Abstract. The psychological reality of the concept of orthographic depth and its influence on visual word recognition were investigated by examining naming performance in Hebrew, English, and Serbo-Croatian. Three experiments were conducted using native speakers and identical experimental methods in each language. Experiment 1 revealed that the lexical status of the stimulus (high-frequency words, low-frequency words, and nonwords) significantly affected naming in Hebrew (the deepest of the three orthographies). This effect was only moderate in English, and nonsignificant in Serbo-Croatian (the shallowest of the three orthographies). Moreover, lexical status had similar effects on naming and lexical decision performance only in Hebrew. Experiment 2 revealed that semantic priming effects in naming were larger in Hebrew than in English and were completely missing in Serbo-Croatian. Experiment 3 revealed that a large proportion of nonlexical tokens (nonwords) in the stimulus list affects naming words in Hebrew and in English, but not in Serbo-Croatian. These results were interpreted as strong support for the orthographic depth hypothesis, and suggest that, in general, phonology in shallow orthographies is generated directly from print, whereas phonology in deep orthographies is derived from the internal lexicon.

Recognition of a word presented in the visual modality is ultimately based upon a match between a printed string of letters and a lexical representation. This match can be mediated by two types of codes: One that is based on some abstract representation of the orthography, and one that refers to phonemic information that is represented by the graphemic structure.
There is some agreement that both code types are automatically activated during the process of word recognition, and act in parallel (but asynchronously) to mediate lexical access (but see Humphreys & Evett, 1985, for a critical review). The relative use of the orthographic and phonemic codes is determined by factors such as the subject's reading ability, the complexity of the stimuli, and task demands. For example, orthographic codes gain priority when the subjects are fluent readers, when the stimuli are very familiar, or phonemically irregular, and when the task emphasizes the graphemic aspects of the printed words. In contrast, phonological codes are employed relatively more by inexperienced readers, when the stimuli are more complex, and when the phonemic aspects of the material are emphasized by the task (for a review, see McCusker, Hillinger, & Bias, 1981).

The data on which the above suggestions have been based were provided primarily by studies conducted in English. Research outside of the English language suggested that in addition to these three factors, a bias toward one or the other code type may be tied to the depth of the language's orthography (Lukatela, Popadić, Ognjenović, & Turvey, 1980). Alphabetic orthographies can be classified according to the complexity of their letter-to-sound correspondences. In a shallow orthography, the phonemic and the orthographic codes are isomorphic; the phonemes of the spoken word are represented by the graphemes in a direct and unequivocal manner. In contrast, in a deep orthography, the relation of spelling to sound is more opaque. The same letter may represent different phonemes in different contexts; moreover, different letters may represent the same phoneme. Comparison of the English and Serbo-Croatian orthographies exemplifies the above distinction. The Serbo-Croatian writing system directly represents the phonology of the word; each grapheme unequivocally represents a single phoneme and each phoneme is represented by only one grapheme. Therefore, it is considered shallower than the English spelling system, which simultaneously represents both the phonology and morphology and mixes these representations inconsistently from word to word (Gleitman & Rozin, 1977). Consequently, generation of phonemic codes from print should be easier in Serbo-Croatian than in English. Several studies revealed that, indeed, lexical access in English is mediated by both orthographic and phonemic codes, while native readers of Serbo-Croatian are biased towards using phonemic codes in word recognition (Lukatela et al., 1980; Feldman, 1980).

The influence of orthographic depth on word recognition has been suggested in several studies that compared lexical decision and naming performance. It has been argued that in a shallow orthography, the extensive use of grapheme-to-phoneme translation for word recognition might efficiently provide the articulatory codes used for pronunciation and, therefore, would minimize involvement of the lexicon in naming printed words. On the other hand, if the grapheme-to-phoneme translation is complex, the translation may be excessively costly in terms of time, and naming may be mediated by a lexical representation of the word. In this case, lexical access would have been achieved by means of an orthographic code, which then affords the word's stored pronunciation. Consequently, lexical processes in naming printed words should be more conspicuous in English than in Serbo-Croatian. Recently, Katz and Feldman (1983) compared pronunciation and lexical decision in English and Serbo-Croatian. In both languages naming was faster than lexical decision, but the difference was smaller in English. Furthermore, semantic priming facilitated lexical decision but not pronunciation performance in Serbo-Croatian, whereas in English, semantic priming was effective in both
tasks. These results are in perfect accordance with the English language's putatively greater dependence on the lexicon for pronunciation.

The influence of orthographic depth on word recognition processes was apparently confirmed by the comparisons between English vs. Serbo-Croatian, but this conclusion is not without criticism. Orthographic depth is not the only dimension along which these two languages differ. English and Serbo-Croatian have different grammatical structures and possibly different lexical organizations (Lukatela, Gligorijević, Kostić, & Turvey, 1980). Since it is not known how those other factors may affect word recognition in English and Serbo-Croatian, attribution of differences in performance only to orthographic depth might be incorrect. Moreover, the effect of orthographic depth on printed word processing is not unanimously accepted. Recently, the claim has been made that the manner in which an orthography encodes phonology has little effect on skilled word recognition (Seidenberg & Vidanović, 1985).

One way to test the validity and psychological reality of the concept of orthographic depth is to find a third language that, although different from either of the other two in many aspects, would represent a third point along the continuum of orthographic depth. Assuming that orthographic depth is indeed the relevant factor and that there is no other relevant dimension on which the three languages may be aligned along a continuum, the effects found in a two-language comparison should be found to extend in a systematic manner to the three-language comparison. An appropriate ordering of the three languages on a given measure would corroborate the psychological reality of the orthographic depth factor more strongly because the predicted ordering would be one out of six possibilities of order (for the three languages), instead of only one out of two possibilities (for the two languages).

