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Is Alphabet Biasing in Bialphabetical Word Perception Automatic and Prelexical?

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Phonologically ambiguous Serbo-Croatian words are identified more slowly and erroneously than their phonologically unique counterparts. Five experiments addressed the reduction of these ambiguity effects when Roman (Cyrillic) targets are preceded by consonants unique to the Roman (Cyrillic) alphabet. Alphabet-specific nonword contexts were presented briefly with masking. With forward masking, performance was better when the phonologically ambiguous target words and their preceding nonword contexts were alphabetically congruent. Similarly, where backward masked contexts acted themselves as backward masks for the target stimuli, identification was highest when the context masks were in the same alphabet as the targets. Results were discussed in terms of automatic, prelexical processes within a network model of visual word recognition in Serbo-Croatian.

Two major features characterize the script system of Serbo-Croatian, Yugoslavia's major language. First, it occurs in two forms, namely, the Roman and the Cyrillic alphabets. These two alphabets share a number of letters (in uppercase, A, E, O, J, K, M, T, H, P, C, and B), some of which (H, P, C, and B) designate one phoneme in one alphabet and another phoneme in the other alphabet (e.g., Lukatela & Turvey, 1980). Second, individual letters within an alphabet map uniquely to individual phonemes, and individual phonemes map uniquely to individual letters; the orthography is shallow (see Frost, Katz, & Bentin, 1987; Lukatela & Turvey, 1980; Lukatela, Popadić, Ognjenović, & Turvey, 1980). Previous research has suggested that a prelexically derived phonology plays a major role in word recognition and word naming in Serbo-Croatian (e.g., Feldman & Turvey, 1983; Frost et al., 1987; Lukatela et al., 1980; Lukatela & Turvey, 1990a). A large part of the empirical support for this understanding has come from the phonological ambiguity effect (PAE).

Some written words in Serbo-Croatian comprise only shared letters. Some words in this subset contain phonemically ambiguous letters. Consider, for example, the letter string BETAP. Read strictly through the letter-to-sound correspondencies of the Cyrillic alphabet, this letter string is pronounced */vetar/* and is a high-frequency noun meaning "wind." Read strictly through the letter-to-sound correspondencies of the Roman alphabet, BETAP is pronounced */betap/*, a pseudoword. Read with a mixture of the two sets of correspondencies, Cyrillic and Roman, leads to the pronunciations */vetap/* and */betar/*, which are also pseudowords. In the Roman alphabet, the word meaning wind is transcribed as VETAR. This letter string can be given only a single reading, */vetar/*. VETAR, unlike its Cyrillic counterpart BETAP, is phonologically unambiguous.

In rapid lexical decision and rapid naming tasks, responses to BETAP and to words like it are considerably longer than the responses to VETAR and to words like it, even though BETAP and VETAR are equal in frequency, syllabic structure, number of letters, and meaning. This contrast defines what is referred to as PAE. It is argued that accepting BETAP as a word is made more difficult by the fact that BETAP activates more phoneme units than VETAR and, thereby, activates many more competing word units than VETAR (Lukatela & Turvey, 1990a; Lukatela, Turvey, Feldman, Carello, & Katz, 1989). Importantly, PAE satisfies Coltheart, Davelaar, Jonasson, and Besner's (1977) and van Orden's (1987) criterial requirement for the demonstration of phonological mediation in lexical access, namely, that phonological manipulations affect positive lexical decisions. Conclusions about phonology's role in visual word recognition based on slowed lexical decisions to homophonous words such as *yoke* (Rubenstein, Lewis, & Rubenstein, 1971) were undermined by experiments that showed that the effect of homophony on positive lexical decisions could be eliminated by including nonwords such as *brane* that are homophonic with real words (e.g., Davelaar, Coltheart, Besner, & Jonasson, 1978). Homophony was found to affect only negative decisions, lending support to the ideas that (a) assembling phonology was strategic, and (b) phonology's influence is limited to nonwords because the relative slowness in processing these

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items allows lexically accessed phonological representations to intrude upon the decision process. Clearly, in the context of the results of research with homophony manipulations, the hypothesis of phonological mediation of lexical access requires, at the very least, evidence of phonological effects on positive lexical decisions, as Coltheart et al. (1977) and van Orden (1987) have duly noted. In this light, PAE with yes responses means that phonology is not necessarily a representation that is delayed relative to visual lexical access (Lukatela & Turvey, 1990a).

An important observation is that PAE can be reduced significantly by a preceding item that specifies the alphabet of a phonologically ambiguous target word. For example, if BETAP is preceded by a letter string that contains letters unique to the Cyrillic alphabet, then the decision and naming latencies for BETAP approximate those for VETAR (Lukatela, Feldman, et al., 1989; Lukatela, Turvey, et al., 1989). The available evidence suggests that a matching alphabetic context does not simply speed up responding to a target. When the target is VETAR, the influence of alphabetic context is negligible (Lukatela, Turvey, et al., 1989). The implication is that the alphabet contextual effect is one of disambiguation.

Below we summarize a model of Serbo-Croatian word recognition that interprets this alphabet reduction of PAE as arising automatically in prelexical processes (Lukatela, Turvey, et al., 1989). An alternative account might place the site of the effect in postlexical processes, arising from strategies in which the subject uses what he or she knows about the context to constrain processing of the after-coming target. Distinguishing between these two possibilities experimentally is not a simple matter. In the present experiments we take the tack of minimizing the opportunities to process the context completely. If complete processing means that a stimulus accesses all levels of processing units, then less than complete processing means that only lower level processing units are thoroughly stimulated. If complete processing means that all parts of a stimulus are processed, then less than complete processing means that only some parts (some letters) are processed. Both senses of incomplete processing can apply. We assume that if the alphabet-biasing effect occurs equally well under conditions that promote incomplete processing in either or both senses, then the effect is more likely to be automatic and prelexical than strategic and postlexical.

