layperson's 'looking' and 'knowing' account can be divided into several distinct stages: eye fixations, encoding of the word, lexical access, determining a single meaning, assigning the meaning to a referent, interpreting the context, and sentence wrap-up where one thought ends and another begins (Carpenter & Daneman, 1981; Carpenter & Just, 1977).

A large body of research has focused on one component of reading: visual word recognition. Word recognition consists of the encoding of visual features and letters, activation of the word's orthographic and phonological representations in the lexicon, output of the selected word, and access to the word's meaning in memory. The emphasis on examining word recognition in the literature is understandable, especially from a developmental perspective: Whereas recognizing a printed word is a primary effort for novice readers, for skilled readers word recognition may be a relatively automatic process (LaBerge & Samuels, 1974).

Almost 100 years ago, Erdmann and Dodge (1898, cited in Oden, 1984) showed that people can accurately identify words at a distance from which the letters are mostly illegible. This was one of the earliest demonstrations of the perceptual advantage that words have over letters and led Erdmann and Dodge to conclude that words are perceived as unified, unanalyzed wholes. This conclusion was not readily accepted (Huey, 1908) and nearly a century later, the issue of whether a word is functionally more than a series of letters is still widely investigated. That is, the question has not been resolved of whether there are psychologically relevant features of a word that are not entirely accounted for by the component letters (Oden, 1984).

Theorists generally agree on how low-level encoding and feature analyses take place during word recognition. In contrast, there has been much debate centred around issues of lexical representation and lexical access. The present research is concerned with the latter issue. In particular, the purpose of the present research was to examine the role of word-specific visual patterns (WSVPs) in accessing representations in the lexicon.

WSVPs are the complete set of visual features that make up a word. It has been suggested that WSVPs may facilitate processing and be critical for achieving skilled levels of reading by gaining access to the lexicon without activating individual letters (Besner, 1989). In the present research, the role of WSVPs in word recognition was assessed using a naming task. Accordingly, a

concomitant consideration for the present research was the way in which phonology is generated.

Models of Word Recognition

In just over 100 years of reading research, there have been many significant theoretical contributions toward describing word recognition. Many models have been proposed in order to account for basic findings as well as more complex interactions in word recognition. One way in which these models differ is with respect to the access code used in the process of word identification. The access code is the mechanism that allows entry into the lexicon or internal 'dictionary'. As will be discussed below, word recognition models differ in how the access code is characterized, both in terms of its nature and in the number of codes used to access the lexicon.

Single-Route Models. Single-route models describe a process of direct access in which there exist links from words to corresponding entries in the reader's internal lexicon (Frederiksen & Kroll, 1976; Glushko, 1979; Taraban & McClelland, 1987). In these models, each word has its own separate dictionary or addressed entry in memory. It is assumed that the orthographic representation of a word is activated first, followed by activation of the word's phonology in a separate representational system.

One of the first comprehensive accounts of word recognition was Morton's (1969) Logogen model. The basic unit in Morton's model is the

logogen. The logogen system consists of a collection of individual logogens that each represent individual words. A logogen is a feature detector that accepts incoming information about a target word from the visual feature-extraction process and counts the informational bits. When the count rises above a threshold, a response that corresponds to the logogen is made available (i.e., a word). Available responses then enter an output buffer where they may emerge as actual responses. The original logogen model did not include assumptions about how a phonological code is produced. In more recent versions of the model, however, a phonological code is assumed to be produced postlexically, that is, after the stimulus has been categorized in the visual input logogen system (Morton & Patterson, 1980).

As an example of the operation of the logogen system, the target word house would cause its own logogen to become activated as well as cause the logogens for the orthographic neighbours horse, hose and chase (etc.), to become partially activated. As the evidence accumulates, logogens representing the orthographic neighbours of the target word would approach threshold faster than more distant neighbours. The first logogen to reach threshold makes its information available to the output buffer. Subsequently, the phonological representation for the word house would become available.

An important consideration for any word recognition model is the effect of word frequency. It has been found that the time required to recognize a

word varies with frequency: High-frequency words are recognized faster than low-frequency words (Morton, 1969; Whaley, 1972). To account for the powerful effect of frequency, Morton assumes that a logogen's threshold varies depending on the frequency of the word. Logogens that correspond to high-frequency words have lower thresholds. This biases the system toward faster recognition of familiar words. Thus, the amount of sensory information needed to reach threshold is less for high- than for low-frequency words and, therefore, responses for high-frequency words become available faster.

In the original Morton (1969) model, logogens are assumed to be directly accessed based on the activation of features. In this view, access to logogens is not mediated by a letter activation stage. One possible interpretation, therefore, is that the access code in this system is a WSVP.

Another influential model of word recognition has been McClelland and Rumelhart's (1981) Interactive Activation Model. In this model, processing proceeds in a bottom-up fashion but also communicates interactively through top-down processes. It is assumed that the word recognition system is made up of a multitude of feature, letter, and word nodes that are organized into levels. The different levels each contribute information toward forming a representation of the input. McClelland and Rumelhart assume that connections exist within and between adjacent levels. The connections within a level (between neighbouring nodes) operate in an inhibitory manner such that there is

lateral inhibition between incompatible nodes. However, the connections between levels can be excitatory or inhibitory. When the nodes between the levels are consistent with each other (e.g., the node for boy and the node for the letter b), then the connections are excitatory. If the nodes are inconsistent (e.g., the node for boy and the node for egg), then the connections are inhibitory. The input from neighbouring nodes increases the activation of a node when the connection is excitatory or decreases the activation of the node when the connection is inhibitory.

McClelland and Rumelhart (1981) assume that the levels interact and that communication proceeds through spreading activation from one level to neighbouring levels. Thus, activated letter nodes spread activation to words consistent with the activated letters. Activated word detectors inhibit other words and send feedback to the letter level, which again strengthens consistent letter activation. The result is that the system behaves in a loop, continually strengthening consistent responses and inhibiting inconsistent responses until a single response emerges. The word frequency effect is explained by assuming that the nodes for high-frequency words have higher resting levels than those for low-frequency words. Accordingly, less activation is required for a high-frequency node to reach threshold.

As with Morton's (1969) model, explicit assumptions regarding phonology are not included in the McClelland and Rumelhart (1981) model. In

general, however, it can be assumed that phonology is generated once a single response emerges from the word level. Therefore, although McClelland and Rumelhart advocate the interactive nature of the word recognition process, access within the system is assumed to be direct. That is, the phonological representation is accessed directly once the orthographic representation has been identified.

McClelland and Rumelhart formulated their model without including a role for WSVPs. Thus, with the inclusion of a letter level of analysis, McClelland and Rumelhart assume that processing proceeds from features, to letters, to words.

Another variation of a single-route approach is the Verification class of models (Becker, 1976; Paap, McDonald, Schvaneveldt, & Noel, 1987; Paap, Newsome, McDonald, & Schvaneveldt, 1982). This class of models is similar to the logogen model in that each word is assumed to have its own entry in the lexicon. Verification models differ, however, in that a lexical search is conducted to match the target to a candidate. Accordingly, word recognition consists of two processes: sensory feature extraction and verification. The feature-extraction process uses information in the sensory store to identify some of the characteristics of the stimulus. The extracted visual information feeds activation to a set of letter representations, referred to as the alphabetum. Activation from the alphabetum in turn feeds into the lexicon and activates

word representations. Through the extraction process, a candidate set of words is formed from the word representations that have surpassed a threshold of activation. The next step is a verification process, where a word is selected from the candidate set and compared to the representation in the sensory store. Recognition occurs when a candidate is successfully matched with the sensory representation. It is assumed that candidates are presented for verification on the basis of frequency, with high-frequency words selected first. In this view, high-frequency words are recognized faster because fewer candidates are rejected before a match is found.

