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Reduction in Alphabet Priming With Delay and Degradation

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Phonologically ambiguous Serbo-Croatian words are named more slowly than their phonologically unique partners. This difference is reduced by nonword primes containing consonants unique to one or the other alphabet. In 2 experiments we investigated the hypothesis that alphabet priming is the inhibition of unique and ambiguous letter units of one alphabet by the unique letter units of the other alphabet. In Experiment 1, ambiguous and unique words followed alphabet-specific nonwords at lags between 100 ms and 1,550 ms. The ambiguous-unique difference increased from 1 ms to 45 ms, consistent with a relaxing inhibitory process. In Experiment 2 we compared priming of ambiguous words with and without visual noise. Priming was less for noisy than for intact stimuli, as would be expected if noise slows processing and if the inhibition responsible for priming weakens further during the additional processing time.

Many native speakers of Serbo-Croatian are proficient in reading the language in both of its alphabetic transcriptions, Roman and Cyrillic. Although largely distinct, these two alphabets share a number of characters. Of this shared subset, some specify the same phoneme in the two alphabets and some specify different phonemes (e.g., H is /ch/ in Roman and /n/ in Cyrillic). Consequently, words that are spelled entirely from shared characters, with at least one of those characters being of the phonemically ambiguous sort, are equivocal with regard to their phonology. Experiments show that both lexical decision times and rapid naming times are lengthened by this source of ambiguity (see the summary in Lukatela & Turvey, 1990a). For example, the word for "wind" (as in "cold wind") is written BETAP in Cyrillic and VETAR in Roman. The Cyrillic version comprises all shared letters with two ambiguous letters, B and P. By contrast, the Roman version contains no ambiguous letters; V, T, and R are unique to the Roman alphabet. What the experiments show is that responses to words of the BETAP kind are always slower than responses to words of the VETAR kind (e.g., Feldman & Turvey, 1983; Lukatela, Feldman, Turvey, Carello, & Katz, 1989; Lukatela, Turvey, Feldman, Carello, & Katz, 1989).

Given this effect of phonological ambiguity on the bialphabetical reader, one might ask whether the effect is circumvented in the ordinary reading of text. Arguably, a text that is Roman will not encourage letter coding according to Cyrillic conventions. It is the case, however, that experiments in which unique Cyrillic letters never appear, and in which ambiguous Roman letters appear rarely, still provide strong evidence for the general slowing of responses to phonologically ambiguous words (e.g., Lukatela, Savić, Gligorijević, Ognjenović, & Turvey, 1978). The implication is that the effect of phonological ambiguity is not easily overridden by the awareness that the material is solely in one or the other alphabet. By contrast, other experiments (Lukatela, Feldman, et al., 1989; Lukatela, Turvey, et al., 1989; Lukatela, Turvey, & Todorović, 1991) provide evidence that the effect of phonological ambiguity can be attenuated significantly, and almost eliminated, by a context that specifies the alphabet in which an immediately following phonologically ambiguous target is a word. The implication of this latter research is that there is an automatic mechanism operating at a short time scale that can suppress one or the other letter-coding conventions. Of particular importance are the experiments of Lukatela et al. (1991). These demonstrated a reduction of the phonological ambiguity effect under conditions in which the alphabetic context (same or other) was forward masked and under conditions in which the alphabetic context (same or other) acted as a backward mask. Given that target lexical access is incomplete with backward pattern masks, and given identical mask parameters, the observation of different effects of same- and other-alphabet masks suggest different alphabetic contributions to the prelexical processes initiated by the targets (see arguments in Lukatela & Turvey, 1990b; Perfetti, Bell, & Delaney, 1988).

The experiments reported in this article were directed at the nature of the mechanism by which the reduction of the phonological ambiguity effect is achieved. The research to date suggests that its operation is confined to low levels of the visual word recognition process. Suppose that the bialphabetical reader of Serbo-Croatian can be modeled, in part, by a network of processing units: featural, letter, phoneme, and word (Lukatela, Turvey, et al., 1989; Lukatela, Carello, & Turvey, 1990). There is evidence to suggest that the letter (processing) units of the Cyrillic and Roman alphabets constitute functionally distinct sets (Lukatela, Savić, Ognjenović, & Turvey, 1978). The model is characterized by four key ideas: (a) At the level of letter units, each ambiguous letter is represented twice, once in the Cyrillic and once in the Roman set; (b) no phoneme units are duplicated; (c) there are multiple inhibitory connections across letter positions; and (d) a two-way interactive process is initiated between the

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phoneme unit and word unit levels. We now present two examples in detail.

