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An Evaluation of the Two-Cycles Model of Phonology Assembly

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In nine lexical decision experiments we evaluated Berent and Perfetti's (1995) hypothesis that, in visual word recognition, consonants and vowels are derived in two consecutive cycles. A nonvisible prime of 14 ms duration within a sequence of mask, nonword prime, and word target provided the operational definition of the first cycle. Contrary to the hypothesis, within the first cycle pseudohomophones (e.g., KLIP–*clip*) primed better than nonwords that conveyed only consonant information (e.g., CLEP–*clip*), vowel-preserving primes (e.g., GLAME–*glaze,* BAK–*bad*) were as effective as consonant-preserving primes (e.g., GLEZE–*glaze,* BYD–*bad*), and vowel complexity seemed to matter. Discussion focused on the assembly of phonology and the immediacy and primacy of phonological codes. © 2000 Academic Press

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There is now considerable evidence that phonology plays a fast-acting, substantial, and possibly leading role in visual word recognition (e.g., Carello, Turvey, & Lukatela, 1992; Frost, 1998; Lesch & Pollatsek, 1998; Lukatela, Frost, & Turvey, 1998a, 1999; Lukatela & Turvey, 1998; Perfetti, Zhang, & Berent, 1992; Rayner, Sereno, Lesch, & Pollatsek, 1995; Van Orden & Goldinger, 1994; Ziegler & Jacobs, 1995). Consequently, experimental inquiry into phonology's involvement can now turn to more technical matters. Among the most pressing questions are (a) By what principles are phonological codes assembled from orthographic information? and (b) How immediate is the expression of phonological codes? Possible answers are provided by the two-cycles model of phonology assembly proposed by Berent and Perfetti (1995).

In the two-cycles model, consonants and vowels are distinct constituents in a word's phonological representation, in agreement with autosegmental theories of phonology (e.g., Goldsmith, 1990; McCarthy, 1989). It is hypothesized that the two types of phonemes are derived by processes that differ in speed and automaticity. Specifically, consonants are derived first by automatic computations and vowels are added subsequently to the evolving representation via strategically controlled computations.

The first and second cycles of phonology assembly can be operationalized in the context of a mask–prime–target presentation sequence with interstimulus intervals of 0 (Berent & Perfetti, 1995, Experiment 7). A prime of 15 ms duration allows for the first cycle but not the second; a prime of 30–40 ms duration or more allows for both cycles. Consider the task of naming a target such as *rake.* When the prime exposure allowed only the first cycle, Berent and Perfetti (1995) found that a consonant-preserving prime (RIKK) resulted in a pronunciation of *rake* that was significantly faster by 28 ms than the pronunciation of *rake* following a vowel-preserving prime (RAIB) and nonsignificantly faster by 7 ms than the pronunciation of *rake* following a homophonic prime (RAIK). In contrast, at the longer prime exposure permitting both cycles, the consonant-preserving prime was found to be significantly less effective by 41 ms than the homophone prime. The implication of the preceding pattern of priming

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effects is that processing is limited to consonant graphemes at a 15-ms prime duration (the effects of RIKK and RAIK were essentially equal) but that vowel graphemes are included in the processing at longer prime durations (RAIK was far superior to RIKK).

A further, and ideally stronger, test of the two-cycles model is warranted by the importance of the theoretical claim that vowels as a class differ from consonants as a class within the visual word recognition system. This categorical division can be made explicit within dual-route models (Coltheart, Curtis, Atkins, & Haller, 1993). For example, it can be argued that consonants are processed over the direct or lexical route and that vowels are processed over the mediated or nonlexical route (Berent & Perfetti, 1995, p. 148). In parallel distributed models, the vowel–consonant division is, at best, implicit, referring to processing differences within a common network (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996; Van Orden & Goldinger, 1994; Van Orden, Pennington, & Stone, 1990). Consonant and vowel orthographic subsymbols simultaneously activate consonant and vowel phonological subsymbols. Although vowel and consonant processing occurs concurrently within one and the same system, the resolution of vowel phonology may on occasion take longer than the resolution of consonant phonology (e.g., Kawamoto, 1988; Kawamoto, Kello, Jones, & Bame, 1998). Such a time difference, when observed, can be attributed to the greater average complexity (in English) of the orthography-to-phonology mapping in the case of vowels.

A focus upon the complexity of mappings has different implications than a focus upon linguistic class. From a complexity viewpoint, whether vowel graphemes are processed more slowly than consonant graphemes depends on the vowels and consonants in question. Strictly speaking, a neural network is not prefigured in terms of a priori linguistic categories. Whatever temporal characteristics and classifications it exhibits are solely the result of the mappings it has acquired. A major lesson from research on fluent readers of Serbo-Croatian's two distinct but partially overlapping alphabets is that the time to complete the assembly of a phonological code for a given letter string depends strictly upon the single valuedness of the individual letter-to-phoneme mappings (Lukatela & Turvey, 1998). Letter strings with single-valued mappings throughout are processed faster than letter strings with one or more violations of single valuedness. In Serbo-Croatian the violations are more likely to occur with consonants (e.g., B is /b/ in the Roman alphabet and /v/ in the Cyrillic alphabet). Consonant violations of single valuedness also typify English (e.g., C is /s/ or /k/ depending upon context) and may be expected to affect processing time (e.g., Lukatela et al., 1999).

Consequently, if there is no categorical distinction between consonants and vowels, and if there is, thereby, no mandatory consecutiveness in the processing of consonants and vowels (with consonant processing completed first), then the following prediction contrary to the two-cycles hypothesis should be given serious consideration. Other things being equal, a nonword prime that shares consonant and vowel phonology with a following target should, at the shortest time scales, be of greater benefit to the processing of the target than a nonword prime that shares only consonantal phonology with the target.

In the present experiments, the two-cycles model was evaluated in the mask–prime–target presentation sequence using lexical decision. Although Berent (1997) conducted experiments with lexical decision that were conceptually motivated by the two-cycles model she did not address the essential claim that the processing of vowels is staggered relative to the processing of consonants. The importance of testing the two-cycles hypothesis in lexical decision should be underscored. It has often been assumed that lexical decision is a more challenging test field than naming for phonologically based hypotheses of visual word recognition (Frost, 1998). A phonological code is an explicit requirement of naming; consequently, significant effects of phonological manipulations on naming are to be expected. In contrast, a phonological code is not an explicit requirement of lexical decision. A decision about a letter string's lexical status could be achieved, in principle, without recourse to the letter string's phonological code. Importantly, experiments show that phonological priming occurs with comparable efficacy at the same time scales in both lexical decision and naming (e.g., Lukatela et al., 1998a, 1999). In consequence, there is no compelling reason for evaluating the two-cycles hypothesis in the naming task if the more conservative lexical decision task can be used for the same purpose.