The method used in these experiments involves two important features. The first feature is that alphabet-specific contexts are presented very briefly under masking conditions. This is done to minimize the explicit identification of the context while still allowing the context to influence the processing of the target. It is expected that such conditions will hinder or even deter the intentional, strategic use of context information (Evett & Humphreys, 1981; Humphreys, Evett, & Taylor, 1982). If they do, and if the contextual reduction in PAE is strategy dependent, then responses to a phonologically ambiguous target item should not differ (at the very most), or differ less (at the very least), as a function of the alphabet in which the context item is written. In contrast, if the source of contextual reduction of PAE is to be found in automatic processes, then responses to a phonologically ambiguous target should be affected significantly by the alphabetic nature of the masked context and to much the same degree as when the context is not masked.

Second, the contextual items in the present experiments are consonant strings (comprising either letters unique to the Roman alphabet or letters unique to the Cyrillic alphabet) rather than words. It has been demonstrated that a nonword cluster of unique consonants and a word containing unique consonants reduce PAE to the same degree (Lukatela, Turvey, et al., 1989). The implication is that the contribution of lexical processes to the reduction of PAE is minimal. Through the conjunction of nonword contexts and masking, we hope to restrict the influences on responding to mechanisms that function reflexively below the level of the lexicon. If the reduction in PAE by alphabetic context observed in previous experiments relies on mechanisms that function intentionally above the level of the lexicon, then the present procedures should yield no such reduction.

The main theoretical backdrop for the research is a model of Serbo-Croatian word perception advanced by Lukatela, Turvey, et al. (1989). A brief overview follows. The letter units of the Cyrillic and Roman alphabets constitute functionally distinct sets (Lukatela, Savić, Ognjenović, & Turvey, 1978). In addition to the shared subset of unambiguous letter units, the set of Cyrillic letter units consists of units that correspond to each of the unique Cyrillic letters and units that correspond to each of the ambiguous letters. Similarly, in addition to the shared subset of unambiguous letter units, the set of Roman letter units consists of units that correspond to each of the unique Roman letters, and units that correspond to each of the ambiguous letters. A major 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.

A second major idea is that each letter unit connects to its corresponding phoneme unit. No phoneme units are duplicated. For the phoneme units connected to the shared unambiguous letter units, there is one letter-unit connection 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 that is connected to one other letter unit (e.g., *l* and *L* both connect to /l/, *B* and *V* both connect to /v/, etc.). These letter unit–phoneme unit connections embody the grapheme–phoneme correspondences of the Serbo-Croatian language.

The third major idea 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. The accessing of word knowledge takes place principally through the phoneme-level–word-level connections.

The preceding describes 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). In particular, 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 assumptions of the present model of single-word processing are 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 (a) the unique letter units of one alphabet and (b) 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 increasingly (probably nonlinear) function of the number of activated units. Importantly, it is assumed that the relaxation time of the induced inhibitory processes is not infinitely brief, which means that the inhibition induced by one letter string can still be in effect during the processing of a subsequent letter string.

Let us see how this model addresses PAE. 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 /*b*/ and /*v*/ and, thereby, raise significantly the activation levels of all word units beginning with these phonemes. 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 /*v*/, and (c) raise significantly the activation levels of all word units beginning with this phoneme. 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 a unique letter (п). When activated, the Cyrillic letter unit п in the third position, which is connected to the phoneme unit /*p*/, 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 /*b*/ and /*p*/. As a result, where BETAP-type letter strings excite two phoneme units in the first position to a common level of activity, BEПAP-type letter strings excite one phoneme unit (/*v*/) strongly and one phoneme unit (/*b*/) weakly. 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 that closely matches that of responses to VEPAR-type letter strings.

Let us now turn to the question of how the model addresses the alphabetic influence on processing phonologically ambiguous items. A preceding 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 be present when the phonologically ambiguous target word appears. For BETAP-type letter strings in a forward context specifying the Cyrillic alphabet, the word units consistent with /*b*/ and /*p*/ in first and last position would be excited only weakly compared with 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 /*v*/ in the first position, /*e*/ in the second position, /*t*/ in the third position, /*a*/ in the fourth position, and /*r*/ in the fifth position.

Suppose that BETAP-type letter strings are presented subsequent to a context that specifies the Roman alphabet (i.e., contains unique Roman characters) rather than the Cyrillic alphabet, in which a BETAP-type letter Serbo-Croatian has a lexical entry. By the preceding argument, word units connected to the phoneme units /*b*/, /*e*/, /*t*/, /*a*/, and /*p*/ 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 /*v*/ and /*r*/ in first and fifth positions would be activated weakly. In its early stages, therefore, the competitive process can be expected to favor word units other than that of wind (/*vetar*/). 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. A number of these expected outcomes have been simulated by a computer implementation of the model (see Appendix).

Experiments 2–4 of the present series evaluate the foregoing interpretation of the influences exerted on phonologically ambiguous items by preceding same- and other-alphabet contexts. The main hypothesis is that if the influences arise automatically in prelexical connections, then they should occur even when the same- and other-alphabet contexts are made weakly identifiable by the presence of masks. The fifth experiment of the series evaluates the same hypothesis for the case in which the masked alphabetic context follows the phonologically ambiguous item.

Experiment 1

The first experiment is a nonmasking experiment that provides a benchmark for Experiments 2–4, which examine the effects of alphabet contexts that are forward masked. The target stimuli in all four experiments were the same. On each trial of the first experiment an unmasked consonant context preceded a phonologically ambiguous target word. The alphabets of the context and target were either the same or different. The subject's task was to name the target as rapidly as possible. On the basis of previous research it was expected that naming responses would be significantly faster when the context's alphabet matched that of the target than when the context and target were printed in different alphabets (Lukatela, Feldman, et al., 1989; Lukatela, Turvey, et al., 1989). Because

PAE is now so well established (see Lukatela & Turvey, 1990a, for a synopsis of all experiments), and because previous experiments have found a negligible effect of alphabetic contexts on unambiguous items (Lukatela, Turvey, et al., 1989), Experiments 1–4 focus only on phonologically ambiguous stimuli (ambiguous and unambiguous forms are not contrasted). The simplified experimental question is, Are such stimuli identified better when preceded by an alphabetically matching context?

