EUROPEAN JOURNAL OF COGNITIVE PSYCHOLOGY, 1990, 2 (4) 375–394

Phonemic Priming with Words and Pseudowords

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The bi-alphabetic nature of the Serbo-Croatian writing system allows unequivocal examination of phonemic similarity unconfounded with graphemic similarity. The Roman and Cyrillic alphabets are largely independent but map onto the same sounds. A lower-case context written in one alphabet bears no visual similarity to an upper-case target written in the other alphabet. One naming experiment and one lexical decision experiment investigated phonemic priming of high-frequency words and pseudowords with word and pseudoword contexts. For naming, targets that were phonemically similar to the preceding context were named significantly faster than were phonemically dissimilar targets. This result was indifferent to the lexicality of the contexts and targets. For lexical decision, in contrast, phonemically similar word–word pairs showed inhibition, whereas phonemically similar pseudoword–word pairs showed facilitation relative to their phonemically dissimilar counterparts. These results were discussed in terms of (1) a model of visual word processing that posits a layer of phoneme units between letter units and word units, and (2) the idea that active word units inhibit one another in proportion to each one's frequency. In this account, phonemic similarity effects in naming are based on the states of the phoneme units, while phonemic similarity effects in lexical decision are based on the states of the word units. These results lend further support to the claim that, for readers of Serbo-Croatian, the visual computation of phonology is automatic and prelexical.

INTRODUCTION

The influences of one word on the mental processing of another word, presented simultaneously or subsequently, comprise an important body of

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This research was supported in part by National Institute of Child Health and Human Development Grants HD-08495 and HD-01994 to the University of Belgrade and Haskins Laboratories, respectively.

data for making inferences about the nature of cognitive mechanims. In this respect, the possibility that processing influences between words can be exerted through phonemic similarity is important to models of word recognition and to models of the organisation of the internal lexicon. Unfortunately, the existence of phonemic priming is uncertain if based solely on the use of English language materials. Hillinger (1980) seemed to provide the most straightforward demonstration, including appropriate controls for graphemic relatedness (*LATE–MATE* and *EIGHT–MATE* showed equal facilitation relative to the control *VEIL–MATE*). He saw his data as evidence for an access file organised by physical similarity, and for an explanation of rhyming facilitation in terms of spreading activation among entries in this file. Martin and Jensen (1988), however, were unable to replicate Hillinger's finding using the same stimuli. Indeed, they failed to find any rhyme facilitation in five experiments, even when contexts were also graphemically related (*PITCH–DITCH*). They suggested that where significant priming for graphemically related rhymes has been obtained (e.g. Hanson & Fowler, 1987; Shulman, Hornak, & Sanders, 1978), it has required the simultaneous presentation of context and target. This presumably makes the graphemic relationship more apparent.

Such a restriction is not necessary to obtain phonemic similarity effects in languages other than English. Using the Italian language, Colombo (1985) has found similarity effects (she does not disentangle graphemic from phonemic) over a range of SOAs. She has also found that the effect can be either facilitatory or inhibitory, depending on the frequency of the word targets and the position of the letters shared by the context and target (Colombo, 1986). These findings have been corroborated in a series of experiments using the Serbo-Croatian language (Lukatela & Turvey, 1990). Moreover, given the nature of the bi-alphabetic Serbo-Croatian writing system – the graphemically dissimilar Roman and Cyrillic alphabets are largely independent and map onto the same set of phonemes – phonemic similarity effects can be shown to be quite independent of graphemic similarity. For example, PASUS-ПАСУЉ is phonemically similar (/pasus–pasulj/) but graphemically dissimilar because the context is written in Roman while the target is written in Cyrillic. ПАСУС-ПАСУЉ is phonemically and graphemically (Cyrillic–Cyrillic) similar. Lexical decisions to targets in these situations are facilitated to the same degree relative to DUVAČ-ПАСУЉ, a phonemically dissimilar (/duvatʃ-pasulj/) and graphemically dissimilar (Roman–Cyrillic) word pair (Lukatela & Turvey, 1990).

Clearly, this aspect of the Serbo-Croatian writing system provides ideal conditions for studying phonemic priming unconfounded by graphemic priming. Phonemic similarity effects are quite robust and are present even when masking renders the context unidentifiable (Lukatela, Carello, &

Turvey, in press; Lukatela & Turvey, 1990, experiment 10). Phonemic similarity effects are also obtained with a naming task, but naming is not sensitive to the same influences as lexical decision. In contrast to lexical decision, phonemic similarity effects in naming are only facilitatory and are not altered by context familiarity, target familiarity, target lexicality, or position of shared phonemes, but can be eliminated if the context and target are stressed differently (Lukatela & Turvey, 1990). Given that naming and lexical decision are understood to be differentially sensitive to lexical influences, such findings have contributed to accounts of prelexical processes in bi-alphabetical word perception, and of inhibitory processes among word units in the internal lexicon (Lukatela et al., 1989b; Lukatela & Turvey, 1990). These accounts are described in the following.

