Orthography and Phonology: The Psychological Reality of Orthographic Depth*

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The representation of meaning by words is the basis of the human linguistic ability. Spoken words have an underlying phonologic structure that is formed by combining a small set of phonemes. The purpose of alphabetic orthographies is to represent and convey these phonologic structures in a graphic form. Just as languages differ one from the other, orthographic systems represent the various languages' phonologies in different ways. This diversity has been a source of interest for both linguists and psychologists. However, while linguistic inquiry aims to explain and describe the origins and characteristics of different orthographies, psychological investigation aims to examine the possible effects of these characteristics on human performance. Consequently, reading research is often concerned with the question of what is universal in the reading process across diverse languages, and what aspects of reading are unique to each language's orthographic system. My first objective in this chapter is to outline the properties of different alphabetic systems that might affect visual word processing. The second objective is to provide some empirical evidence to support the claim that reading processes are determined in part by the language's orthography.

Orthography, phonology and the mental lexicon

The purpose of orthographies is to designate specific lexical candidates. There is, however, some disagreement as to how exactly this purpose is achieved. The major discussions revolve around the role of phonology in the process of visual word recognition. Clearly, phonologic knowledge of words generally precedes orthographic knowledge; we are able to recognize many spoken words long before we are able to read them. Only later, in the process of learning to read, does the beginning reader master an orthographic system, based, in western languages, on alphabetic principles.

The recognition of a printed word is based on a match between a letter string and a lexical representation. This match allows the reader access to the mental lexicon. However, since lexical access can theoretically be mediated by two types of abstract codes: orthographic and phonologic, a question remains about the exact transform of the printed word that is used in the process of visual word recognition: Is it informationally orthographic or phonologic?

One account argues that access to the mental lexicon is mainly phonologic (e.g., Liberman, Liberman, Mattingly, & Shankweiler, 1980). According to this view, orthographic information is typically recoded into phonologic information at a very early stage of print processing. Thus, the lexical access code for printed word perception is similar to that for spoken word perception. The appeal of this model is its parsimony and efficiency of storage; the reader does not need to build a visually coded grapheme-based lexicon, one that matches each of the words to spelling patterns in the language. Instead, a relatively small amount of information—knowledge of grapheme to phoneme correspondences—can recode print into a form every reader already knows: the speech-related phonologic form.

The second approach argues for the existence of an orthographic lexicon in addition to the phonologic one. According to this alternative view, lexical access for print can be achieved through

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**FOOTNOTES**

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1We are well aware that the dictionary meaning of the word *contiguity* stipulates that the events in question be juxtaposed, or adjacent in time, but not overlapping or coterminal. This departs from usage of the term within psychology, where successive and simultaneous arrangements are both considered contiguous. In this paper we remain with this latter usage even though the former might be more justifiable to some scholars.
2Throughout this paper, quotation marks on test item labels indicate a deviation from the nomenclature described under General Method. Here, for example, an “old song” is so labelled because it is the real-word phonetic equivalent of an old song and is not exactly what was heard in the presentation.
3The stimuli were, of course, in no sense true songs. However, we retain the same terminology as used in the other experiments.
4Certainly not in Experiment 4 and 5, where the two constituents did not overlap in time. In Experiment 6, with simultaneous contiguity, masking-like effects could have existed between the melodies and texts. This perceptual interaction is not what we mean by physical interaction, which could not have occurred in any of these experiments.
either system. The extreme position of this approach holds that lexical access is typically based only on the visual (orthographic) information, and the word's phonology is retrieved after lexical access has occurred. Possible exceptions are novel or low-frequency words that may lack an entry in the visually based lexicon (Seidenberg, Waters, & Barnes, 1984; Seidenberg, 1985). The appeal of such models is that visual lexical access is direct and, presumably, faster without the need for a mediating phonologic recoding. However, a model based on visual lexical representations must assume the existence of a memory store of orthographically coded words that parallels, in orthographic coding, most of the information the reader already possesses as phonologic knowledge.

Clearly, the reader is well aware of both orthographic and phonologic structures of a printed word. Hence, the debate concerning orthographic and phonologic coding is merely a debate about priority: is phonology necessary for printed word recognition to occur, or is it just an epiphenomenon that results from it? In other words: is phonology derived pre-lexically from the printed letters and serves as the reader's code for lexical search, or, rather, is lexical search based on the word's orthographic structure while phonology is derived post-lexically?

