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Alphabet Priming in Bi-alphabetical Word Perception

G. LUKATELA

University of Belgrade

M. T. TURVEY

University of Connecticut and Haskins Laboratories

LAURIE B. FELDMAN

Haskins Laboratories

CLAUDIA CARELLO

University of Connecticut

AND

L. KATZ

University of Connecticut and Haskins Laboratories

Serbo-Croatian is transcribed in two partially overlapping alphabets. Some shared letters are pronounced differently in the two alphabets. Consequently, a word composed of shared ambiguous and unambiguous letters and no alphabetically unique letters is phonologically ambiguous. Ordinarily, visual recognition of such words is slowed relative to appropriately controlled, phonologically unambiguous words. Experiments showed that this phonological ambiguity effect is reduced substantially and equally by either a consonant string or a word that immediately precedes the target and specifies its alphabet. Alphabetic priming was also found for targets that contain both ambiguous and unique letters but not for targets without ambiguous letters. Other evidence showed, however, that alphabet priming can be offset by accessed lexical information. Results were discussed in terms of a connectionist model.

The Serbo-Croatian language is written with two partially overlapping script systems, Roman and Cyrillic. Seven upper case letters are shared. Of these common letters, four are ambiguous in the sense that they refer to different phonemes. For example, in IPA notation, H is read in Roman as /xə/ and in Cyrillic as /nə/. Other letters are shared by both alphabets but receive the same phonemic interpretation in each. For example, the letter M occurs in both alphabets but is unambiguous because it is interpreted the same way in each. Because of the two, partially overlapping, script systems, certain words are written with a combination of letters that do not specify the alphabet in which the word is to be read. BETAP and VETAR, for example, are the Cyrillic and Roman spellings, respectively, of the common word "wind" (as in "the wind is blowing"). The five letters in BETAP are shared by the two alphabets, and B and P are assigned different pho-

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nemes in two alphabets. **VETAR**, in contrast, contains the uniquely Roman letters **V** and **R** and is, therefore, phonologically unambiguous. It has been established that lexical decision and naming are much slower for **BETAP**-type words than for **VETAR**-type words, and for **BEMAP**-type pseudowords than for **VEMAR**-type pseudowords (e.g., Feldman & Turvey, 1983; Lukatela, Popadić, Ognjenović, & Turvey, 1980; Lukatela, Feldman, Turvey, Carello, & Katz, 1989). This phenomenon is termed the phonological ambiguity effect.

Lukatela et al. (1989) reported lexical decision and rapid naming experiments directed at contextually reducing the phonological ambiguity effect as defined by the **BETAP–VETAR** and **BEMAP–VEMAR** contrasts. In a typical experiment a target word or pseudoword was preceded by a context word that was written either in the alphabet of the target or in the other alphabet. For example, if the target was a Cyrillic word (e.g., **BETAP**), then the context was a word written either in Cyrillic or in Roman. The main finding was that in both lexical decision and naming tasks the **BETAP–VETAR** difference was reduced substantially when the context was in the same alphabet as the target (Cyrillic for **BETAP** and Roman for **VETAR**).

Collectively, the results of Lukatela et al. (1989) suggest the following. A phonologically ambiguous word such as **BETAP** activates all the phonemic interpretations that its letter structure allows, namely, /və/ and /bə/ in the 1st position, /ɛ/ in the 2nd, /tə/ in the 3rd, /a/ in the 4th, and /rə/ and /pə/ in the 5th position. Any immediately preceding word, whose structure uniquely specifies the alphabet (Cyrillic) in which **BETAP** has a lexical entry, disposes the word processing system to /və/ in the 1st position more than to /bə/, and to /rə/ in the 5th position more than to /pə/. As a result, the lexical entry for "wind" is accessed sooner than when **BETAP** is presented (a) without an immediate context of any kind, and (b) after a word in the other alphabet. If the same-alphabet context word is also a word that is an associate of **BETAP**, such as the word "storm," then "wind" is accessed even faster. From the results obtained by Lukatela et al. (1989), these two contextual influences on **BETAP**, the alphabetic and the associative, do not appear to be related. The effect of one contextual influence is exerted independently of the other, suggesting that they occur at different levels of the word processing system.

In the present article we raise and address four questions that should extend significantly our understanding of the contextual effect of alphabet specification. First, is there an effect of alphabet specification when the context is not a word (Experiment 1)? That is, can the effect be observed when the context has no match in the lexicon? Second, is there an effect of alphabet specification when the target letter string contains at least one unique letter (Experiment 2)? That is, can the effect be observed when the target word contains one or more ambiguous letters but is, in formal terms, phonologically unambiguous? Third, is there an effect of alphabet specification when the target letter string contains no ambiguous letters (Experiment 3)? That is, can the effect be observed when the target word is fully disambiguated? At issue in the foregoing three questions is distinguishing which conditions on the context and target stimuli are necessary and which conditions are sufficient for there to be an effect of alphabet specification. The fourth question is in regard to the dominance of an alphabetic context on the processing of a target item. Can the effect of alphabet specification be attenuated by the activation of a lexical entry that is counter to the alphabet specification (Experiment 4 and 5)? That is, can the biases imposed by an alphabetic context be overcome by accessed lexical information? At issue in the fourth question is the relation between the letter and phoneme processing units that are the presumed site of the alphabet manipulation and the word level units that are the presumed site of the associative manipulation.

EXPERIMENT 1

The phonological ambiguity effect is markedly reduced by a word context that specifies alphabet through the inclusion of one or more unique letters. The question posed in this first experiment is whether or not the presence of unique letters suffices. That is, does the context specifying alphabet have to be a word or will a consonant cluster do just as well? In this experiment the context is either a word containing unique characters of the Roman or Cyrillic alphabet or a consonant string containing unique characters of the Roman or Cyrillic alphabet. If all that is required for attenuating the phonological ambiguity effect is alphabet specification, then a word context and a consonant string context should have equal effects. Such a result would place the locus of the influence of alphabet specification external to the lexicon.

Method

Subjects. Sixty students from the Department of Psychology at the University of Belgrade served as subjects in partial fulfillment of a course requirement. A subject was assigned to one of four groups, according to the subject's appearance at the laboratory, to give a total of 15 subjects per condition.

Materials and design. Target words comprised 32 phonologically ambiguous Cyrillic and 32 phonologically ambiguous Roman words (Table 1). "Phonologically ambiguous Cyrillic" and "phonologically ambiguous Roman" refer, respectively, to letter strings with one or more ambiguous letters and no unique letters. A phonologically ambiguous Cyrillic word (e.g., **BETAP**) is a word by its Cyrillic reading (/vɛtar/ = "the wind") and a nonword by its Roman reading (/bɛtap/). A phonologically ambiguous Roman word (e.g., **PAJAC**) is a word by its Roman reading (/pajats/ = "clown") but a nonword by its Cyrillic reading (/rajas/). For the set of 64 target words, each phonologically ambiguous word is transcribable into the other alphabet to produce a corresponding phonologically unique word. That is, the Roman transcription of the phonologically ambiguous Cyrillic word **BETAP** is the same word, namely, **VETAR** meaning "the wind," in a phonologically unique form. Similarly, the Cyrillic transcription of the phonologically ambiguous Roman word **PAJAC** is **ПАЈАЦ** ("clown"), which is phonologically unique. The 64 target words and the corresponding 64 target pseudowords (see below) were of the consonant–vowel–consonant–vowel- or vowel–consonant–vowel–consonant-type. As such, all targets were orthographically and phonologically legal by both readings and easily pronounceable in both readings. Average frequencies (per million, according to Lukić, 1983) of phonologically ambiguous Cyrillic/phonologically unique Roman and phonologically ambiguous Roman/phonologically unique Cyrillic words were 116 and 63, respectively. All experimental manipulations compared a given word to itself, however, so that frequency was effectively controlled.