EXPERIMENT 1

In Experiment 1, participants received mask–prime–target sequences with interstimulus intervals of 0 ms and a prime duration of 14 ms (one refresh cycle of the computer monitor). Operationally, this very short duration limits processing to the first cycle. The hypothesis that the first cycle is restricted to deriving consonants was evaluated primarily through the comparison of two kinds of prime–target pairs, for example, KLIP–*clip* and CLEP–*clip*. Given that KLIP and CLEP share the same degree of consonantal phonology with *clip,* the two-cycles model of Berent and Perfetti (1995) predicts that no priming difference should be evident at the prime duration of 14 ms. If activation of vowels as well as consonants occurs at this time scale, contrary to the model, then KLIP should be a better prime than CLEP.

A secondary evaluation of the two-cycles model was conducted through the comparison of prime–target pairs such as NAIM–*name* and NALM–*name.* Pairs of this kind constitute the typical form of the *pseudohomophone test* (Humphreys, Evett, & Taylor, 1982; Lukatela et al., 1998a; Lukatela & Turvey, 1994b)—a determination of whether a masked nonword homophonic with a target primes better than a one-letter different nonword that is not homophonic with the target. (KLIP versus CLEP, differing by two letters from each other and by one letter from the target, constitutes an atypical pseudohomophone test.) Ignoring position within the letter string, the homophonic prime NAIM and its orthographic control NALM are alike in that they both share the consonants of the target *name* (as in the REEZ–*rose* example of Berent and Perfetti). They should, therefore, prime equally well at the prime duration of 14 ms. Said differently, the typical form of the pseudohomophone test should not be passed if the two-cycles model is correct. If, contrary to the model, both consonant and vowel phonology are derived at the 14-ms time scale, then the homophonic prime, with its inclusion of the target's vowel as well as the target's consonants, should prove to be more effective than its orthographic control.

There was one other important feature of the design of Experiment 1 that had to do with the mask in the mask–prime–target presentation sequence. In a previous experiment we had failed to obtain evidence for phonological priming at a prime duration of 43 ms (Lukatela et al., 1998a; Experiment 1), in contrast to indications of successful phonological priming at this time scale in the research of Berent (1997). In Berent's study, the durations of mask, prime, and target were substantially reduced from the conventional magnitudes (e.g., Forster & Davis, 1991) without violating the desirable unidentifiability of the prime. The implication of Berent's (1997) study was that priming at extremely brief prime durations depends on the right balance of presentation parameters. In Experiment 5 of Lukatela et al. (1998a), mask and target durations were similarly reduced. Under these conditions, the primes were unidentifiable and successful phonological priming was achieved at a prime duration of 29 ms. The details of the mask–prime–target sequence used in the present research were the result of pursuing reliable priming by a nonvisible prime exposed for 14 ms, that is, within the 15-ms prime duration that Berent and Perfetti (1995; Experiment 7) equated with first-cycle processing within the mask–prime–target sequence. To this end, forward metacontrast masking emerged in pilot investigations as a better experimental tool than forward pattern masking. It is important to note that Berent and Perfetti (1995) did not adhere to the 15-ms criterion throughout their research. Whereas a prime duration of 30 ms was equated with the second cycle in Experiment 7, it was equated with the first cycle in other experiments. This flexibility in interpreting the 30-ms prime duration did not extend, however, to the

15-ms duration. The latter was uniformly interpreted as capturing the first cycle.

It was the case, therefore, that rather than covering the spatial location of the prime in the usual manner (e.g., Berent, 1997; Ferrand & Grainger, 1994; Forster & Davis, 1991; Lukatela et al., 1998), the mask of Experiment 1 (and all subsequent experiments) was spatially adjacent to the prime in the manner of masks used in metacontrast studies. In processing terms, the advantage of a nonoverlapping forward mask is that the integrative phase that yields a single central representation of two almost-simultaneous stimuli (Michaels & Turvey, 1979) would be minimized. The masking of the prime would occur with minimal central contamination of the prime's features by the mask's features. Minimal featural contamination at later, more central, visual processing stages is methodologically significant because the focal issue in the two-cycle model is the temporal limit, not the spatial limit, on the processing of vowel graphemes.

Method

Participants

Twenty-six University of Connecticut undergraduates participated in the experiment in partial fulfillment of a course requirement. A participant was randomly assigned to one of two groups (13 participants per group).

Materials

The stimuli were derived from two base sets of 48 word–word pairs each. In each pair the prime and the target were two identical words with the prime in uppercase and the target in lowercase (to be consistent with Berent, 1997, and Lukatela & Turvey, 1994a, b). Each word was a monosyllable consisting of four or five letters. Short, monosyllabic words were chosen because they have high neighborhood densities—a feature typically assumed to be detrimental to masked form priming (Forster, 1987; Forster & Davis, 1991). From these base identity pairs were derived the experimental stimuli (see Appendix A). The base pairs themselves were never presented.

Because it proved to be the case that the two sets could be distinguished by the complexity of their vowels, one base set was referred to as the M (monopthong) set and the other base set was referred to as the D (dipthong) set.[1] In the M base set, the initial letter of each word was C and each word was a monosyllable consisting of four or five letters (e.g., CLIP–*clip*, CREST–*crest*). These stimuli had been used previously in the investigations of Lukatela et al. (1998). Most of the word bodies were doubly consistent (i.e., bottom-up consistent and top-down consistent) following the terminology of Stone, Vanhoy, and Van Orden (1997). According to Kucera and Francis (1967) the mean frequency of the target words was 23.96 ± 38.85. The neighborhood density of the target words was 8.69 and that of the word bodies 18.58.

The words in the D base set were also monosyllables (e.g., BOAT–*boat*, NAME–*name*). The mean frequency of the words in this set was 95.48 ± 148.35. These words tended to be bottom-up consistent but top-down inconsistent. The neighborhood density of the target words was 13.21 and that of the word bodies was 13.31.

For the experiment, one test set and one control set of 48 pairs were generated from each of the M and D base sets. There were, in addition, two filler subsets. The filler pairs were highly diversified in an effort to make the development of any specific response strategy unlikely.

The M test set. In each prime of the M base set the initial letter C was replaced by the letter K (e.g., KLIP–*clip*, KREST–*crest*) to produce 48 phonologically matched test pairs.

The M control set. In each prime of the M base set the letter representing a vowel was replaced by a letter representing a different vowel (e.g., CLEP–*clip*, CROST–*crest*) to produce 48 phonologically mismatched control pairs.

The D test set. In each prime of the D base set the vowel grapheme was replaced by a homo-

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[1] Some of the stimuli in the M set contain vowel graphemes that are likely to suffer from rhoticization or r-coloring in the speech of New Englanders, for example, the O in CORD and CORK. Also, stimuli such as CULT could involve tongue movement, rendering them "complex."

phonic mate (e.g., BOTE–*boat,* NAIM–*name*) to produce 48 phonologically matched test pairs.

The D control set. In each prime of the D base set the word body was modified to change the vowel from a dipthong to a monopthong (e.g., BOTS–*boat,* NALM–*name*) to produce 48 phonologically mismatched control pairs.

