Psychol Res (1987) 49: 139–146

Psychological Research

Loci of phonological effects in the lexical access of words written in a shallow orthography

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Summary. Three experiments are reported that extend previous observations on the slowing of lexical decisions by phonologically ambiguous forms of Serbo-Croatian words relative to the phonologically unambiguous forms of the same words. The phonological ambiguity arises from the presence of letters whose phoneme interpretation differs between the two Serbo-Croatian alphabets, the Roman and the Cyrillic. In the first experiment, target words were preceded by asterisks or by context words that were associatively related and alphabetically matched to the targets. The effect of word contexts (i.e., priming) was greater for phonologically ambiguous than for phonologically unambiguous targets. The second experiment manipulated the alphabetic match of context word and target word. The effect of this manipulation was limited to phonologically ambiguous words. The third experiment reproduced the details of the first with the addition of visual degradation of the target stimuli on half of the trials. The results of the first experiment were replicated but no interaction between context and visual degradation was observed. The discussion focused on phonologically mediated access of Serbo-Croatian words. A model was proposed in which phonological codes are assembled prelexically according to weighted grapheme-phoneme correspondence rules.

The debate on whether fluent readers of English go from the printed word to its meaning visually or phonologically is still continuing. There is a good deal of evidence to suggest that visual word recognition may be mediated by phonological recoding (e.g., Meyer, Schvaneveldt, & Ruddy, 1974). At the same time, strong arguments can be found for the contrary view, namely that visual word recognition can proceed independently of phonological recoding (e.g., Forster & Chambers, 1973). These contrasting observations have led to the development of dual-route models of word recognition. For these models the real issue, one might claim, is what variables determine the priority of one route over the other on any given occasion. Roughly, the idea is that the skilled reader of English has an option of using either the visual or phonological route and makes his or her "choice" as circumstance demands (McCusker, Hillinger, & Bias, 1981). There is a marked tendency, however, to deemphasize the phonological contribution to word recognition. The deemphasis takes two forms. One promotes visual access as the faster of the two routes and, therefore, the one on which successful reading most commonly depends. The other underscores that most, if not all, of the evidence for phonological processes comes from negative decision data, suggesting that the main contribution of phonological processes is to the perception of letter strings that are pseudowords (Coltheart, Davelaar, Jonasson, & Besner, 1977). The dual-route model proposes that, first, the visual and phonological routes operate in parallel, and second, the phonological code is derived on the basis of "grapheme-to-phoneme correspondences" or GPCs. The idea is that GPCs operate by breaking down a word into its constituent graphemes and assigning each one its appropriate phonemic code.

It has been argued that if prelexical phonological recodings are produced by using GPC rules, then such recodings can only occur for words that conform to these rules, that is, so-called "regular words" (Coltheart, Besner, Jonasson, & Davelaar, 1979). The lexical entries of words that are exceptions to the rules can be accessed only via the visual route, whereas those of regular words can be accessed by either route. Consequently, whether or not the lexical decision task involves the use of GPCs might be evaluated by determining whether performance is better with regular words (that can be accessed in two ways) than with exception words (that can be accessed in only one way). Unfortunately, regularity effects in English word processing prove to be elusive, at least when measured in lexical decisions, and, as a result, the evaluation of the GPC process based upon them is inconclusive (see Humphreys & Evett, 1985). The present paper focuses on Serbo-Croatian, the major language of Yugoslavia. This language is written in two alphabets, Roman and Cyrillic, both of which map onto the same set of phones but comprise two sets of letters. Most of the Roman and Cyrillic letters are *unique* to their respective alphabets. There are, however, a number of letters that the two alphabets have in common. The phonetic interpretation of some of these shared letters is the same whether they are read as Cyrillic or as Roman letters; these are referred to as *common* letters. Other letters among the shared letters have two different phonetic interpretations, one in the Roman reading and one in the Cyrillic reading; these are referred to as *ambiguous* letters. Whatever their category, the individual letters of the two alphabets have phonetic interpretations that are virtually invariant over letter context.