The 64 phonologically ambiguous target words were paired with phonologically unique unrelated words or phonologically unique consonant clusters that were either congruent or incongruent alphabetically with the target words. As a result, there were 16 alphabetically matched word context/word target pairs, 16 alphabetically mismatched word context/word target pairs, 16 alphabetically matched consonant context/word target pairs and 16 alphabetically mismatched consonant context/word target pairs. Each word context contained at least three unique letters. The consonant contexts were strings of 3, 4, or 5 unique consonants. A consonant was never repeated in a string.

Sixty four phonologically ambiguous pseudowords were generated. These consisted of the randomly mixed ambiguous and unambiguous shared letters. The

TABLE 1
ILLUSTRATION OF DESIGN OF EXPERIMENT 1

Type of context	Alphabets of context/target	Experimental group 1	2	3	4
Words					
Word	R[a]/PAC[b]	GUŠA–САН throat–sleep	ŽILA–ВЕТАР tendon–wind	IZLOG–СЕНО window–hay	ŽUČ–РОСА gall–dew
	C[c]/PAC	ИЗЛОГ–СЕНО window–hay	ЖУЧ–РОСА gall–dew	ГУША–САН throat–sleep	ЖИЛА–ВЕТАР tendon–wind
Cluster	R/PAC	ŽLJŠĐ–ВЕТАР –wind	ŽDLJ–САН –sleep	ŠLZ–РОСА –dew	GŠLŽ–СЕНО –hay
	C/PAC	ШЛЗ–РОСА –dew	ГШЛЖ–СЕНО –hay	ЖЉШЂ–ВЕТАР –wind	ЖДЉ–САН –sleep
Word	R/PAR[d]	ZEČIĆ–POTOK bunny–brook	GAZDA–PAJAC owner–clown	GOŠĆA–PAMET guest–mind	LJUTIĆ–BEBA buttercup–baby
	C/PAR	ГОШЋА–PAMET guest-mind	ЉУТИЋ–BEBA buttercup–baby	ЗЕ ЧИЋ–POTOK bunny–brook	ГАЗДА–PAJAC owner–clown
Cluster	R/PAR	DŠĐNJ–PAJAC –clown	LGFG–POTOK –brook	ŠLDŽ–BEBA –baby	FDĐLJ–PAMET –mind
	C/PAR	ШЛДЖ–BEBA –baby	ФДЂЉ–PAMET –mind	ДШЂЊ–PAJAC –clown	ЛГФГ–POTOK –brook
Pseudowords					
Word	R/PA[e]	FILM–COT film–	LAŽ–BOPAK lie–	ŽITO–CATO grain–	ČIČAK–OKAH burr
	C/PA	ЖИТО–CATO grain–	ЧИЧАК–OKAH burr	ФИЛМ–COT film–	ЛАЖ–BORAK lie–
Cluster	R/PA	ŠGŽĐ–BOPAK	ĆŠLJ–COT	GĐLJ–OKAH	GŽDLJ–CATO
	C/PA	ГЂЉ–OKAH	ГЖДЉ–CATO	ШГЖЂ–BOPAK	ЦШЉ–COT
Word	R/PA	KUGLA–POKAP ball–	FLAŠA–PAPOT bottle–	MAGLA–PEHET fog–	ŠALA–HETA joke–
	C/PA	МАГЛА–PEHET fog–	ШАЛА–HETA joke–	КУГЛА–POKAP ball–	ФЛАША–PAPOT bottle–
Cluster	R/PA	ŠGĐ–PAPOT	DLJŠZ–POKAP	ŽFLJ–HETA	GLDF–PEHET
	C/PA	ЖФЉ–HETA	ГЛДФ–PEHET	ШГЂ–PAPOT	ДЉШЗ–POKAP

[a] R = Roman.
[b] PAC = phonologically ambiguous Cyrillic letter string.
[c] C = Cyrillic.
[d] PAR = phonologically ambiguous Roman letter string.
[e] PA = phonologically ambiguous.

pseudowords in this experiment were, therefore, not related to any "source" word. They were divided over four sets of 16 pairs corresponding to the four sets of 16 pairs with word targets. The contexts for the pseudowords were the same types as those for word targets. In addition, 12 phonologically unique Cyrillic forms and 12 phonologically unique Roman forms with alphabetically congruent unassociated word contexts served as filler items. Each subject received 176 trials and each subject saw the same word and pseudoword targets as every other subject but not in the same contexts.

Procedure. Subjects performed a lexical decision task. As each target word appeared, they had to hit a telegraph key with both hands to indicate whether or not it was a word. They hit the further key with the forefingers to indicate that it was a word and the closer key with the thumbs to indicate that it was not. All letter strings were printed in upper case characters and displayed on the monitor of an Apple IIe.

On each experimental trial a subject heard a brief warning signal. Then a context—a word or a row of three asterisks—appeared for 700 ms, slightly above the fixation point. After the context word ended, a delay of 100 ms was interposed before the target stimulus appeared, located slightly below the fixation point. The target stimulus—a word or a pseudoword—was displayed for 1400 ms. Decision latency was measured from the onset of the target. If a response was slower than 1500 ms or incorrect (e.g., the subject responded "word" when the target was a pseudoword) then a message appeared informing the subject of his or her slowness or incorrectness. The interval between trials was 2500 ms. On the average of once every 20 trials, the subject was asked, through a visual prompt, to report orally both of the presented stimuli.

Results and Discussion

The upper limit on acceptable latencies—those to be included in the analysis—was defined as the longest latency above which further increases in the latency cutoff did not result in a significant decrease in the "total error" (sum of incorrect responses and responses slower than the cutoff value). Using this definition meant that total error approached the true error, that is, the number of wrong decisions. The upper latency cutoff was standardized at 1500 ms for similar experiments. If the data, on inspection, did not fit this limit, then the limit was adjusted. The lower limit was standardized at 400 ms.

The mean latencies and errors are given in Fig. 1. For latencies to words only the main effect of context alphabet (other alphabet = 918 ms vs. same alphabet = 826 ms) was significant: min $F'(1,108) = 35.68$, $p < .001$. The min F' for context lexicality (word context = 872 ms vs. consonant string context = 873 ms) was less than one. Similarly, for errors on words only, context alphabet (other alphabet = 34.6% vs. same alphabet = 13.05%) proved to be significant: min $F'(1,85) = 39.18$, $p < .001$. For context lexicality (word = 25.8% vs. consonant string = 21.9%), min $F'(1,97) = 1.54$, $p > .05$. In the pseudoword data the only significant effect (and the only min F' to exceed one) was obtained for context lexicality on rejection latency (word = 930 ms vs. consonant string = 985 ms), min $F'(1,119) = 15.11$, $p < .001$; the rejection times were longer for the consonantal context (see Fig. 1). The absence of an alphabet effect with respect to pseudoword targets is to be expected. Given the way that the pseudowords were generated, the classifications "same alphabet" and "other alphabet" had no meaning.