Yes-response fillers. Thirty-nine prime–target pairs were assembled in which each target was a word. Each prime was an identity word, or an associatively related word, or an unrelated word, or a homophonic nonword, or a nonhomophonc nonword, or a row of Xs (the number of Xs matched the number of letters in the target). All nonword primes were orthographically legal and pronounceable nonwords.

No-response fillers. One-hundred and seventeen prime–target pairs were assembled in which each target was a nonword. Again, all nonwords in this subset were orthographically legal and pronounceable. Each prime was a word, a homophonic nonword, a nonhomophonic nonword, or a row of Xs (the number of Xs matched the number of letters in the target).

Design

The major constraint of the design was that a given participant never encountered a given pair of words more than once. This was achieved by dividing the 26 participants evenly into two groups, A and B. Each participant in Group A saw one half of the pairs from the M test list (KLIP–*clip*), one half of pairs from the M control list (CLEP–*clip*), one half of the pairs from the D test list (NAIM–*name*), one half of the pairs from the D control list (NALM–*name*), 39 Yes-response foil pairs, and 117 No-response foil pairs. Each corresponding participant in Group B saw the other half of each of the M test, M control, D test, and D control sets together with 39 Yes-response foil pairs and 117 No-response foil pairs. In sum, each participant saw a total of 252 stimulus pairs. The experimental sequence was divided into three subsets, with a brief rest after each. Stimulus pairs were presented to each participant in a different order. The experimental sequence was preceded by a practice sequence of 50 stimulus pairs.

Procedure

Participants, run one at a time, sat in front of the monitor of a DIGITAL 466 computer. The ambient light of the room was approximately 0.07 fc and the light from the screen at the participant's viewing point was approximately .5 fc.[2] The viewing distance was about 60 cm. The refresh rate of the VENTURIX monitor was 70 Hz, making a refresh cycle (i.e., a "tick") equal to 14.3 ms. The stimuli appeared on the screen as white characters on a dark background.

Each trial consisted of a sequence of three visual events in the same location on the center of the screen. First, a line was presented for 20 ticks (286 ms). The line was spatially positioned to be below the spatial location of the prime. For example, given the prime KLIP, the mask was __. The underline functioned as a metacontrast mask. It was immediately followed by the prime stimulus for 1 tick (14.3 ms). Immediately following the prime, a target was presented for 5 ticks (72 ms). Because the interstimulus interval was 0, the prime target SOA was equal to the prime's exposure duration. All

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[2] We have found that the conditions of computer screen illumination and ambient illumination are fairly critical to obtaining differences under the extreme stimulus duration restrictions characterizing the present experiments (see also Lukatela et al., 1998a). This finding is not surprising given that three-field visual masking with brief exposures under binocular viewing is highly volatile (Michaels & Turvey, 1979). Tachistoscope experiments permitting precise energy controls reveal that briefly separated binocularly presented stimuli interact peripherally according to their respective energies, as determined by the product of duration and intensity (e.g., Turvey, 1973). These energy-based integrations compromise stimulus separability and, together with the pattern-based integration and backward interruption that occurs centrally, lead to a complex variety of perceptual outcomes in the three-field situation (see Michaels & Turvey, 1979, for a summary of this literature). With computer displays, the light to the eye is very poorly controlled and there are unknown dependencies of visual processing on the ratio of screen illumination to room illumination. Our illumination parameters were arrived at through limited pilot experimentation. We suspect that a thoroughgoing parametric examination of the illumination issue will be required if experimentation on visual word recognition at extremely short time scales is to proceed. Similar sentiments have recently been expressed by Xu and Perfetti (1999).

primes were presented with a number sign (#) left of the initial letter and right of the final letter (e.g., #KLIP#). The number symbols were included to offset the possibility that, at the extremely brief prime duration of 14 ms, the prime's end letters would be less affected than its interior letters by lateral inhibition arising from neighboring letters. Given that vowel graphemes tended to be interior in the M and D stimulus sets, it was conjectured that they might suffer unduly relative to the consonant graphemes.

Presentation and control of stimuli were through DMASTR software (developed at Monash University and University of Arizona by K. I. Forster and J. C. Forster). Participants were told that on each trial there would be a rapid sequence of two letter strings, with the first letter string in uppercase and the second letter string in lowercase. They were warned that the first letter string would be flashed very briefly and would probably be unnoticable. Debriefing following the experiment revealed that not a single participant saw any uppercase letter. Participants were instructed to decide as quickly and as accurately as possible whether the lowercase letter string was an English word, ignoring the uppercase letter string. Their decisions were indicated by pressing a "yes" or "no" key with latencies measured from the onset of the target. If the latency was longer than 1800 ms a warning message ("TRY FASTER!") appeared on the screen and if the decision was wrong a feedback message ("WRONG") appeared on the screen.

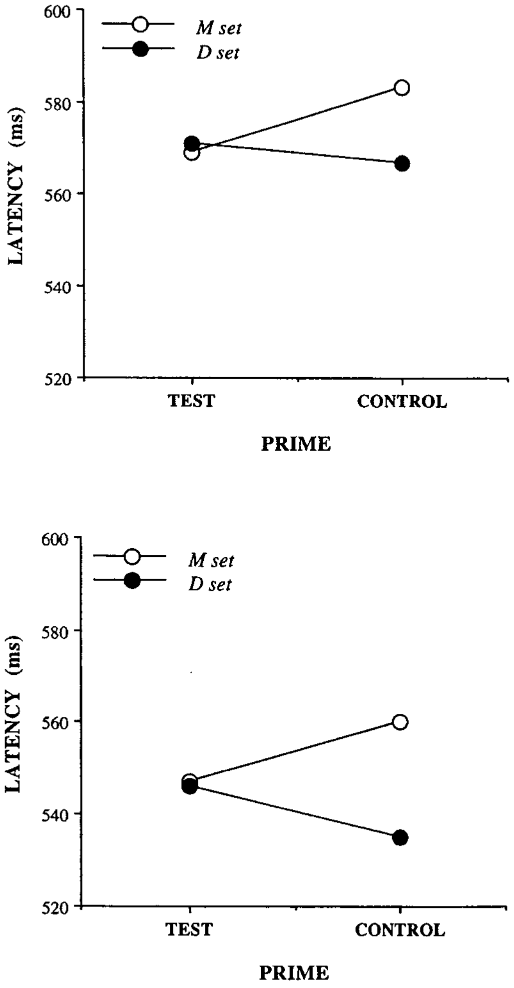

FIG. 1. Mean latency of response to the target stimuli of the M set (e.g., *clip*) and the D set (e.g., *name*) as a function of the test (e.g., KLIP, NAIM) and control (e.g., CLEP, NALM) primes in Experiment 1 (top) and Experiment 2 (bottom).

Results and Discussion

Reaction times (RTs) were trimmed minimally by applying a 100-ms cutoff for fast responses and an 1800-ms cutoff for slow responses. The outliers constituted less than 0.5% of all responses (see criteria for truncation suggested by Ulrich & Miller, 1994, p. 69). The RT and error means for the targets under the four prime conditions were 569 ms and 6.7% for M test primes, 583 ms and 6.7% for M control primes, 571 ms and 5.9% for D test primes, and 567 ms and 5.1% for D control primes. The RT means as a function of conditions are shown in Fig. 1 (top panel).