This question is often approached by monitoring and comparing subjects' responses in the lexical decision and the naming tasks. In lexical decision the subject is required to decide whether a letter string is a valid word or not, while in naming he is required to read the letter string aloud. In both tasks reaction times and error rates are measures of subjects' performance. Note that lexical decisions can be based on the recognition of either the orthographic or the phonologic structure of the printed word. In contrast, naming requires explicitly the retrieval of the printed word's phonology. Phonology, however, can be generated either pre-lexically by converting the letters into phonemes, or post-lexically by accessing the mental lexicon through the word's complete orthographic structure, and retrieving from the lexicon the phonologic information.

Since, at least theoretically, these two alternative processes are available to the reader, one should compare their relative efficiency. It has been suggested that the ability to rapidly generate pre-lexical phonology depends primarily on the reader's fluency, task characteristics, and the printed stimuli's complexity (see McCusker, Hillinger, and Bias (1981), for a review). In our present context, only the factor of stimulus complexity is of a special interest. Complexity is generally related to the amount of effort needed for decoding a given word. One possible source of complexity that merits close examination is the lack of transparent correspondence between orthographic and phonologic subunits. Because the purpose of orthographic systems is the representation of phonology, whether the skilled reader uses this information or not, the relative directness and simplicity—the transparency—of this representation can be of major importance.

Orthographic depth—Evidence from the shallow Serbo-Croatian

Although the transparency between spelling and phonology varies within orthographies, it varies more widely between orthographies. The source of this variance can be often attributed to morphological factors. In some languages, (e.g., in English), morphological variations are captured by phonologic variations. The orthography, however, was designed to preserve primarily morphologic information. Consequently, in many cases, similar spellings denote the same morpheme but different phonologic forms: the same letter can represent different phonemes when it is in different contexts, and the same phoneme can be represented by different letters. The words "heal" and "health", for example, are similarly spelled because they are morphologically related. However, since in this case, a morphologic derivation resulted in a phonologic variation, the cluster "ea" represents both the sounds [i] and [a].

Within this context English is often compared to Serbo-Croatian. In Serbo-Croatian, (aside from minor changes in stress patterns), phonology almost never varies with morphologic derivations. Consequently, the orthography was designed to represents directly the surface phonology of the language: Each letter denotes only one phoneme, and each phoneme is represented by only one letter. Thus, alphabetic orthographies can be classified according to the transparency of their letter to phonology correspondence. This factor is usually referred to as "orthographic depth" (Klima, 1972; Liberman et al., 1980; Lukatela, Popadić, Ognjenović, & Turvey, 1980, Katz & Feldman, 1981). An orthography that represents its phonology in an unequivocal manner is considered shallow, while in a deep orthography the relation of orthography to phonology is more opaque.

Katz and Feldman (1981) suggested that the kind of code that is used for lexical access depends
on the kind of alphabetic orthography facing the reader. Shallow orthographies can easily support a reading process that uses the language's surface phonology. On the other hand, in deep orthographies, the reader is encouraged to process printed words by referring to their morphology via their visual-orthographic structure. Note that orthographic depth does not necessarily have to have a clear psychological reality. For example, it has been argued that visual-orthographic access is faster and more direct than phonologic access (e.g., Baron & Strawson, 1976). By this argument, it might be the case that in all orthographies words can be accessed easily by recognizing their orthographic structures visually. Therefore, the relation between spelling and phonology should not necessarily affect subjects' performance.

Most of the earlier studies in word recognition were conducted with English materials. But in order to validate the psychological reality of orthographic depth experimenters turned to shallower orthographies like Serbo-Croatian.

In addition to its direct spelling to phonology correspondence, the Serbo-Croatian orthography has an additional important feature: It uses either the Cyrillic or the Roman letters, and the reader is equally familiar with both sets of characters. Most characters are unique to one alphabet or the other, but there are some characters that occur in both. Of these, some receive the same phonemic interpretation regardless of alphabet. These are called COMMON letters. Others receive a different interpretation in each alphabet. These are known as AMBIGUOUS letters. Letters string that include unique letters can be read in only one alphabet. Similarly, letters string composed exclusively of common letters can be read in only one way. By contrast, strings composed only of AMBIGUOUS and COMMON letters are bivalent. They can be read in one way by treating the characters as Roman graphemes and in distinctly different way by treating them as Cyrillic graphemes. The two alphabets are presented in Figure 1. This specific feature of the Serbo-Croatian orthography was used in several studies in order to examine phonological processing in visual word recognition (Lukatela et al. 1980; Feldman & Turvey, 1983).