Assumptions about phonology were not originally included in the Verification model. It can be assumed, however, that as in the logogen and interactive-activation models, phonology is accessed directly after verification of the candidate has occurred. The access code in verification models is similar to the interactive-activation code described previously. In order to access the lexicon, processing proceeds from features, to letters, to words. In verification models, therefore, WSVPs do not play a role in lexical access.

In summary, single-route models describe a process of direct access to a memory system that represents individual words. Various processes have been proposed — from feature activation to serial matching of representations stored in memory. These models share the assumption that there is direct, visual access to a memory system that represents individual words. With respect to

phonology, it is commonly assumed that phonology is accessed postlexically. That is, information regarding a word's pronunciation is made available after the word's representation has been accessed in the lexicon. With the possible exception of the original logogen model (in which WSVPs are implied), access to the lexicon is generally depicted as through the processing of feature, letter, and word levels.

Dual-Route Models. Dual-route models are a class of models that describe word recognition and word naming with reference to codes produced along a direct-access (lexical) route (as in the previously described models) as well as computed along a phonological or assembly route (Besner & Johnston, 1989; Carr & Pollatsek, 1985; Coltheart, 1978, 1980; Forster & Chambers, 1973; Paap et al., 1987; Paap & Noel, 1991; Patterson & Morton, 1985). In recognizing and naming a word along the lexical route, a word is identified first and then information on the word's pronunciation is accessed and read out of memory. Therefore, as with single-route models, phonology is generated postlexically. In recognizing a word along the assembly route, a translation occurs using spelling-to-sound correspondence rules (Gough, 1972; Morton & Patterson, 1980; Rubenstein, Lewis, & Rubenstein, 1971): The word is analyzed into smaller subword units that activate corresponding phonological units.¹ The phonological units are then assembled into a phonological sequence that allows for the pronunciation of the word. Based on this route, a word's

phonological representation can be accessed without entry into the internal lexicon (Coltheart, 1978). It is assumed that the assembly and direct-access mechanisms operate separately but in parallel. Both routes are assumed to contribute information used in recognizing and naming words.

Recently, Paap and his colleagues (Paap et al., 1987; Paap & Noel, 1991) have integrated a dual-route approach into their activation-verification model of word recognition. An important addition to the dual-route approach has been Paap's assumption of how the system 'decides' which code is used to generate a pronunciation. According to Paap and Noel (1991), the pronunciation of a word can be derived from either route. Both routes generate codes and whichever code is produced first determines the pronunciation. If the direct-access (or lexical) route generates a code first, then phonology is derived postlexically. If the assembled route generates a code first, then pronunciation is derived from this assembly process. If a lexical and an assembled code are produced at the same time, then a conflict may occur.

In accord with the verification-type model discussed above, processing along the lexical route is assumed to be sensitive to frequency. Conversely, the assembly route is not affected by frequency because of the constructive nature of the assembly process: Representations are constructed in the same way for all words using the spelling-to-sound translation rules. It is also assumed that the assembly of the pronunciation is relatively slow.

Thus, in dual-route models, two access codes are produced. As in the verification model, the lexical route produces a code through feature and letter analysis in order to arrive at a word candidate. Accordingly, a role for WSVPs has not been incorporated in the lexical route. Similarly, WSVPs are not incorporated in the assembly route, as a code is generated using grapheme-to-phoneme translation rules.

Additional Considerations: Word Regularity. As previously stated, research has shown that word recognition is affected by the frequency of a word; high-frequency words are recognized faster than low-frequency words. Consequently, assumptions regarding frequency have been included in most models of word recognition. An additional consideration concerns how differences in the correspondence between spelling and sound influence how words are read (Seidenberg et al., 1984). Most English words follow regular spelling-to-sound patterns (e.g., turn, rink, hunt). However, there exist a large number of English words that have irregular spelling and unpredictable pronunciation (e.g., pint, soot, gauge). These irregular words are often termed exception words. A consistent finding in the literature has been the exception effect, where exception words take longer to pronounce than regular words matched for length and frequency (Coltheart, 1978; Glushko, 1979; Parkin, 1982; Parkin, Mullen, & Graystone, 1986).

In Paap and Noel's (1991) dual-route model, regular words can be pronounced correctly by using either the lexical or assembled route; both routes produce identical codes when a regular word is read. Conversely, exception words can be pronounced correctly only by reference to the lexical route; because exception words do not follow regular spelling-to-sound rules, the code produced by the assembly route generates an incorrect pronunciation. The two codes generated to name an exception word like pint conflict, which results in longer naming times to exception words.

However, the conflict only occurs for low-frequency words. The interaction of word regularity by frequency shows that naming latencies for high-frequency regular words and high-frequency exception words do not significantly differ; however, low-frequency exception words are named more slowly than low-frequency regular words (Seidenberg et al., 1984). Paap and Noel (1991) explain the Frequency by Regularity interaction in terms of competition between the codes produced by the lexical and assembled route. Both regular high-frequency words and exception high-frequency words are processed quickly along the lexical route. The code generated along the assembly route is slower and thus, the lexical code is the first to be produced. Because the first code produced is used, there is no competition between the codes to name high-frequency regular or exception words. For low-frequency regular words, there is a consensus decision delivered by the two routes but

naming time will generally be slower than the time to name high-frequency words because of the extra time required for verification of low-frequency words. The extra time required to verify exception low-frequency words allows the assembled code to catch up to the lexically-produced code.

However, the two codes differ and extra time is required to resolve the conflict between the competing responses that are delivered by the lexical and assembled route. Thus, naming is longer for low-frequency exception words.

One advantage of dual-route models over single-route models is that the ability to pronounce nonwords can be accounted for with the addition of the assembly route. Nonwords are assumed not to have lexical entries and thus, can only be named via the assembly route's grapheme-phoneme conversion. The dual-route approach has also been widely adopted by researchers in explaining acquired dyslexia (Coltheart, 1980; Coltheart, 1981; Patterson, Marshall, & Coltheart, 1985; Rayner & Pollatsek, 1989). For example, both deep and phonological dyslexics are unable to read nonwords and cannot read words that they do not know. It is assumed that these dyslexics have difficulty using the assembled route and thus rely on the lexical route in reading. Their difficulties in reading novel words and nonwords presumably result because they do not have a lexical representation for the new word and cannot sound it out because of the dysfunctional assembly route. In contrast, surface dyslexics appear not to recognize words as wholes, but resort to a strategy of sounding

out words. Consistent with the use of the assembly route, reading aloud of exception words is impaired relative to regular words and nonwords (Coltheart, Curtis, & Atkins, 1992). In addition, surface dyslexics have trouble understanding words that they are able to pronounce. It is assumed that surface dyslexics are able to use the assembled route but not the lexical route to read words. Because surface dyslexics can not directly access the lexical (and therefore, semantic) representation of the word, it is possible for a word to be pronounced correctly but not to be understood (Rayner & Pollatsek, 1989). Thus, the dual-route model has been successfully used as a view toward understanding disordered patterns of reading behaviour as well as describing normal reading.

A Third Route? WSVPs in Word Recognition

Once the step has been taken from a single- to a dual-route approach, the next possibility to consider is the notion of an additional or third access code. Specifically, it is possible that readers use word-specific visual patterns (WSVPs) when reading high-frequency words (Besner & Johnston, 1989; Coltheart & Freeman, 1974; LaBerge & Samuels, 1974; Masson, 1986; Rudnicky & Kolars, 1984). Readers may take advantage of the over-learned set of visual features of highly familiar words (the holistic pattern) and therefore may not need to rely on letter analysis to gain access to the lexicon.