A 2 by 2 by 2 (Group by Prime type by Target type) analysis of variance (ANOVA) was conducted on the correct target RTs with subjects ($F1$) and stimuli or items ($F2$) as the error terms. The interaction of prime type (test versus control) and target type (M versus D) was marginally significant, $F1\ (1, 48) = 5.17$, $p < .05$; $F2\ (1, 92) = 3.55$, $p = .06$. Planned comparisons revealed that the 14-ms priming advantage of M test primes over M control primes (e.g., KLIP–*clip* over CLEP–*clip*) was significant, $F1$ (1, 24) = 7.56, $p <$ .01; $F2$ (1, 46) = 4.31, $p <$ .05, but the −4-ms disadvantage of D test primes over D control primes (e.g., NAIM–*name* relative to NALM–*name*) was not significant, $F1$ (1, 24) < 1; $F2$ (1, 46) < 1. There were no significant effects in the error analysis.

The success of M test primes at the 14-ms prime duration of the present experiment counters the prediction that only consonant graphemes are processed in the first cycle. The advantage of KLIP over CLEP as a prime for *clip* must derive from KLIP's activation of the target's vowel phonology over and above the activation of the target's consonant phonology. The foregoing conclusion that vowels are processed in the first cycle would seem to be compromised, however, by the failure of the D test primes. Contrasts such as those of BOTE versus BOTS and NAIM versus NALM are those of a homophonic nonword (full consonantal and vowel overlap with the word target) and its orthographic control—the fundamental form of the contrast defining the pseudohomophone test (Humphreys et al., 1982; Lukatela et al., 1998a; Lukatela & Turvey, 1994b). Perhaps the proper perspective on the failure of this particular variant of the pseudohomophone test is in respect to the contrast between the monopthongs in the D control primes and dipthongs in the D test primes.

This monopthong–dipthong contrast can be conceived of as a contrast in either orthographic complexity (e.g., the monopthong in NALM is coded by A, the dipthong in NAIM is coded by AI), phonological complexity, or both. In articulation and the consequent acoustics, the quality of a monopthong or pure vowel remains essentially unchanged throughout the syllable in which it is used; in contrast, the quality of a dipthong changes noticeably from its beginning to its end in a syllable. In uttering dipthongs, the tongue movements are roughly movements between positions assumed for pure vowels (Denes & Pinson, 1973). A word's phonological representation might reflect this articulation/acoustic difference.

Dipthongs could have slowed first-cycle processing, therefore, in either one or both of two ways. Because the vowel grapheme in the case of a dipthong consists of multiple letters, its parsing from its letter components might be expected to be prolonged relative to the simpler vowel grapheme in the case of a monopthong. That is, within the first cycle, A in NALM was parsed but AI in NAIM was not. Correspondingly, if the phonological form of a dipthong requires more specification than the phonological form of a monopthong, its resolution might be expected to be more protracted. That is, within the first cycle, /a/ in NALM was resolved but /ey/ in NAIM was not. By either the orthographic or phonological interpretation, if vowel phonology was delayed in processing NAIM, then NAIM should not have primed better than NALM given that (a) NAIM and NALM convey the same information about the target's consonantal phonology and (b) NALM does not convey information about the target's vowel phonology.

Returning to the M test primes, their success in the present experiment is significant in an additional and broader respect. Previous investigations in the mask–prime–target procedure using prime exposures of approximately 30 ms have failed to find evidence for phonological priming (Ferrand & Grainger, 1992, 1994; Humphreys et al., 1982). The fact that orthographic priming occurred in these conditions of failed phonological priming has been used to argue for the independent evolution over time of two codes for lexical access, with the orthographic access code evolving sooner than the phonological access code (e.g., Ferrand & Grainger, 1994). In the present experiment, the orthographic similarity of KLIP to *clip* and CLEP to *clip* (as measured by the number of shared letters) is the same. Nonetheless, KLIP proved to be the superior prime, countering the claim that only orthographic codes are computable at the shortest time scales. Lukatela et al. (1998a, Experiment 5) have provided a similar counterpoint. Within the mask–prime–target procedure they found pseudohomophone priming (KLIP better than PLIP as a prime for *clip*) at a prime duration of 29 ms.[3]

EXPERIMENT 2

Experiment 2 replicated Experiment 1 with a small modification, namely, the omission of the number symbols (#s) that bracketed the primes of Experiment 1. The assumption was that the symbols may have exaggerated the forward metacontrast masking, reducing the overall effectiveness of the primes. Specifically, the number symbols may have reduced, through lateral inhibition, the salience of the initial and final letters.

Method

Participants

Twenty University of Connecticut undergraduates participated in the experiment in partial fulfilment of a course requirement. A participant was randomly assigned to one of two groups (10 participants per group).

Materials, Design, and Procedure

These were the same as those in Experiment 1, with the one exception that the #s were removed from the prime stimuli.

Results and Discussion

Mean RT as a function of conditions are summarized in Fig. 1 (bottom). A 2 by 2 by 2 ANOVA revealed an effect of target type (M set = 554 ms, D set = 540 ms), $F1\ (1, 18) = 5.30, p < .05$; $F2\ (1, 46) = 6.21, p < .01$, reflecting, perhaps, the higher mean frequency of the D targets. The ANOVA also revealed a significant prime type by target type interaction, $F1\ (1, 18) = 7.57, p < .01$; $F2\ (1, 46) = 9.21, p < .01$. Planned comparisons were conducted on the effects of prime type. The 13-ms advantage of M test primes was close to significance, $F1\ (1, 18) = 4.11, p = .06$; $F2\ (1, 46) = 4.01, p = .05$; the −11-ms disadvantage of D test primes was significant, $F1\ (1, 18) = 4.64, p = .05$; $F2\ (1, 46) = 3.83, p = .05$.

The fact that D test stimuli primed less well than D control stimuli suggests that delayed vowel processing in the first cycle may be detrimental to consonant processing. Paraphrasing the argument above, if only vowel phonology was delayed in processing NAIM, then NAIM and NALM should have primed equally effectively given that they convey the same information about the target's consonantal phonology and that NALM does not convey information about the target's vowel phonology. The superior priming of NALM suggests, therefore, that the extra time required to parse and/or resolve the phonology of NAIM's complex vowel grapheme extended the time to resolve the phonology of NAIM's consonant graphemes. Within the first cycle, NAIM's *overall* phonology was less well resolved than NALM's.

Taken together, the outcomes of Experiments 1 and 2 suggest that vowel graphemes are processed phonologically in the first of Berent and Perfetti's two cycles. From the M stimuli we can draw the conclusion that, in the first cycle, consonant and vowel graphemes are processed in the same time frame rather than in successive time frames. From the D stimuli we can draw the conclusion that, in the first cycle, consonant-processing time is dependent on vowel-processing time. Differences in deriving consonant and vowel phonology seem to be, at best, quantitative rather than qualitative (e.g., Kawamoto, 1988; Van Orden & Goldinger, 1994).