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Reasons given against phonological mediation in the fluent reading of English (for example, see Seidenberg, 1985) are not applicable to the fluent reading of Serbo-Croatian. The Serbo-Croatian orthographies are optimal for transcribing the phonology: the Serbo-Croatian GPCs are simple one-to-one relations. One might suppose, therefore, that lexical decision on Serbo-Croatian letter strings exhibits a greater sensitivity to phonology than does lexical decision on English letter strings. Indeed, the experimental evidence favors the hypothesis that there is an obligatory phonological reference in making lexical decisions on Serbo-Croatian letter strings (Feldman & Turvey, 1983; Feldman, Lukatela, & Turvey, 1985; Lukatela, Popadić, Ognjenović, & Turvey, 1980; Lukatela, Savić, Gligorijević, Ognjenović, & Turvey, 1978; Lukatela & Turvey, 1980; Turvey, Feldman, & Lukatela, 1984).

Given the nature of and the relation between the two Serbo-Croatian alphabets, it is possible to construct a variety of letter strings. Two types are especially relevant to the present work: (1) phonologically unique and (2) phonologically ambiguous letter strings. Consider a phonologically ambiguous letter string BETAP. This is a very familiar Serbo-Croation word by its Cyrillic pronunciation where [vetar] means *wind* as in the phrase *wind storm.* Its Roman pronunciation [betap] is a nonword. The Roman transcription of [vetar] is a unique letter string, VETAR, and is phonologically and semantically identical with the letter string BETAP by its Cyrillic reading. Similarly, the phonologically ambiguous letter string PAJAC means *jester* by its Roman pronunciation [pajats] but is a nonword by its Cyrillic pronunciation [rajas]. The corresponding unique Cyrillic letter string ПАЈАЦ, has only one pronunciation [pajats] which is phonologically and semantically identical with the letter string PAJAC by its Roman reading.

When responses to an ambiguous Cyrillic word (e.g., BETAP) are compared to those for the unique Roman transcription of the *same* word (e.g., VETAR) they are found to be slower and more prone to errors (Feldman & Turvey, 1983). This so-called "phonological ambiguity effect" is pursued in the present paper. Within-word comparisons between the phonologically unique and ambiguous Serbo-Croatian letter strings will be explored with a novel technique of "alphabetical priming" that should prove useful for pinpointing the locus of the phonological ambiguity effect.

Experiment 1

With regard to possible loci of phonological effects in word recognition, one should distinguish: first, prelexical processes that involve the graphemic and phonemic encoding of a printed/written word; second, intralexical processes that involve the retrieval of orthographic, phonologic, semantic, and other information associated with particular lexical entries, accompanied by an automatic spread of this information through the internal lexicon; and third, postlexical processes that involve the selection, evaluation, and integration of lexical knowledge, grammatical/syntactical knowledge, and nonlinguistic pragmatic knowledge about the things that can and do happen in the world.

Experiment 1 is concerned mainly with pre- and intralexical processes. Its goal was to collect some information about the nature of a phonological recoding mechanism: Does the phonological recoding per se provide a complete phonological code, sufficient for uniquely identifying a lexical entry? Or does the phonological recoding depend on intralexical processes (e.g., associative or semantic bias provided by context)?

Method

Subjects. Forty-eight high school seniors from the Fifth Belgrade Gymnasium served as subjects. A subject was assigned to one of four groups, according to when the subject appeared at the laboratory, to give a total of twelve subjects per group.

Procedure. A subject was seated before the CRT of an Apple IIe computer in a dimly lit room. A fixation point was centered on the screen. On each trial, the subject heard a brief warning signal after which a letter string or three asterisks in a row appeared for 700 ms above the fixation point. After a 100 ms interstimulus interval another letter string appeared below the fixation point for 1400 ms. Subjects were instructed to decide as rapidly as possible whether or not the second letter string was a word. To ensure that subjects were reading the contexts, they were occasionally asked by the computer to report orally both stimuli after the lexical decision had been made. Decisions were indicated by depressing with both thumbs a telegraph key for a "No" response or by depressing another key, slightly further away, with both forefingers for a "Yes" response. Latencies were measured from the onset of the target. If the response latency was longer than 1400 ms, a message appeared on the screen requesting that the subject respond more quickly. The experimental sequence was preceded by a practice sequence of 40 different stimulus pairs. The intertrial interval was 2500 ms and the whole session lasted about 20 min.

