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Word Recognition in Serbo-Croatian Is Phonologically Analytic

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A lexical-decision task was conducted with bialphabetic readers of Serbo-Croatian. It was shown that letter strings that can be assigned both a Roman and a Cyrillic alphabet reading incur longer latencies than does the unique alphabet transcription of the same word. This within-word phonological-ambiguity effect was obtained for both words and pseudowords, but the effect was more exaggerated with words. In addition, the magnitude of the difference depended on the number and distribution of ambiguous characters in the ambiguous letter string. It was concluded that lexical decision in Serbo-Croatian necessarily involves a phonologically analytic strategy.

Most of the studies on word recognition have been conducted with English materials and native speakers of English, and it is possible that their outcomes reflect, in part, peculiarities of the English orthography rather than general principles of word recognition. In contrast to the English orthography, which tends to be morphophonemic in its referent (Chomsky, 1970), the writing system of Serbo-Croatian preserves a very close relation to (classical) phonemics and reveals morphological relatedness only when the phonology is similar. In Serbo-Croatian, all similar orthographic patterns will sound alike. Even fully systematic phonological alternations in surface forms are represented in the orthography so that visual or orthographic similarity of morphologically related forms may be obscured; for example, nominative singular RUK+A, dative singular RUC+I, nominative singular SNAH+A, and dative singular SNAS+I.[1] In addition, as a result of the tendency toward open syllables, the possible patterning of consonants and vowels is much more restricted in Serbo-Croatian than in English. Not only do the orthotactic (Taft, 1979) rules fully mimic the phonotactic rules but the possibility for ambiguous syllable boundaries due to sequences of consonants is greatly reduced.

The depth of an alphabetic orthography is reflected by the extent to which the spoken form is specified by the orthographic form, that is, by the complexity of the derivational rules that relate the orthographic transcription to some (abstract) description appropriate for speaking. A deep orthography with a complex relation to the spoken form[2] may induce a word-specific strategy that avoids the derivations. In English, the complex relation between written and spoken form is increased because, historically, written and spoken language have not evolved in the same way. Therefore, the graphemic transcription often does not correspond exactly to the phonology, and this could induce a word-specific (lexical) recognition strategy.

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[1] Inflection is the major grammatical device of Serbo-Croatian. The preceding are Roman transcriptions for the words, *arm* and *daughter-in-law*, respectively.

[2] Although alphabetic writing systems (both deep and shallow) refer to the spoken form, this is not meant to imply that an orthography can be phonetic. For the purposes of this article, "spoken form" refers to a surface phonemic form.

In comparison with the derivational rules for English, Serbo-Croatian has maintained a close correspondence between the written and spoken language. This is the outcome of deliberate alphabet reforms introduced by Karadžić and Gaj in the last century that reconstructed the Roman and Cyrillic alphabets in which the Serbo-Croatian language is written according to the simple rule: "Write as you speak and speak as it is written." As a result, the Roman and the Cyrillic orthographies transcribe the sounds of the Serbo-Croatian language in a direct and consistent manner, and there are no (nontrivial) derivational rules. In summary, the orthography is shallow and there are no exception words in Serbo-Croatian. Consequently, a word-specific (lexical) strategy would never be required.

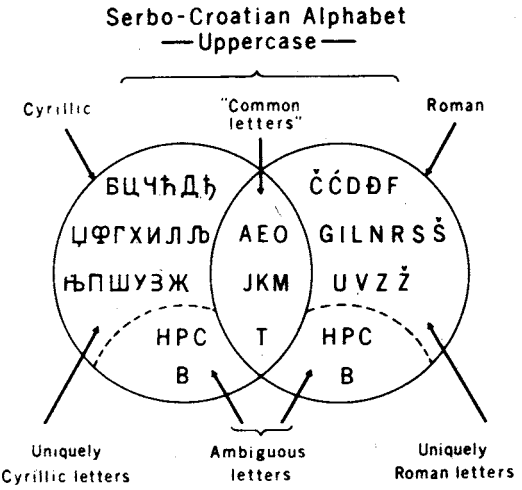

Figure 2. The unique and shared characters of the Roman and Cyrillic alphabets of Serbo-Croatian.

