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Phonological Ambiguity Impairs Identity Priming in Naming and Lexical Decision

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The priming of a visually presented word by itself means that all representations activated by the prime—orthographic, phonological, semantic—are of direct relevance to the processing of the target. The phonological coherence hypothesis (e.g., Van Orden & Goldinger, 1994) suggests, however, that the major constraint on the identity prime's influence is the time needed to achieve a stable phonological code. Serbo-Croatian words such as XAREM (Cyrillic) and ROBOT (Roman) support two phonological codes, one corresponding to the word and one to a nonword. The nonwords XAREM and ROБOT composed from mixed Roman and Cyrillic letters have single phonological codes corresponding to the word readings of XAPEM and ROBOT. With prime-target SOAs ≤ 70 ms, the target was primed by the nonword better than by itself in both naming and lexical decision tasks. At an SOA of 250 ms, the nonword and the identity prime primed equally. Discussion focused on the primacy of phonological codes in visual word recognition. © 1997 Academic Press

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Priming is a frequently used procedure for investigating mechanisms of visual word recognition. The key idea is that when two words have to be processed in rapid succession, if the processes and representations activated by the first presented word (referred to as the prime) are of relevance to processing the second-presented word (referred to as the target), then certain processing benefits should accrue to the second. Intuitively, the optimal case of priming would be that in which the prime and target are the same word, a case referred to as repetition or identity priming. Experimentally, the superiority of identity priming has been demonstrated repeatedly in tachistoscopic word identification (e.g., Evett & Humphreys, 1981; Humphreys, Evett, & Taylor, 1982; Humphreys, Evett, Quinlan, & Besner, 1987; Humphreys, Besner, & Quinlan, 1988), lexical decision (e.g., Forster & Davis, 1984; Norris, 1984; Forster, Davis, Schoknecht, & Carter, 1987; Scarborough, Cortese, & Scarborough, 1977), and naming (e.g., Feustel, Shiffrin, & Salasoo, 1983; Forster & Davis, 1991, Lukatela & Turvey, 1994b). In every case identity primes produced a larger magnitude of priming than any other word or nonword primes.[1]

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[1] An exception is to be found in Forster, Davis, Schoknecht, & Carter (1987), Experiment 7, where morphologically related primes, such as make-MADE, produced priming of the same magnitude as identity primes.

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In identity priming all of the representations activated by the prime would seem to be of immediate relevance to processing and recognizing the target, suggesting that the best prime for a target word is the word itself. This understanding, consistent with intuition and current experimental evidence, is rudely countered, however, by the theory that visual word recognition is based in phonological codes. According to the phonological coherence hypothesis, the various processes that eventuate in a pronunciation of a letter string, or in a decision about its lexical status, or a judgment about its semantic category, rely on the initial achievement of a coherent phonological code (Van Orden & Goldinger, 1994; Van Orden, Pennington, & Stone, 1990). It follows, therefore, that if an identity prime took longer to achieve phonological coherence than a suitably selected nonword prime similarly homophonic with the target, then naming of the target might well be facilitated more by the nonword prime than by the target itself (the identity prime). This greater facilitation by a nonword homophone would be most pronounced at onset delays of the target relative to the prime sufficient for attaining phonological coherence by the nonword prime but not sufficient for attaining phonological coherence by the identity prime. With respect to English, the implication is that words that can be pronounced in more than one way (so-called irregular words, such as PINT) might function poorly as identity primes relative to words that receive a single pronunciation (so-called regular words, such as MUST). To date, the research on identity priming in English has not separated out priming with irregular words from priming with regular words. It is, therefore, an empirical question of whether identity priming in English will be impaired at short SOAs when the words in question can each support more than one phonological code. On the phonological coherence hypothesis, because irregular words take longer than regular words to achieve a single, clear phonological pattern (Van Orden & Goldinger, 1994), identity priming at short SOAs in both naming and lexical decision should be superior for regular words.

TABLE 1

TYPES OF SERBO-CROATION PRIMES FOR EVALUATING THE HYPOTHESIS THAT IDENTITY PRIMING IS WEAKENED BY PHONOLOGICAL AMBIGUITY

Identity word	Ambiguous nonword	Unique nonword
	Roman version	
ROBOT /robot/ /rovot/	POBOT /robot/ /rovot/ /pobot/ /rovot/	ROБOT /robot/
	Cyrillic version	
XAPEM /harem/ /hapem/	HAPEM /harem/ /hapem/ /narem/ /napem/	XAREM /harem/

In the present article the hypothesis that identity priming need not be optimal is evaluated in Serbo-Croatian. As summarized in Table 1, the two phonetically precise alphabets of Serbo-Croatian permit a thoroughgoing evaluation of the efficacy of identity primes that are not phonologically unique. The key feature of the stimuli constructed with the two alphabets is that the effects of phonologically ambiguous and phonologically unique primes can be compared on the same target, a condition that cannot be met in English (consider, e.g., the comparison of identity priming by the phonologically ambiguous PINT and the phonologically unique MUST). For a fluent reader in the two alphabets of Serbo-Croatian, the Cyrillic word XAPEM (meaning harem) supports two phonological codes. /harem/ and /hapem/. because P is /r/ in the Cyrillic alphabet and /p/ in the Roman alphabet. Similarly, the Roman word ROBOT with an ambiguous letter in the third position supports two phonological codes, /robot/ and /rovot/, because B is /b/ in Roman and /v/ in Cyrillic. When a bi-alphabetical reader of Serbo-Croatian processes a letter string, all the phonological codes the letter string can support are generated automatically (e.g., Lukatela, Feldman, Turvey, Carello, & Katz, 1989; Lukatela, Turvey, Feldman, Carello, & Katz, 1989). The Cyrillic letter X in XAPEM can be substituted by the phonemically equivalent Roman letter H to produce the mixed-alphabet nonword HAPEM. Similarly, the Roman letter R in ROBOT can be substituted by the equivalent Cyrillic letter P to produce the mixed-alphabet nonword POBOT. For a reader of Serbo-Croatian fluent in both alphabets, HAPEM supports four phonological interpretations—/harem/, /hapem/, /narem/, /napem/—one of which, /harem/, is homophonic with XAPEM. Similarly, for such a reader, POBOT supports four phonological interpretations—/robot/, /povot/, /rovot/, /pobot/—one of which, /robot/, is homophonic with ROBOT. Importantly, a phonologically unambiguous pseudohomophone can be constructed that preserves perfectly the corresponding phonology of its source word: The Cyrillic letter P in XAPEM can be substituted by the phonemically equivalent (and uniquely) Roman letter R, thus producing the mixed-alphabet nonword XAPEM which can support *only one phonological code*, /harem/; similarly, the Roman letter B in ROBOT can be replaced by the phonemically equivalent (and uniquely) Cyrillic letter Б, thus producing the mixed-alphabet nonword ROБOT which can support *only one phonological code*, /robot/. Previous research has shown that, in the rapid naming task, mixed-alphabet nonwords with both word and nonword pronunciations engender few errors (4%) although named more slowly than words (Lukatela, Turvey, Feldman, Carello, & Katz, 1989). The implication is that participants have little difficulty in determining a pronunciation. If the naming is primed by an associate of the word that corresponds to the phonology of the mixed-alphabet nonword, then the word pronunciation is given in the majority of cases (Lukatela, Turvey et al., 1989).

The test, therefore, of the conjecture that identity priming need not be optimal consists of prime-target pairs of the types XAPEM-xapem, HAPEM-xapem, and XAREM-xapem and the types ROBOT-robot, POBOT-robot, and ROБOT-robot. If the names of words are determined primarily by visual codes—for example, letter patterns activate entries in an orthographic input lexicon which, in turn, activate entries in a phonological output lexicon (e.g., Coltheart, Curtis, Atkins, & Haller, 1993)—then information about the pronunciation of (e.g.) XAPEM should be retrieved perfectly by the prime XAPEM and only partially, if at all, by the primes HAPEM and XAREM. Consequently, at both short and long prime-target SOAs, the target xapem should be named fastest following XAPEM, with the naming latencies following HAPEM and XAREM both longer than that following XAPEM and longer by the same amount given that each differs from the target by a single letter. In contrast, the phonological coherence hypothesis predicts that the target xapem should be primed best by XAREM, especially at short SOAs. According to the phonological coherence hypothesis, the more phonological codes that can be generated from a word's orthography, the slower is the attainment of orthographic-phonological resonance and the weaker is the activation level of any target-specific phonological pattern. The phonological pattern /harem/ will be resolved quickly for the prime XAREM relative to its resolution for the primes XAPEM and HAPEM given that /harem/ is the sole phonological pattern befitting XAREM's orthography.