Figure 1 shows a network model of Serbo-Croatian word recognition for the phonologically unique word EП and the phonologically ambiguous word EP, both meaning *epic.* At the level of *letter units,* shared phonologically unambiguous units are found at the intersection of the Cyrillic and Roman sets; shared phonologically ambiguous units are represented in both sets. At the level of *phoneme units,* none are duplicated; some have connections from two letter units (e.g., /p/ activated by the Cyrillic П in EП and the Roman P in EP). The array of letter units and phoneme units is for a specific position (cf. McClelland & Rumelhart, 1981) so that activation of E in the first position activates, at the level of *word units,* only those words with E in the first position. These word units, in turn, interact with phoneme units in the proper positions (for the sake of simplicity in Figure 1, this aspect of the model is not depicted). The left panel of Figure 1 shows that activation of a phonologically unambiguous shared letter E activates a single phoneme unit. Activation of a phonologically unique Cyrillic letter unit П activates a single phoneme unit and promotes inhibition of Roman letter units at adjacent locations. The right panel of Figure 1 shows that activation of a phonologically unambiguous shared letter E again activates a single phoneme unit. Activation of a phonologically ambiguous shared letter P activates two phoneme units, /r/ from the Cyrillic P and /p/ from the Roman P. In this case, more word units (e.g., /— r — —/ stands for all words with *r̀* in second position) are activated so that it takes longer for a single word unit to dominate the activation.

Alphabetic priming would come about as follows (results of a computer simulation are provided in Lukatela et al., 1991): A context letter string containing one or more unique characters would, as remarked, inhibit strongly the letter units of the other alphabet at the other letter positions. This inhibitory effect will still be present when the phonologically ambiguous target word appears; it has a relaxation time that can exceed the time separating the two successive stimuli. For EP-type letter strings following a consonant context such as CF, which specifies the Roman alphabet, the word units consistent with /r/ in the second position (the Cyrillic interpretation of P) would be excited only weakly in comparison to how they would be excited in the absence of such a context. Therefore, the competitive process at the word unit