SERBO-CROATIAN				
ROMAN		CYRILLIC		
PRINTED UPPER CASE	PRINTED LOWER CASE	PRINTED UPPER CASE	PRINTED LOWER CASE	LETTER NAME IN I.P.A.
A	a	А	а	a
B	b	Б	б	bɛ
C	c	Ц	ц	tsɛ
Č	č	Ч	ч	tʃɛ
Ć	ć	Ћ	ћ	tʃjɛ
D	d	Д	д	dɛ
Đ	đ	Ђ	ђ	dʒjɛ
DŽ	dž	Џ	џ	dʒɛ
E	e	Е	е	ɛ
F	f	Ф	ф	fɛ
G	g	Г	г	gɛ
H	h	Х	х	xɛ
I	i	И	и	i
J	j	Ј	ј	jɛ
K	k	К	к	kɛ
L	l	Л	л	lɛ
LJ	lj	Љ	љ	ljɛ
M	m	М	м	mɛ
N	n	Н	н	nɛ
NJ	nj	Њ	њ	njɛ
O	o	О	о	ɔ
P	p	П	п	pɛ
R	r	Р	р	rɛ
S	s	С	с	sɛ
Š	š	Ш	ш	ʃɛ
T	t	Т	т	tɛ
U	u	У	у	u
V	v	В	в	vɛ
Z	z	З	з	zɛ
Ž	ž	Ж	ж	ʒɛ

Figure 1. The Roman and Cyrillic characters of Serbo-Croatian together with their pronunciation in the notation of the International Phonetics Association (I.P.A.).

Since the Roman and Cyrillic alphabets transcribe the same language, their graphemes must map onto the same set of phonemes. These two sets of graphemes are, with certain exceptions, mutually exclusive (see Figure 1). 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 phonemic interpretation of some of these shared letters is the same whether they are read as Cyrillic or as Roman graphemes; these are referred to as *common* letters. Other members of the shared letters have two phonemic interpretations, one in the Roman reading and one in the Cyrillic reading; these are referred to as *ambiguous* letters (see Figure 2).

Given the nature of and the relation between the two Serbo-Croatian alphabets, it is possible to construct a variety of letter strings. A letter string of uniquely Roman and common letters or of uniquely Cyrillic and common letters would be read in only one way and could be either a word or nonsense. A letter string composed of the common and ambiguous letters is bivalent. It could be pronounced in one way if read as Roman and pronounced in a distinctively different way if read as Cyrillic; moreover, it could be a word in one alphabet and nonsense in the other or it could represent two

different words, one in one alphabet and one in the other, or finally, it could be nonsense in both alphabets (see Table 1).

Whatever their category, the individual letters of the two alphabets have phonemic interpretations that are virtually invariant over letter contexts. Moreover, all the individual letters in a string of letters, be it a word or nonsense, are pronounced—there are no letters made silent by context.[3] Finally, but not least in importance, a large portion of the population uses both alphabets competently. This is due, in part, to an education requirement that both alphabets be taught within the first two grades. The Roman alphabet is taught first in the western part of Yugoslavia and the Cyrillic alphabet is taught first in the eastern part of Yugoslavia.

In sum, the Serbo-Croatian orthography relative to the English orthography permits less variability in its orthotactic patterning relative to phonotactic patterns but more variability in the written form of some base morphemes. The Serbo-Croatian orthography is less concerned with preserving morphological relatedness, and it relates closely to the spoken language.[4] The depth of an orthography reflects the extent to which the phonemic rendition is specified by the orthographic form: Serbo-Croatian is characterized as a shallow orthography.

The complex relation between letter and sound in English is often promoted as a reason why a reliance on phonology should be minimized in the fluent reading of English (Goodman, 1976; Kolers, 1970; Smith, 1971). By analogy, the simple letter–sound relation of Serbo-Croatian should encourage (not discourage) a reliance on phonology. The intuition that the shallow character of the Serbo-Croatian orthography should invite a phonological strategy has received some experimental support: In a lexical-decision task, latencies were longer for phonologically bivalent grapheme strings than for phonologically unambiguous strings (Lukatela, Popadić, Ognjenović, & Turvey, 1980; Lukatela, Savić, Gligorijević, Ognjenović, & Turvey, 1978). In the earlier experiment (Lukatela, Savić, Gligorijević, et al., 1978), both the design of the experiment and the instructions to the subjects were selected to restrict the task to the Roman alphabet: No letter strings contained uniquely Cyrillic letters, and subjects were asked whether the strings were words by their Roman reading. In the later experiment (Lukatela et al., 1980), no alphabet restriction was imposed on lexical decision, and the word interpretation occurred in either the Cyrillic reading, Roman reading, both readings, or neither reading. In both experiments, the prolonged decision times to