EXPERIMENTS 1–3

Three experiments were conducted that differed in the SOA between visually presented prime and target. For binocular viewing, the interactions between successive stimuli presented within 250 ms and beyond the range of influence of stimulus energy (approximately 40–50 ms) are governed by SOA and not by stimulus duration or interstimulus interval (e.g., Michaels & Turvey, 1979; Turvey, 1973). The three SOAs were 51 ms (Experiment 1), 70 ms (Experiment 2), and 250 ms (Experiment 3). In each experiment, the prime was preceded by a pattern mask and the prime and target were separated by a pattern mask. This "four-field" procedure (mask-prime-mask-target) was employed in experiments by Lukatela and Turvey (1994b) that successfully demonstrated phonological priming by pseudohomophones in English. The main purpose of the first mask was to minimize identifiability of the prime (participants were not required to make any explicit response to the prime) and the main purpose of the second mask was to minimize integration of the visual characteristics of the prime and target (see also Humphreys et al., 1988, Experiment 4). In order to guard against the possibility of an "onset effect" (dissimilar initial phonemes produce Stroop-like interference, Forster & Davis, 1991), the manipulation of letters producing the contrasts among the primes was distributed over the letter positions such that only 13% occurred in the first position.

On the phonological coherence hypothesis, it was expected that priming by primes such as XAREM would be superior in Experiments 1 and 2 and matched by XAPEM in Experiment 3. Expectations with respect to the contrast between XAPEM and HAPEM are more complicated. Two mechanisms are responsible for coherence in the case of XAPEM, only one of which is responsible for coherence in the case of HAPEM. The shared mechanism is top-down activation from the semantic level to the phonological level. Because the phonological pattern /harem/ is the only pattern corresponding to a real word, it will receive stronger reinforcement from the semantic level than the competing nonword phonological patterns—one in the case of XAPEM and three in the case of HAPEM. The unshared mechanism is tied to the presence of a unique alphabetic character in XAPEM (X belongs only to the Cyrillic alphabet) versus the absence of such a character in HAPEM (all letters belong to both alphabets). Experimental evidence shows that a single unique letter such as X markedly reduces the effect of phonological ambiguous letters such as H (Feldman, Kostić, Lukatela, & Turvey, 1983; Lukatela, Feldman, Turvey, Carello, & Katz, 1989; Lukatela, Turvey, et al., 1989) and a prime that specifies alphabet can reduce the ambiguity further (Lukatela, Turvey, et al., 1989, Experiment 2). The model of this disambiguation by an alphabetically unique letter assumes that the letter-processing units of the Cyrillic and Roman letters constitute two functionally distinct sets and that there are inhibitory connections between them that effectively select the codings of one alphabet over the other, an assumption that has received experimental support (Lukatela, Turvey, & Todorović, 1992; Lukatela & Turvey, 1990b; Lukatela, Turvey et al., 1989). Thus, X in the first position in XAPEM will inhibit all Roman-alphabet-processing units activated by the letters in the other positions. Given that this inhibitory mechanism must take time to become effective, we should expect its beneficial effects on XAPEM to be present at long but not short SOAs. That is, an advantage of XAPEM over HAPEM should be seen at the SOA of 250 ms but may not be seen at the SOAs of 51 and 70 ms.

Method

Subjects. Fifty-six students from the Graphics High School in Belgrade participated voluntarily in Experiment 1. Fifty-six undergraduates at the University of Belgrade participated in Experiment 2 and another 56 participated in Experiment 3 as part of the introductory psychology course requirement. All participants were fluent readers in both the Roman and Cyrillic alphabets. In each experiment a participant was assigned to one of eight groups, according to his or her appearance at the laboratory, to give a total of seven participants per group.

Materials. Preliminary to the running of the experiments, a list of 100 words (printed on response sheets) was presented individually to each student in a classroom of 26 high-school students. Another list of 100 different words was presented in another classroom of 28 high-school students. Each of the students was requested to write down (in line with a given test word) an evaluation of how familiar the word was to him or her. The familiarity scale was from 0 to 5 (0 standing for a very unfamiliar word and 5 standing for a very familiar word). Each student was urged to respond quickly without corrections.

There were eight sets of the prime-target stimulus pairs of which the first four (Sets 1–4) were of direct relevance to the hypothesis. Four auxilliary sets (Sets 5–8) were designed to address some other contemporary questions in phonological priming.

Set 1: The first set (the base set) consisted of 96 identity word-word pairs, 48 of which were Cyrillic and 48 of which were Roman (e.g., XAPEM-xapem and ROBOT-robot, respectively). One-half of Set 1 were low familiarity (LF, mean value 1.78 ± 0.84) in both prime and target and one-half were high familiarity (HF, mean value 3.88 ± 0.67) in both the prime and target. From Set 1 seven additional sets of 96 pairs were generated by preserving the target stimuli (xapem, robot) and replacing the prime stimuli only.

Set 2: The alphabetically specific and phonologically unambiguous letter or letters in each prime (e.g., X in XAPEM, R in ROBOT) were replaced by their phonologically ambiguous counterparts from the other alphabet (H and P, respectively) to produce a phonologically ambiguous set of nonword-word pairs (HAPEM-xapem, POBOT-robot, respectively). In this set, the prime supported four or more phonological codes. The exact number of codes for any given prime of Set 2 depended on the number of ambiguous letters replacing the alphabet-specific, unambiguous letters in its source prime.

Set 3: The alphabetically nonspecific and phonologically ambiguous letter or letters in each prime (e.g., P in XAPEM and B in ROBOT) were replaced by their phonologically unambiguous counterparts from the other alphabet (R and Б respectively) to produce a phonologically unambiguous set of pseudohomophone-word pairs (XAREM-xapem, ROБOT-robot).

Set 4: Each prime (e.g., XAPEM, ROBOT) was replaced by a word of the same letter length and of similar familiarity to produce a "control" set of word-word pairs (e.g., JEДAP-xapem, DINAR-robot). Prime and target shared no letters in the same position, and the prime was not a prominent associate of the target. Furthermore, the primes contained at least one disambiguating, phonologically unique character permitting adjudication on whether a benefit of Set 3 primes was due to a prior unique letter biasing target processing, rather than a unique phonology.

Additional sets of stimuli, Sets 5–8, were created which permitted the evaluation of issues related to phonological priming.

Set 5: The initial letter in each base prime (e.g., XAPEM, ROBOT) was replaced by a letter that created a rhyming nonword to produce a "rhyming set" of nonword-word pairs (e.g., ДAPEM-xapem, GOBOT-robot).

Set 6: Each base prime (e.g., XAPEM, ROBOT) was replaced by a word of the same length but of a loosely controlled familiarity to produce a set of unrelated word-word pairs (e.g., CИPOB-xapem, LONAC-robot). In this set, the primes had, on the average, more ambiguous letters, and the prime and target could share one letter in the same position. The prime was not a prominent associate of the target.

Set 7: The initial letter (phoneme) of each prime in Set 4 (e.g., JEДAP, RINAR) was replaced by the corresponding initial letter of the prime from Set 1 (e.g., XAPEM, ROBOT) to produce a special set of nonword-word pairs (XEДAP-xapem, RINAR-robot) that shared prime onsets with the base set, Set 1.

Set 8: The initial letter of each nonword prime in Set 7 (XEДAP, GINAR) was replaced by the initial letter of the corresponding rhyming prime from Set 5 (e.g., ДAPEM, GOBOT) to produce an unrelated set of nonword-word pairs (ДEДAP-xapem, GINAR-robot).