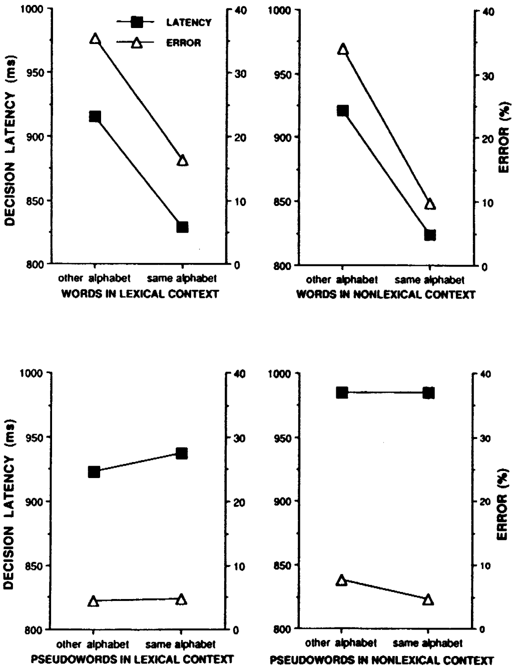

FIG. 1. Lexical decision latency and error as a function of the alphabetic relation between context and target (other alphabet vs. same alphabet), lexicality of context (word vs. consonant string), and lexicality of target (word vs. pseudoword) in Experiment 1.

As can be seen by inspecting Fig. 1, the mean latency to phonologically ambiguous target words in same-alphabet word contexts was reduced by 86 ms relative to the mean latency in the other-alphabet word contexts. This result replicates that of Experiment 2 in Lukatela et al. (1989). The new result is that a reduction of the same magnitude, 97 ms, is produced when the contextual contrast is between consonant strings written with unique consonants from the same alphabet and consonant strings written with unique consonants from the other alphabet. Clearly, the disambiguation in word processing brought about by an alphabetic context is largely independent of the lexicon.

EXPERIMENT 2

The preceding experiment, and the experiments of Lukatela et al. (1989), focused on targets of the **BETAP** type, that is, letter strings that are composed entirely from common unambiguous letters and common ambiguous letters. In this second experiment the focus is target letter strings that are composed mostly of common unambiguous and common ambiguous letters but which are formally unambiguous because they contain at least one unique letter. The main questions posed are: Does the effect of alphabet match and mismatch extend to these letter strings and, if so, is the magnitude of the effect dependent on the number of unique letters that they contain? In the experiment a comparison is made between letter strings containing one unique letter and letter strings containing two unique letters.

The theoretical significance of the experiment pertains to the mechanism of alphabetic priming. If the presence of one or more unique letters in a target acts categorically and automatically to isolate the appropriate set of grapheme–phoneme correspondencies, then a context's alphabet specification should be irrelevant. In contrast, if target processing is conducted in terms of the individual activation levels of multiple letter and phoneme processing units—in the manner suggested by models of the kind advanced by McClelland and Rumelhart (1981)—then a context's alphabet specification should be relevant to processing targets that contain ambiguous and unique letters. The letter and phoneme structure of the context would be expected to bias temporarily the individual activation levels in the direction of phoneme interpretations for ambiguous letters that are consistent with the alphabet of the context.

Method

Subjects. Sixty high school students from Belgrade served as subjects. All had participated previously in reaction time experiments and all were paid for their participation. A subject was assigned to a condition by order of appearance at the laboratory.

Materials. A set of 160 context/target pairs were assembled of which 80 were word targets (nouns) and 80 were pseudoword targets. All targets were of the CVCVC kind (where C stands for consonant and V for vowel) and all began with an ambiguous consonant. For either kind of target, word or pseudoword, the context was always a word (a noun) that bore no associative relation to the target. In 80 pairs the context was in the same alphabet as the target and in 80 pairs it was in the other alphabet. The Roman and Cyrillic alphabets were used evenly. The word and pseudoword targets were further subdivided into 40 containing one unique letter and 40 containing two unique letters. One other distinction was made. Of the 160 pairs, 80 shared the initial consonant at either the letter or phonemic level, that is, the initial consonant in the context word and the initial consonant in the target were either graphemically identical (e.g., НУЛА–HOTAR) or phonemically identical if the initially ambiguous letter is read in the other alphabet (e.g., NULA–HOTAR). This additional manipulation might be expected to enhance the alphabetic effect in the present situation in which all target letter strings were formally phonologically unambiguous.

Design and procedure. There were eight conditions each for target words and target pseudowords. These conditions resulted from combining alphabet (same vs. other), number (one unique letter vs. two unique letters), and similarity (shared initial consonant vs. different initial consonant). A given subject never received a given context or target more than once. This was achieved by dividing subjects into four groups and by dividing the 160 pairs into 16 different subsets. A subject saw 10 pairs from each subset. Presentation and duration of stimuli were as described in the first experiment.

Results and Discussion

The mean latencies and errors are presented in Fig. 2. Considering the word latencies first, alphabet (other alphabet = 796 ms vs. same alphabet = 746 ms) proved significant, min $F'(1,104) = 23.85$, $p < .001$, but number, similarity, and the interactions proved insignificant. With regard to pseudoword latencies no main effects were significant (all min F''s were less than one). The analysis of errors revealed that for word targets, alphabet (other alphabet = 11.54% vs. same alphabet = 7.0%) was significant, min $F'(1,122) = 9.62$, $p < .01$, but the other main effects were not. For pseudoword errors the effect of number (two = 5.58% vs. one = 2.20%) was significant, min $F'(1,134) = 14.8$, $p < .001$.

The main result of Experiment 2, therefore, is that alphabet priming extends to words that are a mixture of ambiguous, shared unambiguous, and unique letters. Feldman et al. (1983) demonstrated that, in the absence of contexts, words that contain one unique letter and one ambiguous letter, such as ТОНИ (“tone” in dative case; И is unique, H is ambiguous), were not responded to more slowly in lexical decision than their other-alphabet counterparts, words that contain one unique letter and no ambiguous letters, such as TONI. That is, the ТОНИ vs. TONI contrast yielded no phonological ambiguity effect, suggesting that the presence of one unique letter suffices ordinarily to eliminate ambiguity. Clearly, however, on the basis of the results of the present experiment we should conclude that the process of phonological disambiguation is a process with gradations. That is, a word like ТОНИ, although responded to normally in isolation (that is, without comparatively long delays), can still benefit from an alphabetically congruent context and/or suffer from an alphabetically incongruent context.