The facilitation provided by WSVPs is conceptualized as a bypass along the lexical route (see Figure 1).

Insert Figure 1 about here

The development of a WSVP route may facilitate processing and be indicative of skilled reading in that step-by-step processing through feature and letter levels is not necessary. Evidence in support of a role for WSVPs in word recognition has come from a variety of research paradigms: word categorization tasks, reading of continuous text, and tasks developed to map the underlying processes during word recognition. A review of the evidence from each of these areas will follow.

Evidence: Word categorization. LaBerge and Samuels (1974) suggest that fast and automatic word recognition results from practice and the ability of the reader to process words holistically. With practice a reader can combine letter and spelling patterns such that an entire word is processed holistically and the access code along the lexical route is unitized (WSVP). Less practiced or unfamiliar words would be processed through the traditional levels of analysis along the lexical route. In testing this assumption, Terry, Samuels, and LaBerge (1976) and Samuels, LaBerge, and Bremer (1978) had subjects categorize words shown normally or transformed in mirror image. It was

suggested that letter-by-letter processing of a word would produce an increase in word categorization latency as the number of letters in a word increased. LaBerge and his colleagues found a significant increase in latency as a function of word length only for words displayed in mirror image. There was no effect of word length for words presented normally. They concluded that words in a normal presentation were processed as holistic units whereas words presented in mirror image were processed letter-by-letter.

Evidence: Identification of letters during reading. Another line of evidence in support of holistic (WSVP) processing has used a letter-detection task during the reading of continuous text. Drewnowski and Healy (1977) used letter detection to investigate the possibility that high-frequency words are processed as a unit rather than letter-by-letter. They suggest that readers use the over-learned set of visual features of highly familiar words (the holistic pattern) instead of relying on letter analysis. In these studies, subjects read passages and were asked to circle each instance of a target letter (e.g., l). Subjects made more errors on high-frequency words (did not circle the l in the word the) than on low-frequency words and failed to detect letters in correctly spelled words more often than in misspelled words (Healy, 1976, 1980; Healy & Drewnowski, 1983; Healy, Oliver, & McNamara, 1987). Thus, when processing at the word-level is possible (e.g., with a highly familiar word such as the), processing is facilitated by WSVP information and individual letters are

not activated, which results in poorer target letter detection. When processing at the word level is impeded (e.g., processing a misspelled word), subjects must process at the letter level, which results in better detection of target letters.

Evidence: Word recognition tasks. In a dual-route framework, it is assumed that the lexical route is faster and more accurate than the assembly route (Besner & Johnston, 1989; Paap et al., 1987; Paap & Noel, 1991; Underwood & Bargh, 1982). One explanation for this advantage may be that the lexical route receives facilitation from WSVPs. WSVP information facilitates word recognition when a word can be identified based on its visual components such that a letter analysis stage is by-passed (see Figure 1). WSVP facilitation is most likely to occur with high-frequency words.

The existence of a facilitatory WSVP route has not been universally supported in the literature (see Paap, Newsome & Noel, 1984; Besner & Johnston, 1989 for reviews). In an initial experiment, Coltheart and Freeman (1974) presented words in alternating upper and lower case. Case alternation distorts the characteristic shape and the overall feature-based pattern of words and thus prevents encoding of WSVPs. However, case alternation does not prevent or distort processing at the letter level. Each letter, whether in upper or lower case, can be encoded. Therefore, if processing along the lexical route is letter-by-letter, then there should be no effect of case alternation. If, on the

other hand, WSVPs are used to gain direct access to the lexicon, then case alternation should slow word naming. Their results showed that word reading was impaired by the case-alternated condition. Coltheart and Freeman (1973) suggest that their results support a model in which WSVPs play a role.

Research by Rudnicky and Kolars (1984) also supports the view that WSVPs facilitate word recognition. Subjects read case-alternated passages where letters were altered either in strings of one, two, four, or eight letters, at word boundaries, or randomly. They found that there was no reliable difference between the reading times of conditions that alternated case within a word; however, all five of those conditions resulted in slower reading than alternation at word boundaries. Thus, alternating at word boundaries was less disruptive than alternating within words. Rudnicky and Kolars (1984) concluded that subjects were sensitive to the visual integrity or configuration of the words: a single-case change had the same disruptive effect as multiple alternations. They suggest that readers develop a sensitivity to the feature configuration of a word that becomes intrinsic to their skill.

Another study supporting the notion of WSVPs was reported by Masson (1986). Masson (1986) concurred with Rudnicky and Kolars in suggesting that WSVPs are used in the development of reading skill. Masson (1986) trained subjects to name alternating-case word triplets where the individual letters were mirror images (e.g., *ɹOɔʌǝʎ*). In the test phase, Masson presented half of

the words in the trained format and the other half in the complimentary pattern (previously upper case letters were shown in lower case and vice versa; e.g., $\alpha O \gamma K \theta Y$ to $H o \gamma K \theta Y$), and had subjects name them. Masson (1986) found that subjects named words trained and tested in the same format faster than words tested in the complementary format. Masson (1986) suggested that individual letters were equally familiar to subjects but that the pattern of interletter features or WSVPs had changed from training to test for part of the words. He concluded that word identification results from letter analysis in conjunction with identification of interletter features and word shape (WSVPs).

In contrast to previous research, Paap et al., (1984) have found evidence against the notion that supraletter features facilitate lexical access. In their experiments, rare and common-shaped words were compared in a lexical decision task. Paap et al., (1984) sorted the entire corpus of four-, five-, and six-letter words from the Kučera and Francis (1967) word-frequency norms into shapes that were defined by the pattern of ascending, descending and neutral letters. Rare-shaped words were either unique in shape (e.g., kept, health), or shared shapes with fewer than six words. Common-shaped words shared their shape with more than six other words. Paap et al., (1984) had predicted that lexical access would be faster for rare-shaped words if word-shape information facilitated lexical access. In contrast to this prediction, words with rare shapes were not accessed faster. It is important to note, however, that Paap et al.'s

(1984) experiment specifically examined word shape and not WSVPs. Whereas both word shape and WSVPs have been considered important in word identification (Rudnicky & Kolars, 1984), word shape refers only to the outline or envelope of a word and WSVPs constitute all the features of a word (including word shape). Therefore, although the results of Paap et al., (1984) do not support a WSVP hypothesis, the notion that WSVPs may facilitate lexical access is not disconfirmed.

Besner and Johnston (1989) have reviewed the evidence for the existence of a WSVP route. In terms of a dual-route model, a WSVP route should facilitate lexical access by feeding accumulated information directly into the word level, bypassing the letter level. In this view, only words should benefit from WSVPs. Nonwords can only be named along the assembly route (as nonwords do not exist in the lexicon) and thus, cannot be facilitated by WSVPs. Besner and Johnston (1989) suggest that if WSVPs are used in word recognition, naming words would be more impaired by alternating case than naming nonwords. However, Besner (1983) did not find evidence in support of this hypothesis. He found a greater effect of alternating case for nonwords than for words.

Besner and McCann (1987) examined naming latencies for high- and low-frequency words in alternating case. If WSVPs facilitate identification of familiar words by bypassing feature and letter identification stages, then

eliminating WSVPs with a case manipulation should affect high-frequency words more than low-frequency words. In contrast to the WSVP hypothesis, Besner and McCann (1987) found a smaller effect of case alternation for high-frequency words than for low-frequency words. It also should be noted that they have not found evidence against the use of a WSVP route but instead have attempted to explain the effects by assuming that the WSVP route is not used.