Materials and design. The types of letter strings that were used as targets in Experiment 1 are shown in Table 1 along with the phonemic interpretations (Roman and Cyrillic) and meaning for each typical sample. Phonologically uni-

Table 1. Types of letter strings in Experiment 1

Sample	Phonological representation		Meaning
	ROMAN	CYRILLIC	
VETAR	/vetar/		WIND
		impossible	–
ПАЈАЦ	impossible		–
		/pajats/	JESTER
VOTAR	/votar/		nonsense
		impossible	–
ПАЈОЦ	impossible		–
		/pajots/	nonsense
BETAP	/betap/		nonsense
		/vetar/	WIND
PAJAC	/pajats/		JESTER
		/rajas/	nonsense
BOTAP	/botap/		nonsense
		/votar/	nonsense
PAJOC	/pajots/		nonsense
		/rajos/	nonsense

que letter strings are shown in the upper half, and phonologically ambiguous letter strings are shown in the lower half of Table 1. Pseudowords were generated from the corresponding words by replacing one letter of the word by another letter from the same phonemic class.

On each trial the subject was presented two successive stimuli. The context stimulus was either a row of asterisks or a phonologically unique word. The target stimulus was either a word or a pseudoword. Targets were evenly divided into phonologically unique and ambiguous letter strings. All letter strings were evenly divided into Roman and Cyrillic script. Each context word was associatively related and alphabetically matched to its target word, that is, the context word was written always in the same alphabet as the related target. When the target was a phonologically ambiguous letter string that had a meaning in the Roman (Cyrillic) alphabet, then the context word was also written in the Roman (Cyrillic) alphabet. The major constraint on the design was that a given subject never encountered a given word or pseudoword in any of the pairs more than once. This was achieved by dividing subjects into four groups and by dividing each set of 28 stimuli pairs into four subgroups. Altogether, there were 16 different sets of prime/target pairs of which eight sets contained phonologically unique targets and eight sets contained phonologically ambiguous targets. In sum, each subject saw seven pairs from each set of 16 stimuli pairs.

Results and discussion

The decision latency of each subject to each type of letter string was the basic datum for analysis. Those responses that were faster than 400 ms or slower than 1400 ms were considered errors, together with "regular" errors, namely, those responses in which the wrong decision was made. A three-way analysis of variance (Alphabet Type by Context by Phonological Ambiguity) was computed using subjects as units. The main effect of Alphabet Type (Cyrillic/Roman) was not significant. Given this fact, the latency and error data were collapsed over the alphabet type variable and a two-way analysis (Context by Phonological Ambiguity) was conducted. The main effect of Context was significant, $F(1,7)125.2$, $P<0.001$, as was the main effect of Phonological Ambiguity, $F(1.47)=47.73$, $P<0.001$. The Context by Phonological Ambiguity interaction was also significant, $F(1,47)=25.83$, $P<0.001$. These results were confirmed by the error analyses.

Mean acceptance latencies and mean error rates are summarized in Table 2. The data in the upper row (for nonprimed targets) concur with previous work (e.g., Lukatela et al., 1980). When a word was readable in both alphabets, lexical decision was slowed and errors were increased.

Table 2. Mean acceptance latencies L (in ms) and error rates ER (in %) in Experiment 1

Condition	Phonological representation of letter strings			
	Unique		Ambiguous	
	L	ER	L	ER
Nonprimed	765	2	848	20
Primed	695	4	718	6

The quantities in the lower row of Table 2 show that contextual priming reduced the response latencies to both phonologically unique and ambiguous target words. They also show that the magnitude of the contextual effect (i.e., the difference between the primed and nonprimed situations) was much larger for phonologically ambiguous than for unique target words. This difference is the source of the significant interaction between contextual priming and phonological ambiguity. Can this interaction be explained in terms of the direct visual access hypothesis and, in particular, in terms of the recently expressed strong form that dismisses dual-route models of word recognition? In the strong form there is no prelexical phonology, and retrieving phonological information is a consequence of a visually based lexical access (Glushko, 1981; Marcel, 1980; Seidenberg, 1985). Let us temporarily assume that lexical access for Serbo-Croatian words is visual rather than phonological and, on the basis of this assumption, see if certain predictions are upheld.

Consider a phonologically ambiguous letter string (e.g., BETAP) and its phonologically unambiguous control (e.g., VETAR). Note that both letter strings BETAP and VETAR are graphemically unique. There is, therefore, no compelling reason to except that the phonologically ambiguous BETAP will be processed visually any differently from its unambiguous control word VETAR; each graphemic pattern making up a word is distinct and should have a unique address in lexical memory. This expectation does not concur with the results of the experiment. One could attempt, nevertheless, to sustain a visual/graphemic hypothesis by arguing that the relatively long response latencies and large error rates that are associated with the phonologically ambiguous letter string BETAP arise after lexical access. That is, lexical access generates more than one phonological code. This argument requires that lexical entries for Serbo-Croatian words that are written in common and ambiguous characters contain information about the phonology of *nonwords*. It may be difficult to reconcile this requirement with the basic definition of the internal lexicon.