EXPERIMENT 3

Can the contextual specification of alphabet affect target processing when the target word contains *no* ambiguous letters? The third experiment addresses this question. One hypothesis might be that the effect of alphabet specification arises primarily because the unique letters in a context inhibit the other-alphabet interpretation of a target's ambiguous letters. If so, then no major effect of alphabet specification should be observed in the present experiment. Target words without ambiguous letters should, of course, be open to contextual influences of other kinds. The experiment

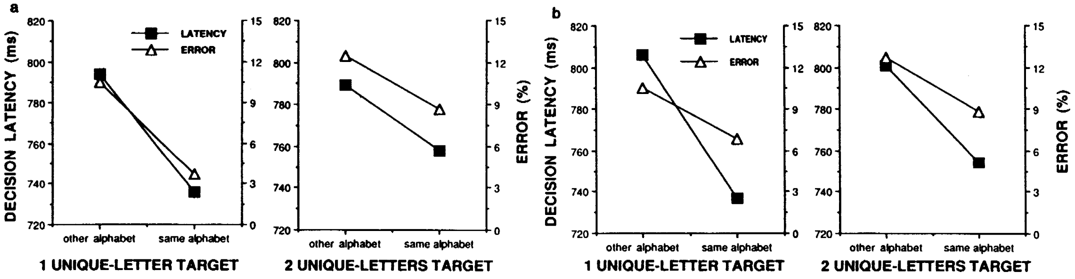

FIG. 2. Lexical decision latency and error as a function of the alphabetic relation between context and target (other alphabet vs. same alphabet), and number of unique letters in word targets in Experiment 2. Contexts and targets have different initial letters in (a) and the same initial letters in (b).

includes, therefore, in addition to the alphabet manipulation, a manipulation of the context's associative relation with the target.

Method

Subjects. Sixty high school students from the Fifth Belgrade Gymnasium participated as subjects in the experiment. None had participated in the preceding experiments.

Materials. There were 56 word and 56 pseudoword targets. The target words were of the kind described in the first experiment with the modification that all were transcribed in the alphabet that made them unique. That is, all targets were of the VETAR type. The corresponding set of 56 pseudowords was created by changing one consonant in each of the 56 phonologically unique words. (For some letter strings, a single letter replacement of the required sort always resulted in another word. In those cases, a single letter common to the two alphabets was added to produce a pseudoword.) All pseudoword targets were orthographically and phonetically legal.

All context stimuli were words containing at least one unique letter. One half were alphabetically matched with the targets, one half were not. One half of the alphabetically matched contexts were associated with the targets and one half were nonassociated with the targets. The same division into associated and nonassociated applied to the alphabetically mismatched contexts. Word contexts for target pseudowords were associated or nonassociated with the source word from which the pseudoword had been derived.

Design. On half of the trials, target words and pseudowords were preceded by an alphabetically matched context and on the other half they were preceded by an alphabetically mismatched context. Half of each type were preceded by an associated context and half were preceded by a nonassociated context. Four experimental conditions were defined, therefore, by the associated, nonassociated, alphabetically matched, and alphabetically mismatched relations of the context to the target. In order that every word and pseudoword target appeared in every condition, and that no subject saw any context or target more than once, four experimental lists were created. Each contained the four experimental conditions defined above, but a given word was in a different condition in each list. Each subject viewed one list. The order of items within a list was random with three exceptions. First, a source word and its derived pseudoword were separated, on average, by 80 items (one half of the list). Second, whether the source word or the derived pseudoword was seen first was counterbalanced. And third, the ordering of experimental conditions within the four lists was identical, although the particular items differed. For example, the first item in every list was a target word preceded by a same alphabet/associative context; the second item was a target pseudoword preceded by a other alphabet/nonassociative context; and so on.

Procedure. Presentation of stimuli, duration parameters, and response measure were as described in Experiment 1.

Results and Discussion

The mean latencies and mean errors are presented in Fig. 3. Considering the word latency data first, the main effect of context association (nonassociate 682.5 ms = vs. associate = 629.5 ms) was significant, min $F'(1,106) = 49.07, p < .001$, the main effect of context alphabet (other alphabet = 662 ms vs. same alphabet = 650 ms) was not significant, min $F'(1,85) = 2.34, p > .05$. Context association (nonassociated = 787 ms vs. associated = 763 ms) was also the only independent variable significant for pseudowords, min $F'(1,79) = 4.91, p$ .05. The analyses conducted on errors for words and pseudowords found no significant effects (all min F''s were less than one).

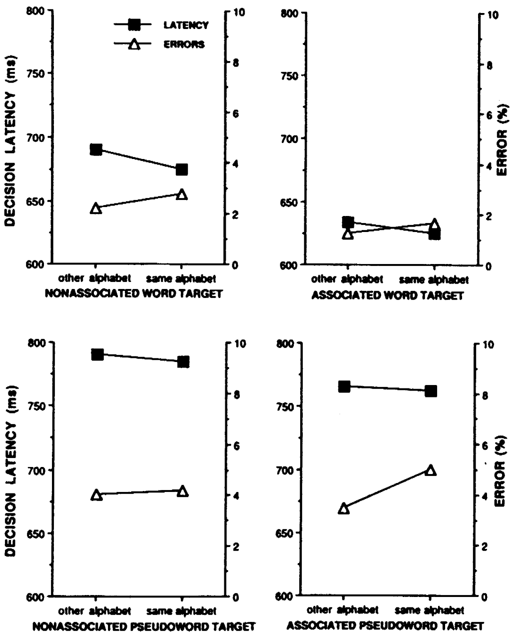

FIG. 3. Lexical decision latency and error as a function of the alphabetic relation between context and target (other alphabet vs. same alphabet), association relation between context and target (nonassociated vs. associated), and lexicality of target in Experiment 3. No targets contain ambiguous letters.

That same alphabet contexts led to numerically faster responses to words written without ambiguous letters than other alphabet contexts is in agreement with observations of Lukatela et al. (1989). Although insignificant in each case, the repeated difference favoring same alphabet contexts suggests a small, but possibly reliable, contribution of alphabet context to the processing of words of the VETAR type. Such a conclusion recalls the conclusion of Experiment 2 that there are gradations of alphabetic priming. Gradations would be in keeping with the idea that the effect of an alphabet context is based on the interactive behavior of multiple individual processing units activated by the context and the target. In the previous experiments that demonstrated significantly faster responses in same alphabet contexts, the target items contained ambiguous letters. Obviously, the alphabet of the context is more relevant to the processing of target words that contain some ambiguous letters than it is to the processing of target words that contain none.

EXPERIMENT 4

We now turn our attention to the limitations on the alphabetic biasing of a target item's processing that might arise as a consequence of lexical access. If a Serbo-Croatian letter string is assigned automatically all of the phonemic interpretations that its orthographic structure permits, then included among the lexical entries activated by a phonologically ambiguous letter string are those that fit a mixing of Roman and Cyrillic phonemic assignments. Consider the phonologically ambiguous pseudoword HAPEM (where H and P are ambiguous). By adopting a Cyrillic or Roman phoneme interpretation for each position independently, the five letter positions can be fitted phonemically in the following four ways: (1) /xə/, /a/, /pə/, /ɛ/, /mə/; (2) /nə/, /a/, /rə/, /ɛ/, /mə/; (3) /xə/, /a/, /rə/, /ɛ/, /mə/; and (4) /nə/, /a/, /pə/, /ɛ/, /mə/. These four phoneme strings can be thought of as four lexical access codes. Only one string (3) has a lexical entry; it gives the phonemic constituents of the Serbo-Croatian word meaning "harem" which is spelled HAREM in Roman and XAPEM in Cyrillic. To produce the "harem" phonemic structure from the letter string HAPEM, the first ambiguous letter (H) is interpreted according to the Roman grapheme–phoneme correspondences (GPCs) and the second ambiguous letter (P) is interpreted according to the Cyrillic GPCs. Letter strings that become words only by mixing the GPCs of the two alphabets can be called virtual words.