One possible limitation of Besner and Johnston's research is that the manipulations used in their investigations may not be sensitive enough. In order to support the existence of the two routes, dual-route theorists use stimuli that will be sensitive to the differences between the two routes. A common manipulation is to use regular and exception words. Naming of regular words results in consensus codes being delivered by the two routes. Naming of exception words results in conflicting codes being delivered by the lexical and assembly route. In Besner's research (Besner, Coltheart, & Davelaar, 1984; Besner & Johnston, 1989; Besner & McCann, 1987), only regular words (words that are pronounced using regular spelling-sound correspondences) are used as stimuli. The inclusion of exception words (words that do not follow regular rules of pronunciation) may result in differences that are otherwise not discernible.² If multiple routes exist, then it should be possible to differentially affect one of the routes and measure the amount of interference that results.

Exception words are useful in accomplishing this task because the lexical and the assembled route provide competing responses.

Present Research

The purpose of the present research was to examine the role of word-specific visual patterns (WSVPs) in visual word recognition. Case alternation was used as a manipulation on the assumption that it disrupts WSVP information (Besner & Johnston, 1989; Kinoshita, 1987; Masson, 1986; Rudnicky & Kolars; 1984). If WSVPs play a role in visual word recognition, naming latencies for words presented in Alternating Case should be impaired. Four classes of word stimuli were used: regular low-frequency words; exception low-frequency words; regular high-frequency words; and exception high-frequency words. In accordance with Paap and Noel (1991), processing along the assembly route is assumed to be slow for all types of words. Processing along the lexical route, on the other hand, is assumed to be sensitive to frequency such that a code is accessed faster with high- as compared to low-frequency words.

Regular low-frequency words. For low-frequency words, processing along the lexical and assembled route is assumed to be slow. On any given trial, naming may be based on input provided by either the lexical or assembled route or by both because both routes provide the correct response. The result of case alternation on naming is that both routes are slowed. Case alternation

disrupts processing along the assembly route by impeding the processing of multi-letter units (e.g., consonant clusters, like sh, which map onto a single phoneme). The effect of case alternation along the lexical route is to slow letter analysis because both lower case and upper case patterns are activated and need to be considered. Therefore, because case alternation affects both routes, the effect should be a large, overall increase in naming latencies.

Exception low-frequency words. Both the assembly route and lexical route are slow to produce codes for low-frequency words. Therefore, the two codes will overlap in the output buffer. Because the assembly route generates an incorrect code for exception words based on the spelling-to-sound translation, the codes will interfere and, therefore, extend naming latencies. Case alternation presumably slows both routes. Accordingly, case alternation does not affect the amount of overlap between the codes in the output buffer. Therefore, alternating case should result in longer overall naming latencies.

Regular high-frequency words. For regular high-frequency words, the assembly route is slow whereas the lexical route is fast. Thus, naming is based primarily on the code produced by the lexical route. The speed of the lexical route can be explained partially with reference to the facilitation provided by the WSVP bypass. The effect of case alternation is to slow both routes and to destroy the WSVP bypass. This should result in slightly longer naming

latencies because (a) the basic processes of the lexical route are slowed and (b) WSVP facilitation is eliminated.

Exception high-frequency words. The code generated by the assembly route is slow and incorrect based on the spelling-to-sound translation of the word. However, the code produced by the lexical route is fast, and thus, naming is usually based on the code provided by the lexical route. As with the regular high-frequency words, the WSVP bypass may facilitate processing along the lexical route. The effect of case alternation is to slow both routes and to destroy the WSVP bypass. This should result in longer reaction times due to slowing of the basic processes of the lexical route via elimination of the WSVP facilitation. In addition, because the lexical route is slowed, there may be overlap between the lexical code and the assembled code. The overlap of the two codes results in interference because for exception words, the lexical code and the assembled code differ. Therefore, the effects of case alternation are predicted to be larger for high-frequency exception words than for high-frequency regular words.

Summary

The existence of a facilitatory Word-Specific Visual Pattern (WSVP) route has been debated in the literature. There has been much research regarding word shape and supraletter features in word recognition with evidence supporting the WSVP hypothesis. Presenting words in alternating

case is one method that has been used to isolate WSVP effects, as it distorts the accustomed word pattern (Besner & Johnston, 1989). Case alternation eliminates the overall feature-based pattern of a word and forces processing from the word level to the letter level. This effect should be evident for high-frequency words in the comparison of regular and exception words.

Experiment 1

In the first experiment, a case alternation manipulation was used to examine WSVPs in word recognition. Subjects were required to name words presented either in lowercase or in alternating case. It was expected that basic findings from the literature would be replicated: the frequency effect (Whaley, 1972), the word regularity effect (Seidenberg et al., 1984), and the effect of case alternation (Coltheart & Freeman, 1974; Rudnicky & Kolars, 1984). There is also an interaction between word frequency and word regularity reported in the literature where naming latencies for high-frequency regular and exception words do not differ; however, low-frequency regular words are named faster than low-frequency exception words (Seidenberg et al., 1984). In addition, Besner and Johnston (1989) reported a word frequency by case alternation interaction for regular words where the effect of alternating case was greater for low-frequency than for high-frequency words. It is expected that these two interactions would be replicated in the present experiment. Finally, a 3-way case alternation by word frequency by word regularity interaction was predicted. It was expected that alternating case would have similar effects on low-frequency exception and regular words. However, alternating case was expected to have a greater effect on high-frequency exception than on high-frequency regular words.

Method

Subjects. Subjects were 40 undergraduate university students who participated to partially fulfil a course requirement or were paid for their participation. Subjects were selected from a pool of students who had been pre-tested on a reading skill battery. Twenty of the students were high skill and 20 were lower skill. Half the subjects were male and the other half were female.

Apparatus. An IBM-AT type computer was used to present letter strings on a Samsung monochrome video screen. A two-button response panel connected to the computer was used to initiate presentation of the words. A Grason-Stadler voice operated relay indicated that a response had been made when subjects spoke into a Sharpe LM6 microphone mounted to a set of Scintrex headphones.

Design and Materials. A 2 (Frequency: high, low) X 2 (Regularity: regular, exception) X 2 (Case: lower, mixed) repeated measures design was used. Eight categories of words were created by crossing: Frequency, Regularity, and Case. There was 10 monosyllabic words in each of the eight categories for a total of 80 words. The words were selected such that (a) there was an equal number of high-frequency and low-frequency words in the regular and exception categories, (b) frequency was balanced across regularity, (c) the words in each Frequency X Regularity group were matched for length, and (d)

no spelling patterns (e.g., read, lead, dead, etc.) were repeated in the categories. A complete list of the words can be found in the Appendix.

Classification of words as exceptions was based on the criteria used by Waters and Seidenberg (1985). Only exception words that have regular spelling patterns but irregular pronunciations were chosen (words with both uncommon spellings such as yacht and ache and irregular pronunciations were excluded to avoid confounding spelling and pronunciation).

Two orders of words were used. Each subject saw one order. In each order, half of the words were in alternating case and half were all in lower case. Words that were case alternated in one order were in lower case in the other order. Each order was constructed randomly with the restriction that not more than 3 lower-case or alternating-case words appear consecutively.