A Model of Serbo-Croatian Word Recognition

In order to understand the requirements for a model of processing Serbo-Croatian letter strings, a few facts about the language should be noted. First, the Serbo-Croatian orthography, unlike the English orthography, is phonologically shallow: All letters are pronounced and their individual pronunciations are not altered significantly by the letter contexts in which they are embedded. Secondly, the writing system is bi-alphabetic. The Roman and Cyrillic alphabets are largely distinct and map onto the same set of phonemes. Thirdly, of those letters where the two alphabets are not distinct in the upper-case form, seven are common and receive the same phonological interpretation in the two alphabets, while four are phonologically ambiguous and receive different interpretations in the two alphabets. We have presented a view of the processing of Serbo-Croatian letter strings as involving, in bottom-up succession, connected layers of featural processing units, letter processing units, phoneme processing units, and word processing units (Lukatela et al., 1989a). Of special significance are the letter units-to-phoneme units connections. These embody the grapheme–phoneme correspondences of the language. In the phonologically shallow Serbo-Croatian orthography, unlike a phonologically deep orthography such as English, these correspondences are straightforward.

In our model (Lukatela et al., 1989b), the network of letter-to-phoneme connections for a single letter position exhibits characteristics that are dictated by the bi-alphabetic nature of the language. Each letter unit connects to its corresponding phoneme unit. No phoneme units are duplicated. For the phoneme units connected to the unambiguous letter units shared by the two alphabets, there is one letter unit per phoneme unit. 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. This pattern of connections is repeated across letter positions.

With the activation of phoneme units by letter units, it is hypothesised that a two-way interactive process is initiated between the phoneme units and word units. The access of word knowledge is seen to take place principally through the phoneme level to word level connections. Turning to phonemic priming, a phonemically similar context activates almost all of the phoneme units of the following target. The shared and unshared phoneme units, in turn, will activate all of the word units that contain these phonemes in the same positions. On presentation of the target, this patterning of phoneme and word units, and the interaction between them, comprise the background against which the target's processing takes place.

The assumptions and hypotheses advanced above comport with a large body of experiments, notably those presented in Lukatela et al. (1989a,b) and Lukatela and Turvey (1990). Let us apply these ideas to phonemic priming in lexical decision and naming.

Phonemic Similarity Effects in Lexical Decision. Our research suggests that the task of lexical decision is constrained primarily by the individual states and collective dynamics of the word units. When a context and a target are phonemically similar, and the target is a highly familiar item, the processing of the context results in inhibition of the target's representation (Lukatela & Turvey, 1990). This outcome is understandable from Grossberg's (1978) principle of self-modulation: The proportion of the net inhibition felt by a given unit (in a set of activated units) is scaled positively to the given unit's level of activity; the given unit's level of activity is scaled positively to its activation threshold; and the given unit's activation threshold is scaled positively to the familiarity of the word that it represents. As a consequence, highly familiar targets are subject to high levels of inhibition during the processing of the context (Colombo, 1986), with the result that phonemic similarity effects with highly familiar targets can be negative.

For target words of low familiarity and for target pseudowords, a phonologically similar context will activate most of the phoneme units to be used in processing the target. In neither case, however, will there be an exceptionally high level of activation in any individual word unit. Consequently, no individual word unit will be subject to high levels of inhibition. For a word target of low familiarity, the low level of inhibition at the word unit level means that the target's processing can benefit from the preactivation of its phoneme units and its word unit. Similarly, processing of a pseudoword target can benefit from the pre-activation of its phoneme units. The lexical decision process, however, may be understandable ultimately as a signal detection problem. If so, then for pseudoword targets, the processing advantages of priming units below the word unit level could be outweighed by post-lexical processing disadvantages (see Lukatela & Turvey, 1990).

Phonemic Similarity Effects in Naming. A number of experiments provide converging evidence for the hypothesis that naming is constrained primarily by the individual states and collective dynamics of the phoneme units (Lukatela et al., 1989a,b; Lukatela & Turvey, 1990). A context that primes the phoneme units of a subsequent letter string should facilitate naming. Moreover, according to our model, it should do so equally for target words and target pseudowords. In isolation, naming a word is distinguished from naming a pseudoword by the contribution of information from accessed word units. When a word is presented, one word unit achieves dominance at the word unit level, reinforcing the states of the phoneme units. When a pseudoword is presented, no word unit – on the average – achieves dominance, and the reinforcement of phoneme units is, therefore, much less pronounced. The lexicality variable, by definition, is manifest primarily at the word unit level; it is a matter of whether or not a word unit is fully activated in the processing of a letter string. The phonemic similarity variable operates, primarily, at the level of phoneme units; it is a matter of whether or not the target's phoneme units are activated. Consequently, in naming, the effects of the one variable should add to the effects of the other variable.