Pseudowords that are virtual words contrast with the pseudowords of the preceding experiments. The latter differed from actual words by a single consonant. That is, each had *n*-1 letters and *n*-1 phonemes in common with a lexical item composed of *n* letters and *n* phonemes. A pseudoword, that is a virtual word, has *n*-1 letters and *n* phonemes in common with a lexical item composed of n letters and n phonemes. Errors on phonologically ambiguous pseudowords in the experiments reported by Lukatela et al. (1989) were not large (e.g., 3.1% and 2.5% in the two contexts of Experiment 2), implying that they rarely activated a lexical entry to a level sufficient to influence responding. By comparison, if the above hypothesis is correct, then errors on virtual words should be substantial, Pseudowords that are virtual words should activate entries in the internal lexicon to behaviorally significant levels. The fourth experiment examines virtual words in contexts that specify either the Roman or Cyrillic alphabet.

Method

Subjects. Sixty high school students from Belgrade were paid to participate in the experiment. All were naive to the experiment's purpose. Most had participated previously in reaction time experiments. Subjects were assigned randomly to one of four experimental groups according to their order of appearance for testing.

Materials. The experimental conditions are shown in Table 2. A basic set of 80 phonologically ambiguous pseudowords of the CV . . . or VC . . . type was generated. This syllabic structure allowed both Roman and Cyrillic GPCs to be applied to each letter, that is, no consonant clusters that were illegal in one of the alphabets were included. For a given letter string (e.g.,

TABLE 2
ILLUSTRATION OF DESIGN OF EXPERIMENT 4

Alphabet of context	Relation of context	Experimental group			
		1	2	3	4
Pseudowords (virtual words)					
C	Associate	СУЛТАН–Н̲АР̄ЕМ [harem] sultan–harem	ВОЈНИК–В̲ОР̄АС [borats] soldier–fighter	КРАЉ–С̲АР̄ [tsar] king-tsar	МРШТЕЊЕ–В̲ОР̄А [bora] frown–wrinkle
	None	СЛОН–С̲АР̄ [tsar] elephant-czar	ДОЖИВЉАЈ–В̲ОР̄А [bora] experience-wrinkle	БЕЗДАН–Н̲АР̄ЕМ [harem] abyss-harem	ИЗЛЕЖАВАЊЕ–В̲ОР̄АС̲ [borats] leisure-fighter
R	Associate	MATERIJAL–P̄OB̲A [roba] material–cloth	SVINJA–B̄EP̲AP̄ [vepar] swine–boar	MELODIJA–H̄AP̲EB̄ [napev] melody–tune	HORIZONT–H̄EB̲O [nebo] horizon–sky
	None	HEKTOLITAR–H̄EB̲O [nebo] hectoliter–sky	GLUHOĆA–H̄AP̲EB̄ [napev] deafness–tune	BATINANJE–B̄EP̲AP̄ [vepar] beating–boar	ŠAPUTANJE–P̄OB̲A [roba] whisper–cloth
Words					
C	Associate	ВОЈНИК–БОРАЦ soldier–fighter	СУЛТАН–ХАРЕМ sultan–harem	МРШТЕЊЕ–БОРА frown–wrinkle	КРАЉ–ЦАР king–tsar
	None	ДОЖИВЉАЈ–БОРА experience-wrinkle	СЛОН–ЦАР elephant–tsar	ИЗЛЕЖАВАЊЕ–БОРАЦ leisure–fighter	БЕЗДАН–ХАРЕМ abyss–harem
R	Associate	SVINJA–VEPAR swine–boar	MATERIJAL–ROBA material–cloth	HORIZONT–NEBO horizon–sky	MELODIJA–NAPEV melody–tune
	None	GLUHOĆA–NAPEV deafness–tune	HEKTOLITAR–NEBO hectoliter–sky	ŠAPUTANJE–ROBA whisper–cloth	BATINANJE–VEPAR beating–boar

Note. In virtual words, underlined letters are given a Roman interpretation (e.g., P = /p/); letters with a bar are given a Cyrillic interpretation (e.g., P̄ = /r/).

HAPEM) both the completely Cyrillic (/narem/) and the completely Roman (/xapem/) interpretations of the letters produced pseudowords, but an appropriately mixed interpretation yielded a word (/xarem/ meaning "harem"). These virutal words have two phonologically unique transcriptions, one in Cyrillic (**XAPEM**) and one in Roman (**HAREM**), that may be considered control words. From the pool of 160 control words, 80 were chosen (40 phonologically unique Roman forms and 40 phonologically unique Cyrillic forms) with the restriction that they have a phonologically unambiguous letter in the initial position. The control for **HAPEM**, therefore, would be **XAPEM** not **HAREM**. Similarly, for the letter string **HEBO** (completely Cyrillic /nevo/, completely Roman /xebo/) a mix produces /nebo/ meaning "sky" and its control would be the Roman **NEBO**, not the Cyrillic **HEБO**.

For each control word, an associatively related context word (with at least two phonologically unique letters) was chosen that either (1) did not share any ambiguous letters with its virtual word counterpart, or (2) if it shared an ambiguous letter, then that letter had a different phonemic value from its virtual word reading. For example, **MELODIJA** ("melody") and **HAPEB** (virtual word /napev/ meaning "tune") have no ambiguous letters in common; **CYЛTAH** (/sultan/) and **HAPEM** (virtual word /xarem/) share the letter **H** but it takes the interpretation /nə/ in the context and /xə/ in the target. These restrictions were imposed in order to avoid a phonemic bias that favored the virtual word interpretation. Associatively unrelated context words followed the same prescriptions and had the same number of letters as their corresponding associated contexts.

Phonologically unique filler items included 20 associated word–word pairs, 20 unrelated word–word pairs, and 40 word–pseudoword pairs. These were not included in the analyses.

Design and procedure. The four experimental conditions were defined by whether or not the target was a (control) word or a virtual word and whether or not the context was related associatively to the target (by its word reading). The counterbalancing paralleled that of the preceding experiments. The manner of stimulus presentation and the stimulus durations were the same as in Experiment 1.

Results and Discussion

For this experiment, the strategy outlined in Experiment 1 for deciding on the latency cutoff yielded an upper limit of 2000 ms. The mean latencies and mean errors for each condition are reported in Fig. 4. With respect to latencies, word type (control = 780 ms vs. virtual = 978 ms) proved significant, min $F'(1,126) = 119.6$, $p < .001$. Context association (nonassociate = 896 ms vs. associate = 863 ms) was not significant, min $F'(1,98) = 2.29$, $p > .05$, but its interaction with word type was significant (difference for nonassociate = 254 ms vs. difference for associate = 142 ms), min $F'(1,123) = 18.85$, $p < .001$. The reason that context association failed to reach significance is evident from inspection of Fig. 4. An associated context, relative to an unassociated context, speeded up decisions on control words (+89 ms) but slowed down decisions on virtual words (−23 ms). The errors exhibited the same pattern as

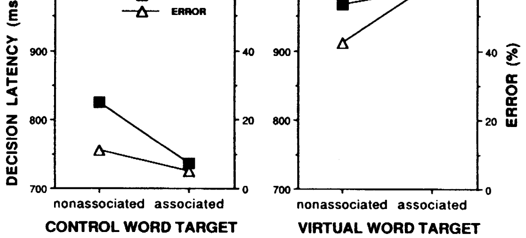

FIG. 4. Lexical decision latency and error as a function of context (nonassociated vs. associated) and target type (control word vs. virtual word) in Experiment 4.

the latencies, namely, word type (control = 7.95% vs. virtual 50.8%) and the Word Type × Context Association interaction (difference for nonassociate = 31% vs. difference for associate = 54.67%) were significant but context association (nonassociated = 26.6% vs. associated 32.2%) was not: min $F'(1,136) = 112.46, p < .001$, min $F'(1,102) = 10.5, p < .01$, min $F'(1,91) = 1.43, p > .05$, respectively.