Table 1
Types of Letter Strings and Their Lexical Status

Composition of letter string	Phonemic interpretation	Meaning
	Ambiguous and Common	
CABAHA[a]	Cyrillic/*savana*/	*savanna*
	Roman/*tsabaxa*/	nonsense
KOBAC	Cyrillic/*kovas*/	nonsense
	Roman/*kobats*/	*hawk*
KACA	Cyrillic/*kasa*/	*safe*
	Roman/*katsa*/	*pot*
HEPECTAC[a]	Cyrillic/*neretas*/	nonsense
	Roman/*xepetats*/	nonsense
	Common	
JAJE	Cyrillic/*jaje*/	*egg*
	Roman/*jaje*/	*egg*
TAKA	Cyrillic/*taka*/	nonsense
	Roman/*taka*/	nonsense
	Unique and Common	
SAVANA[a]	Cyrillic (impossible)	
	Roman/*savana*/	*savanna*
NERETAS[a]	Cyrillic (impossible)	
	Roman/*neretas*/	nonsense
КОБАЦ	Cyrillic/*kobats*/	*hawk*
	Roman (impossible)	
ПУДАЛ	Cyrillic/*pudal*/	nonsense
	Roman (impossible)	

[a] Letter-string type included in the present experiment.

[3] There are exceptions to this characterization: For example the *d* in *predsednik* is generally interpreted as /*t*/. However, the number of violations is small.

[4] Two aspects of vowel accent (i.e., tone: rising/falling; and length: long/short) are not captured by the written form. Whereas vowel accent may differentiate between two semantic interpretations, this distinction is often ignored, especially in the dialects of the larger cities (Magner & Matejka, 1971). Moreover, vowel identity, at least as it is defined by formant structure in some restricted phonemic environments, is not distorted by variations in accent (Kalić, 1964).

all phonologically bivalent letter strings as compared to phonologically unique letter strings suggested that subjects were unable to suppress a Cyrillic alphabet reading when the letter string permitted one. Further, there was no indication that presenting some words in Roman and some words in Cyrillic interfered more with performance than did printing all words in one alphabet: The detriment with bivalent letter strings occurred in both a pure Roman context and in a mixed Roman and Cyrillic context. Noting that the phonological bivalence of graphemes should exert no influence on visual matching and that words composed of shared characters with a common phonemic value in both alphabets were recognized no more slowly than were pure Roman strings, Lukatela, Savić, Gligorijević, et al., (1978) and Lukatela et al. (1980) concluded that for Serbo-Croatian, lexical access always proceeds with reference to phonology.

A feature of the experiments cited above (Lukatela, Savić, Gligorijević, et al., 1978; Lukatela et al., 1980) was that different words occurred in the phonologically unique and phonologically bivalent conditions. That is, the effect of phonological bivalence was determined by a comparison of latencies between different words. In the present experiment, the effect of phonological bivalence was assessed by comparing decision latencies to the ambiguous Cyrillic and the unique Roman transcriptions of the same word (e.g., *CABAHA/SAVANA*) or pseudoword (e.g., *HEPETAC/NERETAS*). This within-word comparison eliminates the effects due to word frequency, word length, and richness of meaning when assessing the effect of phonological bivalence.

Using this within-word procedure, the present experiment addressed the following questions with regard to visual word recognition in Serbo-Croatian: (a) Does phonological bivalence impair performance for both words and pseudowords? If it does, then it would appear that a phonological strategy is mandatory regardless of the lexical status of the letter string. (b) Assuming that the answer to (a) is positive, is impairment due to phonological bivalence greater for words than for pseudowords? If it is greater for words, then it would seem unlikely that a phonological strategy can be optional for words but mandatory for pseudowords, as it is sometimes claimed (Coltheart, Besner, Jonasson, & Davelaar, 1979). (c) Similarly, is the impairment due to phonological bivalence greater for low-frequency words than for high-frequency words? If it is not, then reliance on a phonological strategy is independent of word frequency. (d) Does the effect of phonological bivalence vary with the number and/or position of the ambiguous letters within a letter string? If it does so vary, then it would describe a strategy that is analytic and phonological (i.e., phonetically derived rather than word-specific and linguistically unanalytic of visual form).

Method

Subjects

Twenty-eight first-year students of psychology at the University of Belgrade participated in this study to partially fulfill course requirements. All were native speakers of Serbo-Croatian, and all had learned the Cyrillic alphabet first.