Design. The major constraint on the design was that a given participant never encountered a given word or nonword more than once. Using just the Cyrillic example, there were eight prime types (identity word XAPEM, phonologically ambiguous pseudohomophone HAPEM, phonologically unambiguous pseudohomophone XAREM, control word JEДAP, rhyming nonword ДAPEM, unrelated word CИPOB, shared-onset nonword XEДAP, and unrelated nonword ДЕДАР). Each participant was presented with 12 stimulus pairs from each of the above eight types, with the prime in upper case and the target in lower case. In Sets 1–8, target words were divided evenly into those named through the mappings of the Roman alphabet and those named through the mappings of the Cyrillic alphabet. With the exceptions of Sets 2 and 3, the prime and target composing a pair were written in the same alphabet; the pseudohomophone primes in Set 2 were alphabetically neutral and those in Set 3 were alphabetically mixed. In total, a participant saw 120 stimulus pairs (with each participant seeing a foil set of 24 unrelated word-word pairs). The experimental sequence was divided into three parts, with a brief rest after each part. Stimulus types were ordered pseudorandomly within each participant. The experimental sequence was preceded by a practice sequence of 38 different unrelated stimulus pairs.

Procedure. Participants, run one at a time, sat in front of the CRT of an APPLE IIe computer in a well-lit room. Each trial consisted of an auditory warning signal followed by a sequence of visual presentations: a pattern mask of 500-ms duration, a prime of 26-ms (Experiment 1), or 35-ms (Experiment 2), or 125-ms (Experiment 3) duration, a second pattern mask of 25-ms (Experiment 1), or 35-ms (Experiment 2), or 125-ms (Experiment 3) duration, and finally a target of 400-ms duration. All interstimulus intervals were zero (ISI = 0) making the SOAs of the three experiments 51, 70, and 250 ms, respectively. (Control of stimulus durations and SOAs was made possible by modifications of the machine code of the Apple IIe.) The above exposure durations are "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 actual durations for a given nominal exposure fluctuate between a "shorter exposure" (which is, from the lower side, the closest to the nominal exposure) and a "longer exposure" (which is, from the upper side, the closest to the nominal exposure). This pseudorandom occurrence of shorter and longer exposures, if recorded over many trials, will result in a statistical mean that converges on the nominal exposure. For example, the nominal 125-ms exposure of Experiment 3 was satisfied across trials by the mixture of exposures of 116.9 ms (7 × 16.7 ms) and 133.6 ms (8 × 16.7 ms).

Each participant in each experiment was told that he or she would be viewing on each trial a sequence of two letter strings, with the second letter string being always a word in lower case, and that his or her task was to name out loud the lowercase word as quickly and as accurately as possible. In all conditions, latencies from the onset of the target to the onset of the response were measured by a voice-operated trigger relay. Naming was considered erroneous when the target word was mispronounced or preceded by any other sound, the pronunciation was not smooth (i.e., subject hesitated after beginning to name), or the response was not loud enough to trigger the voice key. If the naming latency was longer than 1 s, a message appeared on the screen requesting the subject to name more quickly. All latencies, including those longer than 1 s, were stored in the computer memory.

Results

For each participant in each experiment, naming latencies more than 2 SD above or below the subject's mean in all conditions were considered errors. For the error analysis, these "latency" errors were combined with the "pronunciation" errors described in the preceding paragraph. Latencies and errors under the priming by the identity prime, the nonword phonologically ambiguous prime, the nonword phonologically unique prime, and the baseline prime are summarized for each experiment in Tables 2–4. An overall summary of the results of the three experiments as expressed by latency differences between the experimental primes and the baseline prime is provided in Table 5.

Experiment 1 (SOA = 51 ms). A 4 × 2 (Prime type × Target Familiarity) analysis of variance (ANOVA) was conducted on the naming latencies. Prime type (identity = 569

TABLE 2

Mean Naming Latencies L (in ms) and Error Rate ER (in %) with the Corresponding Standard Deviations by Subjects and by Items for the Identity, Nonword Ambiguous, Nonword Unique, and Baseline Primes of Experiment 1

Identity (ROBOT-robot)		Ambiguous nonword (POBOT-robot)		Unique nonword (ROБOT-robot)		Baseline control (DINAR-robot)	
L	ER	L	ER	L	ER	L	ER
				Low frequency			
582[a]	4.76	583	6.25	571	4.46	581	5.36
75[b]	7.60	68	10.33	65	8.70	61	9.05
47[c]	9.00	49	12.12	48	10.27	41	9.14
				High frequency			
555	3.57	557	1.49	546	3.57	562	3.27
53	7.60	58	4.80	63	6.90	61	8.05
31	7.51	35	5.30	35	7.51	45	6.75

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

ms, ambiguous nonwords = 570 ms, unique nonwords = 559 ms, controls = 572 ms) failed to reach significance by participants, $F1(3,165) = 2.32$, $p > .05$, and by stimuli, $F2(3,282) = 1.05$, $p > .05$. Target familiarity (LF = 565 ms vs HF = 543 ms) was signifi-

TABLE 3

Mean Naming Latencies L (in ms) and Error Rate (ER, in %) with the Corresponding Standard Deviations by Subjects and by Items for the Identity, Nonword Ambiguous, Nonword Uunique, and Baseline Primes of Experiment 2

Identity (ROBOT-robot)		Ambiguous nonword (POBOT-robot)		Unique nonword (ROБOT-robot)		Baseline control (DINAR-robot)	
L	ER	L	ER	L	ER	L	ER
				Low frequency			
529[a]	6.85	542	7.44	520	4.17	535	3.27
53[b]	9.42	64	8.94	59	8.56	55	7.40
38[c]	11.78	33	15.02	40	8.82	43	7.93
				High frequency			
515	2.38	519	1.19	503	4.17	515	3.27
62	6.69	56	4.33	51	8.56	48	6.68
36	5.38	35	3.99	31	9.30	33	6.75

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

TABLE 4

MEAN NAMING LATENCIES L (IN MS) AND ERROR RATE (ER, IN %) WITH THE CORRESPONDING STANDARD DEVIATIONS BY SUBJECTS AND BY ITEMS FOR THE IDENTITY, NONWORD AMBIGUOUS, NONWORD UNIQUE, AND BASELINE PRIMES OF EXPERIMENT 3

Identity (ROBOT-robot)		Ambiguous nonword (POBOT-robot)		Unique nonword (ROБOT-robot)		Baseline control (DINAR-robot)	
L	ER	L	ER	L	ER	L	ER
			Low frequency				
522[a]	5.06	549	7.14	520	5.36	563	3.57
49[b]	8.94	62	9.98	48	8.47	57	7.60
44[c]	9.08	52	12.50	42	9.14	40	9.99
			High frequency				
502	3.57	525	1.49	501	4.46	545	2.08
44	8.24	47	4.80	49	7.45	44	6.41
33	6.91	33	5.30	35	7.88	35	5.89

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

cant, $F1(1,55) = 55.56$, $p < .001$, $F2(1,94) = 8.78$, $p < .01$, but its interaction with prime type was not (Fs < 1). In the ANOVA on errors, only familiarity (LF = 3.94% vs HF = 1.71%) reached significance, $F1(1,55) = 11.06$, $p < .001$, $F2(1,94) = 4.27$, $p < .05$. The planned comparisons showed insignificant priming advantages relative to controls of identity primes (3 ms), both Fs < 1, and ambiguous nonword primes (2 ms), both Fs < 1. In contrast, the priming advantage (14 ms) relative to the controls of the unique nonwords was very reliable, $F1(1,55) = 11.30$, $p < .001$, $F2(1,94) = 15.53$, $p < .001$. The unique nonwords also primed better than the identity primes, $F1(1,55) = 9.79$, $p < .003$ and $F2(1,94) = 6.39$, $p < .01$, and the ambiguous nonword primes, $F1(1,55) = 9.47$, $p < .003$ and $F2(1,94) = 9.66$, $p < .002$, which did not differ from each other (Fs < 1).

Experiment 2 (SOA = 70 ms). The 4 × 2 ANOVA revealed an effect of prime type (identity = 522 ms, ambiguous nonwords = 531 ms, unique nonwords = 512 ms, controls

TABLE 5

SIZE OF PRIMING EFFECT (IN MS) RELATIVE TO BASELINE CONTROL AS A FUNCTION OF SOA (IN MS) AND PRIME TYPE IN EXPERIMENTS 1–3

Experiment	SOA	Identity (ROBOT)	Ambiguous nonword (POBOT)	Unique nonword (ROБOT)
1	51	3	2	14[a,b]
2	70	3	−5	13[a,b]
3	250	42[a,b]	17[a,b]	43[a,b]

[a] Significant by participants.
[b] Significant by stimuli.