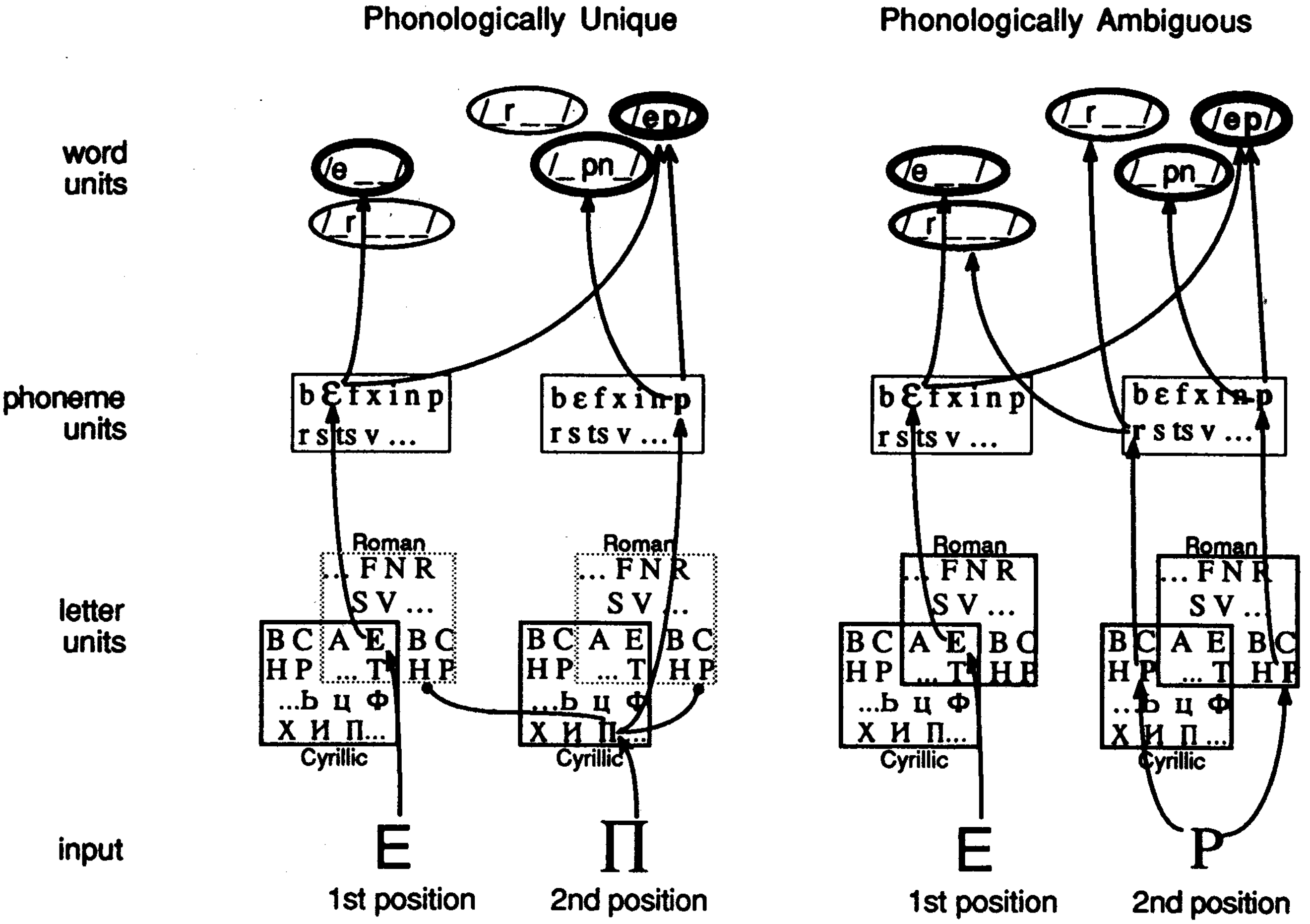

Figure 1. A network model of Serbo-Croatian word recognition. (Connections between levels are represented by lines ending in arrowheads. Inhibition within a level is indicated by lines ending in large dots. For simplicity, top-down influences from the word units to the phoneme units are not depicted. See the text for details of this example.)

level would be defined mainly, but not exclusively, over the word units excited by the phoneme units /e/ in the first position and /p/ in the second position (and so on for longer words).

Suppose that EP-type letter strings are presented subsequent to a consonant context such as Цф that specifies the Cyrillic alphabet (i.e., contains unique Cyrillic characters) rather than the Roman alphabet in which an EP-type letter string has a lexical entry. According to the preceding argument, word units connected to the phoneme units /e/ in the first position and /r/ in the second position (and so on for longer words) would be activated strongly at the onset of the target, and those connected with the phoneme unit /p/ in the second position would be activated weakly. In its early stages, therefore, the competitive process can be expected to favor word units other than that of "epic" (/ep/). As the competitive process proceeds, however, the word unit for "epic" is more likely than any other unit to assume dominance because no other word unit satisfies simultaneously all of the constraints. This means that although EP-type letter strings would be responded to more slowly in the Cyrillic (other) alphabet context than in the Roman (same) alphabet context, they would nonetheless be responded to correctly on more occasions than they would be responded to incorrectly.

Experiment 1

In the first experiment we conducted a test of the hypothesis that the benefits of alphabetic priming decrease with the delay between (a) a context specifying the alphabet in which a phonologically ambiguous target word is a word and (b) the phonologically ambiguous target word. If the basis of the alphabetic priming that reduces the phonological ambiguity effect is an inhibitory process that decays with time, then the ambiguity effect ought to increase as the onset asynchrony of context and target increases. The experiment was conducted with naming latency as the dependent measure. In our model of Serbo-Croatian word recognition, naming is based on the states of phoneme units, whereas lexical decision is based on the states of word units. According to the model, the inhibition generated among letter units affects the phoneme units most directly.

As implied in the introduction, the preferred strategy for examining the phonological ambiguity effect uses words for which there is both a unique form and an ambiguous form. Thus, the Roman form VETAR is unique (analogous to the unique Cyrillic ЕП in Figure 1), whereas its Cyrillic form BETAP is ambiguous (analogous to the ambiguous Roman EP in Figure 1). We therefore addressed the time course of the hypothesized inhibitory process through contrasts of the BETAP versus VETAR kind. Given BETAP and VETAR, both preceded by a same-alphabet context at stimulus onset asynchronies (SOAs) of 100, 550, 1,050, and 1,550 ms, the difference between them should be least at the briefest SOA and most at the longest SOA, implicating a decline in the inhibitory influence of the same-alphabet context with time.

Method

Subjects. Forty students from the Department of Psychology at the University of Belgrade participated in partial fulfillment of a course requirement. A subject was assigned to one of eight groups, with 5 subjects per group.

Materials. A set of 40 phonologically ambiguous Cyrillic (e.g., BETAP /vetar/ = "the wind") and 40 phonologically ambiguous Roman (e.g., BOCA /botsa/ = "the bottle") words were used as target stimuli. All words were of the consonant–vowel–consonant–vowel (CVCV) or VCVC type. As such, all letter strings were orthographically and phonotactically legal by both readings and easily pronounceable in both readings. Most (approximately 75%) were four to five letters in length and bisyllabic. The remainder were mono- or trisyllabic. In addition, the phonologically ambiguous words were transcribed in the "other" alphabet to produce another set of 40 phonologically unique Roman (e.g., VETAR /vetar/ = "the wind") and 40 phonologically unique Cyrillic (БОЦА /botsa/ = "the bottle") target words. (These 80 words virtually exhaust the set of words in the language that satisfy the BETAP–VETAR form; that is, they are words that are ambiguous when written in one alphabet and unique when written in the other.) The contexts were three, four, or five consonant letter strings, with all letters in a string unique to either the Roman or the Cyrillic alphabet.