Procedure

Subjects performed a lexical-decision task. As each letter string appeared, they had to tap a key with both hands to indicate "yes" (further key) or "no" (closer key) with respect to the string's lexical status. All letter strings were typed on Prima U Film, and the Cyrillic and Roman typeface were closely matched for size and form. (Common characters were identical in the two typefaces.) Stimuli were presented for 750 msec in one channel of a Scientific Prototype model GB tachistoscope. A blank field immediately preceded and followed the display interval. The interval between experimental trials was about 2,000 msec, and reaction times were measured from the onset of the stimulus display. A brief pause was introduced halfway through the experimental session.

The instructions directed subjects to judge whether each letter string was a word by either its Roman or its Cyrillic reading. Subjects were informed that words would appear in both Roman and Cyrillic. During the experimental session, subjects were advised of their mistakes. Each subject viewed 246 slides, which included 30 practice trials. Half of the letter strings were words and the other half were pseudowords that were actually derived from other real words by changing two or three letters in the latter portion of the letter string. Half of the items contained two syllables (with five or six letters) and the other half contained three syllables (with six or seven letters). All words were nouns familiar to college students as judged by consensus among several native speakers.

Stimuli

Three types of words and pseudowords, defined by the manner in which they were presented across subject

groups, were included. Control items were printed in Roman for both groups of subjects (e.g., *MUZIKA*). Control letter strings contained some characters that are unique to Roman. Pure items were printed in Cyrillic for half of the subjects (Group 1) and in Roman for the other half (Group 2). The pure letter strings contained some characters that are unique to an alphabet (either Cyrillic or Roman) in both their Roman and Cyrillic transcriptions. Ambiguous items were chosen because they contained only common and ambiguous characters in the Cyrillic rendition. In contrast, in the Roman version, these same letter strings contain characters that are unique to the Roman alphabet. Within the ambiguous letter strings, number and position of ambiguous characters were systematically varied. For the three-syllable items, two or three ambiguous characters were distributed over two or three syllables. For the two-syllable items, one or two ambiguous characters were distributed over one or two syllables (see Table 2).

Design

Each group of subjects saw 18 Cyrillic words and 18 Cyrillic pseudowords intermixed with 90 Roman words and 90 Roman pseudowords. Group 2 subjects saw 18 ambiguous Cyrillic words (e.g., *САВАНА/savana/*), all of which could also be read as a pseudoword in Roman (*/tsabaxa/*), and 18 pure words in Roman (e.g., *FABRIKA /fabrika/*), as well as 18 ambiguous Cyrillic pseudowords (e.g., *НЕРЕТАС /neretas/* or */xepetats/*) and 18 pure pseudowords in Roman (e.g., *EDOGOM /edogom/*). In addition, they saw a control set of 72 words and 72 pseudowords written in Roman. Group 1 subjects saw the same ambiguous words, now written in Roman (e.g., *SAVANA*, where they are no longer ambiguous), and the pure words written in Cyrillic (e.g., ФАБРИКА), as well as 18 ambiguous pseudowords written in Roman, in which they are no longer ambiguous, and 18 pure pseudowords written in Cyrillic. Group 1, like Group 2, saw the control words and pseudowords written in Roman (see Table 3).

In summary, there were two groups of subjects who performed a lexical-decision task. All comparisons between groups were performed on the same set of words where the alphabet changed (for the pure and for the ambiguous word sets) across subject groups. If Group 1 saw a particular word type in its Roman version, then Group 2 saw that same word type in an ambiguous Cyrillic version. Conversely, the pure Cyrillic word type from Group 1 appeared in Roman for Group 2. The two types of Cyrillic words differ in one important respect: The Cyrillic words for Group 2 (i.e., ambiguous words), are also readable in Roman. This is not true for the other type, the pure words, which were presented to Group 1. Phonological bivalence was restricted to Group 2's Cyrillic words and pseudowords.

Results

An analysis of variance (ANOVA) for lexical decision, with minimum and maximum latencies set at 250 msec and 2,500 msec, revealed highly significant effects for lexicality (word/pseudoword), $F'_{min}(1, 21) = 21.15, p < .001$; for Group (1/2), $F'_{min}(1, 15) = 20.28, p < .001$; for word type (ambiguous/pure/control), $F'_{min}(2, 16) = 22.35, p < .001$; and for length in syllables (two/three), $F'_{min}(1, 11) = 6.22, p < .05$. In addition, the Type × Group interaction was significant, $F'_{min}(2, 16) = 20.73, p < .001$. The Lexicality × Type × Group interaction was also significant, $F'_{min}(2, 20) = 6.66, p < .01$.