Method

Subjects. Twelve high school seniors from the Fourth Belgrade Gymnasium were paid for participation in the experiment. Each subject was assigned to one of two counterbalancing groups, according to his or her appearance at the laboratory.

Materials. An experimental set of 32 phonologically ambiguous Cyrillic (e.g., BETAP */vetar/* = the wind) and 32 phonologically ambiguous Roman (e.g., BOCA */botsa/* = the bottle) words were used as target stimuli. All words were of the CVCV... or VCVC... type. As such, all letter strings were orthographically and phonotactically legal by both readings and easily pronounceable in both readings. Most (80%) were 4–5 letters in length and bisyllabic. The remainder were mono- or trisyllabic. The contexts were all three-, four-, or five- consonant letter strings, with all letters in a string unique to either the Roman or the Cyrillic alphabet. One half of the targets were preceded by same-alphabet contexts, and one half of the targets were preceded by other-alphabet contexts. Importantly, the phonemic representation of the context preceding a given target was the same in both counterbalancing lists of stimuli. There was also a filler set of 24 target words. These words were composed of unique and common letters. Half of these phonologically unambiguous words were Roman, and half of the words were Cyrillic. They were similarly preceded by consonant contexts that either agreed or disagreed in alphabet. The average frequency of occurrence of the filler words (96) was approximately equal to the average frequency of occurrence (93) of the experimental words (based on Lukić's, 1981, count of a corpus of 1,500,000 words).

Design. A given subject never encountered a word or a consonant string more than once, but every subject saw every type of context-target pair (Roman and Cyrillic, same alphabet and other alphabet, experimental and filler). These conditions were met with two counterbalancing groups. In total, each subject saw 64 experimental plus 24 filler pairs ordered pseudorandomly.

Procedure. A subject was seated comfortably before the cathode-ray tube (CRT) 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 70 ms horizontally centered at the fixation point. After a 30-ms interstimulus interval (ISI) another letter string appeared. It was centered at the fixation point for 250 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. This means that all actual durations of (for example) the nominally 70-ms exposure varied in a random manner, with a uniform probability between 70 and 86 ms, whereby the statistical mean exposure was 78 ms.

Subjects were instructed to pronounce each target letter string as rapidly and as distinctly as possible. 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 included one or more phonemes different from those in the name of the target word, when the pronunciation was not smooth (i.e., the subject hesitated after beginning the name), or when the response was not initiated within the cutoff latencies (minimum = 200 ms; maximum = 1,200 ms). All naming responses were taped so that preliminary classifications of response adequacy could be checked. Mean latency measures were based only on correct responses. (To ensure that subjects were reading the contexts, a computer message appeared on five randomly selected trials requesting that the subject report orally both stimuli after the target word had been named. Given that the context was a consonant string, this message was a prompt to report as many of the 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. The intertrial interval (ITI) 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

An analysis of variance (ANOVA) limited to subjects is sufficient given the small set from which the stimuli were drawn. The ANOVA on correct naming times found a significant effect of alphabet context, $F(1, 11) = 21.55$, $MS_e = 4{,}113$, $p < .001$, with a mean for the same-alphabet condition of 667 ms and a mean for the other-alphabet condition of 788 ms. Errors revealed a similar outcome, $F(1, 11) = 77.80$, $MS_e = 79.12$, $p < .001$, with a mean for the same-alphabet condition of 16.7% and a mean for the other-alphabet condition of 48.7%. It is worth underlining that these large error rates do not index an inability to come up with a name for the presented target letter string. They reflect something more subtle, namely, a tendency to read one or more ambiguous letters incorrectly (e.g., reading the B in BETAP as */b/* rather than as */v/*) and a tendency to falter momentarily in pronunciation. These tendencies were more exaggerated when there was an alphabetic mismatch. In Experiment 1 of Lukatela, Turvey, et al. (1989), a lexical decision experiment with contexts and targets similar to those of the present experiment, the corresponding error rates were 13.05% and 34.60%. These were obtained under conditions in which the context appeared for 700 ms, followed 100 ms later by the target, which was exposed for 1,400 ms. Clearly, the present data, obtained under conditions of much reduced exposure times, are analogous to data collected previously on alphabet biasing. For purposes of comparison, it may be noted that the mean naming latency and mean error rate for the unique words (filler items) in the present experiment were 627 ms and 6.60%, respectively.

Finally, we consider those trials on which the context had to be reported. There were 60 such occasions (5 probes for each of 12 subjects). On every such occasion, some number of letters from the context was reported; that is, the subjects were always aware of the contexts on the probe trials. Of the 240 letters in the probed contexts (60 probes × 4 context letters on the average) that they could have reported, they reported correctly 129 (i.e., 53.80%).

Experiment 2

In the second experiment the context–target stimulus pairs of the first experiment were repeated under a different set of presentation conditions. Most notably, the context was shortened to 18-ms duration and was preceded, at an ISI of 0 ms, by a masking pattern of 500-ms duration. The choice of parameters was determined in a preliminary study. This preliminary study found that under the above presentation conditions, subjects could report, on the average, 10% of all the presented letters. To maintain a check on the level of context identification in the present experiment, a signal appeared on a random basis calling for a report of whether any letters other than those of the target word had been seen on that trial. As in the first experiment, the response was rapid naming of the target. It was hypothesized that, under these conditions of minimal context identification, the pattern of results obtained in Experiment 1 should be replicated with similar quantitative contrasts if the effects of alphabet context on phonologically ambiguous items do not depend on intentional strategies.