The Hebrew language provides a natural third point on the continuum of orthographic depth. In Hebrew, consonantal information is represented by letters, and vowels are mainly conveyed by small diacritical marks added to the consonants. These vowel marks, however, are omitted from regular reading material such as literature (except poetry), newspapers, advertisements, street signs, etc. Although the full writing system (consonants and vowel marks) is taught in the first two grades of elementary school, the adult reader is exposed almost exclusively to unvowelized print. Therefore, the Hebrew orthography is an extreme example of ambiguity. Because several words may share an identical consonant structure, many consonant strings can be pronounced in several ways, each producing a different legal Hebrew word. This is in complete contrast to Serbo-Croatian and is essentially different from English as well. (English has only a few heterophonic homographs: bow, wind, read, etc. An English reader can get some feeling for the adult Hebrew orthography by imagining an English orthography in which the vowels are omitted: The string "bttr" would stand for "batter," "better," "bitter," and "butter" and, of course, a large number of nonwords, e.g., "bottir," etc.). Clearly, in Hebrew orthography, the full phonemic code of the word is less transparent than it is in either English or Serbo-Croatian, Hebrew representing the third, deepest, point along the continuum of orthographic depth.2

Previous studies have already suggested that, in Hebrew, orthographic codes play a more important role in the process of word recognition than do phonemic codes, especially in comparison with the roles played in other languages. For example, it was found that rejection of nonwords in a lexical decision task is slower if they are orthographically similar than if they are
phonemically similar to real words (Bentin, Bargai, & Katz, 1984). Moreover, addition of the missing phonemic information (vowel marks) did not facilitate or even delay lexical decision (Bentin & Frost, in press; Koriat, 1984).

None of the studies mentioned, however, made a controlled comparison between languages, and therefore the relative importance of phonemic and orthographic codes in different languages was not directly examined. The present study sought to fill this gap. We hoped to improve the validity of the interlanguage comparison (1) by using identical methodology and apparatus for all three languages and (2) by studying all three in their native environments to insure that the language a subject was tested on was, in fact, the actual language environment of the subject. Thus, we hoped to provide clearer evidence for or against the notion that the directness with which an orthography represents its language's phonology determines the relative use of orthographic vs. phonological codes in printed word perception.

General Methods

Because this study was conducted in three different countries, special care was taken to standardize procedures, materials, and apparatus. The same experimenter ran identical experiments in Israel, Yugoslavia, and the United States.

Stimulus selection and word-frequency evaluation. All stimuli in each language were two-syllable nouns that had a stop consonant as their first letter. Native speakers constructed the word data base in each language, but, wherever possible, literal translations were used. Homographs and homophones were not used. In Hebrew all stimuli were undotted (i.e., without vowel marks), but could be pronounced as only one real word. Because there are no reliable sources of standard objective word frequency in Hebrew and in Serbo-Croatian, we devised a procedure for estimating subjective frequencies. Recently, subjective and standard objective word frequencies were found to be highly correlated (Gordon, 1985). The same procedure of frequency estimation was used in all three languages: Two hundred words that conformed to the above criteria were printed on two pages (in Hebrew, without the vowel marks). Fifty undergraduates were asked to rate each word on a five-point scale ranging from least frequent (1) to most frequent (5). Estimated frequency for each word was calculated by averaging the ratings across all fifty judges. Based on these ratings, groups of high- and of low-frequency words were selected.

Experiment 1

This experiment was designed to assess the effect of lexical factors on naming of words and of nonwords across Serbo-Croatian, English, and Hebrew and to relate naming to lexical decision performance in the three languages. This technique was employed in order to assess the hypothesis that the deeper the orthography, the more the reader will depend on lexical information for naming.

Previous studies in English suggested that naming and lexical decision performance are significantly correlated; this correlation was interpreted as evidence that naming in English is usually lexically mediated (Forster & Chambers, 1973; see also Forster, 1979; Theios & Muise, 1977; and West & Stanovitch, 1982). More recently, Katz and Feldman (1983) used the same
Frost et al.: Word Recognition and Orthographic Depth

technique to assess the extent of lexical mediation for naming in Serbo-Croatian and to compare it to English. In that study, they also used semantic priming as a manipulation that was assumed to affect only lexically mediated processes. Semantic priming effects were found for lexical decision in both languages, but for naming, only in English. Moreover, in English, but not in Serbo-Croatian, they found significant lexical decision-naming correlations, regardless of the semantic relationship between target words and previously presented primes. Based on these results, the authors concluded that naming is less mediated by lexical information in the orthographically shallow Serbo-Croatian; naming in that language was apparently dependent on prelexical phonological coding. However, attributing the differences between the two languages specifically to orthographic depth is problematic because they differ in other ways as well (as discussed above).

Assessment and interpretation of the effects that orthographic depth might have on word recognition is further complicated by the results of two recent studies: Hudson and Bergman (1985) revealed that if only words are to be named (in a blocked condition), lexical involvement (as reflected by word frequency effects) may be found even in Dutch, which has a shallow orthography. In addition, phonological manipulations had a similar effect on naming words in the deep Chinese logography and in the English alphabetic orthography. In both languages only very infrequent words were affected (Seidenberg, 1985).

The present study addresses these controversies; we attempted to assess the validity of the orthographic depth hypothesis (1) by using a three-language comparison and (2) by using the lexical decision results for each language only as a reference point against which its naming results could be interpreted. Thus, Experiment 1 investigates how factors that are generally agreed to involve lexical processing affect naming in each language; we consider the effects of the same factors on lexical decision only as a point of reference.

The most obvious lexical factor is the difference between words and nonwords. Although some authors have suggested that nonwords might be pronounced by referring to related lexical entries for words (Glushko, 1979), few would suggest that nonwords are represented in the lexicon. Therefore, one can reasonably assume that, in most cases, pronunciation of nonwords is mediated by a process of grapheme-to-phoneme translation performed outside the lexicon. However, if the grapheme-to-phoneme translation is the route chosen for naming both words and nonwords, the lexical status of the stimulus should have only a small effect on performance. On the other hand, if the lexical route is the strategy usually chosen for naming words, naming nonwords should be delayed by the lack of a lexical entry.

A similar argument can be made about the effects of word frequency. It can be expected that for processes that depend on lexical search, word frequency should affect performance more than for processes that do not involve lexical mediation. Although the frequency of the word may confound prelexical and lexical factors, there is little doubt that both levels influence lexical access. To the extent that naming depends primarily on prelexical (i.e., phonologic) information, word frequency should affect word pronunciation less.
Assuming that orthographic depth indeed affects word recognition, we predicted that: (1) lexical factors would influence naming in Hebrew more than in English, and in English more than in Serbo-Croatian, and (2) because naming and lexical decision would share more commonality in deep than in shallow orthographies, the influence of lexical factors on the two tasks should be more similar in Hebrew than in English, and more similar in English than in Serbo-Croatian.

Methods

Subjects. The subjects were all undergraduates who participated as part of the requirements of psychology courses. There were 48 students from the Hebrew University, 48 from the University of Connecticut, and 48 from the University of Belgrade. They were all native speakers of Hebrew, English, and Serbo-Croatian, respectively. A different set of 24 subjects in each language were employed in the naming and in the lexical decision tasks.