Two counterbalanced lists of 130 context–target pairs were prepared. In each list there was a set of 40 phonologically ambiguous target words, 40 phonologically unambiguous target words, and a filler set of 50 phonologically ambiguous target words. The filler words were ordinary words in the sense that they did not become unambiguous when written in the alternative alphabet and therefore had no same-word control (to reiterate, words of the BETAP–VETAR kind are limited in number). The 80 targets were preceded by same-alphabet contexts, and the 50 fillers were preceded by other-alphabet contexts. Half of the stimuli were transcribed in Cyrillic letters and half were transcribed in Roman letters. The analysis was restricted to the 80 targets preceded by same-alphabet contexts. This latter feature was motivated by the desire to keep the division of the limited BETAP–VETAR set to a minimum so that the ambiguous versus unambiguous contrast in same-alphabet contexts could be evaluated with the largest possible number of pairs (i.e., 40 vs. 40). Because it is well established that same-alphabet contexts lead to faster naming than other-alphabet contexts (see the introduction), we did not think that a further examination of the comparison in this experiment was necessary. The focus of this experiment was to determine whether the benefits to processing unambiguous words due to same-alphabet contexts would dissipate with SOA.

Design. There were four delays between the context and target. Those interstimulus intervals (ISIs) were 50 ms, 500 ms, 1,000 ms, and 1,500 ms. A given subject never encountered a word or consonant string more than once, never encountered both the ambiguous and unambiguous forms of a word, and never encountered the pseudowords created from the presented words, but every subject saw every type of experimental context–target pair (phonologically ambiguous and phonologically unambiguous targets) at four different ISIs. These conditions were met with eight counterbalancing groups. In total, each subject saw 80 experimental plus 50 filler pairs ordered pseudorandomly.

Procedure. A subject was seated comfortably before the monitor of an Apple IIe computer in a dimly lit room. A fixation point was centered on the screen. This point was removed from the screen only during presentations of stimuli. On each trial, the subject heard a brief warning signal, after which a consonant string appeared for 50 ms, horizontally centered at the fixation point. After a pseudorandomly variable ISI (50 ms, 500 ms, 1,000 ms, or 1,500 ms), a target word appeared that was also centered at the fixation point for 200 ms. These temporal quantities were nominal rather than exact because display changes, in reality, occurred within the standard 16-ms scan rate of the Apple IIe monitor.

Subjects were instructed to pronounce each target letter string as rapidly and distinctly as possible. No special instructions were needed concerning the fact that the stimuli were phonologically ambiguous words given that there was nothing extraordinary about them in the subjects' everyday experiences. Latency from the onset of the target to the onset of the response was measured by a voice-operated trigger relay. Naming was considered to be erroneous when the pronunciation was not smooth (i.e., a subject hesitated after beginning the name). All naming responses were taped. (To ensure that subjects were reading the contexts, a computer message appeared on five randomly selected trials requesting that they report orally the context after the target word had been named. Given that the context was a consonant string, this message was a prompt to report as many consonants as possible.) If the response latency was longer than 1,200 ms, a message appeared on the screen requesting that the subject name more quickly. All response latencies (including those longer than 1,200 ms) were stored in the computer memory. The intertrial interval was 2,000 ms. The experimental sequence was preceded by a practice sequence of 20 different stimulus pairs. The whole session lasted about 20 min.

Results and Discussion

Data analyses were restricted to the 80 target items preceded by same-alphabet contexts. Mean latencies, mean errors, and standard deviations are presented in Table 1. Because the items nearly exhaust the set of BETAP–VETAR words, an items analysis is not warranted. An analysis of variance (ANOVA) on subject means for the latency measure revealed a significant main effect of ambiguity, $F(1, 39) = 31.76$, $p < .001$, and a significant main effect of SOA, $F(3, 117) = 90.48$, $p < .001$. (The latencies decreased, on the average, with increasing delay between the context and the target, from 692 ms to 588 ms. Such inverse dependencies in reaction time data are not uncommon; Gottsdanker, 1980.) Additionally, there was a significant Ambiguity × SOA interaction, $F(3, 117) = 8.15$, $p < .001$. As can be seen in Table 1, the effect of phonological ambiguity (ambiguous minus unambiguous) increased with an increasing SOA from 1 ms at SOA = 100 ms to 46 ms at SOA = 1,550 ms. An ANOVA on errors showed a significant effect only of ambiguity, $F(1, 39) = 22.99$, $p < .001$.