As expected, virtual words produced a large number of errors, 59.5% and 42.1% in the two contexts. Analysis showed that the number of errors was significantly greater when the context was a word associated with the virtual word, min $F'(1,99) = 9.87$, $p < .01$. The latencies of these incorrect responses (when the subject pressed the key identifying that the stimulus was a word rather than the key identifying that the stimulus was a nonword) were analyzed as if they were *correct* responses. That is, they were analyzed as if a word rather than a pseudoword had been presented and that the subject had assessed this fact correctly. In the associated context, the mean latency of these "yes" responses was 779 ms; in the nonassociated context their mean latency was 890 ms. The difference of 111 ms compares favorably with the 89 ms difference between the control word latencies in the two contexts.

Returning to our major example, it would seem that HAPEM was processed as /xarem/, and that the positive lexical decision latency was facilitated significantly by the preceding presentation of CYJITAH (/sultan/). Two conclusions to be drawn are that a phonologically ambiguous letter string gives rise automatically to (a) *all* the phoneme orderings that its letter structure allows and (b) the activation of all the lexical entries consistent with these phoneme orderings. The present data point to a further conclusion, namely, that if a lexical item is fully accessed, then that *lexical access can overide alphabet priming*. The letter string HAREM supports four phoneme orderings, as noted. Of these, two are derived purely from one set of GPCs: /narem/ is produced from the Cyrillic GPCs, and /xapem/ is produced from the Roman GPCs. The word contexts were always specific to one or the other alphabet. Alphabet priming ought to have resulted in a predominance of correct rejection latencies because it would have predisposed the word processing system to either /narem/ or /xapem/, which are both nonwords. The evidence that /xarem/ was arrived at 42.1% of the times it was presented in a nonassociated context and 59.5% of the times it was presented in an associated context is, therefore, evidence to suggest that lexical activation overcame alphabet biasing.

EXPERIMENT 5

To repeat, the important result of Experiment 4 was that lexical decision in an alphabetic context was dominated more by the virtual word aspect of the target HAPEM than by the alphabet of the context word. The fifth experiment reproduces Experiment 4 in all details of design, materials, and procedure with the exception of the response, which is naming rather than lexical decision. Assembling the pronunciation of a Serbo-Croatian word seems to be based on the pattern of activity at the level of phoneme units (Lukatela et al. 1989). That pattern is affected by context in the sense that it is adjusted temporally to the alphabet specified by the unique letters of a preceding letter string. Suppose, however, that the phoneme level can be wrested from the influence of alphabet by a highly activated word unit, then we should expect the results of the present naming experiment to replicate those of the preceding lexical decision experiment. In short, we should expect to see in the present experiment a greater tendency to pronounce HAPEM as /xarem/, the word produced by mixing Roman and Cyrillic GPCs, than as either /narem/, the name of the pseudoword that is produced from the Cyrillic GPCs and biased by a Cyrillic context, or as /xapem/, the pseudoword that is produced from the

Roman GPCs and biased by a Roman context. Furthermore, we should see this tendency enhanced by a context that is an associate of /xarem/.

Method

Subjects. The subjects were 60 high school students from the Fifth Belgrade Gymnasium. Some had participated in other experiments of the present series. None had participated in Experiment 4. Each was assigned to one of four conditions to give 15 subjects per condition.

Materials and design. The stimuli used and the experimental conditions were as described in Experiment 4.

Procedure. The response was naming the target letter string aloud as rapidly as possible. In all conditions, latencies from the onset of the target to the onset of the response were measured by means of a voice operated trigger relay. The duration of the context was 600 ms, the interval was 110 ms, and the duration of the target was 300 ms.

Errors in pseudoword naming deserve a comment. Given the phonetic precision of the Serbo-Croatian script system, the pronunciation of an unambiguous pseudoword is well defined. This is also true, of course, for an ambiguous pseudoword, although the absence of a unique character allows options. The naming of either kind of pseudoword was considered to be erroneous when the pronunciation included a phoneme not specified by the characters in the letter string or when the pronunciation was not smooth, that is, when the subject hesitated after beginning the name. Added to these types of errors is the standard type of not initiating the response within the cutoff latency.

Results and Discussion

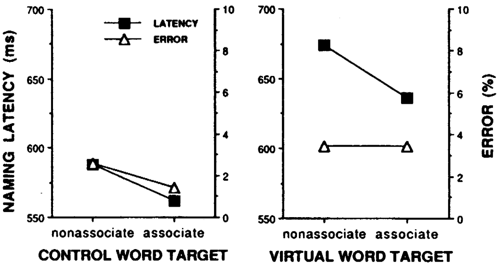

FIG. 5. Naming latency and error as a function of context (nonassociated vs. associated) and target type (control word vs. virtual word) in Experiment 5.

The mean latencies and mean errors per condition are shown in Fig. 5. Here errors are pronunciations that (a) exceeded the latency cutoff or (b) were marked by hesitation following initiation. With respect to latency, both main effects were significant: association (nonassociated = 631 ms vs. associated = 599 ms), min $F'(1,104) = 8.28$, $p < .01$; ambiguity (control = 575 ms vs. virtual = 655 ms), min $F'(1,126) = 51.49$, $p < .001$. The interaction was not significant: min $F'(1,106) < 1$. Only ambiguity (control = 1.99% vs. virtual = 3.42%) was significant in the error analysis: min $F'(1,123) = 5.47$, $p < .05$.

The speed of the responses and the small number of errors suggest that the subjects had little difficulty determining pronunciations for the ambiguous pseudowords. As expected, however, under the task demands of rapid naming, a disproportionate number of pseudowords were named as words (the virtual words produced by mixing GPCs). In the associative context 60.5% were given the name of the virtual word; in the nonassociative context the percentage of virtual word responses was 39.6%. (It will be recalled that several names were derivable from the letters in the stimulus. One of these names was a nonword name that was always consistent with the alphabet of the context and one of these names was always the name of a word.) The means of the naming latencies when the pseudowords were named as words were 610 ms in the associative context and 642 ms in the nonassociative context.

Lukatela et al. (1989) suggested that a word unit activated by within-level connections (that is, associatively) cannot exert sufficient influence on the phoneme units to overcome alphabet biasing. Here, in the present experiment, we have observed that a word unit activated by between-level connections can modify significantly the pattern of activity at the phoneme level. To repeat, phoneme units consonant with the target virtual word dominate the utterance of the letter string HAPEM more so than phoneme units consonant with the context's alphabet.

DISCUSSION

With respect to the questions raised in the introduction it can be concluded that the effect of an alphabetic context on the processing of target Serbo-Croatian letter strings (a) does not require that the context be a word, (b) is observed when a target comprising ambiguous letters in part is made formally unambiguous by the inclusion of at least one unique letter, (c) is practically nonexistent when the target contains no ambiguous letters, and (d) can be overidden in particular circumstances by the activation of a lexical entry.