Stimuli and apparatus. The same list of 48 words and 48 nonwords was used for lexical decision and for naming. All stimuli were 3 to 7 letters long. Because vowels are omitted in Hebrew, the average number of letters per word was smaller than in either English or Serbo-Croatian, which did not differ between themselves. Note, however, that the range of phonemes per word was similar in the three languages (4 to 6 phonemes), and the means did not differ significantly. The word stimuli were composed of 24 high-frequency and 24 low-frequency words selected from those that were rated above 4.0 or below 2.0 respectively. The mean ratings of the high-frequency groups were 4.42, 4.40, and 4.30, and of the low-frequency groups were 1.72, 1.71, and 1.68 in Hebrew, English, and Serbo-Croatian, respectively. Each nonword was produced by replacing one letter of a real word. All letters were normal characters generated by a computer on the center of a CRT screen. On the average, a stimulus subtended a visual angle of approximately 2.5 degrees.

Lexical decisions were communicated by pressing either a "Yes" or a "No" button. The dominant hand was always used for the "Yes" (i.e., Word) responses and the other hand for the "No" (i.e., Nonword) responses. In the naming task, subjects' verbal responses were recorded by a Mura-DX 118 microphone connected to a voice key. Reaction times were measured in milliseconds from stimulus onset.

Procedure. Subjects were randomly assigned to either the lexical decision or the naming task. They were tested individually in a semi-darkened room. The instructions were to respond as quickly and as accurately as possible by pressing one button (in the lexical decision task) or by pronouncing the word (in the naming task). Following the instructions, 15 practice trials were presented. A trial began by presenting a stimulus, which was removed by the subject's response. Following the practice trials, the 96 test trials were presented in one block at a 3-sec inter-trial interval. In the naming task, incorrect pronunciations were recorded by the experimenter and scored as errors.

Results

Each subject's distribution of reaction times was normalized by excluding RTs that were above or below two standard deviations from the subject's own mean. The percent of outliers was similar across all word conditions, less
than 2.5%. This procedure was followed for all subsequent experiments reported in this paper. An analysis of variance assessed the effects of Language (Hebrew, English, Serbo-Croatian), Task (Lexical Decision, Naming), and Stimulus Group (High-Frequency Words, Low-Frequency Words, Nonwords). The mean reaction times for conditions are presented in Figure 1.

![Figure 1](image)

**Figure 1.** Average response time to high-frequency words, low-frequency words and nonwords in the naming task (dashed lines), and in the lexical decision task (solid line), in Hebrew, English, and Serbo-Croatian.

All main effects and two-way interactions were significant; however, the most important result was the three-way interaction, which was significant both for the stimulus analysis, $F(4,207)=9.07$, MSe=1482, and for the subject analysis, $F(4,276)=6.30$, MSe=2051, with $\text{min}F'(4,46)=3.72$, $p<.02$. This interaction demonstrates that each task was affected differently by the stimulus group manipulation in each language. In the naming task, the reaction time difference between nonwords and high-frequency words systematically decreased from 157 ms in Hebrew, to 101 ms in English, and to 56 ms in Serbo-Croatian. In contrast, in the lexical decision task, these differences were similar across languages (217 ms, 192 ms, and 198 ms for Hebrew, English, and Serbo-Croatian, respectively).

The influence of the language on naming was more conspicuous when comparing words and nonwords than when comparing high- and low-frequency words. This observation was tested by analyzing separately those two effects on naming. First, a Frequency X Language ANOVA (with the exclusion of nonwords) revealed that Hebrew words were named significantly slower than English and Serbo-Croatian, with no difference between the latter two, $F(2,69)=21.24$, MSe=14314. High-frequency words were named faster than
low-frequency words, $F(1,69)=137.99$, $MSe=478$. However, the interaction between word frequency and language was not significant, $F(2,69)=1.57$, $MSe=478$. The effect of lexicality was assessed by a second ANOVA that compared nonword performance with the mean of high- and low-frequency words. It revealed that both main effects were significant: $F(2,69)=26.36$, $MSe=19548$ for language, and $F(1,69)=159.16$, $MSe=1566$ for stimulus type. More importantly, the interaction between the stimulus type (words/nonwords) and language was significant, $F(2,69)=20.0$, $MSe=1566$, suggesting that lexicality influenced naming differently in each language.

A second important result is the Task by Language interaction. Across stimulus groups, naming was 149 ms faster than lexical decision in Serbo-Croatian, 88 ms faster in English, but it was 17 ms slower in Hebrew. Note, however, that the difference between naming and lexical decision in Hebrew was significant only for the high-frequency words.

Table 1 presents the mean percentage of errors in each condition.

<table>
<thead>
<tr>
<th></th>
<th>LEXICAL DECISION</th>
<th>NAMING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hfreq</td>
<td>Lfreq</td>
</tr>
<tr>
<td>Hebrew</td>
<td>1.0</td>
<td>8.2</td>
</tr>
<tr>
<td>English</td>
<td>0.1</td>
<td>12.5</td>
</tr>
<tr>
<td>Serbo-Croatian</td>
<td>0.5</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Because the number of errors was small, their distribution did not permit a three-factor analysis. However, some trends were observed. The pattern of Stimulus Group effects on lexical decision was similar across languages. In contrast, in the naming task the pattern of the effects was different in each language. This difference is most conspicuous when high- and low-frequency words are compared. In Hebrew, the difference between the number of low- and high-frequency words that were pronounced incorrectly is practically the same as the difference between the number of incorrect lexical decisions made with low- and with high-frequency words. In English this difference is considerably reduced in the naming task relative to the lexical decision task, whereas in Serbo-Croatian an equal percentage of errors was found with high- and low-frequency words.
The results of this experiment substantiated the hypothesis that the deeper the orthography, the more lexical mediation occurs. In Hebrew, naming was affected by lexicality and word frequency, variables that are believed to affect processing in the lexicon. Consistent with the orthographic depth hypothesis, the effects of these factors were smaller in English, and even smaller in Serbo-Croatian. Furthermore, similarity—or the lack of similarity—between tasks in their sensitivity to word frequency and lexicality was revealing. In Hebrew, naming and lexical decision performance were similarly affected by the lexical nature of the stimulus and except for the high-frequency words, the reaction times in the two tasks were practically identical. In contrast, in Serbo-Croatian, which represents the other end of the orthographic depth continuum, lexical factors had only a slight influence on naming even though their effect on lexical decision was almost as strong as in Hebrew. In English, as might be expected by its place on the continuum (deeper than Serbo-Croatian but more shallow than Hebrew), lexical factors affected both lexical decision and naming.