In his recent work, Seidenberg (1985) has asserted that words that are frequently found in print will be accessed visually, while words with a low frequency of occurrence will be dependent on phonological coding for their recognition. In order to check this assertion with regard to our data, we divided the list of phonologically ambiguous words that were used in Experiment 1 into two groups. Based on Lukić's (1981) frequency count of a corpus of 1500000 words, the higher frequency words had a mean frequency of 172, whereas the lower frequency group had a mean frequency of 14. In each group there were 28 phonologically ambiguous words (14 by a Cyrillic and 14 by a Roman reading). The mean reaction times and errors for the data divided according to frequency are given in Table 3. A three-way analysis of variance on items revealed a significant effect of contextual priming, $F(1,54)=74.5$, $P<0.001$, a significant effect of phonological ambiguity, $F(1,54)=22.99$; $P<0.001$, and a significant interaction between priming and ambiguity, $F(1,54)=12.76$, $P<0.001$. Neither frequency by ambiguity nor any other interactions with frequency proved to be significant. This pattern of results was duplicated in the error analysis. The

Table 3. Mean acceptance latencies L (in ms) and error rates ER (in %) in Experiment 1 divided according to frequency items

Frequency	Condition	Phonological representation			
		Unique		Ambiguous	
		L	ER	L	ER
High	Nonprimed	743	1.92	816	19.23
	Primed	668	4.12	687	7.14
Low	Nonprimed	787	4.67	885	32.43
	Primed	731	8.24	753	10.16

absence of an ambiguity by frequency interaction argues against the view that the phonological ambiguity effect is tied systematically to word frequency.

To shed light on the observed interaction between phonological ambiguity and contextual (alphabetic and associative) priming it was necessary to isolate the alphabetic effect per se. Isolating this effect would allow for the assessment of whether the observed interaction could be accounted for by (1) an interactive (automatic) process that feeds higher level compensatory information from the internal lexicon back to a phonological encoder, or (2) a straightforward influence of alphabetical bias on the phonological recoding mechanism.

Experiment 2

The effects of alphabetical contextual priming are, theoretically, present in all languages and orthographies whenever the task is to recognize a printed/written word that had been preceded by at least one printed/written character. The notion of alphabetical priming is, however, meaningless in those languages that, like English, use just one alphabet. In contract, when a Yugoslav third grader reads in his or her reading book, the effects of alphabetical priming must be considered seriously because usually one half of the text is written in Cyrillic and one half in Roman. The power of alphabetical priming per se, and its bearing on the recognition of phonologically unique and ambiguous words, has not been evaluated experimentally heretofore.

As remarked, it is possible that the clear contextual advantage of phonologically ambiguous words over phonologically unique words is not a result of a simultaneous operation of associative intralexical processes and phonological prelexical processes; rather, the contextual advantage may result from a differential influence of the alphabetical bias on phonological encoding mechanisms. Experiment 2 disentangles alphabetical and associative contextual priming.

Method

Subjects. Sixty high school seniors, who had not participated in Experiment 1, served as subjects. A subject was assigned to one of four groups, to give a total of fifteen subjects per group.

Materials and design. These were similar to those of Experiment 1 except for the fact that in Experiment 2 all target words were associatively primed by context words.

Table 4. Mean acceptance latencies L (in ms) and error rates ER (in %) in Experiment 2

Condition	Phonological representation of letter strings			
	Unique		Ambiguous	
	L	ER	L	ER
Mismatch	684	4	772	21
Match	672	4	709	5

One half of the targets of each type (i.e., phonologically unique and ambiguous) were preceded by alphabetically matched and associatively related contexts, whereas the other half were preceded by alphabetically mismatched and associatively related contexts. The procedure was identical to that in Experiment 1.

Results and discussion

Decision latencies and analyses of variance were computed in the same manner as in Experiment 1. The main effect of Alphabet Type (Roman/Cyrillic) was found to be nonsignificant and, again, the data were collapsed over the alphabet type variable. The two-way analysis (Phonological Ambiguity by Alphabetical Match) revealed that the main effect of Phonological Ambiguity was significant, $F(1,59)=115.6$, $P<0.001$, as the main effect of Alphabetical Match, $F(1,59)=25.9$, $P<0.001$. The Phonological Ambiguity by Alphabetical Match interaction was also significant, $F(1,59)=20.2$, $P<0.001$. The same pattern of results was revealed in the error analyses.