The significance of target familiarity in the phonological similarity effect with lexical decision is understood in terms of the degree of inhibition generated at the word unit level. Inhibition, however, does not occur between adjacent levels, only activation; this means that phonemes relevant to the processing of the target will not be inhibited even if the word unit relevant to the processing of the target is inhibited. For both words of high and low familiarity, a phonemically similar context word will activate phoneme units relevant to naming the target. Downward activation from the word unit level may boost these phoneme units, more or less. Although phonemic similarity and target frequency affect naming, they do not interact (Lukatela & Turvey, 1990).

A Simulation

We have implemented the model described above for a lexicon consisting of three-letter word units. There are three complete sets of letter units and phoneme units, one for each letter/phoneme position in the word unit. There are no feature level units. A typical simulation cycle consists of the following sequence of events: (1) visual input, (2) start first cycle, (3) activations of letter units, (4) inhibition between Roman and Cyrillic subset of letter units, (5) intra-level inhibition of letter units, (6) activation of phoneme units by letter units, (7) intra-level inhibition of phoneme units, (8) activation of word units by phoneme units that are contained in the word unit at the appropriate positions, (9) intra-level inhibition of word units, (10) feedback activation of phoneme units by word units that contain the active phoneme units in the appropriate positions, (11) end cycle, start next cycle.

The intra-level inhibition among the word units is designed around the principle of self-modulation (Grossberg, 1978): The magnitude of inhibition (Iw1) received by a given word unit is a function of the summed activation of all other word units (AW) *and* the activation of the considered word unit (Aw1) itself:

1. $(Iw1) = -k\,(Aw1)\,(AW)$

where k is an arbitrary scaling factor. In the simulation, the intra-level inhibition of word units is elaborated to incorporate the individual effects of activated phoneme units. Consider a word unit (w1) with the current activity level (Aw1), and assume a summed activity level (AW) of all other word units (w2, w3, w4, . . .). For simplicity, assume that the word unit w1 comprises a sequence of three phoneme units (p1, p2 and p3), each having the current activity level Ap1, Ap2 and Ap3, respectively. Then, the total inhibitory input (Iw1) to the word processing unit (w1) will consist of three different components. The first component is obtained when the summed input activity (AW) is modulated by the current activity (Ap1) of the phoneme processing unit (p1); the second and third components are obtained in a similar way, and the total inhibition felt by the word processing unit w1 will be given by:

2. $(Iw1) = -\,[k1\,(Ap1) + k2\,(Ap2) + k3\,(Ap3)][(AW)]$

where the scaling factors, k1, k2 and k3, may incorporate different perceptual weights of the initial, middle or final phoneme in three-letter word recognition. Obviously, if perceptual differences among letter/phoneme positions are ignored, then all scaling factors would be equated ($k1 = k2 = k3 = k$) and Eqn (2) is identical with Eqn (1).

The current simulation works with 178 word units – almost the entire set of Serbo-Croatian three-letter words of the consonant–vowel–consonant type. The magnitude and/or decay constant per activation cycle can be specified independently for inter-level excitatory (input-to-letter, letter-to-phoneme, phoneme-to-word, for the first, second and third positions, and word-to-phoneme) and intra-level inhibitory (alphabet, letters, phonemes, words, for the first, second and third positions) processes. The model can handle an input that consists of one or two letter string(s) written in Roman or Cyrillic. The interval between the letter strings can be set to zero, or to any non-zero value. The stimulus presentation period(s) and interstimulus interval are specified in terms of activation cycles. Eighty cycles are possible. For a given input letter string(s), the output is presented either as a numerical table or a graph. A typical graph reveals the time course of the activation states of the letter units, phoneme units and word units, whereby the maximum activation per processing unit is normalised and cannot exceed 1.

The simulations have shown that the behaviour of the model is in fair agreement with relevant empirical data. For example, the phonemic similarity effect has been simulated. Consider four Serbo-Croatian words: BIČ, ДОК, КИЧ, БИК. These can be used to produce three context-target pairs: type 1, ДОК-BIČ; type 2, КИЧ-BIČ; and type 3, БИК-BIČ. In all pairs, the target word is the letter string BIČ written in the Roman alphabet. All context words are written in the Cyrillic alphabet, and all context words are graphemically dissimilar with regard to the target word BIČ. In type 1 (/dok/–bich/), the context and target do not share any phoneme and comprise a phonemically dissimilar pair. In type 2 (/kich/–/bich/), the context and target share all phonemes except the initial one – the phonemically initial-different pair. Type 3 (/bik/–/bich/) is a phonemically final-different pair.