Note that the lexicality effect (the difference between nonwords and the mean of high- and low-frequency words) discriminated between languages more than the word frequency effect. In fact, in agreement with Seidenberg and Vidanović (1985), word frequency (high vs. low) did not have a significantly different effect on naming English and Serbo-Croatian words. However, when we consider nonwords, we see a slightly sharper difference between Serbo-Croatian and English and, when we extend our view to Hebrew, that difference becomes very marked, indeed. If only Serbo-Croatian and English had been studied, and only word frequency effects considered, the results may have led to the incorrect conclusion that orthographic depth has no influence on word recognition (see also Fredriksen & Kroll, 1976).

Further analysis supports this view. A common finding in English and Serbo-Croatian is that naming is faster than lexical decision (cf. Forster & Chambers, 1973; Fredriksen & Kroll, 1976; Katz & Feldman, 1983); this finding is replicated in the present study. In contrast, there is no such ordering for Hebrew; indeed, the opposite appears to be true, at least for high-frequency words. Apparently in Hebrew, naming cannot be accomplished before lexical decision. This result is consistent with the suggestion that naming in Hebrew is lexically mediated and replicates our previous observations (Bentin et al., 1984; Bentin & Frost, in press). Presumably, naming depends on lexical information in Hebrew because the print provides only partial phonemic information.

With regard to the two other languages, the comparison of English and Serbo-Croatian reveals that the difference between lexical decision and naming is smaller for English. This greater similarity between the two tasks for English suggests that naming in English shares more of its processing with lexical decision than is true for Serbo-Croatian. Nevertheless, it can be seen that the relation between naming and lexical decision time is similar in Serbo-Croatian and English for low-frequency words, while the difference is most conspicuous for high-frequency words: In Serbo-Croatian, naming was 86 ms faster than lexical decision, in English, 22 ms, while in Hebrew, the effect was reversed and naming was 43 ms slower than lexical decision. This pattern partially supports the hypothesis that there is a tendency to recognize high-frequency words on a graphemic basis (Seidenberg, 1985).
However, the results of our experiment suggest the qualification that the use of graphemic/orthographic codes depends additionally on the orthography being read. In a very shallow orthography, even recognition of high-frequency words may be mediated by grapheme-to-phoneme translation done outside the lexicon.

Experiment 2

In Experiment 1 we assessed the extent of lexical mediation for naming by manipulating the lexical status of the stimulus (high or low frequency, word or nonword). Although suggestive, these manipulations cannot be unequivocally interpreted as influencing lexical processing and Experiment 2 was designed to offer converging evidence. High-frequency words, low-frequency words, and nonwords differ not only on lexical dimensions but also on orthographic familiarity, a factor that might influence prelexical processes of word recognition (cf., Mason, 1975). Furthermore, recent evidence suggests that lexical access is not the only process that is influenced by word frequency in pronunciation tasks; postlexical processes are also affected (Balota & Chumbley, 1985). Therefore, the link between orthographic depth and the degree of lexical information used in naming needs to be subjected to further evaluation. Experiment 2 was designed to assess lexical involvement in naming Hebrew, English, and Serbo-Croatian words by using the semantic priming technique.

Since the first Meyer and Schvaneveldt (1971) report, numerous studies have shown that words are recognized faster if they are presented simultaneously with, or immediately following, a semantic associate than if they are paired with an unrelated word. Most of these studies used a lexical decision task. Several studies, however, suggested that semantic priming might also be effective in naming (Becker & Killion, 1977; Meyer, Schvaneveldt, & Ruddy, 1975). In comparison to lexical decision, semantic priming effects in naming are usually smaller, and can be obtained only with strongly associated word pairs (Forster, 1981; Lupker, 1984). One possible interpretation of the weaker effect of semantic priming on naming than on lexical decision is that in English the use of lexical information for naming may be limited to a only a subset of words (such as the exception words), while others are named by means of at least some phonological coding directly from print. This interpretation is consistent with the orthographic depth hypothesis; it implies that the size of the semantic priming effect on naming should correlate positively with orthographic depth.

Several authors have suggested that the magnitude of semantic priming can be influenced by the "depth" at which words are analyzed (Henik, Friedrich, & Kellogg, 1983; Smith, Theodor, & Franklin, 1983; In an analogous way, the rationale of Experiment 2 was based on the assumption that semantic information used to prime a target word in the lexicon should facilitate pronunciation of the target only if the naming process is able to utilize lexically activated information. More generally, we would expect the effect of semantic priming to be greatest for an orthography that putatively depends most strongly on lexical information for pronunciation (e.g., Hebrew) and smallest for the orthography that depends least on lexical mediation (e.g., Serbo-Croatian). The effect on English should be intermediate to the others.

Previous inter-language comparisons of semantic priming effects on naming contrasted only English and Serbo-Croatian, and were contradictory. One study reported that in English, semantic priming equally facilitated lexical
decision and naming performance, while in Serbo-Croatian naming was not facilitated at all (Katz & Feldman, 1983). Different results, however, have been recently reported (Seidenberg & Vidanovic, 1985). In that study, naming printed words was equally facilitated by semantic priming in both English and Serbo-Croatian. A major methodological difference between the studies of Katz and Feldman (1983) and Seidenberg and Vidanovic (1985) is the selection of subjects. The first study was conducted in Yugoslavia where the subjects were undergraduate students; the subjects in the second study were mainly less well-educated Yugoslavian workers in Montreal. A second difference concerned the kind of relation between prime and target. For Katz and Feldman, this was a superset-subset relation (e.g., music - jazz), while for Seidenberg and Vidanovic, an associative relation was used. Nevertheless, in both studies, the same stimuli produced semantic facilitation in a lexical decision task. Thus, although the different results may reflect methodological differences between the two studies, Seidenberg and Vidanovic’s report raises doubts about the generality of the orthographic depth effect.

In the present experiment, we hoped that the careful matching of methodology and stimuli in all three languages would allow an unequivocal cross-language comparison. If there is an orthographic depth effect on word recognition, semantically related primes should facilitate naming performance in Hebrew more than in English, and in English more than in Serbo-Croatian.

Methods

Subjects. The subjects were undergraduates studying in Jerusalem, Storrs, and Belgrade who participated in the experiment as part of the requirements of their respective courses in psychology. There were 48 native speakers in each language.