EXPERIMENT 3

In Experiment 3, prime duration was extended from 1 refresh cycle to 20 refresh cycles, that is, from 14.3 to 286 ms. If the Prime type by Target type interaction evident in Experiments 1 and 2 reflected differences in the rate of achieving phonological coherence, then it should be the case that the interaction disappears with a prolonged prime.

Method

Participants

Twenty-six University of Connecticut undergraduates participated in the experiment in par-

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[3] It is noteworthy that the masked priming results of Perfetti and Bell (1991) suggested a time scale for phonology's emergence of between 35 and 45 ms.

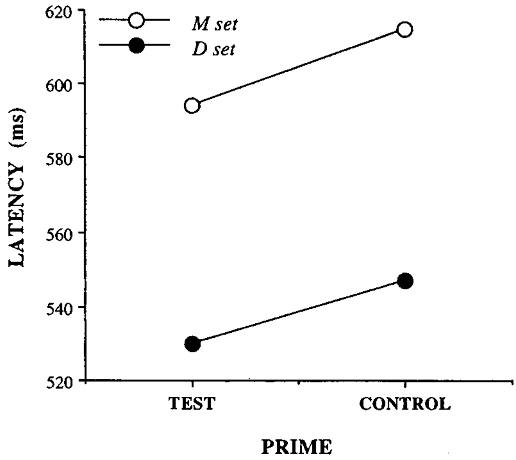

FIG. 2. Mean latency of response to the target stimuli of the M set (e.g., *clip*) and the D set (e.g., *name*) as a function of the test (e.g., KLIP, NAIM) and control (e.g., CLEP, NALM) primes in Experiment 3.

tial fulfilment of a course requirement. A participant was randomly assigned to one of two groups (13 participants per group).

Materials, Design, and Procedure

These were the same as those in Experiment 2 with the exceptions that the durations of the mask, prime, and target stimuli were all set to 286 ms.

Results and Discussion

The results are summarized in Fig. 2. Test primes led to faster lexical decisions than control primes, $F1$ (1, 48) = 30.83, $p < .001$; $F2$ (1, 92) = 14.29, $p < .001$, and did so independently of target type, $F1$ (1, 48) < 1; $F2$ (1, 92) < 1. Planned comparisons revealed that the 21-ms priming advantage of M test primes over M control primes was significant, $F1$ (1, 24) = 14.57, $p < .001$; $F2$ (1, 46) = 9.34, $p < .01$, as was the 17-ms advantage of D test primes over D control primes, $F1$ (1, 24) = 17.16, $p < .001$; $F2$ (1, 46) = 5.36, $p < .05$. The large absolute difference between M and D stimuli derives, in all likelihood, from the higher average frequency of D targets. Apparently, target frequency was a more potent factor under the presentation conditions of Experiment 3 than it was under the presentation conditions of Experiments 1 and 2 (compare Fig. 2 with Fig. 1).

In brief, with the prolonged prime duration of Experiment 3, primes that shared both consonants and vowels with their targets were superior to primes that shared only consonants, and this was so regardless of the complexity of the vowel. The outcome of Experiment 3, therefore, lends support to the interpretation given to the results of Experiments 1 and 2, namely, that consonant and vowel graphemes are processed concurrently, with the processing time for the phonology of consonant grapheme(s) conditioned upon the processing time for the phonology of vowel graphemes. Two particulars of this interpretation should be underscored. First, it is suggested that the vowel graphemes embedded in nonwords such as NAIM are far from fully processed within the 14-ms prime duration of Experiments 1 and 2. Second, it is suggested that this retarded processing of vowel phonology leaks over to the processing of consonant phonology, with the consequence that the consonantal graphemes N and M in NAIM are less well resolved phonologically at the 14-ms time scale than the same consonantal graphemes in NALM. A tentative conclusion is that, at a prime duration of 14 ms, *name* is primed less well by NAIM than by NALM despite the sameness of these primes in the number of letters and consonants they share with the target.

EXPERIMENT 4

In Experiment 4 we returned to the first cycle (14-ms prime) and asked whether the significant Prime type by Target type interaction and related advantages of M test primes and D control primes were evident in the performances of individual participants.

In Experiment 4, all prime–target pairs were presented to a single participant on each of four days. The method adopted in Experiment 4 was suggested and applied by Grainger and Jacobs (1991) and Ferrand and Grainger (1992). It is, essentially, a psychophysical approach to visual word recognition processes insofar as few participants are used and each is subjected to all of the experimental and control conditions. The plausability of the method derives from the fact that the primes are masked. Although a participant may become very familiar with the visible targets, and highly practiced in deciding on their individual lexical status, he or she would remain basically unaware of the nonvisible primes and their particular variations. The special advantage of the method is that it allows for a check on the viability of observed effects: Are they manifest in the data of an individual participant or are they evident only in the data of a group of participants?

Method

Participants

There were four participants. One male graduate student volunteered and one female graduate student and two female undergraduate students were paid $10 per hour to participate in the experiment.

Materials

The stimulus sets were the same as those in Experiment 1.

Design

It will be recalled that a participant in one of Experiments 1 to 3 was assigned to one of two groups, A or B. Each participant in Group A saw one half of the pairs from the M test list (KLIP–*clip*), one half of the pairs from the M control list (CLEP–*clip*), one half of the pairs from the D test list (NAIM–*name*), one half of the pairs from the D control list (NALM–*name*), 39 Yes-response foil pairs, and 117 No-response foil pairs. Each participant in Group B saw the other half of each of the preceding sets together with the 39 Yes-response foil pairs and 117 No-response foil pairs. In Experiment 4, a participant received, on each of 4 days, all of Group A's stimuli followed by all of Group B's stimuli (with the foils interspersed among the A and B stimuli). Thus, a single participant in the present experiment simulated eight participants in one of the preceding experiments.

Procedure

The forms and durations of mask, prime, and target were those of Experiment 2.

Results and Discussion

For Participants 1–4, the mean difference between M test and M control was −12 ms (−2.34%), −5 ms (.53%), −4 ms (.25%) and −11 ms (−3.91%), respectively, and the mean difference between D test and D control was 9 ms (−.01%), 1 ms (1.05%), 11 ms (.49%), and 8 ms (1.57%), respectively. That is, each participant's latencies revealed a numerical advantage for M test over M control (KLIP superior to CLEP) and a numerical disadvantage for D test over D control (NAIM inferior to NALM).