For a given set of parameter values, the context word was presented for 10 cycles, and it was immediately followed by the target word BIČ which lasted until the end of each trial. From numerical tables, as well as from the diagram, we observed the time course of activation of processing units both at the phoneme units level and at the word units level. In order to assess relative speed of activation in various processing units, we had to establish a criterion for the response threshold. Rather arbitrarily, we set the response threshold at approximately 70% of a processing unit's maximum steady-state activation. The "lexical latency" was expressed as the number of processing cycles between the target stimulus onset and the moment when the activation of a given word processing unit reached its response threshold. Roughly speaking, the lexical latency could be thought of as an analogy to the lexical decision latency in the lexical decision task. Similarly, because our experimental data suggest that latency in the rapid naming task depends basically on the state of activation of the set of phoneme units comprising all phonemes of the target word, "prelexical latency" – an analogy of naming latency – was defined as that particular moment when all phoneme processing units of a given set reached their respective response thresholds.

For the phonemically dissimilar pair (type 1), the simulation yielded the pre-lexical latency of approximately 7 cycles, and the lexical latency of approximately 22 cycles. For the initial-different pair (type 2), the pre-lexical latency was approximately 5 cycles, and the lexical latency was approximately 29 cycles. For the final-different pair (type 3), the pre-lexical latency was approximately 5 cycles, and the lexical latency was approximately 38 cycles. These results are in agreement with our theoretical understanding of phonemic similarity effects.

Evaluating the Contrasting Effects of Word and Pseudoword Phonemic Primes

The present experiments were designed to test a prediction of the model that phonemic similarity effects in naming and lexical decision with highly familiar targets should differ as a function of the lexicality of the context. In particular, phonemically similar word and pseudoword contexts should (1) *have a uniformly positive effect on naming*, given that naming speed depends on the state of the phoneme level, which is affected equally in bottom-up processing by word and pseudoword contexts and reinforced by top-down processing, and (2) *interact in their influence on lexical decision*, with maximum inhibition arising with word–word pairs. In lexical decision, a context pseudoword that is phonemically dissimilar to a target will influence neither the appropriate phoneme units nor the target's word unit. A phonemically similar context pseudoword will activate most of the appropriate phoneme units, and partially activate the target's word unit. Much less inhibition is generated at the word unit level, however, compared to a phonemically similar word context, so that the phonemic similarity effect for pseudoword–word pairs should be much less negative. Indeed, if the excitation and inhibition at the word unit level balance each other, then the only residual influence would be felt from appropriately activated phoneme units and the phonemic similarity effect for pseudoword–word pairs could be positive. The sub-predictions (1) and (2) were assessed in two experiments, naming in Experiment 1 and lexical decision in Experiment 2.

EXPERIMENT 1

Based on the results of Lukatela and Turvey (1990, experiment 7), naming of word and pseudoword targets should be facilitated uniformly by phonemically similar word contexts. They also found no difference in facilitation between contexts that varied in familiarity, again because the same phoneme units are highly activated for both. This last fact suggests that facilitation by word and pseudoword contexts should also be equivalent. In the present experiments, phonemic similarity is defined with respect to the last letter of the context and target. Prior research has shown that the effect of phonemic similarity on naming is independent of the position of the phoneme by which the two stimuli are distinguished. In order to ensure that effects are due to phonemic and not graphemic similarity, contexts and targets are written in different alphabets and cases. Contexts are always lower case, targets are always upper case. For half of the trials, context–target pairs are Roman–Cyrillic (e.g. kuvar-ЧУВАР) and for the other half they are Cyrillic–Roman (e.g. кувар-ČUVAR). For all pairs, this yields visual forms that are quite different, both in terms of the individual letters and the "envelope" of the entire letter string. A facilitatory effect of phonemic similarity on naming latencies is expected, as is a main effect of target lexicality. No other main effects or interactions should be apparent.

Method

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

Materials. A total of 125 pairs of words were created that differed only in the final consonant letter (examples are given in Table 1). All words were between four and six letters in length; a context word always had the same number of phonemes as its corresponding target word. Contexts and targets were chosen to be as similar as possible with respect to accent position (i.e. syllable) and type (i.e. short rising, short falling, long rising, or long falling) and without any associative or semantic relationship. All words were masculine nouns in the nominative singular grammatical form. The individual words in these pairs were then judged for familiarity on a 5-point scale (5 = very familiar, 1 = very unfamiliar) by 35 students from the same year as the high school students who served as subjects (cf. Gernsbacher, 1984). Words ranked 4–5 on the average were designated as highly familiar and used in the experiment. On the basis of these judgements, 96 pairs were drawn from the original 125 pairs. Forty-eight pairs were selected such that the mean familiarity measure for the context and target items was between 4 and 5. To create the corresponding pseudoword–word, word–pseudoword and pseudoword–pseudoword pairings, the final letter (phoneme) of the contexts and/or targets was changed. To create the phonemically dissimilar pairs (most letters/phonemes different) contexts were interchanged within each of the four original (phonemically similar) pairs. There were in all, therefore, eight groupings of stimuli with 24 different pairs per group.