Stimuli and design. The critical stimuli were 32 target words, none of which had been used in Experiment 1. The mean word frequency rating was approximately the same for the three languages: 3.32, 3.24, 3.20, for Hebrew, English, and Serbo-Croatian, respectively. Each target word was paired with a semantically related prime. A target and a prime were different examples of one semantic category (e.g., lion-tiger; rifle-canon). Semantic categories were used only once. Whenever possible straightforward translations from language to language were made; otherwise, two other examples from the same category were usually selected. In addition to the critical targets, 16 words (mean frequency 3.30, 3.31, and 3.30 for Hebrew, English, and Serbo-Croatian, respectively) were paired with nonwords. The 48 stimulus pairs were compiled into two stimulus lists. In each list, only 16 out of the 32 critical targets were presented in conjunction with their related primes. The remaining 16 primes were redistributed between the other 16 targets such that no obvious semantic relationship could be found between a prime and a target. Targets presented with semantically related primes in one list were unrelated in the other list, and vice-versa. The nonword-word pairs were the same in both lists.

Half of the subjects were randomly assigned to each list. Each subject was presented with 16 semantically related, 16 semantically unrelated, and 16 nonword-word pairs; each critical target was semantically related to its prime for 24 subjects and unrelated for the other 24.
Procedure. An experimental session consisted of 15 practice trials, followed by one block of 48 test trials. Each trial contained three events: a warning signal, and two consecutive test stimuli, the prime and the target. Subjects were instructed to make a lexical decision for the prime (by pressing a "Yes" or a "No" button as in Experiment 1), and to read the subsequent target aloud as soon as they could. The ISI between the warning stimulus and the prime was 1000 ms. The exposure of the prime was terminated by the subject's manual response. The target's onset was 500 ms from the prime offset, and it was removed from the screen by the subject's vocal response. The inter-trial interval was 3 seconds.

All stimuli were presented at the center of a CRT. The physical characteristics of the stimuli and the apparatus were identical to those in Experiment 1.

Results

Table 2 presents the average reaction times for semantically primed and unprimed conditions in each language. In Hebrew, the target words were named 21 ms faster when they were semantically related to the prime. In English, the priming effect was reduced to 16 ms and in Serbo-Croatian it was nonexistent.

These data were analyzed by a Language (Hebrew, English, Serbo-Croatian) X Semantic Relationship (Related, Unrelated) mixed model ANOVA, with repeated measures. Both main effects were significant for both the stimulus and the subject analysis. However, the most important result was the interaction between the two factors. This interaction was significant for the subject analysis, F(2,141)=4.54, MSe=645, p<.013, but not for the stimulus analysis, F(2,93)=2.40, MSe=731, p<.097, probably because the priming effects in Hebrew and English were not significantly different. Nevertheless, planned t-tests revealed that the priming effect was significant in Hebrew, t(47)=3.94, p<.0001, and t(31)=4.1, p<.0001 for the subjects and stimulus analysis, respectively), and in English, t(47)=6.88, p<.0001, and t(31)=2.08, p<.046 for the subjects and stimulus analysis, respectively. In contrast, for Serbo-Croatian, the differences in naming time in the related and unrelated conditions were insignificant.

Table 2

<table>
<thead>
<tr>
<th></th>
<th>HEBREW</th>
<th>ENGLISH</th>
<th>SERBO-CROATIAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unprimed</td>
<td>619 (15.3)</td>
<td>499 (11.4)</td>
<td>565 (15.7)</td>
</tr>
<tr>
<td>Primed</td>
<td>598 (17.3)</td>
<td>483 (10.6)</td>
<td>565 (17.9)</td>
</tr>
<tr>
<td>Facilitation</td>
<td>21</td>
<td>16</td>
<td>0</td>
</tr>
</tbody>
</table>
Some additional insight was provided by comparing words that were preceded by nonwords with words that were preceded by unrelated words. In Hebrew, words that were preceded by nonwords were named significantly more slowly than words that were preceded by unrelated words (650 ms and 619 ms, respectively). A small difference, but in the same direction, was found for English (509 ms and 499 ms, respectively) but not for Serbo-Croatian (564 ms and 565 ms). A Language X Stimulus Group mixed model ANOVA and Tukey post-hoc analysis revealed that the interaction was significant, \(F(2,141)=14.79, MSe=526, p<.0001\), and that the Stimulus Group effect was significant only in Hebrew.

**Discussion**

The results of Experiment 2 revealed that semantic priming had the strongest priming effect in Hebrew, a slightly smaller effect in English, and no effect in Serbo-Croatian. This pattern replicates Katz and Feldman's (1983) suggestion that naming in Serbo-Croatian is not strongly influenced by lexical processes. Most importantly, the results of this study corroborate the hypothesis that the Serbo-Croatian, English, and Hebrew orthographies are on different points of a dimension that influences the amount of lexical involvement in naming. The reasonable conclusion is that orthographic depth is this dimension.

The discrepancy between our findings in Serbo-Croatian and the findings reported by Seidenberg and Vidanović (1985) is puzzling. One possible explanation is that the discrepancy was caused by differences in the stimuli or subjects employed. Seidenberg's subjects were native Serbo-Croatian speakers, but they were residents in Montreal. It was reported that they spoke little French or English and therefore it was presumed that the environment in which they were tested had little if any influence on their performance. Even if that was the case, there was a second difference to consider. Seidenberg and Vidanović's subjects were less educated than our subjects, who were university students. This difference in the level of education might have decreased the subjective word frequency of the stimuli for these subjects. Since the size of the semantic priming facilitation is larger for low-than for high-frequency words (Becker, 1979), the difference in the subjective frequency of the stimuli in the present study and the former results might explain the difference of the results. Nevertheless, the results of Seidenberg and Vidanović could suggest that in Serbo-Croatian, as in other languages, lexical involvement in naming can be manipulated.