In summary, the outcome of Experiment 1 was consistent with the hypothesis that the presentation of an unambiguous Serbo-Croatian letter string exerts a selective but temporary inhibitory influence on the letter–phoneme connection matrix. The experimental result was that the advantage of preceding a phonologically ambiguous word such as BETAP by an alphabet context matching the alphabet (Cyrillic) in which BETAP is read as the word /vetar/ declined with the delay between the context and BETAP. The greater the delay, the more pronounced became the phonological ambiguity effect: the magnitude of the superiority in speed of naming of VETAR over BETAP. The experimental outcome, however, might entail other hypotheses. For example, given that the experimental stimuli (same-alphabet contexts) exceeded the fillers (other-alphabet contexts) in the ratio of 8:5, subjects may have been biased to expect a target that was alphabetically congruent with the context. Consistent with an expectancy hypothesis is the tendency in the data for latencies in both conditions to shorten with increasing SOA (see Table 1), although such a result is commonplace in reaction time tasks regardless of their form and content (Gottsdanker, 1980). It is generally assumed that expectancy effects operate on a slower time scale than automatic effects given that the underlying mechanism is analogous to a shifting of focus or a switching of encoding mechanisms initiated by the priming stimulus (e.g., Posner & Snyder, 1975). The point is that whereas automatic processes may have been responsible for the elimination of the phonological ambiguity effect at the shortest SOA, expectancy mechanisms may have played a role at the longer SOAs. For example, expectancy mechanisms might aid the unambiguous letter strings more so than their ambiguous counterparts, in which case the restoration of the BETAP versus VETAR difference at the longer SOAs would not be due solely to a relaxation of automatic inhibitory processes. Although such a preferential effect would not be expected from the interactive network depicted in Figure 1, it is a possibility to be considered. In a similar vein, a role for short-term memory processes can be imagined given the nature of the experimental task (and the requirement to keep the context in memory for possibly future recall). Suppose, for example, that for the longer SOAs the subjects must rehearse the context and that this rehearsal is detrimental to the processing of the (putatively) more difficult ambiguous items. The upshot would be, once again, a restoration of the BETAP versus VETAR difference that is not solely due to a relaxation of automatically established inhibitory processes.

Patently, to establish more firmly the relaxation hypothesis, a task is needed in which possible strategic contributions (e.g., bringing to bear expectancy and rehearsal mechanisms)

Table 1
Mean Naming Latencies, Error Rates, and Standard Deviations for Phonologically Ambiguous Words (e.g., BETAP*) and Their Phonologically Unambiguous Counterparts (e.g.,* VETAR*) Following Same-Alphabet Contexts as a Function of SOA in Experiment 1*

	100 SOA				550 SOA				1,050 SOA				1,550 SOA			
	L		ER		L		ER		L		ER		L		ER	
Target	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Ambiguous	693	73	5.1	6.7	613	67	5.1	8.8	591	71	6.5	9.0	611	72	7.2	8.0
Unambiguous	692	81	0.9	2.9	593	66	2.3	4.3	573	65	1.2	3.9	565	67	2.3	4.8
Difference	1.0		4.2		20.0		2.8		18.0		5.3		46.0		4.9	

Note. L = latency (in milliseconds); ER = error rate (in percentages); SOA = stimulus onset asynchrony.

are constant for different levels of the context-induced inhibition. In Experiment 2, these task requirements were met by a manipulation that slowed the processing of the target stimulus for a fixed lag between the alphabet prime and the target. Evidence for the relaxation hypothesis takes the form of a statistical interaction revealing a weakening of the effect of a same-alphabet context under conditions in which the processing of the ambiguous target is protracted.

Experiment 2

It has been argued that a reduction in the quality of a visually presented word retards processing (e.g., Becker & Killion, 1978; Besner & Smith, 1992; Meyer, Schvaneveldt, & Ruddy, 1975). Accordingly, degrading phonologically ambiguous targets such as BETAP should extend the lag time from presentation to activation beyond threshold of the relevant processing units. What consequences would this slowing of processing have for the hypothesized influence of an alphabetic context? Turning to our model, any Cyrillic letter string preceding BETAP will, as noted, inhibit /b/ in the first position and /p/ in the last position by means of the inhibitory connections among letter units. According to the model, this inhibition decays in time, a hypothesis supported by the results of Experiment 1. In consequence, any manipulation that retards the processing of BETAP—such as degradation—should result in a lowered level of inhibition at the time that BETAP activates its respective phoneme units. That is, for the same context–target onset asynchrony, the inhibition of the competing phoneme units /b/ and /p/ will be less when BETAP is degraded than when it is intact. With degradation, the processing of BETAP in a Cyrillic context will approximate more closely the processing of BETAP in the absence of context. Similarly, with degradation, the processing of BETAP in a Roman context—one that inhibits /v/ and /r/ in the first and fifth positions—will approximate more closely the processing of BETAP in the absence of context. In sum, stimulus quality and alphabetic context should interact such that degrading a phonologically ambiguous target should *reduce* the contrast between the same-alphabet context and the other-alphabet context.