Mean number of errors for all items in lexical decision was 4 for Group 1 and 12 for Group 2. Considering only the ambiguous-type items, mean errors were 2 for Group 1

Table 2
Distribution of Ambiguous Letters and Phonemic Interpretation for Ambiguous Cyrillic-Type Items

Letter strings	Phonemic interpretation	Meaning	Number of ambiguous letters	Number of ambiguous syllables
Three syllable				
САВАНА	Cyrillic/*savana*/	*savanna*	3	3
	Roman/*tsabaxa*/	nonsense		
КАРАВАН	Cyrillic/*karavan*/	*caravan*	3	2
	Roman/*kapabax*/	nonsense		
ОСТАВКА	Cyrillic/*ostavka*/	*resignation*	2	2
	Roman/*otstabka*/	nonsense		
Two syllable				
ОРМАН	Cyrillic/*orman*/	*cabinet*	2	2
	Roman/*opmax*/	nonsense		
САНТА	Cyrillic/*santa*/	*iceberg*	2	1
	Roman/*tsaxta*/	nonsense		
КОТВА	Cyrillic/*kotva*/	*anchor*	1	1
	Roman/*kotba*/	nonsense		

Note. Underlined letters in column 1 are ambiguous.

Table 3
Assignment of Item Types Across Groups

	Letter string: Word					
	Item type					
Group	Ambiguous[a]	Pure	Control	Ambiguous[a]	Pure	Control
1	*SAVANA*	ФАБРИКА	*MUZIKA*	*NERETAS*	ЕДОГОМ	*KOTUFLA*
2	*CABAHA*	*FABRIKA*	*MUZIKA*	*HEPETAC*	*EDOGOM*	*KOTUFLA*

[a] These letter strings are phonologically (and alphabetically) ambiguous in their Cyrillic form but are unique in their Roman form.

and 8 for Group 2 (see Table 4). For all items in both groups, there was no evidence of a speed–accuracy trade-off. In fact, reaction time and errors were positively correlated (for Group 1, $r = .33$; for Group 2, $r = .50$). To assess the possibility that subjects were less influenced by phonological ambiguity as they proceeded through the task, the correlation of the difference between the unique Roman and the ambiguous Cyrillic latency for each word (and pseudoword) and position of the item in the list was computed for each item (a large number indicates a position late in the list).[5] For lexical decision, the correlation was not significant ($r = .19$). This result suggests that the effect of phonological ambiguity did not diminish during the experimental session. Similarly, to assess the possibility that the effect of phonological ambiguity varied with word frequency, the reaction time to the unique Roman version of each word was used as an estimate of word frequency, and the correlation between unique Roman latency and the difference between the unique Roman and ambiguous Cyrillic form of each word was computed. In lexical decision, the correlation was not significant ($r = -.17$). Therefore, the effect of phonological ambiguity indicated by the degree of impairment did not vary as a function of word frequency.

Protected t tests (Cohen & Cohen, 1975) between mean reaction times for lexical decision (with the estimate of variance computed from the error term of the subjects' ANOVA) showed that the significant interactions of Type × Group and Type × Group × Lexicality could be attributed to a significant difference between ambiguous Cyrillic/unique Roman form of words (*CABAHA/SAVANA*), $t(13) = 8.89$, $p < .001$ (see Figure 3). Groups did not differ significantly on uniquely Cyrillic or Roman pure words, (ФАБРИКА / *FABRIKA*), $t(13) = 1.09$. These results suggest

[5] The same order of items occurred in the list given to Group 1 and in the list given to Group 2.

Table 4
Summary of All Data for Lexical Decision on Ambiguous Cyrillic/Unique Roman-Type Items

	Length in syllables/lexicality			
Item	Two/word	Two/pseudoword	Three/word	Three/pseudoword
Roman	*ORMAN*	*VAMAS*	*SAVANA*	*NERETAS*
M	632	717	677	769
SD	86	76	89	62
Errors	.4	.3	.7	.6
Cyrillic	*OPMAH*	*BAMAC*	*CABAHA*	*HEPETAC*
M	945	925	984	993
SD	106	144	123	139
Errors	3.3	.5	3.9	.4