In Hebrew, words that followed nonwords were named significantly slower than words that followed words. As discussed in Experiment 1, the only way one can pronounce a nonword is by some process that includes grapheme-to-phoneme translation. Thus, naming words after processing nonwords might have been slowed down by a change from a naming strategy that involves grapheme-to-phoneme translation (for nonwords), to one that is primarily lexically mediated (for words). Note that in Serbo-Croatian, where we have assumed that the same strategy (grapheme-to-phoneme translation) is in effect for naming both words and nonwords, the lexicality of a stimulus has no effect on naming the subsequent stimulus. Therefore, results showing a difference between the naming time for words preceded by nonwords and words preceded by unrelated words might also be determined by orthographic depth. Experiment 3 examined this assumption.
Experiment 3

In Experiment 2 we observed that, in Hebrew, words that followed nonwords were named slower than words that followed words, whereas in Serbo-Croatian this factor had no effect whatsoever on naming time. It is possible that this effect is characteristic only of deep orthographies because only in deep orthographies does switching from naming nonwords to naming words involve a strategic change of the naming mechanism. In shallow orthographies we assume that the same mechanism (grapheme-to-phoneme translation) is employed for naming both words and nonwords, and therefore, naming them in alternation is without cost. In Experiment 3 we attempted to examine this hypothesis by using a technique that discouraged subjects from giving priority to a lexical strategy for naming strings of consonants.

Previous studies in English revealed that word recognition strategies (at least in lexical decision tasks) can be influenced by task demand characteristics and/or by the nature of the stimuli employed. For example, it has been reported that lexical decision for high-frequency words is faster if the list includes only high-frequency words than if high- and low-frequency words are mixed in the list (Glanzer & Ehrenreich, 1979). More relevant to our study are findings suggesting that the use of phonemic encoding of printed words is discouraged if the stimulus list includes a large proportion of homophones (Hawkins, Reicher, Rogers, & Peterson, 1976), whereas the use of visual codes in word recognition is discouraged by backward masking the stimuli (Spoehr, 1978).

We attempted to influence naming strategies by manipulating the proportion of nonwords in the stimulus list. Previous studies reported that frequency effects in naming were more conspicuous when the list contained only words than when words and nonwords were intermixed (Fredriksen & Kroll, 1976; Hudson & Bergman, 1985). One possible interpretation of these results is that naming is less likely to involve lexical mediation when there are many extralexical tokens in the stimulus list. A high proportion of nonwords in the list may have discouraged the subject from using lexical mediation because this route was inefficient most of the time. Consequently, if the grapheme-to-phoneme translation is the natural naming strategy in a shallow orthography and the lexical route is usually employed in a deep orthography, a high proportion of nonwords should impair word naming performance (i.e., increase percentage of errors and RTs in the latter but not in the former orthography).

Methods

Subjects. The subjects were 48 undergraduates from the Hebrew University, 48 from the University of Connecticut, and 48 from the University of Belgrade. None of the subjects employed in this experiment had participated in Experiments 1 or 2, but they were part of the same population of students.

Stimuli and Design. Two lists of 160 stimuli each were assembled in Hebrew, English, and Serbo-Croatian. List 80%-NW consisted of 128 nonwords and 32 words (80% nonwords), and list 20%-NW consisted of 128 words and 32 nonwords (20% nonwords). The target stimuli were 20 words (identical between the lists) that were the last words in the list, dispersed without disrupting the nonword/word ratio in either of the two lists. Both high- and low-frequency words were included among the targets; the mean frequency rating was 2.97, 2.95, and 2.94 in Hebrew, English, and Serbo-Croatian, respectively.
Subjects in each language group were randomly assigned to the two lists, half to each list. The apparatus and experimental conditions were identical to Experiment 2.

Procedure. The procedure was similar to that used in the previous experiments. Subjects were instructed to name words and nonwords that were presented on the screen as quickly and as accurately as possible. In Hebrew, the stimuli were presented without the vowel marks, and the subjects were told to assign the nonwords any vowel combination they preferred. All 160 stimuli were presented in one uninterrupted block. During performance, the experimenter recorded errors verbatim for subsequent qualitative analysis.

Results

The number of mispronounced targets in each list were compared in each language separately. In Hebrew, the number of errors in list 80%-NW (the list with the high proportion of nonwords), was significantly higher than in list 20%-NW, $t(46)=5.44$, $p<.0001$. The same tendency was found in English; however, the difference between the two conditions was marginally significant, $t(46)=1.90$, $p<.063$. In Serbo-Croatian, there were no errors in list 80%-NW and only a nonsignificant number of errors in list 20%-NW (see Table 3).

<table>
<thead>
<tr>
<th>LIST</th>
<th>HEBREW</th>
<th>ENGLISH</th>
<th>SERBO-CROATIAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%-NW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT (SEM)</td>
<td>557 (15.3)</td>
<td>565 (8.0)</td>
<td>578 (15.3)</td>
</tr>
<tr>
<td>ERRORS</td>
<td>12.6%</td>
<td>5.0%</td>
<td>0%</td>
</tr>
<tr>
<td>20%-NW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT (SEM)</td>
<td>627 (14.3)</td>
<td>501 (8.5)</td>
<td>558 (11.0)</td>
</tr>
<tr>
<td>ERRORS</td>
<td>4.1%</td>
<td>2.7%</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

The average naming time to the 20 target words in each list was analyzed by analyses of variance on subjects and stimuli. The interaction between the Language and List factors was significant for both the subject and the stimulus analyses (subject analysis, $F(2,138)=14.087$, $MSe=4019$; stimulus analysis, $F(2,57)=130.10$, $MSe=351$; min$F'(2,58)=12.66$, $p<0.001$). In Serbo-Croatian, the target words were named slightly faster in List 20%-NW than in List 80%-NW. However, Tukey-A post-hoc comparison revealed that the difference between the two lists was not significant $p>.05$). In English and Hebrew, Tukey-A comparisons revealed that the differences in RTs between the
two lists were significant \( p < .01 \), but in different directions. In English, the target words were named 67 ms faster in List 20%-NW than in List 80%-NW. In contrast, words in Hebrew, were named 72 ms faster in List 80%-NW than in List 20%-NW.

**Discussion**

Changing the proportion of nonwords in the stimulus list influenced naming performance differently in each language. Consider first the error data. In Hebrew, the 80%-NW list yielded 8.5% more errors on the 20 target words than the 20%-NW list. In English, the difference was in the same direction but smaller (2.3%). In Serbo-Croatian, there were practically no errors. This systematic pattern is congruent with the hypothesis of orthographic depth. If we assume that naming words in Hebrew is normally mediated by the internal lexicon, subjects must change this strategy for naming nonwords (which have no lexical representation). When the stimulus list contains a high proportion of nonwords, the nonlexical naming strategy is the more efficient one. One consequence of this strategy is that many strings that would have made a word in Hebrew if given the appropriate vowelization, were in fact assigned with incorrect vowels using the nonlexical naming strategy. Thus, the subject pronounced these as a nonword instead of a word. Indeed, in Hebrew, all erroneously read target words were pronounced as nonwords. In contrast to Hebrew, we hypothesized that in Serbo-Croatian naming does not strongly involve the lexicon. Therefore, there is no obvious reason why different strategies should be used for naming words and nonwords. All stimuli can be named via the same mechanism that is based on grapheme-to-phoneme translation. Consequently, the proportion of nonwords in the list should have little influence on word naming performance, as indeed was revealed in this experiment. English, more than the other two languages, combines both lexical and nonlexical routes for naming (cf. Coltheart, 1980). It is conceivable that the nonlexical strategy is used for nonwords and for a subset of words (e.g., low frequency, phonemically regular words), while the lexical strategy is used for naming other words. Consequently, the reinforcement of a nonlexical strategy by the high proportion of nonwords in the list influenced reading of only a part of the words, which explains why the effect was smaller than in Hebrew.