= 525 ms), $F1(3,165) = 11.72$, $p < .001$, $F2(3,282) = 9.61$, $p < .001$, and of familiarity (LF = 532 ms vs HF = 513 ms), $F1(1,55) = 34.29$, $p < .001$, $F2(1,94) = 10.40$, $p < .002$. The prime type × familiarity interaction proved unreliable (*F*s < 1). In the ANOVA on errors, familiarity (LF = 5.43% vs HF = 2.75%) reached significance, $F1(1,55) = 11.48$, $p < .001$, $F2(1,94) = 4.14$, $p < .05$, and interacted significantly with familiarity, $F1(3,165) = 4.91$, $p < .003$, $F2(3,282) = 4.16$, $p < .01$. The planned comparisons showed insignificant priming advantages relative to controls of identity primes (3 ms), both *F*s < 1, and ambiguous nonword primes (−5 ms), both *F*s < 1. In contrast, the priming advantage (14 ms) relative to the controls of the unique nonwords was very reliable, $F1(1,55) = 17.98$, $p < .001$, $F2(1,94) = 15.53$, $p < .001$. The unique nonwords also primed better than the identity primes, $F1(1,55) = 9.53$, $p < .003$, $F2(1,94) = 7.53$, $p < .01$, and the ambiguous nonword primes, $F1(1,55) = 30.85$, $p < .001$, $F2(1.94) = 24.17$, $p < .001$, which did not differ from each other (*F*s < 1).

Experiment 3 (SOA = 250 ms). The 4 × 2 ANOVA on naming latencies revealed reliable effects of prime type (Identity = 512 ms, ambiguous nonwords = 537 ms, unique nonwords = 531 ms, controls = 554 ms), $F1(3,165) = 93.13$, $p < .001$, and for stimuli $F2(3,282) = 55.12$, $p < .001$, and familiarity, $F1(1,55) = 96.26$, $p < .001$, and $F2(1.94) = 11.84$, $p < .001$. The interaction between prime type and familiarity was not significant (*F*s < 1). In the ANOVA on errors, only familiarity (LF = 5.28% vs HF = 2.90%) reached significance, $F1(1,55) = 8.84$, $p < .01$, $F2(1,94) = 4.12$, $p < .05$. The planned comparisons showed significant priming advantages (relative to controls) of identity primes (42 ms), $F1(1,55) = 170.50$, $p < .001$, $F2(1,94) = 88.31$, $p < .001$, ambiguous nonword primes (17 ms), $F1(1,55) = 31.55$, $p < .001$, $F2(1,94) = 15.98$, $p < .001$, and unique nonword primes (43 ms), $F1(1,55) = 234.17$, $p < .001$, $F2(1,94) = 124.98$, $p < .001$. Both the identity and unique nonword primes differed significantly from the ambiguous nonword primes, $F1(1,55) = 44.33$, $p < .001$, $F2(1,94) = 37.62$, $p < .001$ and $F1(1,55) = 67.32$, $p < .001$, $F2(1,94) = 54.66$, $p < .001$, respectively, but did not differ from each other (*F*s < 1).

Additional control conditions in Experiments 1–3. There were four auxilliary conditions (Sets 5–8) directed at additional features of the priming phenomenon. Latencies and errors for these conditions in each of the three experiments are summarized in Tables 6–8.

As noted, in Set 7 each nonword prime (e.g., ХЕДАР, RINAR) shared the initial letter/phoneme with its target word (хapem, robot), whereas all remaining letters/phonemes were identical to those in the unrelated nonword prime (e.g., ДЕДАР and GINAR from Set 8). Any difference in naming latency between Set 7 and Set 8 would support the notion of some "shared-onset" effect in rapid naming under masked conditions (Forster & Davis, 1991). Analysis failed to reveal a difference (all *F*s < 1).

In recent research on English, it has been suggested that at short SOAs rhyming primes are inhibitory in contrast with the facilitatory effect of primes whose phonology is fully identical with that of their targets (Lukatela & Turvey, 1996; see also O'Seaghdha, Dell, Peterson, & Juliano, 1992). Set 5 consisted of rhyming nonword–word pairs. Except for the initial letter/phoneme, each nonword rhyme prime shared its letters/ phonemes with a corresponding prime from Set 1 (e.g., priming nonwords ДАРЕМ and GOBOT for identity primes ХАРЕМ and ROBOT). Controls for a rhyming effect were provided by Set 8. Primes in this set were nonwords (e.g., ДЕДАР, GINAR) that shared only one initial letter/phoneme with the corresponding rhyming nonword prime from Set 5 and shared no letter in the same position with the target word. In agreement with results in English (e.g., Lukatela & Turvey, 1996), Experiment 2 found a significant inhibition by the rhyming primes of −12 ms, $F1(1,55) = 14.50$, $p < .001$ and $F2(1,94) = 10.18$, $p < .002$. In Experiments 1 and 3, however, there was no rhyme priming

TABLE 6

MEAN NAMING LATENCIES L (IN MS) AND ERROR RATE (ER, IN %) WITH THE CORRESPONDING STANDARD DEVIATIONS BY SUBJECTS AND BY ITEMS FOR THE CONTROL PRIMES OF EXPERIMENT 1

Rhyme (GOBOT-robot)		Ambiguous letters (LONAC-robot)		Onset identity (RINAR-robot)		Unrelated nonword (GINAR-robot)	
L	ER	L	ER	L	ER	L	ER
				Low frequency			
582[a]	7.44	586	5.36	582	5.06	589	5.06
72[b]	9.49	61	9.59	65	10.50	76	9.49
42[c]	13.82	36	9.14	45	9.99	46	9.08
				High frequency			
558	0.30	564	2.68	560	2.38	558	2.68
49	2.23	62	6.18	54	5.88	53	7.64
39	2.06	37	7.60	40	6.81	36	5.63

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

effect of any kind (all Fs < 1). These results encourage the assertion that an incomplete phonological overlap per se, in spite of a high degree of visual and phonemic prime-target similarity, may not result in a positive phonological priming effect (Lukatela & Turvey, 1996). Unlike a homophonic prime that would produce an activation pattern identical to that of its target, a rhyme prime would produce an activation pattern that overlaps only in part.

TABLE 7

MEAN NAMING LATENCIES L (IN MS) AND ERROR RATE (ER, IN %) WITH THE CORRESPONDING STANDARD DEVIATIONS BY SUBJECTS AND BY ITEMS FOR THE CONTROL PRIMES OF EXPERIMENT 2

Rhyme (GOBOT-robot)		Ambiguous letters (LONAC-robot)		Onset identity (RINAR-robot)		Unrelated nonword (GINAR-robot)	
L	ER	L	ER	L	ER	L	ER
				Low frequency			
545[a]	7.14	540	6.25	537	3.27	531	5.95
57[b]	10.47	60	10.33	65	7.40	53	9.23
38[c]	12.15	33	12.47	40	6.75	43	10.56
				High frequency			
529	2.08	522	1.79	512	2.08	520	2.68
53	6.41	52	5.20	50	5.56	49	8.27
30	5.10	37	4.77	32	5.89	30	5.63

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

TABLE 8

MEAN NAMING LATENCIES L (IN MS) AND ERROR RATE (ER, IN %) WITH THE CORRESPONDING STANDARD DEVIATIONS BY SUBJECTS AND BY ITEMS FOR THE CONTROL PRIMES OF EXPERIMENT 3

Rhyme (GOBOT-robot)		Ambiguous letters (LONAC-robot)		Onset identity (RINAR-robot)		Unrelated nonword (GINAR-robot)	
L	ER	L	ER	L	ER	L	ER
				Low frequency			
562[a]	3.87	575	3.27	564	4.17	563	7.74
53[b]	7.78	61	7.40	55	8.56	54	11.44
44[c]	7.06	44	6.75	45	9.76	41	16.66
				High frequency			
545	2.68	548	2.08	538	2.68	546	2.08
51	6.95	50	5.56	44	6.95	47	5.56
36	8.15	33	5.10	34	5.63	30	5.10

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

Apparently, this partial overlap at short time scales can be more of a hindrance than a help. Relatedly, an unrelated priming word (e.g., СИРОВ, LONAC from Set 6) that shared few letters (on average about one letter) with its target word (xapem, robot) tended to produce a naming latency that was longer (though insignificantly) than the latency produced by the control word prime (e.g., ЈЕДАР, DINAR from Set 4) which shared no letter/phoneme in same position with its target word.