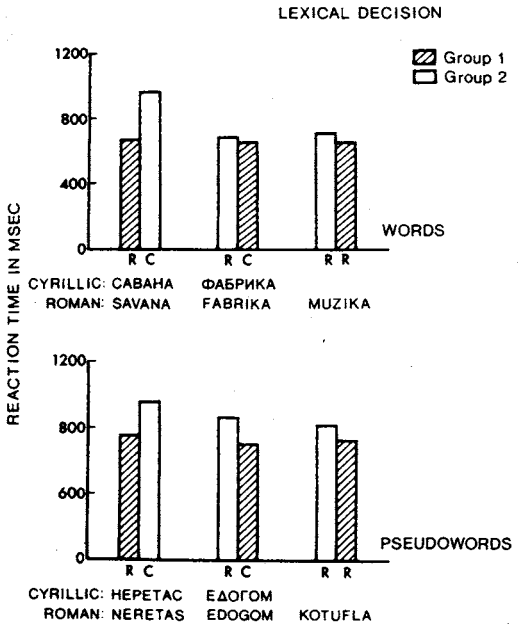

Figure 3. Lexical decision latencies for words and pseudowords as a function of their Cyrillic and Roman transcriptions.

that there was no general tendency for Roman items to be recognized more quickly than the Cyrillic version of those same items. Although the difference between groups on control words (e.g., *MUZIKA*) approached significance, $t(13) = 1.96$, $p < .10$, the magnitude of the difference for ambiguous words was significantly greater, $t(13) = 7.91$, $p < .001$. The unique Roman and the ambiguous Cyrillic forms of the ambiguous-type words differed consistently more than the Roman forms of control words. Overall, pseudowords demonstrated a smaller effect of ambiguity than did words, $t(13) = 3.6$, $p < .001$. Group 2 was always slower than Group 1; however, the magnitude of the difference between groups varied over word types. Ambiguous-type pseudowords differed more in their Roman and Cyrillic forms than did pure-type pseudowords, $t(13) = 3.74$, $p < .01$.

To ascertain the effect of ambiguous characters, another ANOVA was performed, which included only the ambiguous Cyrillic and unique Roman forms of the ambiguous-type words and pseudowords. Because of the special constraints on selecting these words, a Clark (1973) analysis was not performed. Instead, the results of an ANOVA using subject variability as the error term(s) and the results of the stimulus analysis are presented separately.

In this analysis, letter strings were classified according to the number and distribution of ambiguous characters within the letter string. As in the more complete lexical-decision analysis previously discussed, there were significant main effects of group, $F(1, 26) = 99.44$, $MS_e = 159{,}087$, $p < .001$, and length of word in syllables, $F(1, 26) = 9.62$, $MS_e = 11{,}117$, $p < .01$. In addition, the Distribution × Lexicality and Distribution × Group interactions were significant, $F(2, 52) = 3.42$, $MS_e = 8{,}761$, $p < .05$, and $F(2, 52) = 4.88$, $MS_e = 8{,}398$, $p < .05$, respectively. In contrast to previous analyses, however, lexicality only approached significance, $F(1, 26) = 2.48$, $MS_e = 57{,}878$, $p < .20$. Nevertheless, the Distribution × Group × Lexicality interaction was significant, $F(2, 52) = 10.55$, $MS_e = 8{,}761$, $p < .01$. In the stimulus analysis, there were significant main effects of group and syllable, $F(1, 24) = 224.0$, $MS_e = 5{,}563$, $p < .001$, and $F(1, 24) = 6.3$, $MS_e = 7{,}352$, $p < .05$, respectively, but the interaction of Distribution × Group missed significance, $F(2, 24) = 3.14$, $MS_e = 5{,}563$, $p < .10$. The Distribution × Group × Lexicality interaction was still significant, $F(2, 24) = 3.55$, $MS_e = 5{,}563$, $p < .05$.

Because distribution did not interact with number of syllables, means were pooled over two- and three-syllable words. Protected t tests (Cohen & Cohen, 1975) comparing the difference between means for the unique Roman and ambiguous Cyrillic transcription of the same words revealed that when the number of ambiguous syllables was controlled, the number of ambiguous characters increased latencies significantly, $t(13) = 4.58$, $p < .01$, and $t(5) = 2.76$, $p < .05$, respectively. When the number of ambiguous characters was controlled, clustering two ambiguous characters within one syllable was more difficult than having the two ambiguous letters distributed through different syllables, $t(13) = 3.00$, $p < .05$, and $t(5) = 1.81$, $p < .20$, respectively (see Table 5). For pseudowords alone, none of the contrasts among various

Table 5
Mean Reaction Time by Distribution of Ambiguous Characters for Lexical Decision on Ambiguous Cyrillic Words and their Roman Controls

Letter string	Number of ambiguous letters	Number of ambiguous syllables	Cyrillic RT	Roman RT	Difference between Cyrillic and Roman
Three syllable					
САВАНА	3	3	960	676	284
КАРАВАН	3	2	1,038	646	392
ОСТАВКА	2	2	894	710	184
Two syllable					
ОРМАН	2	2	927	655	272
САНТА	2	1	1,001	617	384
КОТВА	1	1	880	625	255

Note. Underlined letters in column 1 are ambiguous. All responses between 250 msec and 2,500 msec are included. RT = reaction time.

distributions of ambiguous letters was significant.