Mean acceptance latencies and mean errors are summarized in Table 4. Bearing in mind that, in the present experiment, all target words under all experimental conditions were associatively primed, one should note that the data in the lower rows of both Tables 2 and 4 refer to the same experimental condition: combined alphabetical and associative priming. It is not surprising, therefore, that the size of the phonological ambiguity effect (i.e., the arithmetical difference between the mean response latencies to phonologically unique and ambiguous words) is approximately the same. This repeated finding illustrates the robustness of the phonological ambiguity effect. Importantly, the phonological ambiguity effect was considerably larger under the alphabetical-mismatch condition (see the

Table 5. Comparison of contextual priming effects in Experiments 1 and 2

Condition	Phonological representation of letter strings			
	Unique		Ambiguous	
	L	ER	L	ER
Alphabet & Associative Contextual effect (Experiment 1)	+70	−2	+130	+14
Alphabetical Contextual effect (Experiment 2)	+12	+1	+ 63	+11

upper row in Table 4) than under the alphabetical-match condition. This underscores the importance of being set into a particular alphabetical mode when one perceives phonologically ambiguous letter strings.

Another (and possibly more enlightening) way to look at these obtained results is to compare the "contextual effects" (i.e., the arithmetical difference between the mean response latencies to contextually primed and nonprimed words) under various experimental conditions. The data in the upper row of Table 5 show that the overall contextual effect due to the combined alphabetical and associative priming was approximately two times larger for phonologically ambiguous words (+130 ms) than for phonologically unique words (+70 ms). On the other hand, as shown in the lower row of Table 5, when the associative context was held constant across all situations so that only alphabetical bias was manipulated, the contextual effect for unique words was quite small (+12 ms), whereas for phonologically ambiguous words it was large (+63 ms). Planned comparisons indicated that 130, 70, and 63 ms contextual effects were significant at the 0.001 level. However, the 12 ms contextual effect for unique words was not significant at the 0.05 level.

Now we face a delicate problem: How does alphabetical context influence decision latencies, and why does it influence phonologically ambiguous and unambiguous words differentially? This question is rather complex and we will offer our explanation gradually. If we were adherents of direct visual access we would probably argue that there are two separate sets of internal graphemic representations of Serbo-Croatian printed words. Each set would contain the representations in one of the two alphabets; for example, the Cyrillic word BETAP would be found in the Cyrillic visual lexicon, but not in the Roman visual lexicon. By the alphabet of the context, lexical search could be biased toward one of the two visual lexicons. A phonologically ambiguous word (e.g., BETAP) would necessarily lie in exactly one of the two sets; by appropriate alphabetic priming the search for that word would be facilitated. One objection to this interpretation is as follows. If there are two distinct lexicons, we should find no differential effect of alphabetical bias with regard to phonologically ambiguous and unambiguous words. Presumably, the existence of a two-alphabet lexical arrangement would be to take advantage of information about the alphabet of the printed stimulus under observation, that is, to eliminate any inefficiency due to phonological ambiguity.

Let us return to the phonological recoding hypothesis. We will assume that under situations where the context and target words are alphabetically matched, prelexical processing is biased toward the appropriate set of grapheme-to-phoneme correspondences (GPCs). For most of the Cyrillic and Roman characters in Serbo-Croatian (i.e., for all unique and common letters) GPCs are simple one-to-one mappings that are absolutely invariant. Consequently, response latencies to phonologically unique words (e.g., VETAR) are not influenced by alphabetical bias. It is only for a small set of ambiguous characters that GPCs are not invariant and depend on the alphabetical mode that has been induced by context. Consequently, only the phonologically ambiguous letter strings will benefit from prior information about the particular GPCs that should be applied to phonological recoding. This is a plausible explanation of the differential effect in alphabetical priming. One should be wary, however, of oversimplifying the model of alphabetical priming. Alphabetical bias should not be construed as some form of simple switching mechanism. If alphabetical bias were acting as a deterministic process, then lexical decisions to all alphabetically mismatched ambiguous target words in Experiment 2 should have resulted in errors because ambiguous words by the "opposite" alphabet reading were always nonwords. Yet, error rates in Table 4 show that alphabetically mismatched ambiguous target words were correctly recognized as words on 79% of the trials, although accompanied by relatively long decision latencies. The implication is that the action of alphabetical priming on phonological recoding of ambiguous words is rather more probabilistic than deterministic.