Method

Subjects. Fourteen high school students from the Fourth Belgrade Gymnasium were paid for participation in the experiment. Each subject was assigned to one of two counterbalancing groups, according to his or her appearance at the laboratory.

Materials and design. These were the same as in Experiment 1.

Procedure. The procedure was similar to that of Experiment 1, except for three modifications: (a) Each context was preceded by a visual mask that consisted of a row of eight hash marks; (b) the exposure times for context and ISI were reduced and of equal duration in the sense that both had statistical mean exposure times of 18 ms; and (c) on five randomly selected trials, after the target had been named, each subject was asked by a computer message, "Have you seen any letters beside the word?" If the subject responded "yes," then the experimenter asked the subject to say what they were and recorded the subject's report.

Results and Discussion

Analysis of correct naming latencies revealed a significant effect of alphabet context, $F(1, 13) = 29.29$, $MS_e = 2{,}186$, $p < .001$, with a mean for the same alphabet condition of 662 ms and a mean for the other alphabet condition of 758 ms. Errors revealed a similar outcome, $F(1, 13) = 70.78$, $MS_e = 75.76$, $p < .001$, with a mean for the same alphabet condition of 16.1% and a mean for the other alphabet condition of 43.8%. (Again, it is valuable to recall that the error measure reflects phonemic misassignments and both hesitant and tardy pronunciations.) This pattern of results and the numerical values are approximately identical to those obtained in the first experiment. The mean naming latency and mean error rate for the unique filler words were 629 ms and 7.7%, respectively, and were very similar to the values obtained in Experiment 1.

The mask and context parameters were chosen to minimize identification of the context. As noted, pilot research revealed a 10% level of identification accuracy on the average under these conditions. A further check was provided by the random probing of a subject's ability to report the contextual material. With respect to the question "Have you seen any letters besides the word?" a positive answer was given on 18 (26%) of the 70 times (5 times per each of 14 subjects) this question appeared. To the immediately subsequent question "What were the letters?" only 6 (2%) out of 280 letters (70 contexts of 4 letters each) were correctly identified.

Despite the much-reduced perception of contexts relative to what must have been the case in Experiment 1, the present results and those of Experiment 1 are, as just noted, qualitatively and quantitatively similar. This sameness is more in keeping with an automatic and prelexical interpretation than a strategic and postlexical interpretation. At the very least, it seems that, in a context–target sequence, little of the context needs to be processed, or processed very deeply, for there to be an influence of context alphabet on the processing of the phonologically ambiguous target items.

Experiment 3

The third experiment constituted a control for Experiment 2. Instead of consonant strings comprising the contexts, a fixed row of three dots was presented ahead of each target on each trial. The forward mask, target stimuli, and presentation parameters were the same as in Experiment 2. The experiment stimulated Experiment 2 even further in that half of the subjects received Set A, and half of the subjects received Set B of the target stimuli, with the stimuli coded as in the first two experiments. It was expected that mean naming latency to the stimuli in the same-alphabet condition should be the same as mean naming latency to the stimuli in the other-alphabet condition. By monitoring the response to the random probe "Have you seen any letters besides the word?" we can obtain from the present experiment an impression of the false-alarm rate associated with the procedure used in Experiment 2.

Method

Subjects. Ten high school seniors from the Fourth Belgrade Gymnasium were paid for participation in the experiment. Each subject was assigned to one of two counterbalancing groups, according to his or her appearance at the laboratory.

Materials. Target words were the same as in Experiments 1 and 2. The consonant strings comprising the contexts of Experiments 1 and 2 were replaced by a row of three dots.

Design and procedure. These were the same as in Experiment 2.

Results and Discussion

Analysis of correct naming latencies revealed no significant difference between same-alphabet and other-alphabet stimulus sets, $F(1, 9) = 3.64$, $MS_e = 523$, $p > .05$, with a mean for the same alphabet set of 693 ms and a mean for the other alphabet set of 712 ms. Errors revealed a similar outcome, $F(1, 9) < 1$, $MS_e = 84.04$, with a mean for the same alphabet condition of 24.06% and a mean for the other alphabet condition of 20.63%. This latter mean value compared with the corresponding mean value of Experiment 2 (43.80%), suggests that a context in the other alphabet increases the error rate to phonologically ambiguous words. That the two experiments are very comparable is suggested by the mean naming latency and mean error rate for the unique filler words. These were 620 ms and 7.1%, respectively, for the present experiment, compared with 629 ms and 7.74% in Experiment 2.

To provide a more direct comparison, a between-subjects ANOVA was conducted on the combined data of Experiments 2 and 3. To equate the numbers of subjects in the two experiments, we omitted from the analysis the last two subjects in each group of Experiment 2. For latencies, the main effect of alphabet was significant, $F(1, 18) = 93.3$, $p < .001$, but that of context (letter context of Experiment 2 = 740 ms vs. no-letter context of Experiment 3 = 702 ms) was not significant, $F < 1$. Importantly, the Alphabet × Context interaction (same alphabet vs. other alphabet for Experiment 2's context = +129 ms, same alphabet vs. other alphabet for Experiment 3's context = +19 ms) was significant, $F(1, 18) = 50.58$, $p < .001$. With context (Experiment 2), the alphabetical priming (same = 676 ms vs. other = 805 ms) was significant, $F(1, 9) = 127$, $p < .001$; without context (Experiment 3), the alphabetical priming (same = 693 ms vs. other = 712 ms) was not significant, $F(1, 9) = 3.64$, $p > .05$.