An ANOVA conducted on the errors in judging the lexical status of unique Roman and ambiguous Cyrillic forms of the ambiguous word type provided the same basic results as did the reaction time analysis: Main effects of lexicality and group were significant, as was their interaction; $F(1, 26) = 38.20$, $MS_e = 65.93$, $p < .001$; $F(1, 26) = 39.08$, $MS_e = 56.32$, $p < .001$; and $F(1, 26) = 31.85$, $MS_e = 65.93$, $p < .001$, respectively. Although in the error analysis, the distribution of ambiguous characters was not significant and did not interact with group, the interaction of Distribution × Group × Lexicality was again significant, $F(2, 52) = 3.82$, $MS_e = 21.29$, $p < .05$.

Discussion

The dominant theories of reading and word recognition have been developed in English and have assimilated the idiosyncracies of this phonologically deep orthography into the theory. Comparisons of the results from experiments with English and from experiments with Serbo-Croatian—a phonologically shallow orthography—permit the differentiation of universal aspects of reading from language-specific aspects. It is often claimed that fluency in reading English entails a shift away from a phonological recognition strategy (Frederiksen, 1981; LaBerge & Samuels, 1974), and this may be true given that the English orthography references morphology as well as phonology. In contrast, fluency in reading Serbo-Croatian may not entail such a shift because the Serbo-Croatian orthography has preserved a consistent reference to surface phonology. In the present experiment with Serbo-Croatian materials and Serbo-Croatian readers, the fact that two phonological interpretations could be assigned to a letter string lengthened lexical-decision times. Latency differences on the order of 300 msec computed on two forms of the same letter string, one phonologically equivocal and one phonologically unequivocal, suggest a mandatory phonological analysis in the visual recognition of Serbo-Croatian words by fluent readers of the language.

Four questions were raised in the introduction. With respect to the first question, it is evident that the effect of phonological bivalence on lexical decision is not restricted to Serbo-Croatian pseudowords. From research on English materials (Coltheart et al., 1979; Coltheart, Davelaar, Jonasson, & Besner, 1977; Meyer, Schvaneveldt, & Ruddy, 1974) it is claimed that a strategy sensitive to phonological detail is (a) more likely to be used for pseudowords and (b) conducted more slowly than a phonologically insensitive strategy (i.e., one that is specific to words). A related claim is that the phonologically sensitive strategy can be suppressed. The subjects in the present experiments all learned

Cyrillic as their first alphabet, and there is evidence that this early experience governs facility with the alphabets, even in mature readers (Lukatela, Savić, Ognjenović, & Turvey, 1978). In the present experiment, all the ambiguous strings that were words, were words in their Cyrillic reading. Given these experimental conditions, it would have been optimal to reduce the availability of the (Roman) pseudoword reading and to enhance the availability of the (Cyrillic) word reading. Apparently, these readers could not suppress their sensitivity to the phonological aspect of the presented letter strings even though it was detrimental to performance on the lexical-decision task.

With respect to lexicality and the second question raised in the introduction of this article, significant interactions of ambiguity with lexicality and of distribution of ambiguous characters with lexicality indicate that the degree of detriment due to phonological bivalence was greater for words than for pseudowords. Again, these findings run counter to the claim based on English words (Coltheart et al., 1979) that the phonological strategy is used only when the word-specific strategy fails. Moreover, with respect to frequency and the third question, the results of bivalence among words do not support the more general claim (Frederiksen, 1981) that the use of a phonological strategy is inversely related to word frequency.[6]