Our probabilistic model of phonological recoding assumes that regardless of context, an ambiguous letter string automatically activates all phonological codes or representations that its graphemic structure permits. For example, a letter string such as BETAP contains two ambiguous characters, *B* and *P*, and, therefore, gives rise to four phonological codes; one of them is [vetar], which means *wind* and has a lexical entry, whereas the other three codes ([vetap], [betar], [betap]) are nonwords. All these phonological representations – according to one model that we might construct – are assembled in parallel. Code generation is fastest for the most probable phonological representation of the letter string. As soon as a code has been assembled it is evaluated against the lexicon. The process is terminated when one of the codes finds its lexical entry, or when all codes fail in their lexical access. The probability with which particular GPCs are applied to ambiguous characters of isolated words (for example, in the asterisk/word pairs) depends on the statistics of speech sounds in particular. When an ambiguous letter string has been alphabetically primed by context, then the probability distribution functions are modified so as to give priority to that particular phonological code that is consistent with the given alphabetical bias. In sum, the appropriate alphabetical bias increases the probability that the correct phonological representation will be activated first, although there remains always a nonzero probability that a wrong coding is the first coding evaluated against the lexicon. So far, we have outlined possible characteristics of prelexical phonological recoding in Serbo-Croatian word recognition. We still do not know, however, whether the Serbo-Croatian word recognition model should incorporate a direct visual route as well. This issue will be addressed in Experiment 3.

Experiment 3

Meyer, Schvaneveldt, and Ruddy (1975) degraded visually presented words by superimposing a dot pattern. This visual degradation had a smaller effect on the processing of words presented in a semantically appropriate context than on the processing of words out of context. Since stimulus degradation can affect only the visual encoding stage, the interaction of stimulus degradation and semantic context suggested that semantic context influences an early stage of visual word recognition in which strings of letters are encoded graphemically prior to any possible grapheme-to-phoneme transformation. Within the framework of the dual-route model, it can be argued that the in-

teraction of associative context and stimulus degradation is a consequence of the fact that the English internal lexicon is predominantly accessed by graphemic representations via a direct visual route. Consequently, interactive processes can arise between the visual encoding stage and the lexicon. The basic assumption that stimulus degradation affects only the stimulus encoding stage was investigated further by Becker and Killion (1977). Using stimulus intensity in place of the dot-pattern degradation, Becker and Killion found that semantic context interacted with intensity. They also obtained converging evidence that the effects of stimulus intensity were largely limited to processes prior to memory search.

In view of the aforementioned observations, Experiment 3 addressed the question of whether or not the context by stimulus degradation interaction, which is so robust in English, would show up in Serbo-Croatian. The expectation was that for Serbo-Croatian words from the mid and low frequency range of occurrence (i.e., for words that were used in Experiments 1 and 2), the Context by Stimulus Quality interaction should not reach statistical significance. This is because the direct visual route is probably not a well-established communication channel between the graphemic encoding stage and the internal lexicon in Serbo-Croatian. Consequently, the associative contextual information accumulated in the internal lexicon cannot directly facilitate the visual encoding of degraded stimuli.

Method

Subjects. The participants in the experiment were 32 students from the Department of Psychology at the University of Belgrade. A subject was assigned to one of four groups to give a total of eight subjects per group.

Procedure. The procedure was identical to that of Experiment 1.

Materials and design. These were similar to those of Experiment 1. There were two modifications; first, all target words and context words were phonologically unique, and, second, onto one half of the targets following asterisks and one half of the targets following words a static random dot pattern was superimposed. Thus, in Experiment 3 there were 16 different sets of prime/target pairs. Eight sets included visually intact targets, and eight sets included visually degraded targets. In sum, each subject saw seven pairs of stimuli from each of the sixteen sets.

Results and discussion

Decision latencies and analyses of variance were computed as in Experiment 1. In the two-way analysis of variance (Context by Stimulus Quality), the main effect of Context was significant, $F(1,31)=45.41$, $P<0.001$, as was the main effect of Stimulus Quality, $F(1,31)=147.83$, $P<0.001$. Importantly, the Context by Stimulus Quality interaction was not significant, $F(1,31)=2.85$, $P<0.10$. The same pattern of results was obtained in the error analyses.