A 2 by 2 by 2 (Group by Prime type by Target type) ANOVA was conducted on the data of each participant separately, with simulated subjects or repetitions providing the error term for $F1$. For the latency data of Participant 1, the prime type by target type interaction was significant, $F1$ (1, 14) = 14.45, $p < .01$; $F2$ (1, 46) = 15.09, $p < .001$, as was the priming advantage of M test primes over M control primes, $F1$ (1, 14) = 11.41, $p < .01$; $F2$ (1, 46) = 9.95, $p < .01$, and the priming disadvantage of D test primes relative to D control primes, $F1$ (1, 14) = 4.39, $p < .05$; $F2$ (1, 46) = 3.88, $p = .05$. There were no significant effects in Participant 1's error analysis. For Participant 2, there were no significant effects in either the latency or error analyses. For the latency data of Participant 3, the prime type by target type interaction was significant, $F1$ (1, 14) = 6.0, $p < .05$; $F2$ (1, 46) = 5.42, $p < .05$, as was the priming disadvantage of D test primes relative to D control primes, $F1$ (1, 14) = 17.38, $p < .05$; $F2$ (1, 46) = 3.88, $p = .05$. Participant 3's error data revealed no significant effects. For the latency data of Participant 4, the prime type by target type interaction was significant, $F1$ (1, 14) = 7.32, $p < .01$; $F2$ (1, 46) = 6.74, $p < .01$, as was the priming advantage of M test primes over M control primes, $F1$ (1, 14) = 5.53, $p < .05$; $F2$ (1, 46) = 4.01, $p < .05$. The same significant effects were also found in Par-

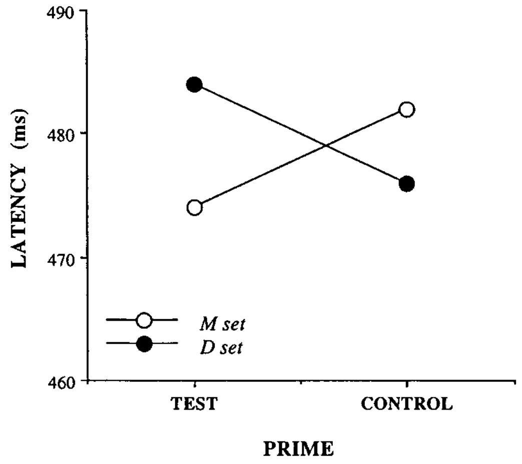

FIG. 3. Mean latency of response to the target stimuli of the M set (e.g., *clip*) and the D set (e.g., *name*) as a function of the test (e.g., KLIP, NAIM) and control (e.g., CLEP, NALM) primes in Experiment 4.

ticipant 4's error data: Prime type by Target type interaction, $F1$ (1, 14) = 9.62, $p < .01$; $F2$ (1, 46) = 6.59, $p < .01$; M test primes versus M control primes, $F1$ (1, 14) = 8.46, $p < .01$; $F2$ (1, 46) = 6.68, $p < .01$.

The RT results averaged over the four participants are shown in Fig. 3. From the corresponding ANOVA conducted on the data of the four participants taken together, the Prime type by Target type interaction was significant, $F1$ (1, 31) = 18.99, $p < .0001$, $F2$ (1, 92) = 13.92, $p < .001$, M test primes were superior to M control primes, $F1$ (1, 31) = 10.35, $p < .01$, $F2$ (1, 47) = 7.99, $p < .01$, and D test primes were inferior to D control primes, $F1$ (1, 31) = 8.68, $p < .01$; $F2$ (1, 47) = 5.59, $p < .05$. The ANOVA on errors revealed the same Prime type by Target type interaction with fewer errors on M test than M control and more errors on D test than D control, $F1$ (1, 31) = 4.39, $p < .05$, $F2$ (1, 92) = 5.67, $p < .05$.

The results of Experiment 4 confirm the findings of Experiments 1 and 2 and strengthen the conclusions drawn from them about the equivalency of vowel grapheme and consonant grapheme processing in the first cycle. The parallels between the present results and those of Experiments 1 and 2 also lend a measure of support to the methodological claim that certain kinds of psycholinguistic research can be conducted according to the psychophysical model (e.g., Ferrand & Grainger, 1992; Grainger & Jacobs, 1991; Grainger & O'Regan, 1992). Circumspection, however, is required. The prime type by target type interaction reproduced by the individual subjects was not identical to that obtained from averaging over multiple participants in Experiments 1 and 2 (compare Figs. 1 and 3). In Experiment 4, M test primes were more effective than D test primes compared to no difference in Experiments 1 and 2. The differences in the participants' experiences with the stimuli and the differences in the kinds of variability entering into the analyses may give rise to important performance differences. Further research directed at specific comparisons of the psychophysical and standard procedures will be needed.

EXPERIMENT 5

Experiments 1, 2, and 4 were directed at a prediction by the two-cycles model of a nondifference; namely, in the first cycle, a nonword prime conveying information about a target's consonants and vowels should not prime any better than a nonword prime conveying information only about the target's consonants. In contrast, Experiment 5 was directed at a predicted difference. According to the two-cycles model, a nonword prime that conveyed information about all of a target's consonants should be superior to a nonword prime that conveyed information about only some of the target's consonants. With respect to the target *clip*, the primes in Experiment 5 were CLEP and PLIP and the prediction evaluated was that CLEP (three shared consonants) should prime better than PLIP (two shared consonants). In continuation of the preceding experiments, Experiment 5 also compared M and D stimuli. The design was the two groups-of-participants design of Experiments 1–3.

Method

Participants

Sixteen University of Connecticut undergraduates participated in the experiment in partial

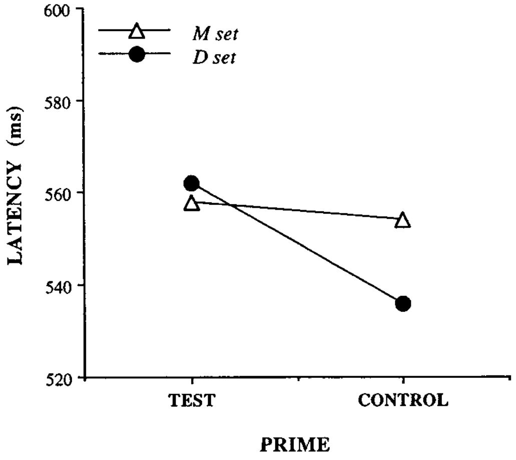

FIG. 4. Mean latency of response to the target stimuli of the M set (e.g., *clip*) and the D set (e.g., *name*) as a function of the test (e.g., CLEP, NAIM) and control (e.g., PLIP, NALM) primes in Experiment 5.

fulfilment of a course requirement. A participant was randomly assigned to one of two groups (8 participants per group).

Materials

With respect to the M stimuli, the test and control primes were the nonwords in the second and third columns, respectively, of Appendix A. The D test and D control primes were the same as those in Experiments 1–4.

Design and Procedure

These were the same as those in Experiment 2.

Results and Discussion

The mean RT data are summarized in Fig. 4. The two-way interaction between prime type and target type failed to reach significance by participants, $F1$ (1, 14) = 1.86, $p > .05$, but did reach significance by items, $F2$ (1, 46) = 4.28, $p < .05$. The −4-ms difference between M test and M control stimuli (here, the difference between CLEP and PLIP, respectively) was not significant, both Fs < 1. In contrast, the −26-ms difference between D test (e.g., NAIM) and D control (e.g., NALM) stimuli was highly reliable, $F1$ (1, 14) = 10.19, $p < .01$; $F2$ (1, 46) = 10.43, $p < .01$.