It is important to underscore that the focus of the present theoretical analyses has been on the time-scale of processes occurring within the SOA, specifically, the delaying of phonological coherence by primes that generate more than one phonological code. The presence of phonologically ambiguous letters in the target words does not pose a problem for this analysis for the following reasons: (a) across experimental conditions only the prime type was varied, whereas the target word was kept invariant; therefore, all individual features of the target stimulus (including possible phonological ambiguity) were eliminated from analytical comparisons; (b) each target word contained at least one alphabet-specific letter and had practically unlimited processing time; therefore, an automatic alphabet selection process, as described above, was probably able to reduce the target's phonological ambiguity to a second-order effect; (c) orthographic mapping from uppercase to lowercase in Serbo-Croatian is not always a one-to-one mapping of phonological ambiguity (e.g., the phonologically ambiguous Roman uppercase letter B corresponds to the phonologically unambiguous lowercase letter b, and so on), hence, some of the phonologically ambiguous primes in Set 1 become phonologically unambiguous targets, and vice versa, creating another distribution of possible phonological ambiguity over target words which was not necessarily correlated with experimental conditions, and (d) the observed total error rate in Experiments 1–3 was on average less than 5%, whereas in previous Serbo-Croatian experiments the rapid naming of words consisting solely of ambiguous and shared letters (i.e., no unique letters) was accompanied by a much higher error rate, typically in the range 15–30% (e.g., Lukatela et al., 1991); this fact complements (a) in suggesting that phonologically ambiguous letters in the target words in the present experiment were not of concern.

EXPERIMENTS 4 AND 5

In Experiment 1, at an average prime-target SOA of 51 ms, and in Experiment 2 at an average prime-target SOA of 70 ms, target words were named faster following the phonologically unique nonwords than following the identity primes and the phonologically ambiguous nonwords, both of which failed to prime. In Experiment 3, at an average prime-target SOA of 250 ms, priming efficacy was equal for the unique nonword primes and identity primes and superior to the ambiguous nonword primes.

In respect to the target xapem, each of the three primes XAREM, HAPEM, and XAPEM activates the target's phonological code, but only the mixed-alphabet nonword XAREM does so uniquely. Where XAREM activates the single phonological code /harem/, XAPEM activates the two codes /harem/ and /hapem/, and HAPEM activates the four codes /harem/, /narem/, /hapem/, and /napem/. The results of Experiments 1 and 2 suggest that the rate at which phonological coherence is established—competition among phonological codes is resolved—dictates the usefulness of a homophonic prime to the processing of its target. The unreliability of priming by the identity prime XAPEM in Experiments 1 and 2 and its reliability in Experiment 3 (see Table 5) reflects the extended time-course of attaining a suitable level of phonological coherence when there are two competing phonological patterns. Relatedly, the superiority of XAPEM over HAPEM in Experiment 3 reflects the mechanism of pruning phonological codes through inhibition by the unique Cyrillic letter X of the unique and ambiguous Roman letter units in the other positions, so that only the codings of the Cyrillic alphabet apply (Lukatela, Turvey, et al., 1989; Lukatela et al., 1991; Lukatela, Carello, & Turvey, 1993). Thus, the generation of the Roman interpretation /p/ for P does not occur. This mechanism of interalphabet inhibition cannot apply in the case of the nonword HAPEM which lacks any letters unique to either one of the two alphabets (see introduction to Experiments 1–3). From all three experiments, it is clearly evident that similarity of form is not of paramount significance. Simply, XAPEM was not the best prime, and XAREM was a dramatically superior prime compared with HAPEM despite their common feature of differing from the target by only a single letter.

Would the lexical decision task reveal the same pattern of results and lead to the same conclusion? In a model of visual word recognition with a dual-route organization (Coltheart et al., 1993; Coltheart & Rastle, 1994), naming the target stimuli would necessarily engage the phoneme system which is activated both lexically and nonlexically. Accordingly, the observed priming effects favoring the unique nonword prime could be attributed to the ambiguity at the level of the phoneme system induced by the identity and the ambiguous nonword prime. The identity prime XAPEM would lead to one pattern of phoneme activation over the lexical route and to two patterns, one the same as that arrived at lexically and one different, over the nonlexical route. The ambiguous nonword prime HAPEM would generate four different patterns of phoneme activation over the nonlexical route. In contrast, the unique nonword prime XAREM, processed on the nonlexical route, would generate only a single pattern of phoneme activation, precisely that corresponding to the word phonology of the target and perfectly suited, therefore, to the task of pronouncing the target. This beneficial effect of the unique nonword relative to the identity prime would not occur, however, if the task was deciding on the lexical status of the target rather than pronouncing it. Via the lexical route, the letter patterns of words activate whole-word forms in an orthographic input lexicon and, in turn, whole-word forms in a phonological output lexicon. Over this lexical route, the identity prime has a distinct advantage. All of its letters match those of a whole-word form, producing thereby maximal priming of the target. For both the ambiguous and unique nonword primes, they fail to match by one letter the whole-word form of the target, producing thereby submaximal priming (Coltheart & Rastle, 1994). In the modern cascaded processing version of dual-route organization, the modules are interdependent, so that the whole-word forms in the sublexicons can also be activated by the outputs of the nonlexical route (Coltheart et al., 1993; Coltheart & Rastle, 1994). All three primes processed over the nonlexical route could activate, eventually, the target's whole-word form in the phonological output lexicon. The use of "eventually" is to underscore that activating lexical forms over the nonlexical route is assumed to be slower than activating them over the lexical route. The upshot is that, in the lexical decision task at very short prime-target SOA, the nonword prime with unique phonology should be at a disadvantage, not at an advantage, relative to the identity prime which can activate the target's lexical form directly. Relatedly, the unique nonword should not be at any special advantage relative to the ambiguous nonword prime, since both would need to activate lexical forms, the requirement for lexical decision, over the longer and slower nonlexical route.

From the perspective of the phonological coherence hypothesis, however, it must be the case that the pattern of results seen in Experiments 1–3 generalizes to lexical decision. According to this hypothesis, the visual processing of a prime proceeds at a rate scaled by the time it takes to resolve a unique and stable phonological code. Thus, the constraint on a prime's ability to influence the decision on a homophonic target's lexical status is no different from the constraint on its ability to influence the determination of the target's pronunciation. In both cases, the success of priming depends on the time to achieve phonological coherence.

In Experiments 4 and 5 we evaluate whether the conclusions of Experiments 1–3 generalize to the lexical decision task. In Experiment 4 the prime-target SOA was 70 ms; in Experiment 5, the prime-target SOA was 250 ms. In contrast to the design of Experiments 1–3, Experiments 4 and 5 included individualized controls for each of the test primes (paralleling Lukatela & Turvey, 1994b). Each individualized control matched its corresponding test prime in length and frequency (defined by the identity prime) and differed from its corresponding test prime in visual form as far as the preceding two constraints permitted. For example, for the target word robot (Roman), the identity prime ROBOT (Roman) was compared with BARON (Roman), the phonologically ambiguous nonword prime POBOT (mixed Roman and Cyrillic) was compared with BAPOH (mixed Roman and Cyrillic), and the phonologically unambiguous nonword prime ROБOT (mixed Roman and Cyrillic) was compared with БARON (mixed Roman and Cyrillic). Similarly, for the target word xapem (Cyrillic), the identity prime XAPEM (Cyrillic) was compared with БETOH (Cyrillic), the phonologically ambiguous nonword prime HAPEM (mixed Roman and Cyrillic) was compared with BETOH (mixed Roman and Cyrillic), and the phonologically unambiguous nonword prime XAREM (mixed Roman and Cyrillic) was compared with БETON (mixed Roman and Cyrillic). Within this design, the test primes could be compared with respect to the degree that they primed differently from their individualized controls. They could also be compared with each other and with a common prime as in Experiments 1–3. In Experiments 4 and 5, the common prime was a row of Xs.