To summarize the results of the present article and those of Lukatela et al. (1989) we present a word-processing mechanism for Serbo-Croatian. The mechanism is a parallel, distributed network in which there are, in successive layers, processing units for features, processing units for letters (Cyrillic and Roman), processing units for phonemes and processing units for words.

General Format

Following convention, it is assumed that each unit provides an additive contribution to the input of the units to which it is connected. The total input to a unit is the weighted sum of the separate inputs from each of the individual units. The inputs from the incoming units are multiplied by a weight and summed to get the overall input to that unit. The weight represents the strength and sense of the connection. The total pattern of connectivity can be represented formally by a weight matrix (Rumelhart, McClelland, et al., 1986).

Within a level a connection is either excitatory or inhibitory. Only excitatory connections exist between levels. Each unit at each level is characterized by a resting value of activation, onto which the unit relaxes in the absence of inputs from other units. When not at its resting level a unit's activation is a function of its excitatory and inhibitory inputs. As a result of the many interconnections, representing the many constraints among units, a time-dependent pattern is defined over the network so that the activation level of each and every unit receiving inputs is time varying. Each unit is continually receiving inputs, continually updating its activation level, and continually sending excitatory and/or inhibitory signals to other units. The upshot is a competitive/cooperative process in which the activation levels of some units grow while the activation levels of other units diminish. Although many units are made active by an input to the network, such as the presentation of a printed word, competition and cooperation ensure that high levels of activation will endure for very few units, namely, the units that are most consistent with the word.

Major Assumptions

The network of connections for a single letter position honors the following assumptions. First, the letter units of the Cyrillic and Roman alphabets constitute functionally distinct sets (Lukatela, Savić, Ognjenović, Turvey, 1978). Common to the two sets are the letter units corresponding to the letters E, A, O, J, K, M, and T. In addition to this shared subset of letter units, the set of Cyrillic letter units consists of (a) units corresponding to each of the unique Cyrillic letters and (b) units corresponding to each of the ambiguous letters. Similarly, in addition to the shared subset of letter units, the set of Roman letter units consists of (a) units corresponding to each of the unique Roman letters and (b) units corresponding to each of the ambiguous letters. A key idea is that at the level of letter units, each ambiguous letter is represented twice—once in the Cyrillic set and once in the Roman set.

The proposed organization of the letter unit level is supported by data on rapid alphabet decision (Lukatela, Savić, Ognjenović, et al., 1978). When Yugoslavians who had learned Cyrillic first were asked to decide rapidly whether or not a presented letter was Cyrillic, the mean latencies ordered as common unambiguous < unique Cyrillic letters < common ambiguous letters. The ordering was preserved in the data of Yugoslavians who had learned Roman first and who were asked to decide rapidly whether or not a presented letter was Roman: common unambiguous < unique Roman letters < common ambiguous letters. This patterning of latencies can be rationalized by assuming that there is (a) a single representation of the shared unambiguous letters, which is used more frequently than any other subset of letter units and (b) a double representation of unambiguous letters (see Lukatela, Savić, Ognjenović, et al., 1978, for more details).

The second assumption is that each letter unit connects to its corresponding phoneme unit. (See Seidenberg and McClelland (1987) for a similar connectionist notion for English.) No phoneme units are duplicated. For the phoneme units connected to the shared unambiguous letter units, there is *one* letter unit per phoneme unit (e.g., A connects to /a/, E connects to /e/, and so on). For all other phoneme units, there are *two* letter unit connections per phoneme unit. That is, each unique Cyrillic, each unique Roman, and each ambiguous letter unit, connects to a phoneme unit which is connected to one other letter unit (e.g., Л and L both connect to /lə/, Γ and G both connect to /gə/, B and V both connect to /və/, and so on).

These letter unit–phoneme unit connections embody the grapheme–phoneme correspondence (GPC) rules of the Serbo-Croatian language. In the Serbo-Croatian orthography, unlike the English orthography, these correspondencies are straightforward. All letters are pronounced (none are made silent by particular contexts of adjacent letters) and their individual pronunciations are not altered significantly by the letter contexts in which they are embedded.

The third assumption is that, with the activation of phoneme units by letter units, a two-way interactive process is initiated between the phoneme unit and word unit levels. Word units in the proposed network reflect the phonemic precision of the orthography. Each word unit represents a particular ordering of phoneme units. In consequence, in this model the accessing of word knowledge is seen to take place principally through the phoneme level to word level connections.

The preceding assumptions, as noted, are with respect to the organization of connections between levels for the processing of a single letter position. The letter units–phoneme units organization just described repeats for each letter position (cf. McClelland & Rumelhart, 1981). That is, if the model is addressing the processing of a five-letter word, then there will be five sets of letter units–phoneme units connections, one for each letter position. The most important assumption of the present model of single word processing is made with respect to the relations between these letter–phoneme organizations across letter positions. It is assumed that, across letter positions, there are multiple inhibitory connections in both directions between the unique letter units of one alphabet and the unique and ambiguous letter units of the other alphabet. When a unique Cyrillic (Roman) letter unit is activated by a stimulus letter in one position, then the activity in all Roman (Cyrillic) letter units in the other letter positions is reduced. If unique Cyrillic (Roman) units are activated by a stimulus letter string at several letter positions, then the strength of the inhibition is an increasing (probably nonlinear) function of the number of activated units.

The Phonological Ambiguity Effect

The Cyrillic **BETAP** ("wind") is composed of three shared unambiguous letters (E,T, and A) and two ambiguous letters (B and P). B in the first position would excite highly two phoneme units /bə/ and /və/ and, thereby, raise significantly the activation levels of all word units beginning with these phonemes (Fig. 6a). The Roman transcription of "wind," namely **VETAR**, is composed of the same three shared unambiguous letters (E, T, and A) and two unique letters (V and R). V in the first position would (a) inhibit all Cyrillic alphabet units in the other positions, (b) excite highly the phoneme unit /və/, and (c) raise significantly the activation levels of all word units beginning with this phoneme (Fig. 6b). The number of word units activated significantly by the first letter of **BETAP** is considerably more than the number activated significantly by the first letter of **VETAR**. Ignoring the details of the temporal patterning of excitatory and inhibitory influences, it can be supposed that when the input to the network is a **BETAP**-type letter string, the interactive–activation process takes longer to condense out a single, dominant word unit than when the input is a **VETAR**-type letter string.