The error analysis was based on the following means: With context (Experiment 2), same alphabet = 15.3%, other alphabet = 40%; without context (Experiment 3), same alphabet = 24.1%, other alphabet = 20.6%. The ANOVA revealed that, of the main effects, alphabet was significant, $F(1, 18) = 19.65$, $p < .001$, context was insignificant, $F(1, 18) = 2.64$, $p > .05$. As was the case in the analysis of latencies, the Alphabet × Context interaction proved highly significant, $F(1, 18) = 34.42$, $p < .001$. With context (Experiment 2), the alphabetical priming (same vs. other = +24.7%) was significant, $F(1, 9) = 98.72$, $p < .001$; without context (Experiment 3), the alphabetical priming (same vs. other = −3.4%) was not significant, $F(1, 9) < 1$.

In the random probe in Experiment 3, in 17% of the 50 trials (5 trials per each of 10 subjects), subjects answered positively to the question of whether letters other than those in the target word had been seen. Given that no context appeared before the target on any trial of the present experiment, the 17% identifies a false-alarm rate for detecting a context in addition to a target. The subjects in Experiment 2 reported seeing something besides the target word on 26% of the times probed. The present probe results suggest that only approximately 10% of those reports were correct reports rather than incorrect guesses.

Experiment 4

The fourth experiment repeats the masking conditions of Experiment 2 with a major difference. An alphabet context in the present experiment consists of a single unique consonant. Previous research has shown that a single unique letter in a context of letters is sufficient to bring about a reduction in PAE, although the effect is larger the more numerous the unique letters (Lukatela, Feldman, et al., 1989; Lukatela, Turvey, et al., 1989). Experiments 2 and 3 of the present series have demonstrated that a reduction in PAE caused by an alphabetic context occurs even when the processing of the context is hindered by masking. As we noted in the introduction, the hindrance might take the form of reducing the number of letters that receive full analysis or reducing uniformly the depth of analysis of all letters. The foregoing results led us to expect that a single unique consonant subject to forward masking ought to affect the naming of a phonologically ambiguous word; naming should be faster and more accurate when the alphabet of the single letter and that of the word are congruent rather than incongruent. At the same time, given the earlier findings, it was expected that the effect of a masked single consonant should not be as great as that of a masked string of consonants. The fourth experiment should replicate the second experiment qualitatively but not quantitatively.

The significance of the present manipulation is twofold. First, masked single consonant contexts will invoke minimal lexical activity. Second, the opportunity, on any given trial, to apply a postlexical strategy based on knowledge about the context will be lessened by the use of a masked single consonant rather than a masked string of consonants. If an effect of alphabetic context could be found under the conditions of the second experiment, then an automatic, prelexical interpretation would seem more suited to the phenomenon in question than a strategic, postlexical interpretation.

Method

Subjects. Twelve students from the fourth Belgrade Gymnasium were paid for participation in the experiment. Each subject was assigned to one of two counterbalancing groups, according to his or her appearance at the laboratory.

Materials. These were the same as in Experiments 1, 2, and 3, with the exception that in the present experiment, the context was a single alphabetically unique (Roman or Cyrillic) consonant.

Design and procedure. These were identical to those in Experiment 2.

Results and Discussion

Analysis of correct naming latencies revealed a significant effect of alphabet context, $F(1, 11) = 6.36$, $MS_e = 1{,}205$, $p < .05$, with a mean for the same-alphabet condition of 633 ms and a mean for the other-alphabet condition of 668 ms. Errors revealed a similar outcome, $F(1, 11) = 11.95$, $MS_e = 118.48$, $p < .01$, with a mean for the same-alphabet condition of 15.1% and a mean for the other-alphabet condition of 30.5%. With respect to the unique filler words, the mean reaction time (RT) was 580 ms, and the mean error rate was 6.6%. There is a suggestion that the size of the alphabet effect on phonologically ambiguous items may be smaller in the present experiment than in the second one. This difference, if real, would be attributable to the single unique, alphabet-specifying letter comprising the contexts of the present experiment. Finally, with respect to the probe data, 12 (21%) of the 60 probed trials (5 per each of 12 subjects) were reported to include a context. Only 1 (2%) of the 60 letters in the probed contexts (60 probed contexts each of 1 letter) was identified correctly. The foregoing numbers compare favorably with the corresponding values of Experiment 2 and in the light of the probe results of Experiment 3 should be interpreted as indicating a very small percentage of trials (4–5%) on which there was an awareness of a context and an even smaller percentage on which the letters comprising those contexts were seen accurately.

Experiment 5

In the fifth experiment, a procedure is used in which the alphabet-specific context follows the target. The context acts to backward mask the target and is itself backward masked by a following patterned stimulus. There are particular advantages and disadvantages to using this backward masking procedure as a tool to investigate the influencing of processing phonologically ambiguous words through alphabet-specific contexts. The main disadvantage is that one cannot easily use latency measures such as rapid naming. Asking subjects to name quickly a stimulus that is followed by a mask and is thereby reduced in discriminability poses problems. The high error rate on the target induced by the context mask and the presence of letters in the context mask render the latency measure unreliable. Percentage correct of target word identification rather than latency is more suited to the backward masking procedure.

Among the advantages of this procedure are the insights that offers it into the word recognition process (Perfetti, Bell, & Delaney, 1988). When a briefly exposed target word is followed closely in time by a pattern, the processing of the target word can be interrupted so that the information derived from it is partial rather than full. If for a given set of stimulus parameters the target word was identified rarely, then it should be concluded that the internal lexicon was accessed rarely. In particular, the mask's effect was such that it prevented the acquisition of enough information to access the target's lexical entry. Suppose that for the same physical parameters a different masking stimulus, identical to the original in figural complexity but related on some linguistic processing dimension to the target word, resulted in a much higher level of target identification. Then it would have to be assumed that the increased performance was brought about by the new mask contributing to the processes needed for accessing the target's lexical representation (Lukatela & Turvey, 1990b; Perfetti et al., 1988).