Method

Participants. Fifty-six senior students at the Ninth Gymnasium in Belgrade participated in Experiment 4 and another 56 senior students from the same school participated in Experiment 5. A student was assigned to one of eight groups, giving 7 students per group. None of the students had participated in Experiments 1–3.

Materials. There were eight sets of stimuli. Sets 1–3 were the same as in Experiments 1–3. The primes in Sets 5–7 were the individualized control primes constructed in the manner suggested above. The primes in Sets 4 and 8 consisted simply of rows of Xs.

Design. Eight counterbalanced experimental lists were prepared for eight groups of subjects. Each subject saw 6 stimulus pairs of 12 different prime types (LF identity word, HF identity word, LF nonidentity word, HF nonidentity word, LF-related ambiguous pseudohomophone, HF-related ambiguous pseudohomophone, LF-unrelated ambiguous pseudohomophone, HF-unrelated ambiguous pseudohomophone, LF-related unambiguous pseudohomophone, HF-related unambiguous pseudohomophone, LF-unrelated unambiguous pseudohomophone, HF-unrelated unambiguous pseudohomophone) and 12 stimulus pairs each with a nonlinguistic neutral prime. In addition to the preceding 96 stimulus pairs with word targets, each participant saw 48 stimulus pairs consisting of a word prime and a nonword target, for a total of 144 stimulus pairs per session. In the nonword target stimulus pairs, the prime was a word drawn from the pool of phonologically ambiguous BETAP-type words used by Lukatela, Feldman, et al., 1989. The corresponding nonword target was constructed by changing a single letter (in arbitrary position) in the source word which was drawn from a pool of the phonologically unambiguous variant of VETAR-type words (also from Lukatela, Feldman, et al., 1989). In each word–nonword pair the prime and target's source word were necessarily two different lexical entries. The experimental sequence was preceded by a practice sequence of 38 stimulus pairs.

Procedure. The procedure in each experiment was the same as that in Experiments 1–3 except that the participant performed a rapid lexical decision on the target stimulus of each stimulus pair. The participant used simultaneously both hands placed on two telegraph keys. One telegraph key was pressed with both forefingers ("YES"), and the second telegraph key was pressed with both thumbs ("NO"). This method of responding was used in previous experiments on lexical decision in Serbo-Croatian (e.g., Lukatela, Feldman, et al., 1989). In Experiment 4, the four-field (average) stimulus exposures (the mask, prime, mask, and target) were 500, 35, 35, and 400 ms (i.e., SOA = 70 ms), respectively; in Experiment 5 they were 500, 125, 125, and 400 ms (i.e., SOA = 250 ms).

Results and Discussion

All correct responses in the range from 100 ms to 1800 ms were included in the analysis. The mean number of excluded correct responses amounted to less than 0.4% (satisfying Ulrich & Miller's (1994) prescription).

Experiment 4 (SOA = 70 ms). Tables 9a and 9b summarize the results. Considering just the test primes, an ANOVA was conducted on the correct reaction times to word targets with participants and stimuli as the error terms. Prime type was significant, $F1(3,165) = 17.80$, $p < .001$, $F2(3,282) = 9.54$, $p < .001$, as was target frequency, $F1(1,55) = 149.70$, $p < .001$, $F2(1,94) = 19.60$, $p < .001$. Planned comparisons revealed that the 22-ms priming difference between ROБOT and ROBOT, $F1(1,55) = 15.23$, $p < .001$, $F2(1,94) = 8.44$, $p < .01$, and the 31-ms priming difference between ROБOT and POBOT, $F1(1,55) = 16.62$, $p < .001$, $F2(1,94) = 11.20$, $p < .001$, were highly reliable. The 7-ms priming difference between ROBOT and POBOT was unreliable, $F1(1,55) = 1.61$, $p > .05$, $F2(1,94) < 1$. ROBOT did prime significantly better than XXXXX, $F1(1,55) = 19.69$, $p < .001$, $F2(1,94) = 7.37$, $p < .01$, but POBOT did so only by participants, $F1(1,55) = 6.15$, $p < .05$, $F2(1,94) = 2.87$, $p > .05$. Experiment 4 (a lexical decision experiment), therefore, replicated Experiment 2 (a naming experiment) in demonstrating that, at an average SOA of 70 ms, the phonologically unique nonword primed the target better than the identity prime which, in turn, primed no better than the phonologically ambiguous nonword.

Turning to the priming measure afforded by the individualized controls, a 4 × 2 × 2 (Prime Type × Relatedness × Target Frequency) ANOVA was conducted on target latencies. Here, the four levels of prime type are defined by the identity primes and their controls, ambiguous nonword primes and their controls, unambiguous nonword primes and their controls, and the row of Xs defining Sets 7 and

TABLE 9a

Mean Lexical Decision Latencies L (in ms) and Error Rate (ER, in %) with the Corresponding Standard Deviations by Subjects and by Items for the Identity, Nonword Ambiguous, Nonword Unique, and Baseline Test Primes of Experiment 4

Identity (ROBOT-robot)		Ambiguous nonword (POBOT-robot)		Unique nonword (ROБOT-robot)		Baseline control (XXXXX-robot)	
L	ER	L	ER	L	ER	L	ER
			Low frequency				
633[a]	11.37	646	15.77	606	11.90	660	13.99
95[b]	13.89	96	13.05	78	12.25	76	14.25
110[c]	16.92	108	18.46	89	19.17	89	18.98
			High frequency				
577	4.76	582	4.17	560	2.08	604	2.68
88	9.38	77	7.28	91	6.41	83	6.18
91	10.76	69	7.77	73	5.89	67	6.36

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

8. The corresponding mean latencies to the targets of 622, 628, 609, and 632 ms, respectively, differed reliably: $F1(3,165) = 9.93$, $p < .001$, $F2(3,282) = 5.42$, $p < .001$. The two levels of relatedness in the present ANOVA are defined by Sets 1–4 versus Sets 5–8. The

TABLE 9b

Mean Lexical Decision Latencies L (in ms) and Error Rate (ER, in %) with the Corresponding Standard Deviations by Subjects and by Items for the Individualized Controls for the Identity, Nonword Ambiguous, Nonword Unique, and Baseline Test Primes of Experiment 4

Identity (BARON-robot)		Ambiguous nonword (BAPON-robot)		Unqiue nonword (БARON-robot)		Baseline control (XXXXX-robot)	
L	ER	L	ER	L	ER	L	ER
			Low frequency				
680[a]	10.71	683	15.48	668	9.52	661	13.69
81[b]	13.64	88	13.05	81	12.25	81	14.25
88[c]	14.29	98	20.59	85	14.54	89	19.31
			High frequency				
598	2.08	599	5.95	601	4.46	604	3.57
66	5.56	73	10.26	78	8.10	81	8.24
72	5.10	75	12.44	78	11.09	75	7.51

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

mean target latency for Sets 1–4 was 608 ms and that for Sets 5–8 was 637 ms. This contrast was reliable, $F1(1,55) = 45.76, p < .001$, $F2(1,94) = 32.70, p < .001$. Also reliable was the main effect of target frequency (LF = 654 ms vs HF = 591 ms), $F1(1,55) = 366.23, p < .001$, $F2(1,94) = 28.69, p < .001$, and the two-way interaction between prime type and relatedness, $F1(3,165) = 8.45, p < .001$, $F2(3,282) = 5.60, p < .001$. All other interactions were unreliable (all $Fs < 1$). With respect to the corresponding ANOVA on errors, only prime type, $F1(3,165) = 4.17, p < .01$, $F2(3,282) = 3.70, p < .01$, and target frequency (LF = 12.80 vs HF = 3.72%), $F1(1,55) = 98.63, p < .001$, $F2(1,94) = 21.13, p < .001$, were reliable.