Lukatela et al. (1980) investigated lexical decision performance in Serbo-Croatian, for words printed in the Cyrillic and the Roman alphabets. They demonstrated that words that could be read in two different ways were accepted more slowly as words than words that could be read in one way. Thus, the fact that one orthographic form had two phonologic interpretations slowed subjects' reaction times. This outcome suggested that the subjects were sensitive to the phonologic structure of the printed stimuli, while making lexical decisions. Lukatela et al. concluded that lexical decisions in Serbo-Croatian are necessarily based on the extraction of phonology from print. Similar results were found by Feldman and Turvey (1983) that compared phonologically ambiguous and phonologically unequivocal forms of the same lexical items. They have suggested that the direct correspondence of spelling to phonology in Serbo-Croatian results in an obligatory phonologic analysis of the printed word that determines lexical access. Moreover, in contrast to data obtained in English, the skilled reader of Serbo-Croatian demonstrates a bias towards a phonologically analytic strategy.

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**Evidence from the deeper Hebrew orthography**

The term "orthographic depth" has been used with a variety of related but different meanings. Frost, Katz, and Bentin (1987), suggested that it can be regarded as a continuum on which languages can be arrayed. They proposed that the Hebrew orthography could be positioned at the extreme end of this continuum, since it represents the phonology in an ambiguous manner.

Hebrew, like other Semitic languages, is based on word families that are derived from triconsonant roots. Therefore, many words share an identical letter configuration. The orthography was designed primarily to convey to the reader the word's morphologic origin. Hence, the letters in Hebrew represent mainly consonants, while the vowels are conveyed by diacritical marks presented beneath the letters. The vowels marks,
however, are omitted from regular reading material, and can be found only in poetry, children literature or religious scripts (for a detailed description of the Hebrew orthography see Navon & Shimron, 1984). When the vowels are absent, a single printed consonantal string usually represents several different spoken words (sometimes up to seven or eight words can be represented by a single letter string). The Hebrew reader is, therefore, regularly exposed to both phonologic and semantic ambiguity. An illustration of the Hebrew ambiguous unvoweled print is presented in Figure 2.

Although it is clear that the Hebrew orthography is an example of a very deep orthography, this is for different reasons than those presented in the context of the English vs. Serbo-Croatian distinction. English is labeled as deep because of the opaque correspondence between single graphemes and phonemes in the language's spelling system. In contrast, this correspondence is fairly clear in Hebrew, since the consonants presented in print, aside from a few exceptions, correspond to only one phoneme. However, because the vowels are absent, the Hebrew orthography conveys less phonologic information than many other orthographies. Hence, it is not just ambiguous, it is incomplete. This characteristic of Hebrew, as I will argue, is not only linguistic but also psychological, in that it provides a possible explanation of differences in reading performance revealed in this language.

In order to assign a correct vowel configuration to the printed consonants to form a valid word, the reader of Hebrew has to draw upon his lexical knowledge. The choice among the possible lexical alternatives is usually based on contextual information: the semantic and syntactic contexts constrain the possible vowel interpretations. For an unvoweled word in isolation, however, the reader cannot rely on contextual information for the process of disambiguation.

Several studies have examined reading processes of isolated Hebrew words. Bentin, Bargai, and Katz (1984) examined naming and lexical decision for unvoweled consonantal strings. Some of these strings could be read as more than one word while some could be read as one word only. The results demonstrated that naming of phonologically ambiguous strings was slower than naming of unambiguous ones. In contrast, no effect of ambiguity was found in the lexical decision task. These results suggest that the reader is indeed sensitive to the phonologic structure of the orthographic string when naming is required. Contrarily, lexical decisions are not based on a detailed phonological analysis of the printed word in Hebrew. Note, that this outcome is in sharp contrast to the results obtained in the shallow Serbo-Croatian.

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<tr>
<th>Unvoweled form</th>
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<td>Voweled forms</td>
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<td>Phonemic transcriptions</td>
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<td>saper</td>
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Meanings: book, he said, tell, was, he, count, border, barber, told, counted, past.