TABLE 1
Examples of the Kinds of Context–Target Pairs Used in Experiments 1 and 2. Phonemically Similar Pairs Differ in the Final Phoneme. The Contexts were Presented in Lower Case and Targets in Upper Case. The Context and Target in a Pair were Written in Different Alphabets

Type of Pair	*Phonemic Similarity*	*Example*[a]	
		Context	*Target*
Word–Word:			
Experimental	Yes	pasus	ПАСУЉ
Control	No	duvač	ПАСУЉ
Pseudoword–Word			
Experimental	Yes	pasud	ПАСУЉ
Control	No	duvag	ПАСУЉ
Word–Pseudoword			
Experimental	Yes	гусар	GUSAD
Control	No	факин	GUSAD
Pseudoword–Pseudoword			
Experimental	Yes	гусањ	GUSAD
Control	No	факил	GUSAD

[a]Examples with word targets are shown in Roman–Cyrillic. Examples with pseudoword targets are shown in Cyrillic–Roman.

Design. The two word–word, two pseudoword–word, two word–pseudoword and two pseudoword–pseudoword conditions were manipulated within subjects. A given word context was seen by an individual subject twice, once preceding the word target and once preceding the pseudoword target. When the word target was Roman, the corresponding pseudoword target was Cyrillic, and vice versa. The same was true of pseudoword contexts: A given pseudoword context was also seen by an individual subject twice. A subject never encountered a target word or target pseudoword in any of the pairs more than once, but every subject saw every type of pair. Targets that appeared in each condition were counterbalanced over subjects. These constraints were met with two counterbalancing groups. Each subject was presented with 24 stimuli pairs in each of the eight conditions for a total of 192 pairs. The experimental sequence was preceded by a practice session of 32 different pairs of the same eight types.

Procedure. A subject was seated before the CRT of an Apple IIe computer in a dimly lit room. A fixation point was centred on the screen. On each trial, the subject heard a brief warning signal after which a letter string appeared for 500 msec above the fixation point. After a 100 msec interstimulus interval, another letter string appeared below the fixation point for 500 msec. The inter-trial interval was 2000 msec. Subjects were required to pronounce the second letter string as quickly and distinctly as possible. To ensure that the subjects were reading the contexts, they were asked occasionally by a computer message to report the context after the target had been named (on average, approximately every 15 trials). In all conditions, latencies from the onset of the target to the onset of the response were measured by a voice-operated trigger relay. If the response latency was longer than 1500 msec, a message appeared on the screen requesting that the subject respond more quickly. Naming was considered to be erroneous when the pronunciation included a phoneme not specified by the characters in the letter string, the pronunciation was not smooth (i.e. the subject hesitated after beginning the name), or the response was not initiated within the cut-off latency. After each quarter of the trials, there was a brief rest. Within each quarter, context-target types were ordered randomly.

Results and Discussion

The mean latencies and errors for words and pseudowords are presented in Table 2. Inspection of Table 2 reveals that phonemic similarity was facilitatory of both word and pseudoword naming times independent of context lexicality. A 2 (phonemic similarity) × 2 (context lexicality) × 2 (target lexicality) analysis of variance was conducted on the latencies and errors. Both phonemic similarity [similar = 543 msec, dissimilar = 561 msec: min $F'(1, 120) = 11.03$, $P < 0.001$] and target lexicality [words = 535 msec, pseudowords = 569 msec: min $F'(1, 35) = 16.38$, $P < 0.001$] were significant. Context lexicality was not significant, nor were any of the interactions (all min $F' \approx 1$). There were no significant effects in the error analyses.

As expected, naming of word and pseudoword targets was facilitated uniformly by phonemically similar word and pseudoword contexts. These results are consistent with the claim that the naming of Serbo-Croatian words is based on the states of the phoneme processing units. The difference between naming latencies for word and pseudoword targets is also expected. While it is the case that a name is derived from letter-to-phoneme correspondences, the activity at the phoneme unit level is modulated or reinforced by feedback from the level of word units (Carello, Lukatela, & Turvey, 1988; Lukatela et al., 1989a,b; Lukatela & Turvey, 1990). This involvement of units at the word level is dictated, in part, by the fact that although the Roman and Cyrillic alphabets are largely distinct, they do share some letters. Some of these shared letters are pronounced

TABLE 2
Mean Naming Latencies (L, msec) and Error Rate (ER, %) with the Corresponding Standard Deviations by Subjects and by Items in Experiment 1