Planned comparisons revealed that the 34-ms priming difference between identity primes and their controls, $F1(1,55) = 24.48$, $p < .001$, $F2(1,94) = 9.93, p < .01$, and the 52-ms priming difference between unambiguous nonword primes and their controls, $F1(1,55) = 38.93, p < .001$, $F2(1,94) = 33.97, p < .001$, were all reliable. The partial interactions involving the unique nonwords and their controls were both insignificant but they were favorable: With respect to the identity primes and their controls, $F1(1,55) = 3.36, p = .07$, $F2(1,94) = 3.16, p = .07$; with respect to the ambiguous nonwords and their controls, $F1(1,55) = 5.81, p < .05$, $F2(1,94) = 1.77, p > .05$.

In sum, the analyses based on individualized controls reveal not only the supremacy of unique nonwords at the average prime-target SOA of 70 ms, but also the efficacy of identity primes and ambiguous nonword primes—an efficacy that was less clear in the previous analysis of Experiment 4 based solely on the test primes and a row of Xs as baseline. The importance of this result is that it confirms identity priming at brief SOAs, offsetting the negative impression obtained in the naming experiments, Experiments 1 and 2.

Experiment 5 (SOA = 250 ms). Tables 10a and 10b summarize the results. Considering just the test primes, the ANOVA on correct latencies revealed a main effect of prime type, $F1(3,165) = 134.41, p < .001$, $F2(3,282) = 86.07, p < .001$, and a main effect of target frequency, $F1(1,55) = 132.45, p < .001$, $F2(1,94) = 17.62, p < .001$. Planned comparisons revealed an unreliable 3-ms priming difference between ROБOT and ROBOT, $Fs < 1$, in contrast to a reliable 45-ms priming difference between ROБOT and POBOT, $F1(1,55) = 53.54, p < .001$, $F2(1,94) = 35.64, p < .001$, and a reliable 48-ms priming difference between ROBOT and POBOT, $F1(1,55) = 54.66, p > .001$, $F2(1,94) = 39.68, p < .001$. All planned comparisons with XXXXX were reliable. Experiment 5 (a lexical decision experiment), therefore, replicated Experiment 3 (a naming experiment) in demonstrating that, at an average SOA of 250 ms, identity priming is matched by the priming induced by the phonologically unique nonwords with the latter more effective than the priming induced by the phonologically ambiguous nonwords.

In the ANOVA on target latencies incorporating the individualized controls, prime type (580, 605, 585, and 637 ms, respectively) was significant, $F1(3,165) = 69.48, p < .001$, $F2(3,282) = 45.47, p > .001$, as were relatedness (test primes = 568 ms, individualized controls = 636 ms), $F1(1,55) = 376.90, p < .001$, $F2(1,94) = 164.71, p < .001$, and target frequency (LF = 627 ms vs HF = 577 ms), $F1(1,55) = 195.88, p < .001$, $F2(1,94) = 24.74, p < .001$. Additionally, the two-way interaction between the prime type and relatedness was significant, $F1(3,165) = 72.03, p < .001$, $F2(3,282) = 42.72, p < .001$. Other interactions were unreliable. In the corresponding ANOVA on errors, prime type was not significant (all $Fs < 1$) but relatedness, $F1(1,55) = 21.32, p < .001$, $F2(1,94) = 16.93, p < .001$, and target frequency (LF = 8.30% vs HF = 3.01%), $F1(1,55) = 60.02, p < .001$, $F2(1,94) = 11.72, p < .001$, were reliable. No other main effect or interaction was significant (all $Fs < 1$).

Planned comparisons on the latency data revealed reliable priming differences between identity primes and their controls (106 ms), $F1(1,55) = 288.64, p < .001$, $F2(1,94) =$

TABLE 10a

MEAN LEXICAL DECISION LATENCIES L (IN MS) AND ERROR RATE (ER, IN %) WITH THE CORRESPONDING STANDARD DEVIATIONS BY SUBJECTS AND BY ITEMS FOR THE IDENTITY, NONWORD AMBIGUOUS, NONWORD UNIQUE, AND BASELINE TEST PRIMES OF EXPERIMENT 5

Identity (ROBOT-robot)		Ambiguous nonword (POBOT-robot)		Unique nonword (ROБOT-robot)		Baseline control (XXXXX-robot)	
L	ER	L	ER	L	ER	L	ER
			Low frequency				
546[a]	5.36	597	7.74	551	5.95	667	8.33
86[b]	9.59	81	11.88	84	9.76	93	11.01
76[c]	10.05	91	13.17	76	12.44	99	13.45
			High frequency				
509	0.60	553	3.27	509	1.49	613	1.49
70	3.12	63	6.68	73	5.75	72	4.80
63	2.88	70	7.36	53	6.75	78	5.30

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

144.30, $p < .001$, ambiguous nonword primes and their controls (60 ms), $F1(1,55) = 90.48$, $p < .001$, $F2(1,94) = 44.10$, $p < .001$, and unambiguous nonword primes and their controls (110 ms), $F1(1,55) = 197.51$, $p < .001$, $F2(1,94) = 133.03$, $p < .001$.

TABLE 10b

MEAN LEXICAL DECISION LATENCIES L (IN MS) AND ERROR RATE (ER, IN %), WITH THE CORRESPONDING STANDARD DEVIATIONS BY SUBJECTS AND BY ITEMS FOR THE INDIVIDUALIZED CONTROLS FOR THE IDENTITY, NONWORD AMBIGUOUS, NONWORD UNIQUE, AND BASELINE TEST PRIMES OF EXPERIMENT 5

Identity (BARON-robot)		Ambiguous nonword (BAPON-robot)		Unique nonword (БARON-robot)		Baseline control (XXXXX-robot)	
L	ER	L	ER	L	ER	L	ER
			Low frequency				
667[a]	10.71	658	7.74	671	11.90	656	8.63
78[b]	13.64	79	10.52	99	13.38	91	11.46
79[c]	14.59	77	13.49	92	15.96	80	14.66
			High frequency				
599	4.76	613	3.27	609	5.65	611	3.57
59	9.38	73	8.66	63	9.14	67	9.91
63	11.91	74	6.75	71	10.10	86	7.51

[a] Mean.
[b] Standard deviation by subjects.
[c] Standard deviation by items.

The partial interactions consolidate the results of the ANOVA. The 106-ms priming advantage of the identity primes over their controls was significantly larger than the 60-ms priming advantage of the phonologically ambiguous nonwords over their controls, $F1(1,55) = 24.04$, $p < .001$, $F2(1,94) = 19.14$, $p < .001$; similarly, the 110-ms priming difference between unique nonwords and their controls exceeded the 60-ms difference between the phonologically ambiguous nonwords and their controls, $F1(1,55) = 23.46$, $p < .001$, $F2(1,94) = 20.11$, $p < .001$. The priming advantages of identity primes and unique nonword primes were indistinct; for the partial interaction between them, both Fs < 1. All three priming advantages (of identity, ambiguous nonword, and unique nonword primes) were reliably superior (for all Fs, $p < .001$) to the −6-ms difference between the nonlinguistic controls (i.e., the row of Xs designated as List 4 vs the row of Xs designated as List 8).

In sum, Experiment 5 in comparison with Experiment 4 reveals in lexical decision the important shift in the relative status of identity and unique nonword primes that had been seen in naming. Whereas the identity prime was weaker than the unique nonword prime at SOA = 70 ms, it was the equal of the unique nonword prime at SOA = 250 ms. Compared with the ambiguous nonword prime, the identity and unique nonword primes were both superior at the longer SOA, but only the unique nonword prime was reliably better at the shorter SOA. The results of the lexical decision experiments replicated those of the naming experiments, in agreement with expectations from the phonological coherence hypothesis and in disagreement with expectations from the cascaded processing dual-route model.