The same prediction can be made for the naming of phonologically ambiguous pseudowords despite the absence in their case of a straightforward application of matching alphabet context versus mismatching alphabetic context. For a pseudoword generated by changing a word, the designations "same alphabet" and "other alphabet" refer to the match between the alphabet of the context word and the alphabet of the source word from which the pseudoword was derived. For example, if BEMAP is a phonologically ambiguous pseudoword derived from BETAP (the Cyrillic form of the word for "wind"), then an unambiguous Cyrillic context would be designated "same alphabet" and an unambiguous Roman context would be designated "other alphabet." Previous research has shown that BEMAP is named faster when preceded by a "same-alphabet" context (i.e., Cyrillic) than an "other-alphabet" context (i.e., Roman; Lukatela, Feldman, et al., 1989). Analysis of the phonemic content of the naming responses (how many were named using purely the Cyrillic code, using purely the Roman code, and using a mixture of both) revealed that when BEMAP was preceded by an other-alphabet context, it was named 52.5% of the time in that context and that when BEMAP was preceded by a same-alphabet context, it was named 73.6% of the time in the alphabet of that context. In terms of the model, the activation patterns defined over the phoneme units are shaped by alphabetic priming and by the feedback influences from the level of word units. The structure of the names given to pseudowords such as BEMAP is therefore consistent with the understanding that the patternings imposed on the phoneme level by alphabetic priming were at odds in the other-alphabet context and in agreement in the same-alphabet context (Lukatela, Feldman, et al., 1989). As a result, pseudowords such as BEMAP are named faster following a same-alphabet context. For this experiment, the consequence of the preceding is that any manipulation that retards the processing of BEMAP (e.g., degradation) should result in a lowered level of context-induced inhibition at the time BEMAP activates its respective phoneme units and thereby a reduction in the benefits of a same-alphabet context over an other-alphabet context.

Method

Subjects. A total of 56 high school seniors from the Fifth Belgrade Gymnasium were paid for their participation in the experiment. They were assigned randomly to one of four counterbalancing groups according to their appearance at the laboratory.

Materials. A basic set of 28 phonologically ambiguous Cyrillic and 28 phonologically ambiguous Roman words was selected. All words were of the CVCV or VCVC type. As such, all letter strings were orthographically and phonotactically legal by both Cyrillic and Roman readings and easily pronounceable in both readings. Most (80%) were four to five letters in length and bisyllabic. The remainder were mono- or trisyllabic. A corresponding set of 56 phonologically ambiguous pseudowords was created from the set of 56 phonologically ambiguous words by changing one or two letters.

Contexts were drawn from a set of 56 randomly selected phonologically unique words. The ability to reduce phonological ambiguity is identical for phonologically unique consonant strings as contexts (as used in Experiment 1) and phonologically unique words as contexts (Lukatela, Turvey, et al., 1989). We felt that the subject's interest level could be more easily maintained with context stimuli that were words. With respect to target words, on half of the trials the context word was written in the same alphabet as that in which the target word was readable as a word, and on half of the trials the context word was written in the alphabet in which the target word was not readable as a word. These defined, respectively, the same-alphabet and other-alphabet conditions. For the pseudowords, the designations same alphabet and other alphabet referred to the match between the alphabet of the context word and the alphabet of the source word from which the pseudoword was derived.

There were equal numbers of Roman–Roman, Roman–Cyrillic, Cyrillic–Cyrillic, and Cyrillic–Roman pairs. Half of the targets were degraded and half were intact. Degradation was achieved by superimposing a random arrangement of 72 dots. Thirty-two unambiguous word and 32 unambiguous pseudoword fillers were included, 24 of each preceded by a row of Xs and 8 of each preceded by unrelated word contexts written in the same alphabet as the target. These filler items were to provide a baseline with which to compare the reduction in the phonological ambiguity effect that was expected as a function of alphabetic priming.

Design. In contrast to Experiment 1, only one SOA was used. On the basis of the delay-dependent effects reported in Table 1, and in order to avoid forward masking (given the increased susceptibility due to degradation), we chose an intermediate context–target SOA of 800 ms. A given subject never encountered a word or pseudoword in any of the pairs more than once, but every subject saw every type of pair (alphabetically same and different, degraded and intact, and experimental and filler), and every experimental target appeared with both types of contexts and as degraded and intact. When a word was alphabetically primed, its derived pseudoword was not and vice versa. These conditions were met with four counterbalancing lists. In total, each subject saw 112 experimental plus 64 filler pairs ordered randomly.

Procedure. The presentation of stimuli was the same as that used in Experiment 1. Latencies were measured from the onset of the target. If the response latency was longer than 1,400 ms, a message appeared on the screen requesting that the subject respond more quickly. The intertrial interval was 2,500 ms.

Results and Discussion

Average latencies, standard deviations, and errors for word and pseudoword targets are shown in Table 2. In a 2 (alphabetic context) × 2 (stimulus quality) × 2 (lexicality) ANOVA on subject means for target latencies, all main effects were significant: alphabetic context, $F(1, 59) = 53.25$, $MS_e = 3{,}375$, $p < .001$, with same-alphabet contexts eliciting faster responses (770 ms) than other alphabet contexts (809 ms); stimulus quality, $F(1, 59) = 179.77$, $MS_e = 4{,}099$, $p < .001$, with degraded targets eliciting slower responses (828 ms) than intact targets (750 ms); and lexicality, $F(1, 59) = 283.6$, $MS_e = 16{,}047$, $p < .001$, with words faster (691 ms) than nonwords (887 ms). The all-important interaction between alphabet and stimulus quality was significant, $F(1, 59) = 10.31$, $p < .01$, as was Stimulus Quality × Lexicality, $F(1, 59) = 4.08$, $p < .05$. The remaining two-way interaction and the three-way interaction were insignificant ($Fs < 1$).