Procedure. Subjects were tested individually in sessions lasting approximately 30 minutes. A trial began with an asterisk (*) in the centre of the video screen. Subjects were asked to fixate on the asterisk and to push a button on the response panel to begin each trial. When a button was pushed, the asterisk was replaced 300 milliseconds later by a word. The word was written either in lower case (e.g., give) or in mixed case (e.g., gIvE) with the first letter always in lower case. Subjects were required to pronounce words as quickly and as accurately as possible. The word remained on the screen until it

was pronounced. A variable inter-trial interval (ITI) elapsed while the experimenter inputted whether the pronunciation of the word was correct.

Subjects completed 16 practice plus 80 experimental trials for a total of 96 pronunciation trials. Subjects were then given 20 minutes to complete the comprehension section of the Nelson-Denny Reading Test (Form F: Brown, Bennett, & Hanna, 1981). For the comprehension section of the Nelson-Denny, subjects read short paragraphs and answered multiple choice questions based on the content of the paragraphs. This test was employed as an additional skill measure. Analysis of the skill data did not reveal any differences and thus, will not be discussed further.

Results and Discussion

The primary dependent measure was pronunciation latency. Means were derived by including latencies from words pronounced correctly. Latencies from words that were pronounced incorrectly or from trials where there was an equipment failure were not included. The results are shown in Figure 2. The mean latencies are shown in Table 1 along with percent errors.

Insert Figure 2 about here.

Insert Table 1 about here

Response times. Latencies were examined with a 2 (Word type) X 2 (Case type) X 2 (Frequency) repeated measures ANOVA. This analysis showed that high-frequency words (612 ms) were pronounced faster than low-frequency words (665 ms), $F(1, 39) = 83.39$, $MSe = 3640.97$, $p < .001$, thus replicating the word-frequency effect found throughout the literature (e.g., Whaley, 1978). Regular words (639 ms) were pronounced significantly faster than exception words (664 ms), $F(1, 39) = 24.16$, $MSe = 2172.83$, $p < .001$. Case type was also significant, $F(1, 39) = 57.03$, $MSe = 3828.17$, $p < .001$; words printed in lower case (625 ms) were responded to faster than words printed in alternating case (678 ms).

Besner et al., (1984) and Besner and McCann (1987) found a larger effect of case alternation for low- than for high-frequency words; however, this result was not replicated in the present experiment, $F < 1$. An important difference between the present experiment and the results of Besner and colleagues is that Besner did not include exception words in his stimulus list. An analysis of only the regular words from the present experiment showed the interaction between frequency and case alternation to be significant, $F(1, 39) = 5.70$, $MSe = 1614.78$, $p < .05$. This replicates the pattern of results found by

Besner et al., (1984) and Besner and McCann (1987). There was a small difference between naming high-frequency words in lower (599 ms) versus in mixed case (626 ms). However, there was a larger effect between naming low-frequency words in lower (637 ms) versus in mixed case (694 ms).

A word frequency by word regularity interaction has been reported in the literature (Seidenberg et al., 1984). This interaction was replicated in the present experiment, $F(1, 39) = 5.08$, $MSe = 1130.06$, $p < .05$: Whereas for high-frequency words, the difference in naming latencies for exception (630 ms) and regular (613 ms) words was small, for low-frequency words, the difference in latencies was greater for exception (700 ms) than for regular (666 ms) words. The interaction between Case type and Word type was also significant, $F(1, 39) = 4.18$, $MSe = 1954.46$, $p < .05$. There was a small difference in naming latencies for exception (634 ms) and regular words (618 ms) presented in lower case. However, latencies for exception words in mixed case (696 ms) were greater than latencies for regular words (660 ms).

The primary hypothesis was that case alternation would slow processing along the lexical route for high-frequency words by disabling the WSVP route. Accordingly, in the case-alternated condition, it was expected that pronunciation latencies for high-frequency exception words would be slower than high-frequency regular words because the slowing of the lexical route and the elimination of WSVP facilitation would result in the incompatible lexical and

assembled codes overlapping in the output buffer. Thus, a greater effect of case alternation was predicted for high-frequency exception than for high-frequency regular words. Low-frequency regular and exception words were not expected to show differential effects. The hypothesis was supported as the Case type X Word Type X Frequency interaction was significant, $F(1, 39) = 8.49$, $MSe = 1385.27$, $p < .01$. Separate Case type X Word type analyses of the high-frequency words showed that there was no difference in naming exception and regular words in lower case; however, in alternating case, exception words were pronounced slower than regular words, $F(1, 39) = 14.85$, $MSe = 1331.68$, $p < .001$. A similar Case type by Word type analysis of the low-frequency words was not significant, $F < 1$. Case alternation had an additive effect on low-frequency exception and regular words.

Error data. The percent errors are shown in Table 1. Only words that were pronounced incorrectly were included as errors. Trials on which the equipment failed were not included in the analysis. On average, equipment malfunctions accounted for 1.8% of the trials in Experiment 1. Errors were examined with a 2 (Word type) X 2 (Case type) X 2 (Frequency) repeated measures ANOVA. The analysis showed that more pronunciation errors were made naming low- (10.2%) than naming high-frequency words (1.6%), $F(1, 39) = 86.81$, $MSe = 88.14$, $p < .001$. Word regularity was also significant,

$F(1, 39) = 44.70$, $MSe = 85.61$, $p < .001$; more errors were made naming exception words (9.3%) than naming regular words (2.5%).

There was a Frequency X Word type interaction, $F(1, 39) = 24.52$, $MSe = 66.38$, $p < .001$. For high-frequency words, there was a small difference in errors made naming exception (2.5%) and regular words (0.6%). However, for low-frequency words, there were more errors made naming exception words (16.0%) than naming regular words (4.4%).

Summary

The results from Experiment 1 supported the main hypothesis: Case alternation slowed processing along the lexical route for high-frequency words by eliminating the WSVP route. Accordingly, in the case-alternated condition, pronunciation latencies for high-frequency exception words were slower than high-frequency regular words. On high-frequency exception trials, the slowing of the lexical route and the elimination of WSVP facilitation resulted in the incompatible lexical and assembled codes overlapping in the output buffer. Thus, there was a greater effect of case alternation for high-frequency exception than for high-frequency regular words. Low-frequency regular and exception words did not show differential effects because alternating case slowed both routes such that the two codes did not overlap in the output buffer.

Experiment 2

The results from Experiment 1 are consistent with the notion of a facilitatory WSVP route within a dual-route framework. An alternative possibility, however, is that case alternation affects an encoding stage prior to the activation of codes along the lexical and assembly routes. This hypothesis seems unlikely given the differential effects of case alternation on naming high-frequency regular and exception words found in Experiment 1. Clearly, however, conclusions concerning the role of WSVPs would be stronger if the effects of case alternation could be empirically dissociated from those associated with another variable that is known to slow stimulus encoding.

Research suggests that degrading the quality of a stimulus word (e.g., through contrast reduction, decrease in brightness) only affects encoding (Paap et al., 1987; Stanners, Jastrzembski & Westbrook, 1975). Stanners et al. (1975) examined the relationship between word frequency and stimulus quality during word recognition. They found that frequency and stimulus quality were additive in a lexical decision task, suggesting that stimulus quality affected encoding but not lexical access (Besner & Swan, 1982; Stanners et al., 1975, Sternberg, 1969). Accordingly, Experiment 2 examined the effect of stimulus quality on naming. Based on additive factors logic, stimulus quality should be additive with frequency and regularity.

Two blocks of words were used. One block included words in a non-degraded format and the other block contained words that were viewed through a filter that lowered brightness and contrast. As predicted earlier, degrading stimulus quality should slow encoding but not lexical processing.

Method

Subjects. A group of 40 students participated to partially fulfil a course requirement or were paid for their participation. Half the students were male and half were female. None of the subjects had participated in the previous experiment.