GENERAL DISCUSSION

In the present research we have taken advantage of special features of the Serbo-Croatian writing system to create a strong test of the idea that visual word processing proceeds at a rate scaled by the temporal evolution of a unique and stable phonological code (Van Orden & Goldinger, 1994; Van Orden et al., 1990). Unlike phonetically imprecise writing systems such as English, the phonetically precise Roman and Cyrillic alphabets transcribing the Serbo-Croatian language do not allow either homophones or pseudohomophones. It is the case, however, that because the two largely independent alphabets share a small number of letters with the property of signifying one phoneme in Roman and a different phoneme in Cyrillic, it is possible to craft very particular pseudohomophones by mixing the alphabets. Thus, the nonwords XAREM and ROБOT composed by mixing Roman and Cyrillic letters have single phonological codes corresponding to the word readings of XAPEM (Cyrillic) and ROBOT (Roman), letter strings that—from the perspective of a fluent bialphabetical reader—can be read in two ways, with one way corresponding to the word and the other way corresponding to a nonword. Experiments 1 and 2 (naming experiments) and Experiment 4 (a lexical decision experiment) showed that at brief prime–target SOAs (≤70 ms), the phonologically unambiguous nonwords (XAREM and ROБOT) primed their corresponding words (xapem and robot) better than the words primed themselves. If the time to achieve a coherent phonological representation dictates the time course of stabilizing the other codes relevant to word recognition, then the phonologically unambiguous prime would have an advantage at short SOAs over the identity prime; that is, the achievement of a phonological code appropriate to processing the target would be more probable with the nonword primes XAREM and ROБOT than with the identity primes XAPEM and ROBOT. Of significance to this argument from the phonological coherence hypothesis are the outcomes of Experiment 3 (naming) and Experiment 5 (lexical decision). In these experiments, the prime target SOA was prolonged (250 ms). Given the longer time scale for achieving a unique and stable phonological code, it is noteworthy that when SOA is sufficiently large, the reliable priming by the phonologically unique nonword is no longer superior to the reliable priming by the identity prime.

Support for the Phonological Coherence Hypothesis

The identical pattern of results with the naming and lexical decision tasks is essential to the proof of the phonological coherence hypothesis. The temporal development of fully resolved, stable codes mediating pronunciation (e.g., articulatory codes) and fully resolved, stable codes mediating the determination of lexical status (e.g., semantic codes) is constrained in both cases by the time it takes to achieve a coherent phonological representation. Finding an invariant pattern of results across the two tasks is in keeping with the findings of an early phonological constraint on word processing in a wide variety of experimental settings involving very different response measures—accuracy of letter identification under backward masking (e.g., Perfetti, Zheng, & Berent, 1992; but see Verstaen, Humphreys, Olson, & D'Ydewalle, 1995 for a cautionary remark), speed and accuracy of letter search (e.g., Ziegler & Jacobs, 1995), speed and accuracy of semantic category judgments (e.g., Van Orden, 1987), and efficacy of associative and pseudoassociative priming of naming (e.g., Lukatela & Turvey, 1994a). These various results point to a pivotal role for phonology in visual language processing that is task independent. A closely related implication of the commonality between the results of Experiments 1–3 and Experiments 4–5 is that while naming and lexical decision may contrast on a number of dimensions, they are, at base, more similar than they are different. That is, they are both dependent, in a fundamental way, on phonology (although they might not be dependent in equal degree—in English, consistency effects occur in naming but not in lexical decision). A further general implication of the present results is that words and nonwords are processed similarly (Seidenberg & McClelland, 1989; Van Orden & Goldinger, 1994). As Experiments 1–5 have shown, novel letter strings, equal to familiar words in phonology, prime word pronunciations and word representations as well as the words themselves. Experiments with English language materials have led to the same conclusion about the equivalence of words and nonwords in activating pronunciation codes and lexical knowledge (e.g., Lukatela & Turvey, 1993, 1994a; Van Orden, Stone, Garlington et al., 1992).

An important issue is whether details of the present results generalize to other writing systems that are less oriented to transcribing phonology than Serbo-Croatian. Specifically, will identity priming in other orthographies prove to be dependent upon the phonological purity of the words in question? As noted in the introduction, the question with respect to English is whether words pronounceable in several ways (e.g., PINT) function less well as identity primes than words pronounceable in only one way (e.g., MUST). Because research on identity priming in English has not yet distinguished priming with irregular words from priming with regular words, it remains an empirical question of whether identity priming will be impaired at short SOAs when the words in question can each support more than one phonological code. Because irregular words take longer than regular words to achieve a single, clear phonological pattern (Van Orden & Goldinger, 1994), identity priming at short SOAs in both naming and lexical decision may well be superior for regular words. Against this expectation is the possibility that visual word recognition in English is considerably less influenced by phonological codes than is visual word recognition in Serbo-Croatian and other "shallow" writing systems. Our own work in both languages, however, inclines us to the view that phonological codes are major early sources of constraint whatever the depth of the orthography (see summary in Carello et al., 1992).

Orthography's Role Reconsidered

The pattern of outcomes observed in Experiments 1–5 is counter to expectations from models that assign the leading role to orthographic codes (e.g., Coltheart et al., 1993; Coltheart & Rastle, 1994). According to Coltheart and Rastle (1994), the phonological representation of a visually presented word can activate an entry in the orthographic input lexicon only if a majority of the activated input graphemes (in appropriate positions) supports that activation. For example, the pseudohomophone KOAT is expected to activate the lexical entry of COAT, whereas the pseudohomophone KOTE should fail to produce lexical activation. Applied to the stimuli of the present experiments, XAPEM should have been the best prime, and XAREM should have been as ineffective as HAPEM. A similar emphasis on orthographic codes is to be found in the experiments on French by Grainger and Ferrand (1994). In masked priming they found that the degree of orthographic similarity to the target word produced a reliable effect under the provision that the primes were homophonic with their targets (fois–FOIE vs sans–CENT). Grainger and Ferrand (1994) interpreted their findings as evidence that visual word recognition is directly influenced by orthographic information. As underscored by the data of Experiments 1–5, however, phonology remains the key factor: The contribution of the prime's orthographic similarity to target pronunciation is contingent on the prime's phonological relation to the target word. Extensive support for the latter is provided by Lukatela and Turvey (1994b). In a nutshell, they find reliable phonological priming for COTE–coat pairs but no priming at all for COTS–coat pairs (note that COTE and COTS differ from the canonical form COAT in identical letter positions). More recently, Ferrand and Grainger (1994) have reported that the French word NERF is primed better by the nonword homophone nert than the nonword homophone nair. The difference is seen as evidence that orthographic codes lead phonological codes in lexical activation. Two alternative interpretations are possible. The close temporal proximity of graphemically similar prime and target (with no intervening pattern mask, see Humphreys et al., 1988; Lukatela & Turvey, 1994b) would foster stimulus integration with a consequent boosting of target-relevant activity in the orthographic level of processing. This amplification of target-relevant orthographic activity would facilitate orthographic-phonological resonance and accelerate the development of the target-relevant phonological code. The second alternative interpretation notes that, given a source word in its canonical visual form (e.g., the English word COAT) and its possible pseudohomophones (KOAT, COTE, KOTE), it might be the case that the prelexical computation of phonology proceeds faster for canonical rather than for noncanonical orthographic patterns. Such an expectation follows from the understanding that the weights of the orthographic-phonological connections reflect the reader's experience with the frequencies of covarying orthographic and phonological subpatterns. Consequently, the more the orthographic form of a pseudohomophone prime differs from the target word's (canonical) orthographic form, the slower will be the rate at which phonological codes are computed. Again, what matters is phonology, not orthography.

Concluding Remarks

A large number of experiments conducted through a variety of techniques in different orthographies have established the immediacy of phonological influences on word recognition (for reviews see Carello, Turvey, & Lukatela, 1992; Frost, 1994; Lukatela & Turvey, 1991, 1994a, 1994b; Perfetti, Zhang, & Berent, 1992; Van Orden & Goldinger, 1994; Van Orden et al., 1990; Ziegler & Jacobs, 1995). Accordingly, modern dual-route theory no longer assumes that phonological codes operate late, or are bypassed, in the visual processing of words. There is recognition of the need for a fast-acting nonlexical route, possibly commensurate in speed with the lexical route (note Coltheart & Rastle's [1994] argument to accommodate the data of Perfetti et al. [1992] and the parallel arguments of Paap, Noel, & Johansen [1992]). However, recognition of very early phonological constraints is not the same as recognition of the primary role of phonology in the word recognition process. Explicit recognition of this primacy is the hallmark property of the phonological coherence hypothesis (Van Orden & Goldinger, 1994; Van Orden et al., 1990). The results of Experiments 1–3 using the response measure of rapid naming and Experiments 4–5 using the response measure of lexical decision may be considered as further reason to promote the view of visual word recognition as primarily constrained by the temporal evolution and form of phonological codes.

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