Figure 2. Unvoweled and voweled forms of the Hebrew tri-consonantal root זפ (sfr).
Lexical decisions and naming of isolated Hebrew words were further investigated in a study by Bentin and Frost (1987). In this study subjects were presented with phonemically and semantically ambiguous consonantal strings. Each of the ambiguous strings could have been read either as a high-frequency word or as a low-frequency word, pending upon different vowel assignments. Decision latency for the unvoweled consonantal string was compared to the latencies for both the high and the low-frequency voweled words. The results showed that lexical decisions for the unvoweled ambiguous strings were faster than lexical decisions for either of their voweled (therefore disambiguated) alternatives. This outcome was interpreted as evidence that lexical decisions for Hebrew unvoweled words were given prior to the process of phonological disambiguation. The decisions were probably based on the printed word's orthographic familiarity (cf. Balota & Chumbley, 1984; Chumbley & Balota, 1984). Thus, it is likely that lexical decisions in Hebrew involve neither a pre-lexical phonologic code, nor a post-lexical one. They are based upon the abstract linguistic representation that is common to several phonemic and semantic alternatives.

These results are in contrast to studies on lexical ambiguity conducted in English. Lexical disambiguation in English can be examined by employing homographs. Such studies have suggested that, at least initially, all meanings high- as well as low-frequency are automatically accessed in parallel. (Onifer & Swinney, 1981; Tanenhaus, Leiman & Seidenberg, 1979; and see Simpson, 1984, for a review). It should be noted, however, that in most cases the ambiguity in English resides only in the semantic and syntactic levels. With a few exceptions (e.g., "bow", "wind"), English homographs have only one phonologic representation, and the reader, usually, does not have to access two different words related to one printed form.

Although lexical decision in Hebrew might be based on an abstract orthographic representation, there is no doubt that the process of word identification continues until one of several phonological and semantic alternatives are finally accessed. This process of lexical disambiguation is more clearly revealed by using the naming task. Bentin and Frost (1987) investigated the process of selecting specific lexical candidates by examining the naming latencies of unvoweled and voweled words. In contrast to the result obtained for lexical decisions, naming of ambiguous strings was found to be just as fast as naming the most frequent voweled alternative, with the voweled low-frequency alternative slowest. In the absence of constraining context, the selection of one lexical candidate for naming seems to be affected by a frequency factor: the high-frequency alternative is selected first.

In a recent study (Frost & Bentin, in preparation), the processing of ambiguous consonantal strings in voweled and unvoweled Hebrew print was investigated by using a semantic priming paradigm. Subjects were presented with consonantal strings that could be read as a high- or a low-frequency word. These strings served as primes to targets that were related to one of the two alternative meanings. In order to minimize conscious attentional processes, targets followed the primes at a short SOA (stimulus onset asynchrony) of 100 ms (see Neely, 1976; 1977, for a discussion of this point). It was assumed that if a specific meaning of the ambiguous consonantal string was accessed, it would be reflected by a semantic facilitation for its respective target. Thus, lexical decisions for targets that are related to that specific meaning would be facilitated.

In contrast to studies on priming at short SOA's in English (e.g., Seidenberg, Tanenhaus, Leiman, and Bienkowski, 1982), no semantic facilitation for the low-frequency meanings was found in the unvoweled condition at 100 ms SOA. In the voweled condition there was a significant semantic facilitation for both the high- and the low-frequency meanings. This result suggests that in the voweled condition both the high-frequency and the low-frequency meanings of the consonantal strings were clearly depicted by the disambiguating vowel marks.

Apparently, since the Hebrew reader almost never reads voweled print, he uses the consonantal information for accessing the lexicon. The phonologic representation of the high-frequency is selected first. Only at a second stage does the reader consider the low-frequency alternative.

In conclusion, the deep unvoweled Hebrew orthography represents primarily the morphology of the Hebrew language, while phonemic information is conveyed only partially by print. Consequently, in addition to a phonologic lexicon the Hebrew reader has probably developed a lexical system which is based on phonologically and semantically abstract consonantal strings that are common to several words. Lexical processing occurs, at a first phase, at this
morphological level. The reader accesses the abstract string and recognizes it as a valid morphologic structure. Lexical decisions are usually given at this early stage and do not necessarily involve deeper phonological processing. The complete phonological structure of the printed word can only be retrieved post-lexically, after one word candidate has been accessed. The selection of a word candidate is usually constrained by context, but in its absence it is based on frequency factors.