Design and Materials. A 2 (Frequency: high, low) X 2 (Regularity: regular, exception) X 2 (Stimulus quality: normal, degraded) repeated measures design was used. The same stimulus set of 80 words used in Experiment 1 was employed. However, the words were separated into two blocks of 40 words for naming: one block of words was presented with a filter covering the screen and one block was presented under normal conditions. The filter consisted of three sheets of coloured transparency film (2 green and 1 red). Four orders of 80 words were created. Each order consisted of two blocks: half of the words in each block (40 words) were high-frequency and half were low-frequency. Also, half of the words were regular words and half were exception words. Each subject saw one order.

Procedure. Other than the blocked presentation of the words and, therefore, a change in the instructions, the procedure was identical to that of Experiment 1. Subjects were instructed to pronounce each word as quickly and as accurately as possible. Half of the subjects pronounced words from the degraded block first and the other half pronounced words from the non-degraded block first. Subjects completed 10 practice trials before the degraded block and 10 practice trials before the non-degraded block plus 80 experimental trials for a total of 100 pronunciation trials.

Results and Discussion

Response times. The results are shown in Figure 3. Only latencies for words pronounced correctly were included in the analysis.

Insert Figure 3 about here

Latencies were examined with a 2 (Word type) X 2 (Stimulus quality) X 2 (Frequency) repeated measures ANOVA. This analysis showed that high-frequency words (626 ms) were pronounced faster than low-frequency words (687 ms), $F(1, 39) = 91.74$, $MSe = 3176.85$, $p < .001$. Regular words (642 ms) were pronounced significantly faster than exception words (671 ms), $F(1, 39) = 31.41$, $MSe = 2143.03$, $p < .001$. Stimulus quality was also significant, $F(1, 39) = 90.55$, $MSe = 15\,075.74$, $p < .001$, such that words

presented at normal quality (591 ms) were responded to faster than words degraded by the filter (723 ms). The mean latencies and percent errors can be seen in Table 2.

Insert Table 2 about here

The interaction between word frequency and word regularity reported in the literature (Seidenberg et al., 1984) and in Experiment 1 was also replicated in the present experiment, $F(1, 39) = 15.65$, $MSe = 1207.53$, $p < .001$. For high-frequency words, there was a small difference in naming latencies for regular (619 ms) and exception words (634 ms). However, for low-frequency words, exception words (709 ms) were named slower than regular words (664 ms).

Importantly, the 3-way interaction between Frequency, Regularity and Stimulus quality was not significant, $F > 1$. The absence of an interaction is consistent with previous research (Paap et al., 1987; Stanners, Jastrzembski & Westbrook, 1975) and supports the assumption that degradation affects a pre-lexical stage.

Error Data. The percent errors are shown in Table 2. As in the first experiment, trials on which the equipment failed were discarded. On average, equipment malfunctions accounted for 1.8% of the trials in Experiment 2.

Errors were examined with a 2 (Word type) X 2 (Stimulus quality) X 2 (Frequency) repeated measures ANOVA. This analysis showed that fewer errors were made naming high- (1.0%) than low-frequency words (7.2%), $F(1, 39) = 68.27$, $MSe = 56.92$, $p < .001$. In addition, more errors were made naming exception words (7.6%) than regular words (0.6%), $F(1, 39) = 87.81$, $MSe = 62.15$, $p < .001$.

The Frequency X Word type interaction was also significant, $F(1, 39) = 60.82$, $MSe = 69.84$, $p < .001$. For high-frequency words, there was a small difference in errors made naming regular (0.3%) and exception words (1.8%). However, for low-frequency words, relatively more errors were made naming exception (13.5%) than naming regular words (0.9%).

Summary

The results of Experiment 2 showed an additive relationship between stimulus quality, frequency and regularity. These results are in contrast to those of Experiment 1, in which case alternation was found to interact with frequency and regularity. The dissociation between stimulus quality and alternating case is important in isolating the effects of these factors during word recognition. Whereas stimulus quality slows encoding, case alternation influences post-encoding processing in the word recognition system.

Experiment 3

A comparison of the results from Experiment 1 and 2 supports the assumption that changes in stimulus quality affects encoding whereas case alternation affects post-encoding processes. This conclusion, however, is compromised somewhat by methodological differences between Experiment 1 and 2. Specifically, although the same words were used in both experiments, the presentation format differed.

In Experiment 1, a randomized presentation was used in which subjects did not know whether the next word presented would appear in mixed or regular case. In Experiment 2, subjects were informed of the presentation style (normal versus degraded) for the block of words. In order to provide a more direct comparison of case alternation and stimulus quality effects, Experiment 3 used a blocking procedure similar to that used in Experiment 2: One block of trials contained words only in lower case, the other block contained words in mixed case. Thus, the purpose of Experiment 3 was to replicate the results of Experiment 1 under the conditions of Experiment 2.

Method

Subjects. A group of 40 students participated to partially fulfil a course requirement or were paid for their participation. Half the students were male and half were female. None of the subjects had participated in the previous experiments.

Design and Materials. A 2 (Frequency: high, low) X 2 (Regularity: regular, exception) X 2 (Case: lower, mixed) repeated measures design was used. The same stimulus set of 80 words used in Experiment 1 was employed. However, the words were separated into two blocks of 40 words for naming: one block of words displayed in lower case and one block of words displayed in mIxEd cAsE. Four orders of 80 words were created. Each order consisted of two blocks: Half of the words in each block (40 words) were high-frequency and half were low-frequency. Also, half of the items were regular words and half were exception words. Each subject saw one order.

Procedure. The procedure was identical to that of Experiment 2. Subjects were instructed to pronounce each word from the lower-case block and the mixed-case block as quickly and as accurately as possible. Half of the subjects pronounced words from the mixed-case block first and the other half pronounced words from the lower-case block first. Subjects completed 10 practice trials before the mixed-case block and 10 practice trials before the lower-case block plus 80 experimental trials for a total of 100 pronunciation trials. The experimental session lasted approximately 20 minutes.

Results and Discussion

Response times. The results are shown in Figure 4. Only latencies from words pronounced correctly are included in the analysis.

Insert Figure 4 about here

Latencies were examined with a 2 (Word type) X 2 (Case type) X 2 (Frequency) repeated measures ANOVA. As reported in Experiment 1 and 2, high-frequency words (582 ms) were pronounced faster than low-frequency words (631 ms), $F(1, 39) = 140.33$, $MSe = 1362.48$, $p < .001$, and regular words (592 ms) were pronounced faster than exception words (621 ms), $F(1, 39) = 40.01$, $MSe = 1617.46$, $p < .001$. Case type was also significant, $F(1, 39) = 42.44$, $MSe = 4573.68$, $p < .001$, such that words printed in lower case (582 ms) were responded to faster than words printed in alternating case (631 ms). The mean latencies and percent errors can be found in Table 2.

Insert Table 3 about here

An analysis of only the regular words replicated the pattern of results from Experiment 1 and those of Besner (Besner et al., 1984; Besner and McCann, 1987) in showing a significant Frequency by Case interaction, $F(1, 39) = 10.12$, $MSe = 1488.70$, $p < .01$. There was a small difference between naming high-frequency words in lower (559 ms) versus mixed case

(580 ms). There was a larger effect between naming low-frequency words in lower (585 ms) versus mixed case (645 ms).