As is evident from comparing Tables 1 and 2, the errors for the same-alphabet conditions were similar in magnitude to those in the comparable conditions of Experiment 1. The large error rates for the different alphabet conditions compare favorably with previous research (e.g., Lukatela, Turvey, et al., 1989) and typify the phonological ambiguity effect. In the ANOVA on errors, alphabet was significant (same = 8.3%, different = 21.8%), $F(1, 55) = 72.8$, $MS_e = 139$, $p < .001$, and stimulus quality (intact = 13.3%, degraded = 20.5%) was significant, $F(1, 55) = 55.4$, $MS_e = 118$, $p < .001$, but lexicality (words = 15.3%, pseudowords = 18.5%) was marginally insignificant, $F(1, 55) = 3.6$, $MS_e = 360$, $p > .05$. The two-way interaction of alphabet and stimulus quality was not significant, $F(1, 55) = 1.08$, $p > .05$, but both of the two-way interactions involving lexicality were significant: for alphabet and lexicality, $F(1, 55) = 14.37$, $MS_e = 155$, $p < .001$; for stimulus quality and lexicality, $F(1, 55) = 18.34$, $MS_e = 105$, $p < .001$. The three-way interaction was not significant ($F < 1$).

Table 2
Mean Naming Latencies, Error Rates, and Standard Deviations for Phonologically Ambiguous Words and Pseudowords as a Function of Stimulus Quality and Alphabet Context in Experiment 2

	Same alphabet context				Different alphabet context			
	L		ER		L		ER	
Target/quality	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Words								
Intact	627	71	7	8	686	90	20	16
Degraded	712	89	10	10	740	103	24	17
Pseudowords								
Intact	819	126	11	11	867	113	15	12
Degraded	920	128	21	14	940	125	27	16

Note. L = latency (in milliseconds); ER = error rate.

Consistent with the findings of Lukatela, Turvey, et al. (1989), Lukatela, Feldman, et al. (1989), Lukatela et al. (1991), and Experiment 1, there was an alphabetic priming effect. (In addition to the analyses described earlier, we can note that the latencies to intact phonologically ambiguous words in a same-alphabet context were comparable to the latencies to the unique filler words; 627 ms versus 618 ms.) Of major theoretical significance was the finding that degradation reduced the facilitation of naming speed by alphabetic priming (same alphabet minus different alphabet equaled 54 ms for intact and 24 ms for degraded).

General Discussion

The phonemic precision and bialphabetism of Serbo-Croatian suggest a unique set of constraints on the initial processes of word recognition. We have characterized these constraints in terms of a highly particular network of inhibitory connections between two functionally distinct sets of letter-processing units representing the Roman and Cyrillic alphabets and excitatory connections between letter-processing units and phoneme-processing units (Lukatela, Turvey, et al., 1989). The two experiments were directed at properties of the proposed network's dynamics. Specifically, in Experiment 1 we tested, and found evidence for, the assumption that the inhibitory process initiated by a letter string on the pattern of letter-to-phoneme connections relaxes or decays over a time scale that appears to be (a) sufficiently long to facilitate the processing of a phonologically ambiguous word following within approximately 1–2 s; and (b) sufficiently short to require reinitializing every 1 or 2 s if the reading of ordinary text, with the standard complement of phonologically ambiguous words, is to proceed with minimal impedance from the built-in ambiguities of the written language. As noted, the experiments of Lukatela, Savić, Gligorijević, Ognjenović, and Turvey (1978) failed to eliminate the phonological ambiguity effect through experimentwide conditions that restricted the presented stimuli to one of the two alphabets and directed subjects to regard all stimuli as transcribed in only one alphabet. The upshot is that the control over the letter-coding convention in reading Serbo-Croatian is achieved by a short-term mechanism that operates automatically, triggered by letters unique to one alphabet. The control is by "local" stimulation not by "global" strategy.

In Experiment 2 we tested the prediction that stimulus quality should interact with alphabetic context to reduce the effect of alphabetic context. The results of the second experiment were consistent with the prediction: Naming latencies to degraded words were affected less by alphabetic context than naming latencies to intact words. The result of Experiment 2 should be compared with the finding of a number of experiments with English-language materials that visually degraded words are affected *more* by semantic or associative contexts than visually intact words (e.g., Becker & Killion, 1978; Massaro, Jones, Lipscomb, & Scholz, 1978; Meyer et al., 1975). Do the contrasting observations of degradation reducing alphabet priming and enhancing associative priming point to a qualitative difference in the interactive processes between the lower and higher levels of the word-processing system? Our suspicion is that they do not. Rather, we think that the difference is a function of the different time scales of activation and relaxation at the letter and word levels. A reasonable assumption is that the rise and fall of activity at the level of letter-processing units occur at faster rates than at the level of word-processing units. Where given conditions of stimulus presentation (e.g., an SOA of 500 ms) may find the inhibitory processes at the lower letter-units level in decline, they may find the excitatory processes at the higher word-units level in ascendancy. An implication of this conjecture is that the direction (increase vs. decrease) of context by stimulus quality interactions will depend importantly on SOA. With target degradation, parametric variation in lag time should reveal both increases and decreases in both alphabetic priming and associative priming. If the differential time scales hypothesis is correct, then the latter fact points to a potential influence of type of writing system (e.g., patterns of orthographic–phonological covariation, orthographic depth) on the level-specific time scales.