Target	Context	Phonological Relation			
		Similar		Dissimilar	
		L	*ER*	*L*	*ER*
Word	Word	527[a]	5.00	541	3.96
		70[b]	2.18	67	3.16
		42[c]	2.45	36	3.09
	Pseudoword	528	5.83	543	4.17
		71	2.49	77	2.34
		35	2.02	39	2.79
Pseudoword	Word	552	5.63	574	5.00
		91	2.45	92	3.20
		47	2.02	47	1.44
	Pseudoword	566	4.17	584	5.63
		97	3.02	101	2.80
		47	2.79	62	1.44

[a]Mean; [b]standard deviation by subjects; [c]standard deviation by items.

differently in the two alphabets, rendering certain letter strings phonologically ambiguous. In such cases, the automatically realised connections between individual letters and individual phonemes will yield a number of possible pronunciations at the level of phoneme units. The connections between the levels of word and phoneme units contains the information needed to specify uniquely the pronunciation of phonologically ambiguous words. Within the proposed model for Serbo-Croatian word perception, equivocality in pronunciation is resolved through the automatic two-way interaction between phoneme processing units and word processing units. Because of the automatic nature of these processes, however, they apply to all letter strings, whether phonologically ambiguous or not, whether word or pseudoword (Carello et al., 1988; Lukatela et al., 1989a,b; Lukatela & Turvey, 1990). It follows, therefore, that phoneme units activated by a word have more to gain from the interactive phoneme level–word level processes than phoneme units activated by a pseudoword. In consequence, a word will be named faster than a pseudoword, even though letter–phoneme connections determine the basic form of the pronunciation of each.

EXPERIMENT 2

The influence of contextual information on visual word processing has been found to depend not only on the kind of context but also on the nature of the task. Lexical decision and naming have emerged as necessary converging operations in order to distinguish lexical from pre-lexical influences (e.g. Carello et al., 1988). Whereas naming reflects sensitivity to pre-lexical influences only, lexical decision reflects a decision bias as well as sensitivity to pre-lexical influences. Further, whereas naming time reflects the states of phoneme units, lexical decision time reflects the states of the the word units. Therefore, in contrast to the naming task of Experiment 1, lexical decision should show a differential phonemic similarity effect for word and pseudoword contexts. Again, a comparison of familiar and unfamiliar contexts in previous work is instructive. When phonemic similarity is defined with respect to the last letter, familiar word contexts produce more inhibition than unfamiliar word contexts (Lukatela & Turvey, 1990, experiment 4). A similar interaction should obtain between phonemic similarity and context lexicality (word *vs* pseudoword) with significant inhibition characterising phonemically similar word–word pairs and insignificant inhibition or facilitation characterising phonemically similar pseudoword–word pairs.

Method

Subjects. Thirty-two high school seniors from the Fourth Belgrade Gymnasium were paid to serve in the experiment. Each subject was assigned to one of four counterbalancing groups according to his or her appearance at the laboratory.

Materials. A total of 80 word–word final-different pairs were selected from the same list of phonemically similar pairs as those in Experiment 1. Eight psuedoword contexts were generated by changing the final letter in the corresponding (phonemically similar) word target. Pseudoword targets were generated from a different set of 80 highly familiar words from those used in Experiment 1, with the source words serving as their contexts. This change meant that a given context was seen only once by each subject. As before, phonemically dissimilar pairs were created by interchanging contexts within each of the four original (phonemically similar) pairs. There were in all, therefore, eight groupings of stimuli with 20 different pairs per group.

Design. In the present experiment, a given subject never encountered a word or a pseudoword in any of the pairs more than once, but every subject saw every type of pair, and every target appeared in every type of pair. These constraints were met with four counterbalancing groups. In total, each subject saw 160 experimental stimulus pairs. The experimental sequence was preceded by a practice session consisting of 40 different pairs. In all other respects, the design was the same as in Experiment 1.

Procedure. All presentation parameters and cut-off latencies were the same as in Experiment 1. The subjects were instructed to decide as rapidly as possible whether or not the second letter string was a word. Their decisions were indicated by depressing with both thumbs a telegraph key for a "No" response or by depressing another key, slightly further away, with both forefingers for a "Yes" response. Latencies were measured from the onset of the target. If the response latency was longer than 1400 msec, a message appeared on the screen requesting that the subject respond more quickly, but long decision times were included in the analysis. All other procedural features were the same as in Experiment 1.