The implication of the null difference for the M stimuli is that, in the case of lexical items with pure vowels, it is the number rather than the type of shared phonemes that matters in the first cycle. (Both primes CLEP and PLIP share three phonemes with the target; CLEP shares three consonants, PLIP shares two consonants and a vowel.) The implication of the large negative difference for the D stimuli remains as above: Given a complex vowel, the processing of both vowel and consonant graphemes is slowed.

EXPERIMENT 6

We have presented the results of Experiments 1–5 as countering the two-cycles hypothesis. However, the nature of our stimuli invites consideration of an alternative interpretation of the data. At issue is the relative spelling-to-sound consistencies of the letters K and C. Specifically, the advantage of KLIP over CLEP as a prime for *clip* may have arisen from the fact that K is pronounced /k/ but C is pronounced as either /k/ or /s/. The implication of the lower consistency of C is that CLEP's inferiority as a prime may not have been due to its lack of vowel information but to the ambiguity of its initial consonant grapheme. The ANOVA involving all four participants in Experiment 4 was repeated excluding prime–target pairs with ambiguous initial C. Minimal differences were found in mean RTs and mean errors and none of the significances were altered, suggesting that the lower consistency stimuli made no special contributions to the outcomes of Experiments 1–5.

In order to provide a strict experimental evaluation of the preceding alternative, Experiment 6 compared CLEP–*clip* to CLIP–*clip*. That is, all primes began with C. According to the preceding alternative interpretation, and according to the two-cycles hypothesis, there should be no advantage within the first cycle of CLIP over CLEP given that the two primes are identical in their consonant graphemes. In contrast, according to the hypothesis advanced in Experiments 1–5, CLIP should prime better than CLEP.

Method

Participants

Twenty-two University of Connecticut undergraduates participated in the experiment in partial fulfilment of a course requirement. A participant was randomly assigned to one of two groups (11 participants per group).

Materials

The nonword primes of Appendix A were made into word primes by substituting C for K. No stimuli from Appendix B were included.

Design and Procedure

These were the same as those in Experiment 2.

Results

The mean RT and mean error for CLIP–*clip* were 547 ms and 9.7%; for CLEP–*clip* they were 568 ms and 7.0%. The contrast in RTs was significant, $F1$ $(1, 20) = 15.15, p < .001$; $F2$ $(1, 46) = 11.85, p < .001$. The error contrast was not significant, $F1$ $(1, 20) = 1.79, p > .05$; $F2$ $(1, 46) = 3.53, p = .07$. The advantage in Experiments 1–5 of nonword primes conveying both consonant and vowel information such as KLIP over nonword primes conveying only consonant information such as CLEP seems not to have been due to the greater letter–sound consistency of K. Rather, it seems that the advantage is tied to vowel graphemes and their processing in the first cycle.

We note that, aside from issues of initial consonant ambiguity, the interpretation of the priming superiority of CLIP could be given in terms of its greater orthographic similarity with the target. Against this interpretation, however, are the results of Experiment 5, as noted, and Experiments 1–3 of Lukatela et al. (1998a). In the latter, at the prime duration of 57 ms, both KLIP and PLIP were superior to CLEP as a prime for *clip* despite the common degree of orthographic similarity.

EXPERIMENT 7

A shortcoming of Experiments 1–6 was rectified in Experiment 7. The restriction of stimuli to the class of four-letter initial-C targets raises the question of the generality of the results. Will the evidence for the processing of consonant and vowel phonology in the same time frame hold for other sets of stimuli and, further, will it hold when experimental manipulations exclude the first phoneme? In addition, in Experiments 1–6 tests of the Berent and Perfetti (1995) hypothesis that consonant and vowel phonemes are derived by processes that differ in speed and automaticity were conducted in parallel with the pseudohomophone test (e.g., Lukatela et al., 1998a). The latter, it will be recalled, is a determination of whether a masked nonword homophonic with a target primes the target better than an orthographic control.

In Experiment 7, the stimuli were the nonhomophonous primes and targets of Berent and Perfetti's (1995) Experiment 4. For a target such as *stain* (a regular, low-frequency word with a graphemically complex vowel), the vowel-preserving prime was STAIP, the consonant-preserving prime was STAUN, and the control prime was PROOK. For a target such as *blast* (a regular, low-frequency word with the vowel and consonants matched in graphemic complexity, that is, a monopthong), the vowel-preserving prime was BLANT, the consonant-preserving prime was BLIST, and the control prime was GREMP. (Equivalently, for a low-frequency exception word such as *wand* the primes were WAHD, WUND, and METH, respectively.) As implied by the examples, the phoneme manipulations excluded the initial phoneme and targets with either simple or complex vowels were factored into regular and exception words of high and low frequency.

As Berent and Perfetti (1995) argue, the importance of the simple versus complex vowel contrast is that a graphemic account would predict superior priming by a consonant-preserving prime when the targets are complex but not when they are simple. When the targets are complex, vowel phonemes emerge late in processing because parsing them from their letter components is more complex. When the targets are simple, the parsing of vowel phonemes is no more arduous than the parsing of consonant phonemes. For Berent and Perfetti (1995), only a phonological interpretation of the two-cycles hypothesis would predict an advantage of consonant-preserving primes in the case of simple targets.

Berent and Perfetti's (1995) Experiment 4 was a target identification experiment in which the aforementioned primes were backward masks. In the present Experiment 7, the experimental task was the same as that of the preceding Experiments 1–6, namely, lexical decision on a target word following a masked prime. If the results of Experiments 1–6 are general (that is, they extend beyond the four-letter initial-C targets and the conditions of prime–target homophony), then same-vowel primes should be as effective as same-consonant primes in the first cycle.

Method

Participants

Thirty-three University of Connecticut undergraduates participated in the experiment in partial fulfilment of a course requirement. A participant was randomly assigned to one of three groups (11 participants per group).

Materials

The stimuli were identical to those of given in Berent and Perfetti's (1995) Appendix D. These stimuli consist of two base sets, 48 Complex Vowel targets and 48 Simple Vowel targets, and their derivatives. Each base set was evenly divided into four subgroups of Low-Frequency (LF) Regular, LF Exception, High-Frequency (HF) Regular, and HF Exception target words. Each word was a monosyllable consisting of three, four, or five letters. A given target word (e.g., *glaze*) was preceded by a vowel-preserving nonword (e.g., GLAME–*glaze*) or by a consonant-preserving nonword (e.g., GLEZE–*glaze*), or by a nonoverlapping control nonword (e.g., PROFT–*glaze*). That is, for each target word three different sets of prime–target pairs were generated. The prime was written in uppercase and the target in lowercase. There were, in addition, two filler subsets identical to those in Experiment 1.

Design

The major constraint of the design was that a given participant never encountered a given pair of words more than once. This was achieved by dividing the 33 participants evenly into three groups, A, B, and C. Each participant in each group saw one third of the targets from the Complex Vowel base set and one third of the targets from the Simple Vowel base set. Specifically, participants in Groups A, B, and C saw, respectively, targets 1–4, targets 5–8, and targets 9–12, in each of the Berent and Perfetti subsets (see their Appendix D).