**Evidence from cross-language studies**

Conducting experiments in different languages contributes important insights concerning the role of pre- or post-lexical phonology in deep and shallow orthographies. Nevertheless, conclusive inferences cannot be drawn from these studies unless they are supported by results obtained in cross-language designs. Cross-language designs allow a direct comparison of native speakers' performances when the independent variables under investigation are controlled between languages, under identical experimental conditions. Hence, they can provide direct evidence concerning the effects of the orthography's characteristics on the process of word recognition. Obviously, cross-language designs are not without potential pitfalls; language differences may be confounded with nonlinguistic factors. For example, differences in the subjects' samples due to motivation, education, etc., might interact with the experimental manipulation. The interpretation of the results, thus, hinges on whether they are likely to be free of such confounding.

Katz and Feldman (1983) compared semantic priming effects in naming and lexical decision in English and Serbo-Croatian. In this study, semantic facilitation was assumed to reflect lexical involvement in both tasks. The results demonstrated semantic facilitation for both lexical decision and naming in English. In contrast, semantic priming facilitated only lexical-decision in Serbo-Croatian. The authors suggested that phonology, which is necessary for naming, is derived post-lexically in English: hence the semantic facilitation in this task. In contrast, the extraction of phonology from print in Serbo-Croatian does not call for lexical involvement but is derived pre-lexically. An additional finding in the study was a high correlation of reaction times for lexical-decision and naming in Serbo-Croatian without semantic context. This result was interpreted as evidence for an articulatory code used in this language for both lexical decisions and naming.

The interpretation of differences in reading performance between two languages, as reflecting subjects' use of pre- vs. post-lexical phonology, can be criticized on methodological grounds. The correspondence between orthography and phonology is only one dimension on which two languages differ. English and Serbo-Croatian, for example differ in their grammatical structures, and in the size and organization of their lexicon (Lukatela, Gligorjevic, Kostic & Turvey, 1980). These confounding factors, it can be argued, have affected subjects' performance in a similar way.

Frost, Katz, and Bentin (1987) endeavored to address this possible criticism by comparing three languages simultaneously. They examined lexical decision and naming performance in Hebrew, English, and Serbo-Croatian. Although any comparison between two of the languages might be confounded by other factors, the set of confounds is different for each of the three possible pairs of comparisons. The only factor that displays consistency with the dependent measure is orthographic depth. Assuming that it is indeed the main factor that influences subjects' performance, predictions concerning a two languages comparison should be extended to the third language. But, note that while the probability of obtaining a predicted correct ordering of performance in the two languages is one out of two, the probability is one out of six, when three languages are compared. Thus, an appropriate ordering of subjects' performance in three languages would corroborate more strongly the psychological reality of orthographic depth.

In their first experiment Frost et al. (1987) compared, in each language, reaction times for both lexical decision and naming of high-frequency words, low-frequency words, and nonwords, in English, Serbo-Croatian, and Hebrew. The results showed that the lexical status of the stimulus (being a high- or a low-frequency word, or a nonword), affected naming latencies in Hebrew more than in English, and in English more than in Serbo-Croatian. Moreover, only in Hebrew were the effects on naming very similar to the effects on lexical decision: Just as the lexical status of the stimulus affected lexical decisions, it also affected naming latencies. This outcome confirmed that in deep orthographies like Hebrew, phonology is derived post-lexically. In contrast, in a shallow orthography like Serbo-Croatian, naming performance is much less affected by lexical status. Given the direct
correspondence of orthography to phonology, the extraction of phonology from print does not call for lexical involvement.

In a second experiment, Frost et al. compared semantic priming effects in naming. Semantic priming usually facilitates lexical access. Hence, if the word's phonology is derived post-lexically in deep orthographies but pre-lexically in shallow orthographies, then naming should be facilitated more in Hebrew than in English, and again, more in English than in Serbo-Croatian. As hypothesized, the results revealed a relatively strong effect of semantic facilitation in Hebrew (21 ms), a smaller but significant effect in English (16 ms), and no facilitation in Serbo-Croatian whatsoever. These results were taken to strongly support the validity of the orthographic depth factor in word recognition.