The purpose of Experiment 3 was to provide a replication of the findings of Experiment 1 under the blocked conditions of Experiment 2. The results from Experiment 1 supported the existence of a facilitatory WSVP route: Case alternation slowed processing along the lexical route for high-frequency exception words by disabling the WSVP route. As in Experiment 1, it was expected that for high-frequency words, pronunciation latencies would be slower for exception words than for regular words because the slowing of the lexical route and the elimination of WSVP facilitation would result in the incompatible lexical and assembled codes overlapping in the output buffer on exception word trials. Low-frequency regular and exception words were not expected to show differential effects. As in Experiment 1, the hypothesis was supported as the Case type X Word Type X Frequency interaction was significant, $F(1, 39) = 7.18$, $MSe = 1790.97$, $p < .05$. Separate Case type X Word type analyses of the high-frequency words showed that there was no difference in naming exception and regular words in lower case; however, in alternating case, exception words were named slower than regular words, $F(1, 39) = 12.70$, $MSe = 1488.78$, $p = .001$. A similar Case type by Word type analysis of the low-frequency words was not significant, $F < 1$. Case alternation had an additive effect on low-frequency exception and regular words.

Error data. Trials on which equipment failed accounted for 0.2% of the trials in Experiment 3 and were excluded from the analysis. Errors were examined with a 2 (Word type) X 2 (Case type) X 2 (Frequency) repeated measures ANOVA. This analysis showed that more errors were made on case alternated (6.6%) than on lower case (4.6%) trials, $F(1, 39) = 6.38$, $MSe = 0.50$, $p < .05$. In addition, more errors were made on low-frequency (9.8%) than on high-frequency trials (1.3%), $F(1, 39) = 80.65$, $MSe = 0.72$, $p < .001$. Word regularity was also significant, $F(1, 39) = 46.91$, $MSe = 0.81$, $p < .001$, such that fewer errors were made naming regular words (2.1%) as compared to exception words (9.0%).

Consistent with the previous experiments, there was a Frequency X Word type interaction, $F(1, 39) = 34.85$, $MSe = 0.52$, $p < .001$. For high-frequency words, there was a small difference in errors made on exception (2.4%) and regular words (0.3%). However, for low-frequency words, more errors were made naming exception words (15.6%) than naming regular words (4.0%).

Summary

The results from Experiment 3 replicated the findings from Experiment 1 under blocked conditions. The results are consistent with the notion of a facilitatory WSVP route within a dual-route framework: Case alternation slowed processing along the lexical route for high-frequency exception words

by disabling the WSVP route. The results of Experiment 3 also showed the strength of the first experiment's results. The blocked design did not reduce the magnitude of the alternating case effect; repeated presentation of mixed-case words in the blocked design could have enabled subjects to develop a strategy. The results showed that subjects in Experiment 3 pronounced words faster overall but showed the same pattern of results as in Experiment 1.

General Discussion

The purpose of the present research was to examine the role of word-specific visual patterns (WSVPs) in visual word recognition. The three experiments reported here provide evidence for a facilitatory WSVP route within a dual-route framework. A WSVP route facilitates word recognition by circumventing letter analysis along the lexical route for high-frequency words. Thus, word representations in the lexicon are directly accessed based on the activation of features. In this view, readers extract information from the complete set of word features to enable processing at the word level.

The existence of WSVP facilitation was demonstrated in Experiment 1 by using case alternation as a manipulation to destroy usable WSVP information. Case alternation eliminates the overall feature-based pattern of a word. Of primary importance was the finding that case alternation slowed naming of high-frequency exception words more than the naming of high-frequency regular words. The slowing of the lexical route and the elimination of WSVP facilitation resulted in the incompatible lexical and assembled codes overlapping in the output buffer during naming of high-frequency exception words. Low-frequency regular and exception words did not show differential effects.

The goal of the second experiment was to establish the effects of case alternation on word processing. Case alternation could affect encoding

processes or processes involved in lexical access. Therefore, in Experiment 2, stimulus quality was varied as it has been shown to affect encoding: Results from stimulus quality studies show an overall slowing of performance but no interaction with factors that affect post-encoding processes (e.g., word frequency) (Paap et al., 1987; Stanners, et al., 1975). A comparison of the results from Experiments 1 and 2 suggested that degrading stimulus quality slowed encoding and, importantly, that case alternation affects post-encoding processes.

A direct comparison of the results from the first and second experiments was difficult given that the experiments' designs were not equivalent; the presentation of words in Experiment 1 was randomized and the presentation in Experiment 2 was blocked. Thus, Experiment 3 used a blocking procedure in order to provide a direct comparison of case alternation and stimulus quality effects. The results supported the pattern of results from Experiment 1 in that naming of high-frequency exception words was slower than high-frequency regular words.

Although the results of the present research support a WSVP interpretation, two other possible effects of case alternation could be predicted within a dual-route framework. First, a case manipulation could affect both routes equally. This would result in a general slowing of both the lexical and assembly routes with neither route being differentially affected. This is not a

viable alternative as was shown in the first two experiments. Case alternation had a differential effect on the two routes when compared to degradation (Experiment 2).

A second possible effect could be that case alternation could slow processing along the assembly route. This would result in the elimination of any competition from the assembled code in instances where the lexical and assembled codes conflict (i.e., low-frequency exception words). Paap and Noel (1991) investigated this possibility by slowing processing along the assembled route with a rehearsal task that made formation of a phonological code difficult. With the rehearsal task, they found faster naming latencies for low-frequency exception words but slower latencies for low-frequency regular words. However, in the present research, naming case-alternated low-frequency exception and regular words did not result in differential effects. Thus, it can be concluded that the dominant effect of case alternation is to disable WSVP facilitation and slow processing along the lexical route.

The results from the reported studies bolster the accruing evidence in support of a role for supraletter features in recognizing words. Most research has concentrated on investigating the processes involved in recognizing single words. However, proofreading of text for misspellings is one experimental task that has been used to gather evidence for the importance of WSVPs in continuous reading of text (Healy & Cunningham, 1992; Healy & Drewnowski,

1983; Healy, Oliver, & McNamara, 1987; Monk & Hulme, 1983; Walker, 1987). In proofreading tasks, subjects are asked to read a passage for comprehension and as a secondary task, circle any words that are misspelled. Thus, subjects approximate normal, continuous reading in completing the task. Misspellings can be created by deleting either ascending, descending, or neutral letters of target words (e.g., market, sample, vanish). The deletion of a neutral letter (e.g., vanish to vanih) results in a similar word shape, however, the deletion of an ascender or descender results in a larger alteration of the shape of the word (e.g., market to maret). Healy and Cunningham (1992) suggest that if word shape influences word recognition, deletions that change word shape should be more noticeable than deletions that preserve word shape.³

Healy and Cunningham (1992) had subjects proofread passages typed either in lower case or in upper case. Lower case print contains word-shape information in the pattern of ascender, neutral, and descender letters, whereas upper case print eliminates word-shape information because the letters are the same height. Target words were misspelled by deleting either an s, c, k, or p. The errors (not detecting a misspelling) showed that subjects were sensitive to word-shape changes: Words with s or c deletions were missed more than k or p deletions in the lowercase passage but not in the uppercase passage. Thus, subjects were more likely to notice misspellings when the misspellings changed word-shape in lower case. Processing of these words at the word-level was

impeded as reflected in the decrease in proofreading errors. Healy and Cunningham (1992) concluded that their findings were inconsistent with the notion that word recognition is achieved solely on the basis of processing features and letters.