Results and Discussion

The mean latencies and errors for words and pseudowords are presented in Table 3. Inspection of Table 3 reveals that phonemic similarity was inhibitory of word acceptances with word contexts but facilitatory of word acceptances with pseudoword contexts. A 2 (phonemic similarity) × 2 (context lexicality) × 2 (target lexicality) analysis of variance was conducted on the latencies and errors. The only significant main effect was lexicality [words = 642 msec, pseudowords = 704 msec: min $F'(1,78) = 37.06$, $P < 0.001$]. Neither phonemic similarity (similar = 674 msec, dissimilar = 673 msec) nor context lexicality (words = 670 msec, pseudowords = 676 msec) reached significance (min $F' < 1$). The influence of these factors can be seen in the significant three-way interaction [min $F'(1, 138) = 12.05$, $P < 0.001$]. Given the significant three-way interaction, the word target and pseudoword target data were analysed separately. The analyses revealed that similarity and context lexicality interacted for word targets (dissimilar/similar for words, −21 msec; dissimilar/similar for pseudowords, +25 msec: $F(1, 101) = 10.58$, $P < 0.002$], but not for pseudoword targets [$F(1, 108) = 2.69$, $P > 0.10$]. Indeed, there was no similarity effect for pseudoword targets ($F = 1$). None of the two-way interactions were significant (all min $F' \approx 1$). There were no significant effects in the error analyses.

As expected, and in contrast to naming, the effect of phonemic similarity was altered by the lexicality of the context. This outcome is consistent with the hypothesis that the negative rhyming effect is linked to inhibitory

TABLE 3
Mean Decision Latencies (L, msec) and Error Rate (ER, %) with the Corresponding Standard Deviations by Subjects and by Items in Experiment 2

		Phonological Relation			
		Similar		*Dissimilar*	
Target	*Context*	*L*	*ER*	*L*	*ER*
Word	Word	649[a]	6.09	628	5.63
		94[b]	5.78	91	3.05
		61[c]	9.74	50	9.92
	Pseudoword	634	7.66	659	9.06
		105	5.40	109	6.15
		61	11.85	61	12.42
Pseudoword	Word	698	6.72	705	6.56
		101	3.73	97	4.10
		56	12.25	55	10.89
	Pseudoword	713	7.66	699	6.41
		103	4.92	96	4.26
		55	11.16	53	10.52

[a]Mean; [b]standard deviation by subjects; [c]standard deviation by items.

processes acting on word units. A context word activates not only phoneme units, but its representation at the word unit level as well. For familiar words of the sort used here, this generates, by the model sketched above, a good deal of inhibition on similar word units. A phonemically similar target word, therefore, is processed under conditions of inhibition of its word unit, whereas a phonemically dissimilar target word encounters no relevant inhibition at the word unit level. Therefore, word context–word target pairs with high target familiarity exhibit an inhibitory effect of phonemic similarity. A pseudoword context also activates phoneme units. But because it has no representation at the word unit level, it generates very little or no inhibition at the word unit level. A subsequent word target that is phonemically similar will access the lexicon quickly relative to a subsequent word target that is phonemically dissimilar because (1) the appropriate phoneme units are already active for the former, and (2) inhibition at the word unit level is not pronounced. Therefore, pseudoword context–word target pairs will not exhibit a negative phonemic similarity effect and can exhibit a positive phonemic similarity effect.

The lack of similarity effects on pseudoword rejection latencies can be understood in the same way. Phonemically dissimilar contexts, whether words or pseudowords, do not activate the appropriate phoneme units, nor do they activate any similar word units. Subsequent pseudoword targets that are phonemically dissimilar, therefore, are processed under basically neutral circumstances at the word unit level. Phonemically similar contexts activate the appropriate phoneme units, but they also partially activate a number of phonemically similar word units. When those contexts are pseudowords, no word unit receives enough activation to emerge, thereby causing a delay at the response level (Colombo, 1986; McClelland & Rumelhart, 1981) that essentially counters the advantage that was gained at the phoneme unit level. When those contexts are words, they also highly activate one particular word unit. This has the effect of generating noise that effectively dilutes the advantage gained at the phoneme unit level. On balance, therefore, subsequent pseudoword targets that are phonemically similar are also processed under basically neutral circumstances at the word unit level. Consequently, the absence of phonemic similarity effects and context lexicality effects on pseudoword rejections is to be expected.

GENERAL DISCUSSION

The present experiments, showing that pseudowords can act as phonemic primes, add to our preceding research (Lukatela & Turvey, 1990) in demonstrating robust phonemic similarity effects in the absence of graphemic similarity in both lexical decision and naming with Serbo-Croatian materials. The present and past results contrast, therefore, with the results of research using English language materials that suggest that such effects are unreliable (Martin & Jensen, 1988). In summarising their negative results, Martin and Jensen (1988) made three suggestions as to what might be needed to demonstrate the weaker form of phonemic priming (that occurring with graphemically similar items), namely:

1. Simultaneous presentation of the two stimuli.
2. Contexts comprising several similarly pronounced words.
3. Targets that can be recoded phonemically in more than one way.

None of these conditions were satisfied in the present research, yet significant phonemic priming of the strong form (that is, with graphemically dissimilar stimuli) was observed.