To summarize, the two experiments reported in this article lend support to the model of Serbo-Croatian word recognition proposed by Lukatela, Turvey, et al. (1989; see also Lukatela & Turvey, 1990a; Lukatela et al., 1991). The hypothesized network of letter units and phoneme units is a highly particular product of reading and hearing the Serbo-Croatian language, of learning the covariances in that language between letters and phonemes (see Van Orden, 1987). The partial confirmation by these experiments of this processing architecture specific to a reader of Serbo-Croatian is buttressed by other experiments in which forward and backward masking of nonword alphabet contexts suggest that the processes responsible for alphabet priming are automatic and prefatory to the level of word units (Lukatela et al., 1991). In our view, an important implication of these various experiments is that a complete theory of visual word recognition will need to honor the differences in processing architectures induced by differences in writing systems. As Henderson (1982) has remarked with respect to the commonly held view that lexical access is routinely visual and occasionally phonological,

> so vigorous have been the attempts to apply the dual-process conception to the diverse types of orthography . . . that we have laid too much stress upon the universality of cognitive processes in the reading of various scripts. The question as to which strategies are universal and which script-specific remains open and inviting. (p. 7)

References

Becker, C. A., & Killion, T. H. (1978). Interaction of visual and cognitive effects in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 3,* 389–401.

Besner, D., & Smith, M. C. (1992). Models of visual word recognition: When obscuring the stimulus yields a clearer view. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 468–482.

Feldman, L. B., & Turvey, M. T. (1983). Word recognition in Serbo-Croatian is phonologically analytic. *Journal of Experimental Psychology: Human Perception and Performance, 9,* 288–298.

Gottsdanker, R. (1980). The ubiquitous role of preparation. In G. E. Stelmach & J. Requin (Eds.), *Tutorials in motor behavior* (pp. 355–372). Amsterdam: North-Holland.

Henderson, L. (1982). *Orthography and word recognition in reading.* San Diego, CA: Academic Press.

Lukatela, G., Carello, C., & Turvey, M. T. (1990). Phonemic priming with words and pseudowords. *European Journal of Cognitive Psychology, 2,* 375–394.

Lukatela, G., Feldman, L. B., Turvey, M. T., Carello, C., & Katz, L. (1989). Context effects in bi-alphabetical word perception. *Journal of Memory and Language, 28,* 214–236.

Lukatela, G., Savić, M., Gligorijević, B., Ognjenović, P., & Turvey, M. T. (1978). Bi-alphabetical lexical decision. *Language and Speech, 21,* 142–165.

Lukatela, G., Savić, M., Ognjenović, P., & Turvey, M. T. (1978). On the relation between processing the Roman and Cyrillic alphabets: A preliminary analysis with bi-alphabetical readers. *Language and Speech, 21,* 113–141.

Lukatela, G., & Turvey, M. T. (1990a). Phonemic similarity effects and prelexical phonology. *Memory & Cognition, 18,* 128–152.

Lukatela, G., & Turvey, M. T. (1990b). Automatic and pre-lexical computation of phonology in visual word identification. *European Journal of Cognitive Psychology, 2,* 325–343.

Lukatela, G., Turvey, M. T., Feldman, L. B., Carello, C., & Katz, L. (1989). Alphabetic priming in bi-alphabetical word perception. *Journal of Memory and Language, 28,* 237–254.

Lukatela, G., Turvey, M. T., & Todorović, D. (1991). Is alphabet biasing in bi-alphabetical word perception automatic and prelexical? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 653–663.

Massaro, D. W., Jones, R. D., Lipscomb, C., & Scholz, R. (1978). Role of prior knowledge on naming and lexical decisions with good and poor stimulus information. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 4,* 498–512.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88,* 375–407.

Meyer, D. E., Schvaneveldt, R. W., & Ruddy, M. G. (1975). Loci of contextual effects on visual word-recognition. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance* (Vol. 5, pp. 98–118). San Diego, CA: Academic Press.

Perfetti, C. A., Bell, L. C., & Delaney, S. M. (1988). Automatic (prelexical) phonemic activation in silent reading: Evidence from backward masking. *Journal of Memory and Language, 27,* 59–70.

Posner, M. I., & Snyder, C. R. R. (1975). Facilitation and inhibition in the processing of signals. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance* (Vol. 5, pp. 669–682). San Diego, CA: Academic Press.

Van Orden, G. C. (1987). A ROSE is a ROSE: Spelling, sound, and reading. *Memory & Cognition, 15,* 181–198.

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