Experiments 1–4 reinforce the notion that PAE is due to automatic prelexical processes and can be alleviated by alphabetic biasing of those processes, as identified in the model advanced by Lukatela, Turvey, et al. (1989) and described in the introduction. Let us see how the preceding logic of the backward masking procedure applies within the context of that model. In this fifth experiment, briefly exposed target words are identified under backward masking conditions in which the masks are consonant strings that specify one or the other alphabet and that are themselves followed by patterned stimuli to reduce identifiability and, thereby, guessing strategies about target–mask relationships. Suppose that BETAP is the target and фЖфдЂ (Cyrillic) or FZFDĐ (Roman) is the context mask. As a phonologically ambiguous item with two ambiguous letters, BETAP will activate seven phoneme units, namely, */b/*, */v/*, */e/*, */t/*, */a/*, */p/*, and */r/*. A following Roman mask will terminate the processing of BETAP and suppress the activity of the phoneme units */v/* and */r/* representing the Cyrillic interpretations of B and P. A Roman mask, therefore, will reduce further the likelihood of BETAP activating the word unit */vetar/*. In contrast, a following Cyrillic mask will terminate the processing of BETAP and suppress the phoneme units */b/* and */p/* representing the Roman interpretations of B and P. A Cyrillic mask, therefore, will increase the likelihood of BETAP activating the word unit */vetar/*. The upshot is that alphabetic congruity between mask and target will effectively reduce, and alphabet incongruity will effectively augment, the interruption of central processing normally induced by the mask. A phonologically ambiguous target preceding an alphabetically matched mask will be identified better than a phonologically ambiguous target preceding an alphabetically mismatched mask. The idea is that irrelevant word units activated partially by a phonologically ambiguous target will be suppressed, and the dominance of relevant word units thereby enhanced, by a subsequent alphabetically congruent mask.

Method

Subjects. Sixty high school seniors from the Fourth Belgrade Gymnasium were paid for participation in the experiment. Each subject was assigned to one of four counterbalancing groups, according to his or her appearance at the laboratory.

Materials. The set of target stimuli consisted of 32 (16 Cyrillic and 16 Roman) phonologically ambiguous words (e.g., Cyrillic BETAP meaning wind) and their 32 (16 Cyrillic and 16 Roman) corresponding unambiguous versions in the other alphabet (e.g., Roman VETAR meaning wind). Targets were printed in uppercase. All target words were paired with each of two mask types—same alphabet and other alphabet. Both mask types were strings of alphabetically unique uppercase consonants. Each mask was of the same length (i.e., it was composed of the same number of letters or phonemes) as the preceding target word. Four types of the target–mask pairs were constructed (see Table 1). In same-alphabet ambiguous pairs, both the target and the mask were written in the same (either in the Cyrillic or in the Roman) alphabet, and the target was phonologically ambiguous. In other-alphabet–ambiguous pairs, the target was phonologically ambiguous, and the target and the mask were written in different alphabets. In same-alphabet–unambiguous pairs, the target word was written in its phonologically unambiguous form, and the mask was written in the same alphabet. In other-alphabet–unambiguous pairs, the target word was written in its phonologically unambiguous form, and the mask was written in the other alphabet. For a given target word, the phonemic value of the mask was the same regardless of the type of pair.

Design. A given subject never encountered a word in any of the pairs more than once, but every subject saw every type of pair. These conditions were met with four counterbalancing groups. In total, each

Table 1
Examples of Target–Mask Pairs Used in Experiment 5

	Stimulus	
Type of pair	Target	Mask
Same alphabet ambiguous	BETAP	фЖфдђ
Other alphabet ambiguous	BETAP	FZFDĐ
Same alphabet unambiguous	VETAR	FZFDĐ
Other alphabet unambiguous	VETAR	фЖфдђ

Note. All targets are phonetically transcribed as */vetar/*; all masks are phonetically transcribed as */fzfddj/*.

subject saw 64 experimental pairs (16 same-ambiguous, 16 other-ambiguous, 16 same-unambiguous, and 16 other-unambiguous) ordered randomly.

Procedure. The subject was comfortably seated before the cathode-ray tube of an Apple IIe computer in a dimly lit room. Target words and strings of consonants were displayed in a dark-on-light format. The target and mask had nominal exposures of 40 ms each. As in the previous experiments, these exposure durations were nominal rather than exact because display changes in reality occurred within the standard 16-ms scan rate of the Apple IIe monitor. This means that all actual durations of the nominally 40-ms exposure varied in a random manner with a uniform probability between 40 and 56 ms, whereby the statistical mean exposure was 48 ms.

Each trial was initiated by a subject pressing the space bar on the keyboard. A fixation point appeared in the center of the screen and the subject heard a brief warning signal, after which a target word appeared for the nominal 40-ms duration, replacing the fixation point. The target was followed (with a zero ISI) by a mask (i.e., a string of alphabetically unique consonants), which replaced the target. The mask was presented for 40 ms and was followed by a row of six hash marks that remained on the screen until the next trial. The subject was instructed to write down on a prepared form the word he or she believed to have seen during the brief presentation of stimuli. The subject was encouraged to write, in default, just a single letter.

Results and Discussion

An ANOVA was conducted with factors of alphabet (same vs. other) and ambiguity (phonologically ambiguous vs. phonologically unique). Both main effects were significant. Same alphabet led to more identifications (35.62%) than other alphabet (31.41%), $F(1, 59) = 16.99$, $MS_e = 62.84$, $p < .001$, and the phonologically unique forms of the target words were identified better (38.75%) than the phonologically ambiguous forms of the same words (28.28%), $F(1, 59) = 37.63$, $MS_e = 174.73$, $p < .001$. The interaction (ambiguous items: same alphabet = 31.77%, vs. other alphabet = 24.79%; unique items: same alphabet = 39.48%, vs. other alphabet = 38.02%) was also significant, $F(1, 59) = 5.93$, $MS_e = 77.16$, $p < .02$.