In a recent study, Frost and Katz (1989) investigated how the different relations between spelling and phonology in English and Serbo-Croatian are reflected in the ability of subjects to match printed and spoken stimuli. They presented subjects simultaneously with words or nonwords in the visual and the auditory modality, and the subject's task was to judge whether the stimuli were the same or different. In order to carry out the matching process, the subjects had to mentally recode the print to phonology, and compare it to the phonologic information provided by the speech. Performance was measured in three experimental conditions: (1) Clear print and clear speech, (2) clear print and degraded speech, and (3) clear speech and degraded print. Within each language, the effects of visual and auditory degradation were measured relative to the baseline undegraded presentation.

When the visual or the auditory inputs are degraded, subjects are encouraged to restore the partial information in one modality by matching it to the clear information in the other modality. When subjects are presented with speech alone, restoration of degraded speech components has been shown to be an automatic lexical process (see Samuel, 1987). However, in addition to this ipsimodal restoration mechanism, subjects in the Frost and Katz experiment had the additional possibility of a compensatory exchange of speech and print information. Thus, the technique of visual and auditory simultaneous presentation and degradation provided insight concerning the interaction of orthography and phonology in the different languages.

The results showed that for Serbo-Croatian, visual degradation had a stable effect relative to the baseline condition (about 20 ms), regardless of stimulus frequency. For the English subjects, the effect of visual degradation was three to four times stronger than for the Serbo-Croatians. The inter-language differences that were found for visual degradation were almost identically replicated for auditory degradation: The degradation effects in English were again three to four times greater than in Serbo-Croatian. Thus, the overall pattern of results demonstrated that although the readers of English were efficient in matching print to speech under normal conditions, their efficiency deteriorated substantially under degraded conditions relative to readers of Serbo-Croatian.

These results were explained by an extension of an interactive model (see McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982), that rationalizes the relationship between the orthographic and phonologic systems in terms of lateral connections between the systems at all of their levels. The structure of these lateral connections is determined by the relationship between spelling and phonology in the language: simple isomorphic connections between graphemes and phonemes in Serbo-Croatian, but more complex, many-to-one, connections in English. The concept of orthographic depth has direct bearing on the question of the relation between the phonologic and orthographic systems. Within such interactive models, the way in which connections are made between the two systems should be constrained by the depth of the orthography that is being modeled. In a shallow orthography, a graphemic node can be connected to only one phonemic node, and vice versa. Also, because words are spelled uniquely, each word node in the orthographic system must be connected to only one word node in the phonologic system. In contrast, in a deeper orthography, a graphemic node may be connected to several phonemic alternatives, a phonemic cluster may be connected to several orthographic clusters, and finally, a word in the phonologic system may be connected to more than one word in the orthographic system, as in the case of homophony (e.g., SAIL/SALE) or, vice versa, as in the case of homography (e.g., WIND, READ, BOW, etc.). A representation of the different intersystem connections is demonstrated in Figure 3 for a word that exists in both the English and the Serbo-Croatian languages. The Serbo-Croatian word, KLOZET, is composed of unique letter-sound correspondences while the corresponding English word, CLOZET, is composed of graphemes, most of which have more than one possible phonologic representation, and phonemes,
most of which have more than one orthographic representation.

**SERBO-CROATIAN**

![Orthographic Network](image1)

**ENGLISH**

![Orthographic Network](image2)

The importance of orthographic depth: critique and conclusions

The psychological reality of orthographic depth is not unanimously accepted. Although it is generally agreed that the relation between spelling to phonology in different orthographies might affect reading processes to a certain extent, there is disagreement as to the relative importance of this factor. Seidenberg and his associates (Seidenberg et al. (1984); Seidenberg, 1985; Seidenberg & Vidanović, 1985) have argued that the primary factor determining whether or not phonology is generated pre-lexically is not orthographic depth, but word frequency. Their claim is that in any orthography, frequent words are very familiar as visual patterns. Therefore, these words can be easily recognized through a fast visually-based lexical access which occurs before a phonologic code has time to be generated pre-lexically from the print. For these words, phonologic information is eventually obtained, but only postlexically, from memory storage. According to this view, the relation of spelling to phonology should not affect recognition of frequent words. Since the orthographic structure is not converted into a phonologic structure by use of graphemes-to-phonemes conversion rules, the depth of the orthography does not play a role in the processing of these words. Orthographic depth exerts some influence, but only on the processing of low-frequency words and nonwords. Since such verbal stimuli are less familiar, their visual lexical access is slower, and their phonology has enough time to be generated prelexically.