Mean acceptance latencies and mean errors are summarized in Table 6. The first thing to be noted is that the left column gives evidence of a replication of the contextual (associative and alphabetical) effect (+82 ms) for the phonologically unique and visually intact letter strings that was observed in Experiment 1 (see the data in the left column of Table 2, for comparison). The absolute magnitude of latencies in Experiment 1 was generally larger than in Experiment 3, presumably because in Experiment 1 the subjects were high school seniors, whereas in Experiment 3 university students served as subjects. In contrast to research with English, the contextual effects for phonologically unique and visually degraded words (see Table 6) were smaller in magnitude (+53 ms) than they were for phonologically unique and visually intact words (+82 ms). Planned comparisons indicated that the 53, and 82 ms contextual effects were significant at the 0.001 level.

Table 6. Mean acceptance latencies L (in ms) and error rates ER (in %) in Experiment 3

Condition	Intact		Degraded	
	L	ER	L	ER
Nonprimed	704	7	792	11
Primed	622	4	739	6

As already noted, there is an argument that words of higher frequency are more likely to involve direct visual access of the internal lexicon. For this reason, it was expected that if a Context by Quality interaction is to be found with Serbo-Croatian materials, then it would more likely be found for higher rather than lower frequency words. For the post hoc analysis it was conventient to use the same groups of higher and lower frequency words that were described in Experiment 1, since all words in Experiments 1 and 3 were semantically identical.

For the group of higher frequency words, with a mean frequency of 172, the two-way (Context by Stimulus Quality) item analysis revealed significant main effects of contextual priming, $F(1,27)=19.76$, $P<0.001$, and stimulus quality, $F(1,27)=6.24$, $P<0.001$, and no Context by Quality interaction $F(1,27)=1.5$, $P<0.23$. Mean latencies for primed and nonprimed visually intact words were 605 ms and 693 ms, respectively. For primed and nonprimed visually degraded words they were 725 and 772 ms, respectively.

For the group of lower frequency words with a mean frequency of 14, the two-way item analysis showed significant main effects of Context, $F(1,27)=12.67$, $P<0.001$, and Stimulus Quality, $F(1,27)=63.98$, $P<0.001$, and no interaction, $F(1,27)<1$. The mean latencies for primed and nonprimed visually intact words were 644 ms and 738 ms, respectively. For primed and nonprimed visually degraded words they were 780 ms and 844 ms, respectively. Results of the analyses for the two frequency groups of words were very similar. For both groups, the critical interactions were nonsignificant. The higher frequency Serbo-Croatian words did not show even the slightest tendency to be like regular English words. This finding provides further support for the claim that fluent reading of Serbo-Croatian depends most commonly on phonologically mediated lexical access.

General discussion

The aim of this paper has been to investigate the loci of phonological ambiguity effects that have been obtained in

lexical decision tasks with bi-alphabetical Serbo-Croatian readers (for a review, see Turvey et al. 1984). As a general framework, we used dual-route models of visual word recognition that have been offered in recent years by investigators of reading in English (e.g., Coltheart et al., 1977; Morton & Patterson, 1980). The basic assumptions underlying dual-route models are that the visual and phonological routes operate in parallel and that both routes mediate lexical access. The efficiency of prelexical processes operating along these routes differs, most probably, from language to language. With regard to the latter possibility, we have hypothesized that if there is a real automatic bias toward direct visual or toward phonologically mediated lexical access, then this bias is tied to the depth of the orthography in which a given language is written. In other words, our hypothesis is that whether the match between a printed written word and its lexical representation is mediated by abstract figural aspects or by phonological constituents of the word, depends mainly on the linguistic level that is primarily represented by the writing system. The shallower the orthography, the more transparent are grapheme-to-phoneme correspondences, and the more enhanced is the phonologically mediated lexical access. The Serbo-Croatian writing system, which simply represents phonology, is markedly shallower than the English orthography, which simultaneously represents phonology and morphology while mixing them inconsistently from word to word (Gleitman & Rozin, 1977). The reader of English, therefore, might be encouraged to rely more heavily on abstract figural aspects of visually presented words. A similar encouragement, however, would not exist for the reader of Serbo-Croatian. Our previous work and the present experimental evidence concur: Yugoslavian readers exploit a phonological access strategy in recognizing words even when the experimental conditions do not favor its use.