Importantly, the data of the present experiment conform in all respects to the usual pattern of results obtained with the more standard procedure of unmasked stimuli and the more standard measures of rapid lexical decision and rapid naming (Lukatela, Feldman, et al., 1989; Lukatela, Turvey, et al., 1989). Alphabetic influences on the processing of phonologically unique words (e.g., VETAR) are usually small or nonexistent, and such words are usually perceived at a higher level than their phonologically ambiguous versions (BETAP). The fact that the alphabet relation between a nonword backward mask and a word target affected identification may be taken as demonstrating that alphabet specification affects a printed word prefatory to lexical access and does so automatically. A higher level of phonologically ambiguous target identification under same-alphabet masking relative to other-alphabet masking can be said to reflect the following: (a) inhibition, under same-alphabet masking, of irrelevant letter–phoneme connections, and (b) inhibition, under other-alphabet masking, of relevant letter–phoneme connections. The connections in question are those activated initially in the incomplete processing of the target. It should be underscored that the nature of the stimuli rules out a visual interpretation of the results along the lines that the same-alphabet context mask contained alphabet-specific figural qualities in common with the target. Targets contained only alphabetically neutral letters. For example, all five letters of BETAP are used in both alphabets, thus there are no special figural qualities that a following same-alphabet mask could specifically enhance. The alphabet effects observed in the present experiment (and the preceding experiments) can only be understood in terms of the particular connectivities of letters and phonemes defining the two alphabets.

With respect to the autonomy claim, the design of the experiments did not provide opportunity for task-specific strategic processes, such as resolving a target letter's ambiguity on the basis of the target's alphabetic relation with the mask. Across stimuli, the masks in one alphabet were paired equally often with targets in the other alphabet. Moreover, the nonword consonant masks were themselves masked.

In sum, where a mask is of the same alphabet as the phonologically ambiguous target, it can compensate for the interruption in processing by suppressing the irrelevant letter–phoneme connections activated by the target. Where a mask is of the other alphabet, it can amplify the interruption in processing by suppressing the relevant letter–phoneme connections activated by the target. Such effects would be prelexical because the connections suppressed by the masks would be those activated previously during the incomplete processing of the target.

General Discussion

In the present article we have investigated a feature of visual word recognition that is specific to the Serbo-Croatian language situation but that has implications for a more general understanding of the microstructural processes subserving visual word perception. Because of the language's bialphabetism, there are Serbo-Croatian words that can invoke more than one phonological interpretation. Such words are identified more slowly and with greater error rates than phonologically unique words. Research has shown that if such words are preceded by words or letter strings containing letters unique to one or the other alphabet, then the effects of phonological ambiguity can be substantially reduced. In particular, when a preceding letter string specifies an alphabet, that specification can affect the processing of an immediately following phonologically ambiguous item. An interpretation of this particular alphabetic context effect has been presented in the form of a model in which letter units with inhibitory connections defined, in part, by alphabet, connect through excitatory connections to phoneme units that in turn connect through reciprocating excitatory connections with word units. An alphabet-specific context item adjusts temporarily the states of the letter–phoneme connections, biasing processing in favor of the letter–phoneme correspondencies of one alphabet rather than those of the other. (In the absence of an alphabet-specific context, the letter–phoneme connections of both alphabets are equally excitable.) By this account, the slowed, more erroneous processing of phonologically ambiguous words in isolation arises in the letter–phoneme connections. By biasing these connections, an alphabetic context can alter the processing and error rates for phonologically ambiguous words.

Through the experiments reported in this article, we have attempted to verify the hypothesized automatic and prelexical nature of the influence of an alphabetic context. To this end, we used masking procedures in Experiments 2–4 to reduce the identifiability of context on the assumption that that would lessen the likelihood of a subject adopting a processing strategy dependent on explicit appreciation of the relation between the stimuli. In Experiment 5, this method was taken a step further in that the identifiability of the target was also markedly reduced. The outcome of these experiments reproduced the basic pattern of alphabet-specific influences: Latencies and error rates were smaller and identification accuracy was higher when a phonologically ambiguous word was processed in the context of a same-alphabet item relative to an other-alphabet item. This replication of the basic pattern under conditions of minimal identification bolsters the assumption of our model that the effect of alphabet-specific contexts on the processing of phonologically ambiguous items is more automatic than strategic.

Other aspects of the data lend support to further assumptions of our model, namely, that the effect of alphabet-specific contexts is tied to the activation of letter-processing units rather than word-processing units and that the processing benefits of a same-alphabet context accrue primarily in connections below the word-unit level. The contexts lacked lexical referents—they were nonword letter strings consisting of one, three, or five consonants unique to one or the other alphabet—and they were subjected to severe masking. It is reasonable to believe, therefore, that they invoked minimal activity at the level of word units but moderate to considerable activity at the level of letter units and that the latter activity sufficed to induce the effect. Experiment 5 addressed the site of the effect specifically. Identification of masked targets was higher when the nonword context masks were in the same alphabet as the targets than when they were in the other alphabet. Given (a) the assumption that backward pattern masks prohibit complete lexical access (Michaels & Turvey, 1979; Turvey, 1973) and (b) the identity of same- and other-alphabet stimulus display parameters, it seems that the differences between the effects of same- and other-alphabet masks must have been due primarily to their different contributions to the prelexical processes initiated by the targets. We recently reached a similar and converging conclusion with respect to the computation of phonology (Lukatela & Turvey, 1990b). Word identification was higher when an after-coming graphemically dissimilar consonant string was homophonic with the target than when it was nonhomophonic. As in the present experiment, the consonant strings as backward masks were themselves masked. We concluded that phoneme units activated by the target were further activated by the homophonic mask, and word units incompletely activated by the target were, thereby, completely activated by the now enhanced input from the phoneme level.