Monk and Hulme (1983) provided similar evidence supporting the role of WSVPs. In addition to a letter-deletion condition, Monk and Hulme also included a condition in which target letters were substituted. They sought to demonstrate that changes in word shape affect processing at the word level and that word shape is a supraletter feature. Monk and Hulme (1983) found that the number of proofreading errors was substantially larger, especially in short words, when the shape of the word was not changed by the letter substitution. However, in the letter-substitution condition, errors could be explained as a letter-level effect (e.g., changing *t* to *c* is more noticeable than changing *s* to *c*). In the deletion condition, however, the target letter is deleted and can not influence the letter identification process. Accordingly, letter deletions were less likely to be noticed by subjects than letter substitutions. Monk and Hulme (1983) concluded that changes to word shape affect a word level of processing.

The research by Healy and colleagues (Healy & Drewnowski, 1983; Healy, et al., 1987) and Monk and Hulme (1983) supports (a) the existence of reading units larger than the individual letter and (b) the importance of supraletter features in word recognition. Their research has concentrated on

examining the influence of word shape information on reading rather than on WSVPs per se. However, Healy's (Drewnowski & Healy, 1977; Healy & Cunningham, 1992; Healy & Drewnowski, 1983; Healy et al., 1987)

interpretation of the word shape findings corresponds to a WSVP hypothesis.

The Unitization hypothesis (Healy & Drewnowski, 1983), assumes that when given a text, the reader's primary goal is to determine its meaning.

Comprehension is achieved by identifying progressively larger, and thus, more meaningful units of text. In order to achieve this goal, the reader terminates processing of constituent lower-level units (letters) once higher units have been identified. Thus, when reading a familiar word such as the, processing may be completed at the word-unit level without completing processing at the letter level. Disruptions to word shape reduce the information contributing to the word level such that letter processing can be completed.

Consistent with the WSVP hypothesis and the Unitization hypothesis, Graf and Ryan (1990) have suggested that skilled reading involves only minimal analysis of low-level units. As a result of repeated exposures to words, reader's accumulate a set of highly efficient word processing procedures that eliminates the need for extensive low-level analysis. A lack of skill, either with an individual word (low-frequency) or in general ability, forces the readers into an extensive target analysis of the target word.

Mitterer (1982) has provided a similar interpretation of skilled reading. He suggests that the skilled reader is a flexible information processor that relies on two different skills for accessing word meaning: a recoding skill, and a whole-word skill. The recoding skill involves a greater reliance on (a) a sound-based code and (b) on sub-morphemic units, particularly letters, than does the whole-word skill. Recoding generally involves a letter-by-letter, left-to-right analysis. He suggests that depending on the task at hand, the skilled reader uses both skills interchangeably. These skills are roughly comparable to codes produced along the lexical route and the WSVP route from the dual-route framework.

One variable that had been of interest for the present research was whether the activation of codes would differ depending on subjects' level of skill. Individual differences are important to consider because of the possibility that different readers use different processing strategies. The subjects from the first experiment were divided into fast and slow groups (based on their naming latencies to regular words) after completion of the naming task. When skill was included as a factor, the analysis from Experiment 1 showed that skill did not interact with any factor in the analysis. Thus, case alternation had the same effects on word naming regardless of whether subjects were fast or slow readers. These results were surprising as lower-skill subjects had not been expected to be as sensitive to WSVPs. However, the university students used

as subjects in the present research are not representative of readers in general: With an average of almost two decades of practice at reading, the typical university student has developed a repertoire of well-practiced word identification procedures. Thus, an examination of a broader sample of readers could yield different results.

Conclusion

The present research supports the notion that WSVPs play a role in accessing lexical representations. WSVPs have been described as facilitating processing for highly familiar words such that they are processed at the word level. In this view, letter-by-letter processing is executed only for less familiar words. Thus, depending on the demands of the task, readers can demonstrate flexibility in how they read a passage. The absence of individual differences in the present research suggest that the basic way in which information is initially encoded and processed is similar for skilled readers. As a basic processing strategy, WSVPs are a unitizing step in accomplishing the reader's primary goal: Comprehension of the text.

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Appendix

Word Stimuli Used in Experiments 1-3 with Word Frequencies

Reg/High Freq		Exc/High Freq		Reg/Low Freq		Exc/Low Freq	
we	2653	do	1363	gum	14	mow	1
can	1770	are	4394	gap	17	sew	6
did	1044	put	438	wig	1	wad	1
best	351	both	731	beam	21	aunt	22
club	145	come	630	clam	3	bowl	231
dark	185	does	485	deed	8	bush	14
hope	178	done	320	dusk	9	deaf	12
made	1122	give	389	frog	1	pear	6
more	2216	move	171	peel	3	pint	13
must	1013	said	1961	pump	11	soot	1
neck	81	says	200	sank	18	wand	1
page	66	want	328	slam	3	warp	4
soon	199	warm	67	snag	3	wool	10
stop	120	were	3286	rang	21	worm	4
week	275	work	762	wink	7	caste	3
block	66	break	88	carve	3	flood	19
group	390	great	665	float	3	plaid	1
place	571	gross	66	flung	14	spook	1
which	3560	shall	268	grape	3	swamp	5
while	680	watch	81	plank	7	sweat	23

Reg = regular word Exc = exception word Freq = frequency

Footnotes

¹ Whereas the rule system has been generally referred to as a spelling-sound translation, it is more precisely referred to as a system of translation rules which converts a letter or letter group that corresponds to a single phoneme (e.g., c, th, igh, eigh). Paap and Noel (1991) and Coltheart, Curtis and Atkins (1992) have adopted the term grapheme-to-phoneme conversion (or GPC) for the sake of accuracy.

² This is a valid concern. Kinoshita (1987) attempted to replicate Besner's (1983) and Besner and McCann's (1987) account of the effects of case alternation in lexical decision tasks. Kinoshita's results did not support Besner's previous results. One explanation for the discrepancy was the stimulus materials used by Besner: Kinoshita's stimuli consisted of equal numbers of high- (32) and low-frequency words (32) whereas Besner's (1983) stimuli were mostly high-frequency words (25 of 32) words.

³ Word shape is used as a general term by Healy and her colleagues to refer to the wholistic pattern of a word. As such, the use of the term "word shape" can be seen as equivalent to WSVPs.

Table 1

Mean pronunciation latencies (ms) and percent errors (in brackets) for regular and exception words in Experiment 1

	Case presentation				
	Lower case		Mixed Case		
	RT	%E	RT	%E	
Regular words					
High frequency	599	(0.3)	626	(1.0)	
Low frequency	637	(2.5)	694	(2.5)	
Exception words					
High frequency	594	(2.5)	665	(6.3)	
Low frequency	673	(16.0)	726	(16.0)	

Table 2

Mean pronunciation latencies (ms) and percent errors (in brackets) for regular and exception words in Experiment 2

		Stimulus Quality			
		Normal		Degraded	
		RT	%E	RT	%E
Regular words					
High frequency	558	(0.0)	681	(0.5)	
Low frequency	567	(1.0)	699	(2.8)	
Exception words					
High frequency	594	(1.0)	735	(1.0)	
Low frequency	646	(14.0)	772	(13.0)	

Table 3

Mean pronunciation latencies (ms) and percent errors (in brackets) for regular and exception words in Experiment 3

		Case presentation			
		Lower case		Mixed Case	
		RT	%E	RT	%E
Regular words					
High frequency	559	(0.0)	580	(0.5)	
Low frequency	562	(1.3)	627	(3.5)	
Exception words					
High frequency	585	(2.3)	645	(5.8)	
Low frequency	621	(14.8)	673	(16.5)

Figure 1: A dual-route model of word recognition

Exp 1: Pronunciation latencies of regular and exception words in lower and mixed case

Exp 2: Pronunciation latencies of regular and exception words - Normal and Degraded

Exp 3: Pronunciation latencies of regular and exception words - Blocked presentation

END

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FIN