Pseudoword phonemic priming bears on the very general issues raised by the dual-process theory of visual word identification (Coltheart, 1978). By that theory, once a word unit has been activated directly on the basis of its orthographic properties, phonological information about the word is made available. Suppose that the direct visual access is mandatory (automatic) and that the phonological mediation way is optional (non-automatic), as has been frequently proposed. Then under masking conditions that minimise optional strategies, only the lexical way should work. On the basis of the preceding argument, Humphreys, Evett, and Taylor (1982, p. 581) hypothesised that: "If phonological information is activated via a nonlexical route, a pseudohomophone priming effect should occur." Finding that the pseudohomophone condition (tial–TILE) in their masking experiment did not differ from its graphemic control condition (tirl–TILE), Humphreys et al. (1982) concluded that the lexical (direct visual access) way of deriving phonology is the only one of the two that is automatic and is probably the only way to activate phonological information. Results from Serbo-Croatian, in contrast, confirm the hypothesis advanced by Humphreys et al. (1982): "Pseudohomophone priming" under masking has been demonstrated successfully (Lukatela & Turvey, 1990, experiment 10). The implication, therefore, is that it is the phonological access route that is automatic and (continuing their logic) is the only one available. The results of the present experiments (without masking) reinforce this opinion.

One possible source of the discrepancy between the English and Serbo-Croatian results is a potential difference between the two languages in visual word processing. In several papers (e.g. Feldman & Turvey, 1983; Lukatela, Popadić, Ognjenović, & Turvey, 1980; Lukatela & Turvey, 1980; 1990), we have suggested that the difference lies in the relative prominence of a level of processing units representing the phonemes of the language. The extreme view is that while such a layer exists for Serbo-Croatian, intermediary between letter units and word units, it does not exist for English. Many models of English word processing conform to this view in making little, if any, use of phonological information in word identification (e.g. Aaronson & Ferres, 1983; Baron, 1973; Becker, 1980; Kolers, 1970; Paap, Newsome, McDonald, & Schvanaveldt, 1982; Smith, 1971). The moderate view is that a level of phoneme units does exist and does participate in English word processing, but that its contribution is less distinct than in Serbo-Croatian. Recent experiments with English may be taken as consistent with this moderate position (Perfetti, Bell, & Delaney, 1988; Rosson, 1985; van Orden, 1987; van Orden, Johnston, & Hale, 1988). An appreciation of why a phoneme level may differ in the distinctiveness of its role across languages is provided through the notion of co-variant learning (Lewicki, 1986; van Orden, 1987). The basic hypothesis is that any linguistic features that frequently co-vary with orthographic features will become associated. As a consequence of co-variant learning, a word's spelling will activate most strongly those linguistic features that co-vary to the highest degree with its orthographic features. Thus, the process of identifying a particular word will be dominated by the subset of linguistic features that are most likely to be functional for the multiple occurrences of that word. In Serbo-Croatian, the consistency of letter–phoneme correspondences in the written language will bias the word processing mechanism, through co-variant learning, to a marked dependency on letter units–phoneme units connections. Because the consistencies in written English may range across several linguistic levels (Rozin & Gleitman, 1977), the involvement of a phonemic level of processing will be less distinguished, and the dependency on letter–phoneme connections less pronounced.

The foregoing ideas converge on a possible understanding of the different status of phonemic priming in the two languages. We hypothesise that phonemic priming depends on particular characteristics of (pre-lexical) letter–phoneme connections. In English, the number of these connections would be very large. There would be many connections representing the many relations at the grain size of individual letters, and probably at coarser grains involving multiple letters. In Serbo-Croatian, by contrast, the number of these connections would be very small. Besides a contrast of number, these connections in English and Serbo-Croatian would contrast in mean strength, specifically, the mean level of activation of a letter unit required to activate a phoneme unit. The connections would be stronger on the average in Serbo-Croatian than in English, with greater uniformity of strengths across the letter-to-phoneme connections in Serbo-Croatian than in English. Phonemic priming would seem to require that very much the same pre-lexical activity occurs in context and target processing. The opportunity for such homogeneity across many varied letter strings would be greater the more compact is the pre-lexical network and the more uniform are its connections.

Our hypothesis can now be stated more directly: If the pre-lexical letter–phoneme connections are few and uniformly strong (as in Serbo-Croatian), then phonemic priming is likely to be reliable. Or, alternatively, if the pre-lexical letter–phoneme connections are many and uniformly weak (as in English), then phonemic priming is likely to be unreliable. Cross-language experiments, together with simulations of the processing microstructures, will be needed to clarify this hypothesis, identifying possible contrasts between the two orthographies in the opportunities they provide for phonemic priming.

Manuscript received July 1989
Revised manuscript received May 1990

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