Although the assumptions of our model have received reasonable support from the present series of experiments, questions remain about the efficacy of the masking manipulations and, therefore, about the quality of the experimental evidence for automaticity and prelexicality. It will be necessary in future experiments to include more direct measures of the effects of masking and to vary systematically the masking parameters. Within the masking paradigm, rates of letter identification and influences upon those rates depend markedly on the stimulus onset asynchrony and on the viewing conditions (e.g., monocular or binocular vs. dichoptic) (Michaels & Turvey, 1979). Moreover, a complex of controls is needed to determine the relative magnitudes of explicit and implicit letter identification (Holender, 1986).

Concluding Remarks

The modeling of cognition in recent years has shown increasing concern for the microstructure of cognitive processes (e.g., McClelland, 1988). With regard to visual word recognition, we have pursued the idea that differences in orthographies realize differences in the processing microstructures subserving word recognition. Unlike most other languages, Serbo-Croatian has two alphabets. In microstructural terms, the consequence of this bialphabetism is a particular inhibitory interconnectedness of letter-processing units. A reader immersed from birth in the Serbo-Croatian language and its writing systems, who must cope continuously with the potential ambiguity afforded by partially overlapping letter sets, develops a microstructure adaptive to the task. Simultaneously, the native reader must develop a microstructure in conformity with the tight covariation of letters and phonemes (see van Orden, 1987) found in the written Serbo-Croatian language. The resultant is a particular interconnectedness unique and specific to the task of reading Serbo-Croatian. In these terms, the present research may be taken as providing further evidence for the processing microstructure spelled out in the model of Lukatela, Turvey, et al. (1989) and as underlining the need to consider the specializations of the reading mechanism for the different orthographies that visually transcribe languages (Frost & Katz, 1989; Frost et al., 1987).

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Appendix

Simulating Alphabet Priming by a Neural Network

The visual word-processing model proposed by Lukatela et al. (1989) for Serbo-Croatian is closely related to the interactive model of McClelland and Rumelhart (1981). This implies an intralevel inhibition among processing units at each level of letter units, phonemic units, and word units. There are also excitatory interlevel connections: a bottom-up feed forward, as well as a feed back from the word-processing units to the phoneme-processing units. This network provides for lateral inhibition among activated processing units. The inhibitory as well as excitatory processes are not inertialess: They are not permitted to build up or turn off instantaneously. Our model secures a smooth change of the processing-unit activation over time by using an equivalent of a low-pass filtering operation. Instantaneous activation of the processing unit $a(t)$ is integrated over the previous time interval, T, to yield the filtered output activation of the processing unit:

$$A(T) = \int [a(x)\ exp[-(T - x)R]d(x), \qquad \text{(A1)}$$

in which R represents the decay constant and the limits of integration are $-\infty$ and T. By an appropriate choice of the T and R parameters, it is possible to account for effects between sequentially presented stimuli. Figure A1 gives one such example involving the successive activation of the word-processing units {/*dug*/} meaning debt and {/*san*/} meaning dream. The context word {/*dug*/} is written *DUG* in Roman and ДУГ in Cyrillic; the target word {/*san*/} is written *SAN* in Roman and *CAH* in Cyrillic.

Activation levels are given in arbitrary units, and time is expressed in operational cycles. The context letter string *DUG* was presented for 10 cycles (from −15 to −5), the ISI was 5 cycles long (from −5 to 0), and the target letter string *SAN* or *CAH* was presented for 35 cycles (from 0 to 35). Parameter values of $T = 5$ and $R = 0.90$ were selected, with an activation threshold of 60 units. With respect to alphabetical priming, the activation of a given target word unit

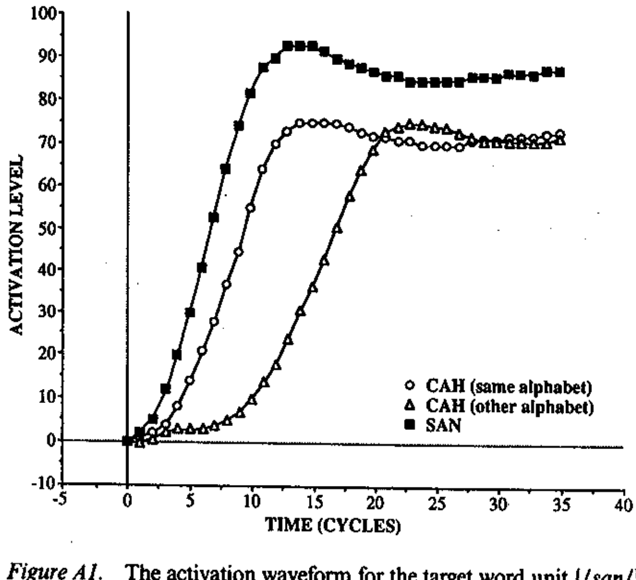

Figure A1. The activation waveform for the target word unit {/*san*/} when the input was the phonologically ambiguous CAH in the context of ДУГ (same alphabet), the phonologically ambiguous CAH in the context of DUG (other alphabet), and the phonologically unambiguous SAN in the context of DUG (same alphabet). (Phonologically unique letter strings are unaffected by the alphabet of context; SAN with and without DUG would have much the same activation profile.)

depends on two factors: (a) the phonological ambiguity of the input letter string and (b) the alphabetical relation between the context and target input letter string. Figure A1 presents the activation waveforms for three different situations: (a) *DUG-SAN*, when the target is phonologically unambiguous and alphabetically congruent with the context, (b) ДУГ-САН, when the target is phonologically ambiguous and alphabetically congruent with the context, and (c) *DUG-CAH*, when the target is phonologically ambiguous and alphabetically incongruent with the context. The approximate value of the rise time for the word unit {*/san/*}, as shown in Figure A1, is approximately 7.5 cycles, 11 cycles, and 18.5 cycles, for Situations (a), (b) and (c), respectively. In sum, the phonologically ambiguous item reached threshold more slowly than the phonologically unambiguous item, and the phonologically ambiguous item reached threshold more quickly in the same-alphabet context than in the other-alphabet context.

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