Observations of the nature of the errors in Hebrew and in English provided further support of the hypothesis. If a nonlexical strategy is applied to name words that are usually named via the lexicon, the errors should primarily consist of naming words as nonwords. On the other hand, lexical substitution should be more prevalent when the lexicon is involved in naming. Indeed, in English, the nature of the errors found in the 80%-NW list was as in Hebrew, primarily reading words as nonwords. In contrast, in the 20%-NW list, the errors were mainly substitutions of words by other words (for example "degree" instead of "degree").

The influence of the proportion of nonwords in the list on naming time was less systematic. Although the results in Serbo-Croatian and English appear straightforward, those for Hebrew are not. In Serbo-Croatian, naming time in the two nonword conditions was similar, thereby supporting the hypothesis that word naming strategy was not influenced by the proportion of nonwords in the list. In English, words were named significantly slower in the 80%-nonwords condition than in the 20%-nonwords condition. Because the increase in naming time was followed by an increase in the percent of errors, it is clear that
naming performance was interfered with when the stimulus list contained a high percent of nonwords. Although other interpretations might be possible, the explanation provided by the orthographic depth hypothesis is simple and straightforward. In contrast to Serbo-Croatian, grapheme-to-phoneme translation in English is not only constrained by phonemic rules, but also by morphophonemic factors (Chomsky & Halle, 1968). Therefore, in the absence of lexical information, the grapheme-to-phoneme translation is sometimes a complex and painful process. No wonder it takes more time to complete.

The interpretation of the naming data in Hebrew is less straightforward. According to the simple rationale elaborated above, we should have observed a delay in naming words in the 80%-NW condition, which should have been even larger than in English. In contrast, naming the word targets in this condition was significantly faster than in the 20%-NW condition. There is, however, one interpretation that, although admittedly post-hoc, can account for these results. This explanation is based on the insight that in contrast to English, Hebrew phonology has very few constraints on naming nonwords; the subject is free to choose almost any arbitrary set of vowels in order to make the consonantal structure pronounceable. Therefore, when the list contains both words and nonwords, the limiting factor operating on naming time is determined by some (as yet unspecified) competition between lexical search and grapheme-to-phoneme translation for consonants coupled with arbitrary addition of vowels. Before applying a nonlexical strategy, the subject must make sure, with some degree of certainty, that the presented consonant string is not a word. Therefore, naming is slow not only for words but also for nonwords. However, when subjects do not expect words, as in the 80%-NW list, they may be more inclined to change their strategy, and use an idiosyncratic arbitrary selection of vowels for both words and nonwords. This change should result in different speed-accurracy trade-off strategies in the 20%-NW and the 80%-NW lists. In the latter list, subjects might have been inclined to spend less time analyzing the stimulus in reference to lexical information. In many cases the fast analysis was sufficient to generate a correct response, but in some cases incorrect (nonword) responses were made. In the 20%-NW list, since subjects expected words to appear, they referred to the lexicon to find the correct pronunciation of the stimulus. This procedure increased naming time but decreased the probability that a word would be read as a nonword.

This interpretation is certainly not the only one possible but it is supported by several observations. Recall that the average naming time was calculated based on all 20 targets, that is, both errors and correct responses were included. Comparison of the naming time in the 80%-NW list revealed that the same words were read slower by the subjects who named them correctly (559 ms), than by the subjects who read them as nonwords (531 ms). Therefore, some portion of the difference between the naming time in the two lists can be explained by the errors that may have been read without lexical mediation. However, even considering only correctly read words, the difference in naming time between the two lists remains considerably large (561 ms in 80%-NW vs. 625 ms in the 20%-NW list). Therefore, naming difference between the two lists should be accounted for by a factor that affects naming of all stimuli in the list, words and nonwords. As previously mentioned, a change in the speed-accuracy trade-off strategy is a reasonable explanation. There is additional evidence in support of our interpretation. If naming strategy was changed in the way we suggest, naming nonwords should have also been accelerated when words are not expected. We verified this hypothesis by comparing naming time to 32 nonwords presented in List 20%-NW with naming time
In conclusion, we suggest that the error data are in complete agreement with the orthographic depth hypothesis, and the RT data can be reasonably explained without a necessity to change it. Therefore, we consider the results of Experiment 3 as additional support for the validity of the orthographic depth concept.

General Discussion

This study was designed to test the psychological validity of the orthographic depth hypothesis. According to this hypothesis, in a shallow orthography lexical word recognition is mediated primarily by phonemic information generated outside the lexicon by grapheme-to-phoneme translation. In contrast, in a deep orthography, lexical access for word recognition relies strongly on orthographic cues, while phonology is derived from the internal lexicon. One implication of this hypothesis is that in a shallow orthography, the normal strategy for naming is to generate the major phonological information needed for word pronunciation prelexically by means of grapheme-to-phoneme translation. In contrast, in a deep orthography, such prelexical information for naming is either absent or too complex to be used efficiently. Therefore, pronunciation is based on information stored in the lexicon.

We tested the hypothesis by investigating naming performance in Hebrew, English, and Serbo-Croatian. These languages are located, respectively, at deep, average, and shallow points on the orthographic depth continuum. Our rationale was to examine the effects on naming performance of factors that were assumed to influence lexical processing; comparisons were made among the three languages, that is, as a function of orthographic depth. Thus, we were primarily interested in the interactions of effects of the lexical manipulations with the language factor, rather than in main effects that could reflect a multitude of factors.