The results of Experiment 1 – under conditions where phonological coding was biased against – replicated our previous findings that words that could be read in two different ways were accepted more slowly and with greater error than words that could be read only one way. In Experiment 1 matters were arranged so that it was punitive to access the lexicon via phonology because that entailed simultaneous activation of the Roman and Cyrillic phonological codes. Far more prudent would have been a strategy restricted to the visual route, but Serbo-Croatian subjects apparently were unable to suppress the phonological route. The other major result of Experiment 1 was the finding of an interaction between contextual priming and phonological ambiguity. To reiterate, it was found that phonologically ambiguous words displayed a larger contextual effect than phonologically unique words. When one turns from this formal interaction to a consideration of the contextual mechanisms and their loci, the results leave ample room for at least two mutually exclusive explanations. The fact that context interacted with phonology suggests an integrative model in which prelexical phonological recoding benefits from the information that has been intralexically provided by the associatively related context words. Such a model invites the additional assumption that phonological recoding is generally more complex and difficult with phonologically ambiguous than with unique letter strings. Consequently, phonologically ambiguous words may call for higher level associative contextual processes to facilitate phonological recoding, whereas phonologically unique words may not require that kind of facilitation.

Another possible explanation of the Context by Phonology interaction builds upon the fact that contextual priming in Experiment 1 was simultaneously associative *and* alphabetical. Hence, the observed interaction may be due to alphabetical rather than associative contextual priming. The latter possibility received strong support from Experiment 2, which demonstrated that alphabetical priming produced a significant contextual effect with phonologically ambiguous words, whereas phonologically unique words remained practically unaffected by the alphabetical match/mismatch manipulation. Given the aforementioned results, a probabilistic model of phonological recoding in Serbo-Croatian can be entertained. This model relies on several assumptions: First, a phonologically ambiguous letter string automatically activates all phonological codes that are consistent with the given graphemic pattern; second, phonological codes are assembled prelexically and in parallel; third, code generation is fastest for the most probable phonological representation and as soon as a code is assembled it is evaluated against the lexicon; fourth, lexical access is terminated when one of the codes finds its lexical entry, or when all codes fail in their search; and fifth, alphabetical bias influences the probability distribution which, in turn, governs the priority order of phonological codes. In sum, the model assumes that the alphabetically matched context increases the probability that the correct phonological code will be the first one to access the lexicon. Nevertheless, there remains a nonzero probability that some wrong code may be the first one generated and the first one evaluated against the lexicon. In contrast, alphabetical bias is ineffective on decision latencies and error rates for phonologically unique letter strings because these strings cannot support more than one phonological code.

The results of Experiment 3 provide indirect evidence for the argument we have advanced that direct visual access in Serbo-Croatian plays a minor role as compared with phonologically mediated access to the lexicon. In particular, Experiment 3 demonstrated no interaction between contextual priming and visual degradation of stimuli, although interactions of this type were consistently displayed in the English studies (e.g., Becker & Killion, 1977; Meyer et al., 1975; Stanovich & West, 1983). The fact that in English visually degraded words have always shown an associative (semantic) contextual advantage over visually intact words suggests, in our view, that English word recognition may be characterized by simultaneous operation of contextual processes and graphemic feature extraction mechanisms (see Rumelhart, 1977). When the rate of feature extraction is slowed (for example, by superposition of a random dot pattern) the higher level contextual processes will have, by some compensatory processing (see Stanovich, 1980), a greater influence on overall performance. We hypothesize that for interactive compensatory processing, the prequisite is a well-established and highly efficient communication between prelexical feature extraction and intralexical associative (semantic) contextual priming. If we are correct in this conjecture, then the failure of Experiment 3 to show an increased contextual effect when stimulus quality was degraded speaks against a well-established direct visual route in Serbo-Croatian. Collectively, the results of the present experiments suggest that

for Serbo-Croatian word recognition a lexical entry is accessed by the phonological code that has been prelexically generated on a probabilistic basis.

Acknowledgements. This research was supported in part by NICHD Grants HD-08495 and HD-01994 to the University of Belgrade and Haskins Laboratories, respectively. The analyses and discussion of the experiments reported are preliminary. The experiments belong to a series of experiments investigating contextual effects (alphabetic, associative, phonemic) on phonologically ambiguous items in the rapid lexical decision and rapid naming tasks. An account of this series is in preparation.

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Received December 6, 1985/January 7, 1987