Two alternative accounts can be proposed for the longer lexical-decision times associated with phonologically bivalent words and pseudowords. These alternatives differ in the locus of the effect of bivalence relative to lexical access. One account is that the effect of phonological bivalence is postlexical. It arises at response output subsequent to lexical search. Phonologically ambiguous words are slowed (and more prone to error) because the "yes" response engendered by the Cyrillic reading and the "no" response engendered by the Roman reading conflict. Two pieces of evidence run counter to this account. First, as observed by Lukatela and his colleagues (Lukatela, Savić, Gligorijevic, et al., 1978; Lukatela et al., 1980), lexical decision to bivalent strings that were words by either alphabet reading (e.g., *KACA*), was no faster than lexical decision to strings that were words in Roman and pseudowords in Cyrillic (e.g., *KOBAC*). Similarly, in the present experiment, phonologically bivalent pseudoword strings in which both readings necessitated a negative response (e.g., *HEPETAC*) were slowed no less (and no more) than bivalent word strings with conflicting responses (e.g., *CABAHA*). In summary, decision latency to ambiguous letter strings associated with two responses that were either both positive or both negative was no less than decision latency to ambiguous letter strings that were associated with conflicting positive and negative responses.

The second piece of evidence against a postlexical account of phonological bivalence was the failure to find a positive correlation between the magnitude of the latency difference between the Cyrillic and Roman versions of the same word and that word's frequency. A significant effect of frequency would have provided some support for a lexicon-oriented account, given the argument that word frequency effects in lexical decision reflect lexical search and access. To the extent that the present data do reveal a trend, that trend is negative, which suggests that latency differences between the phonologically ambiguous Cyrillic version of a word and the phonologically unequivocal Roman version of a word were more pronounced the greater the word's frequency of occurrence (and the shorter the word's reaction time).

The other account of the locus of the effect of phonological bivalence suggests that it may arise prior to lexical access, and there are two versions of this account: (a) Perhaps processing letter strings in the Roman alphabet and processing letter strings in the Cyrillic

[6] It must be pointed out that the nonsignificant correlation could reflect a restricted range of word frequency. In the present experiment, all words were sampled from the midrange of word frequency. Moreover, no direct measure of word frequency was available. Instead, the unique Roman version of each word was used as an indirect measure of word frequency. In an analogous naming task conducted with the same materials (Feldman, 1981), however, a significant correlation did occur ($r = .54$). This finding suggests that neither reduced range nor indirect measure of word frequency provides an adequate interpretation for the lack of a frequency effect in lexical decision.

alphabet represent two distinct nonlinguistic modes. In this case, the detriment to performance incurred with letter strings containing ambiguous and common letters represents a conflict between two different but mandatory perceptual modes rather than a conflict between phonological interpretations. This nonlinguistic, visual account is weakened by two observations: First, as described elsewhere (Lukatela et al., 1980) and later replicated (Feldman, Kostić, Lukatela, & Turvey, 1981), in contrast to letter strings that contain common and ambiguous letters, letter strings composed entirely of common letters (e.g., *TAKA*), are not slowed in the lexical-decision task. As Lukatela and his colleagues have pointed out (Lukatela et al., 1980), to accommodate this fact into any visual account, the phonological distinction between ambiguous and shared characters needs to be introduced. Second, the nonlinguistic visual account fails to accommodate a major finding of the present study, that is, the interaction of ambiguity with lexicality. The composition of a letter string containing ambiguous and common letters affected positive lexical decisions (to words) more than negative lexical decisions (to pseudowords). (b) Alternatively, there may be a prelexical step in which letter strings are processed as Roman letter strings or as Cyrillic letter strings in which these processes represent two aspects of a linguistically analytic mode. The data that speak to the fourth question identified in the introduction support this second prelexical interpretation of the bivalence effect. The detriment incurred by phonologically bivalent letter strings varied with the number and distribution of ambiguous characters in the letter string. Counter to any standard account of word recognition based on English materials, these effects associated with ambiguous characters were more stable for words than for pseudowords. They suggest that skilled readers of Serbo-Croatian performing a lexical-decision task analyze the characters of letter strings in a manner that is sensitive to its phonological properties.

To summarize, the present results indicate that (a) irrespective of their lexical status, phonologically bivalent letter strings are associated with slower lexical decisions, (b) the detriment due to ambiguity is greater for words than for pseudowords, and (c) the degree of detriment due to bivalence does not vary with word frequency, although (d) it is sensitive to the number and distribution of ambiguous characters. Evidently, skilled readers of Serbo-Croatian are not able to suppress a phonological analysis, even when it is advantageous to do so.

Collectively, the results of the present experiment suggest a nonoptional analysis for word recognition in Serbo-Croatian that proceeds in terms of the phonology, is independent of specific lexical entries, and is sensitive to component orthographic structure. To conclude, in contrast to the data obtained on skilled readers of English, which often demonstrate a bias toward a word-specific strategy, the data obtained from skilled readers of Serbo-Croatian demonstrate a bias toward a phonologically analytic strategy.

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