In support of this hypothesis, Seidenberg (1985) demonstrated that there were few differences between Chinese and English subjects in naming frequent printed words. This outcome was interpreted to mean that in both logographic and alphabetic orthographies, the phonology of frequent words was derived postlexically, after the word had been recognized on a visual basis. Moreover, in another study, Seidenberg and Vidanović (1985) found similar semantic priming effects in naming frequent words in English and Serbo-Croatian, suggesting again that the phonology of frequent words is derived postlexically, whatever the depth of the orthography. These results are consistent with a recent study by Carello, Lukatela, and Turvey (1988), that demonstrated associative priming effects for naming in Serbo-Croatian. Although Carello et al. did not manipulate word-frequency in their study, their results question the inevitability of pre-lexical phonology in a shallow
orthography; some lexical influence on word recognition may be possible.

The resolution of these conflicting results is certainly not a simple task. A possible approach for examining the source of these differences could consist of examining the experimental characteristics of these studies. One salient feature of most of the experiments discussed above is that they were conducted exclusively in the visual modality; that is, print alone was used to study the relationship between orthography and phonology. The experimental manipulation of phonology, therefore, has been indirect, having been derived from manipulating the orthography. One can criticize this methodology for studying the processing consequences of the relation between phonology and orthography: Because phonologic variation is typically obtained through orthographic variation, one can never be certain which of the two is controlling the subject's responses. A simple example can be given in the case of homophones. The common assumption that two homophones (e.g., bear/bare; sale/sail), share a phonologic but not an orthographic structure (see e.g., Rubenstein et al., 1971) is, in a way, misleading. Homophones always share printed consonants or vowels, and the task of disentangling the effect of the shared phonology from the shared orthography is complicated. Moreover, doubts have been raised about the adequacy of the lexical decision and naming tasks for measuring lexical as contrasted with prelexical involvement (see Balota & Chumbley, 1984, 1985).

The technique of simultaneous visual and auditory presentation with degradation proposed by Frost and Katz (1989); (see also Frost, Repp, & Katz, 1988), furnishes partial solutions to these methodological problems. First, phonology is presented to the subjects through a spoken word and does not have to be inferred from print. More importantly, by degrading the print or the speech, the technique affords a way to independently manipulate the perception of orthography and phonology. By using this method, Frost and Katz (1989) have demonstrated that orthographic depth and not word frequency is the primary factor that affects the generation of pre- or post-lexical phonology.

However the assessment of the role of orthographic depth in reading cannot be resolved solely with methodological arguments. One important conclusion from two decades of studies in reading is that the reader uses various strategies in processing printed words. (see McCusker et al., 1981). These strategies have been shown to depend on factors like orthographic regularity (Parkin, 1982), word frequency (Scarborough, Cortese, & Scarborough, 1977), ratio of words and nonwords (Frost et al., 1987), or special demand characteristics of the experimental task (e.g., Spohr, 1978). By the same argument, one cannot fully account for the reader's processing without taking into consideration the reader's linguistic environment. Although the skilled reader in every orthography becomes familiar with his own language's orthographic structures, I suggest that the depth of the orthography is an important factor.

One common misinterpretation of claims concerning the importance of orthographic depth is to view a language's orthographic system as constraining the reader to only one form of processing. For example, although Frost et al. (1987) have shown no semantic facilitation for naming a specific set of stimuli in Serbo-Croatian, it does not follow that Serbo-Croatian readers never generate phonology post-lexically. One should always give the reader credit for extensive flexibility. If the words in the experiments were closely associated, even the Serbo-Croatian reader might find the extraction of phonology post-lexically more efficient then a pre-lexical extraction. But under similar conditions, relative differences should be found between deep and shallow orthographies.

In conclusion, the argument concerning the effect of orthographic depth is an argument concerning the priority of using a specific processing strategy for generating phonology in different orthographies. Research conducted in English Serbo-Croatian and Hebrew suggests that orthographic depth has indeed a strong psychological reality.

REFERENCES


Orthography and Phonology: The Psychological Reality of Orthographic Depth


**FOOTNOTES**


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