In Experiment 1, we showed that the lexical status of the stimulus (i.e., being a high-frequency word, a low-frequency word, or a nonword) affected the speed of naming in Hebrew more than in English, and in English more than in Serbo-Croatian. Furthermore, only in Hebrew were the effects on naming very similar to the effects on lexical decision. In Experiment 2, the results suggested that semantic priming (a factor that presumably operates on the lexicon) facilitates naming in Hebrew, has a smaller effect in English, while in Serbo-Croatian it has no effect at all. Finally, in Experiment 3, the results indicated that presenting a large proportion of nonlexical items (nonwords) in a stimulus list encouraged the use of a nonlexical strategy that, in Hebrew, speeded naming at the expense of treating many words as nonwords. This manipulation had a similar, but smaller, effect on the reader of English, while in Serbo-Croatian the proportion of nonwords in the list had no effect on naming. We interpreted this to mean that Hebrew readers normally use an orthographic code to access the lexicon for naming but may abandon it when it becomes intractable (as when they must name many nonwords, which have no lexical representation). Note that in each experiment there were six different permutations possible for ordering the three languages in terms of a given effect, but only one order predicted by the orthographic depth
hypothesis. Most importantly, in all the three experiments, different lexical factors affected naming systematically in perfect agreement with the order predicted by the orthographic depth hypothesis. Therefore, we suggest that the concept of orthographic depth is psychologically real and that it influences word recognition. In what follows, we will elaborate some of the implications of this conclusion and incorporate it into current thinking on the process of word recognition.

Many reports suggest that the reader of English uses both orthographic and phonemic cues in word recognition (see the review by McCusker et al., 1981). Even when performance requires the generation of phonological codes for output, as in naming, grapheme-to-phoneme translation is the only available route (Coltheart, 1980; Forster & Chambers, 1973; Fredriksen & Kroll, 1976). Is this strategic flexibility limited to orthographies, like English, located in the middle of the orthographic depth continuum? The results of this study suggest that this is probably not the case. The change in strategies observed in Experiment 3 suggests that the nonlexical route, although not accurate, can predominate even in Hebrew when it appears to be more efficient. Note, however, that there is no evidence in our data to imply that words were named correctly without previous lexical access. The extent of using the lexical route in Serbo-Croatian has not been tested. However, other studies support this possibility (Seidenberg, 1985; Seidenberg & Vidanović, 1985). Considering the converging evidence, it seems plausible that both orthographic and phonological information are available prelexically in all languages and probably interact during the process. Therefore, the relevant question should not be what are the codes used in each specific situation but what is the nature of this interaction and how orthographic depth might influence it.

One attempt to disclose the nature of the interaction between orthographic and phonemic codes in word recognition is the version of McClelland and Rumelhart's (1981) parallel interactive model suggested by Seidenberg and his associates (Seidenberg, Waters, & Barnes, 1984; Seidenberg, 1985). Their version of the model emphasizes the relative time course of the phonological and orthographic code activation suggesting that prelexical generation of the two code types is mandatory, and that since the phonological code depends on prior orthographic analysis, it usually lags behind. Consequently, they suggest that orthographic information accumulates faster than phonemic information and, for many (perhaps most) words, lexical access occurs before a recognizable prelexical phonological code is generated. Recognition on the basis of an orthographic code, however, automatically provides the lexical representation of the phonological code, which can then be used in overt naming. We adopt this model as a working hypothesis, but suggest some extensions to explain how orthographic depth may affect naming strategies. Most authors have so far emphasized the importance of the time course of the orthographic code for word recognition, implicitly assuming that it is coding speed that determines whether word naming is based on nonlexical processes or is mediated by the lexicon. However, this implicit assumption may be incorrect. Instead, one could plausibly assume that the time lag between generation of the graphemic and the phonemic codes may begin with the prior onset of the orthographic analysis but then is increased or decreased by the time course of orthographic code generation and by the time course of the phonological code. The results of the present study suggest that the time course of phonological code generation is affected mainly by the simplicity of the rules governing the spelling-sound correspondence. Thus, it is possible that at the extreme shallow end of the orthographic depth continuum, a
sufficient portion of the phonological code can accumulate before the orthographic analysis can help word recognition.

The time it takes to extract sufficient graphemic information for lexical access is determined primarily by the familiarity of the stimulus (Balota & Chumbley, 1984; Mason, 1975). It is possible, however, that prelexical generation of phonemic codes is performed by a parallel interactive process, analogous to the process of orthographic code generation (see also Seidenberg et al., 1984). In this case, nodes would consist of phonemic rather than graphemic features, but their activation would be governed by the same rules as proposed by McClelland and Rumelhart (1981). This hypothesis implies that stimulus familiarity should affect the time course of the phonemic code generation much in the same way as it affects the generation of the orthographic code, and probably for the same reasons. Thus, familiarity of the stimulus should not change the relationship between the time course of the two code types. However, in addition to familiarity, prelexical generation of phonemic codes is also affected by orthographic depth. In a shallow language, the process might be based on idiosyncratic application of grapheme-to-phoneme translation rules. Such a process might get very fast access to the word's phonology and, in parallel, provide the articulatory mechanism with the necessary phonological information. In contrast, in a deeper orthography, simple grapheme-to-phoneme translation is difficult and may frequently lead to incorrect responses. Therefore, generation of the phonemic code is more complex, is frequently dependent on units larger than the single grapheme, and is, therefore, slower. In extreme cases like unworeled Hebrew a full phonemic code cannot be generated before information about the whole word has accumulated and some lexical decisions about its meaning are made. Therefore, we suggest that the major factor that determines the origin of the phonetic codes in naming is not the speed of orthographic code generation, but rather the ease of the generation of the phonemic codes.

This study concentrated on naming performance. Nevertheless, we suggest that orthographic depth affects lexical access in a similar way. Indeed, in Experiment 1, we observed that the lexical status of the stimulus had a similar pattern of influence on lexical decision performance in each language. However, we agree with Balota and Chumbley (1985) that the lexical decision task is probably not a very good way to examine this hypothesis. A better approach would be to examine, in each language, how factors that are related to the phonology and the orthography influence word recognition performance in semantic tasks. To this end, we believe that the data of the present study strongly support the validity of the orthographic depth factor in word recognition.

References


Frost et al.: Word Recognition and Orthographic Depth


Footnotes

1Throughout this paper we will use the term grapheme-to-phoneme translation with the understanding that the process often involves units larger than single letters.
The ambiguity in English pronunciation and the ambiguity in Hebrew pronunciation are different in kind. Nevertheless, it seems reasonable to assume that it is more difficult to get to the correct pronunciation in Hebrew words than in English.