Consider now **BEПAP** ("boar") that consists of shared unambiguous letters (E, A) and ambiguous letters (B, P) but includes

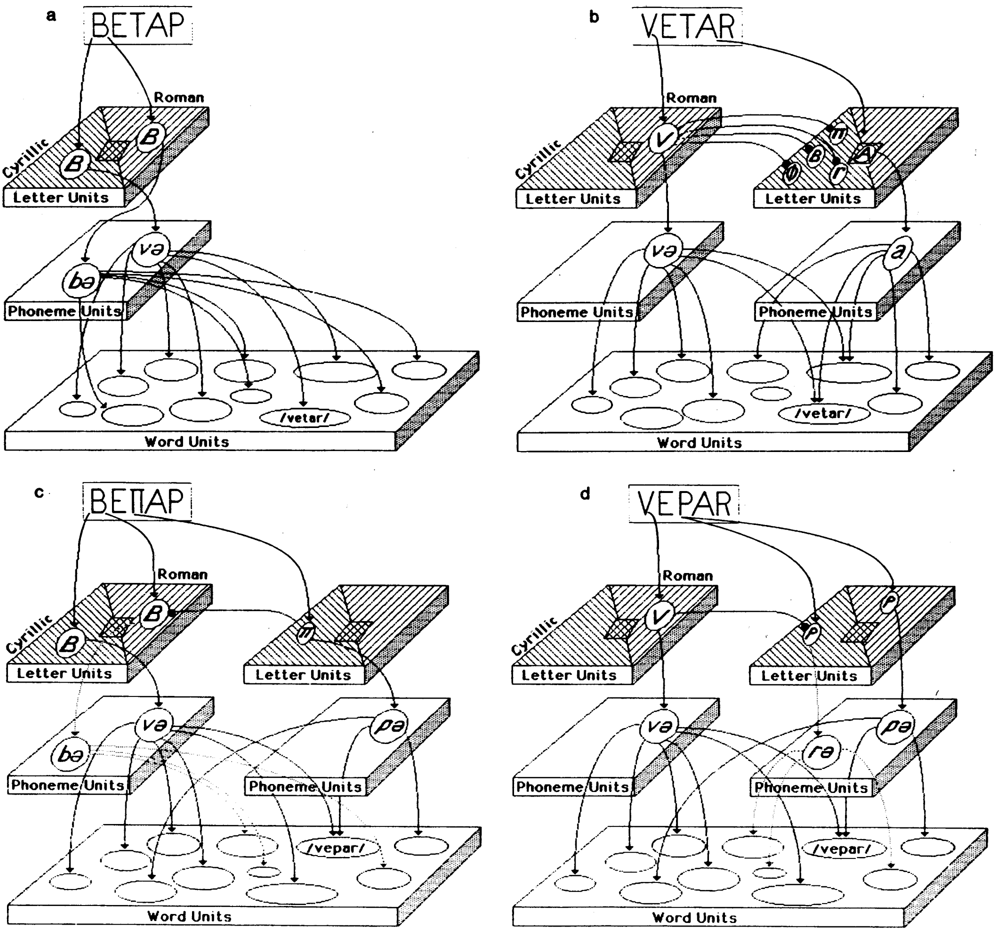

FIG. 6. Connections among levels of units in the processing of (a) BETAP, (b) VETAR, (c) BEПAP, and (d) VEPAR.

a unique letter (**П**). When activated, the Cyrillic letter unit **П** in the third position, that is connected to the phoneme unit /pə/, strongly inhibits the unique and ambiguous Roman letter units in the other positions including, therefore, those letter units **B** and **P** that are connected to the phoneme units /bə/ and /pə/. As a result, where **BETAP**-type letter strings excite two phoneme units in the first position to a common high level of activity, **BEПAP**-type letter strings excite one phoneme unit (/və/) strongly and one phoneme unit (/bə/) weakly (Fig. 6c). Consequently, for **BEПAP**-type letter strings the number of highly competitive word units is fewer than for **BETAP**-type letter strings. **BEПAP**-type letter strings should, therefore, be responded to in lexical decision faster than **BETAP**-type letter strings and at a speed more closely resembling that of responses to **VEPAR**-type letter strings (Fig. 6d).

Alphabetic Priming

In familiar terms, associative priming would occur through the raising of the activation level of the target word unit, lessening the time for this unit to achieve ascendency in the competitive process following the target's presentation. Alphabetic priming would come about in a different fashion. A context letter string (word or nonword, Experiment 1 of the present article) containing one or more unique characters would, as remarked, inhibit strongly the letter units of the other alphabet at the other letter positions (see Fig. 6b and c). This inhibitory effect will decay with time, but it may still be present to a significant degree when the phonologically ambiguous target word appears. For **BETAP**-type letter strings in a context specifying the Cyrillic alphabet, the word units consistent with /bə/ and /pə/ in first and last position would be excited only weakly in comparison to how they would be excited in the absence of such a context. The competitive process at the word unit level, therefore, would be defined mainly, but not exclusively, over the word units excited by the phoneme units /və/ in the first position, /ɛ/ in the second position, /tə/ in the third position, /a/ in the fourth position, and /rə/ in the fifth position. The upshot is that alphabet priming and associative priming can proceed quasi-independently, the former occurring at the letter unit level, the latter at the word unit level (Experiment 3 of Lukatela et al. (1989)). That the two processes are largely independent of each other is reinforced by the fact that alphabetic priming is as strong with consonant-string contexts as it is with word contexts (Experiment 1 of the present article).

Suppose that **BETAP**-type letter strings are presented subsequent to a context word that specifies the Roman alphabet (that is, contains unique Roman characters) rather than the Cyrillic alphabet in which a **BETAP**-letter string has a lexical entry. By the preceding argument, word units connected to the phoneme units /bə/, /ɛ/, /tə/, /a/, and /pə/ in first, second, third, fourth, and fifth positions would be activated strongly at the onset of the target and those connected with the phoneme units /və/ and /rə/ in first and fifth positions would be activated weakly. In its early stages the competitive process can be expected, therefore, to favor word units other than that of "wind" (/və/ + /ɛ/ + /tə/ + /a/ + /rə/). As the competitive process proceeds, however, the word unit for "wind" 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 **BETAP**-type letter strings would be responded to more slowly in the Roman (other) alphabet context than in the Cyrillic (same) alphabet context, they would, nonetheless, be responded to correctly on more occasions than they would be responded to incorrectly (Experiment 2, Lukatela et al. (1989)).

Virtual Word Phenomenon

Finally, we consider how the model addresses the processing of a **HAPEM**-type letter string, that is, a virtual word, in a context that is always alphabetically consonant with the virtual word. A Cyrillic context would render /nə/ more active than /xə/ as the phonemic interpretation of the letter in the first position. Among the activated word units, however, that which has the phoneme ordering /xə/, /a/, /rə/, /ɛ/, /mə/, will tend to dominate because it satisfies the pattern of activity at the phoneme level more fully than other word units. As a consequence, excitation fed back from the word level will favor /xə/ in the first position rather than /nə/. The resultant shift in phoneme level excitation will enhance further the dominance of the word unit for "harem," increasing the probability that its activation level will exceed that required for positive lexical decision. The significance for the model of the virtual word result of Experiments 4 and 5 of the present article is that it suggests that a strongly activated word unit can offset the biases established at the phoneme-unit level by alphabet induced inhibition at the letter-unit level.

Summary

We have observed that the phonological ambiguity effect characterizing visual word processing in Serbo-Croatian (e.g., **BETAP** responded to slower than **VETAR**) can be largely eliminated by an immediately preceding word that specifies the alphabet (Cyrillic) of the phonologically ambiguous word (**BETAP**). Investigations of this contextual effect suggest a parallel, distributed processing model with the following properties: (a) three connected layers of units (beyond the layer of feature units), namely, letters, phonemes, and words, in that order; (b) phoneme units as the major activators of word units; and (c) inhibitory connections—in both directions—between Cyrillic and Roman letter units. Further experiments and simulations will be needed to assess fully the appropriateness of the model and the assumptions that it embodies.

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