Consider a participant in Group A, for example. He or she saw (a) four vowel-preserving (e.g., GLAME–*glaze*), four consonant-preserving (e.g., LOCE–*lace*), and four control (e.g., DRIS–*pale*) primes from the Complex Vowel LF Regular subset, (b) four vowel-preserving (e.g., BLANT–*blast*), four consonant-preserving (e.g., WALD–*weld*), and four control (e.g., DEETH–*grass*) primes from the Simple Vowel LF Regular subset, (c) four vowel-preserving (e.g., GLUPH–*glove*), four consonant-preserving (e.g., LOIR–*lure*), and four control (e.g., TLIMT–*prove*) primes from the Complex Vowel LF Exception subset, (d) four vowel-preserving (e.g., BUHR–*bush*), four consonant-preserving (e.g., WELSP–*wasp*), and four control (e.g., BIBTH–*gross*) primes from the Simple Vowel LF Exception subset, (e) four vowel-preserving (e.g., NOLE–*note*), four consonant-preserving (e.g., GOME–*game*), and four control (e.g., JOONG–*while*) primes from the Complex Vowel HF Regular subset, (f) four vowel-preserving (e.g., BICK–*big*), four consonant-preserving (e.g., WIST–*west*), and four control (e.g., MISF–*went*) primes from the Simple Vowel HF Regular subset, (g) four vowel-preserving (e.g., NUCK–*none*), four consonant preserving (e.g., GOOV–*give*), and four control (e.g., NAISK–*would*) primes from the Simple Vowel HF Exception subset, and (h) with four vowel-preserving (e.g., BOTE–*both*), four consonant-preserving (e.g., WAIRD–*word*), and four control (e.g., MOUD–*war*) primes from the Complex Vowel HF Exception subset. In addition each participant in Group A saw 39 Yes-response filler pairs and 117 No-response filler pairs.

In sum, each participant in each group saw a total of 252 stimulus pairs. Other features of the design were the same as those in Experiment 1.

Procedure

The procedure was the same as that of Experiment 2. Debriefing following the experiment revealed that not a single participant saw any uppercase letter.

Results and Discussion

With respect to the ANOVA, it was decided beforehand to exclude the factors of Regularity and Frequency because (a) there would be too few observations per cell in a Group by Prime type by Vowel Complexity by Regularity by Frequency ANOVA and (b) the main issue under investigation did not directly involve target regularity and target frequency. The resulting 3 by 3 by 2 ANOVA on correct target RTs found prime type to be significant by subjects, $F1$ (2, 120) = 4.27, $p < .01$, $F2$ (2, 180) = 2.66, $p < .07$. The mean RTs for the targets under the three prime conditions were 569 ms for vowel-preserving primes, 567 ms for consonant-preserving primes, and 580 ms for the control primes. No other main effects and no interactions achieved significance by either $F1$ or $F2$. The corresponding ANOVA on errors found prime type to be significant by both subjects and items, $F1$ (2, 120) = 3.16, $p < .05$; $F2$ (2, 180) = 3.06, $p < .05$. The mean error rates for the targets under the three prime conditions were 9.5% for vowel-preserving primes, 11.0% for consonant-preserving primes, and 8.0% for the control primes. With respect to the other effects and the interactions, only vowel complexity (Complex = 7.7% vs. Simple = 11.3%) reached significance by at least one of the analyses: $F1$ (2, 60) = 8.57, $p < .01$, $F2$ (2, 90) = 1.86, $p > .05$.

Given the absence of a complexity by prime type interaction, planned comparisons were conducted on the prime types averaged over complexity. Both the 11-ms priming advantage of vowel primes over control primes (e.g., GLAME–*glaze* over PROFT–*glaze*) and the 13-ms priming advantage of consonant primes over control primes (e.g., GLEZE–*glaze* over PROFT–*glaze*) were significant: $F1$ (1, 60) = 4.51, $p < .05$; $F2$ (1, 90) = 4.15, $p < .05$, and $F1$ (1, 60) = 9.23, $p < .01$, $F2$ (1, 90) = 4.52, $p < .05$, respectively. The latter advantage was qualified by a 3.0% error disadvantage of consonant primes relative to control primes, $F1$ (1, 60) = 5.70, $p < .05$, $F2$ (1, 90) = 4.82, $p < .05$. (The 1.5% error difference between vowel-preserving and control primes was not significant.) The 2-ms priming advantage of consonant primes over vowel primes (e.g., GLEZE–*glaze* over GLAME–*glaze*) was not significant, Fs < 1.

In sum, with respect to the main issues, Experiment 7 found that (a) the vowel and the consonant primes produced significant priming relative to the common control primes, (b) vowel primes approximated consonant primes in priming efficacy, and (c) there were no effects due to, or involving, the complexity of the targets' vowel graphemes. The results, therefore, are in contrast to those of Berent and Perfetti's (1995) Experiment 4 but are consistent with the major understanding derived from the present Experiments 1–6: Within the first cycle, vowel graphemes are processed to the same degree as consonant graphemes. Additionally, the present results, when taken in conjunction with the results of Experiments 1–6, imply that the priming equivalency of vowel preserving primes and consonant preserving primes may not vary significantly with differences in the location of the grapheme/phoneme that distinguishes prime from target.

There is one subsidiary issue that needs addressing, namely, the relation between the complexity manipulation of Experiment 7 and the D versus M manipulation of Experiments 1–5. In the present experiment, the D versus M contrast was carried by the contrast between the forms GLAME–*glaze* and BLANT–*blast*. Although the mean RT to GLAME–*glaze* type stimuli was 11 ms larger than the mean RT to BLANT–*blast* type stimuli, paralleling the direction of difference between D and M stimuli in Experiments 1, 2, 4, and 5, the difference was not reliable, Fs < 1. Unlike these prior evaluations of the D versus M contrast, the evaluation of the D versus M contrast in Experiment 7 was by means of prime–target pairs that did not share a common target. Experiment 7's design, therefore, was not the ideal design for evaluating the effect of vowel complexity. Possibly more to the point, however, is the fact that in Experiment 7, the D versus M contrast was conducted with nonhomophonic D stimuli. There are reasons to believe that the significance of certain variables may vary as a function of whether prime and target share phonology completely or partially (see General Discussion).

EXPERIMENT 8

As a further examination of the generality of Experiments 1–6, same-vowel primes and same-consonant primes were compared in Serbo-Croatian. In the phonemically precise orthography of Serbo-Croatian, vowel and unique consonant graphemes are of equal complexity (see Lukatela & Turvey, 1998).

Experiment 8 applied the psychophysical procedure of Experiment 4. In each of six experimental sessions, a participant saw 16 instances of prime–target pairs corresponding to each of three nonhomophonous prime types (vowel-preserving nonword, consonant-preserving nonword, and nonoverlapping control nonword). The expectation was that, for priming within the first cycle, both vowel- and consonant-preserving primes would be superior to the control primes but not different from each other.

Method

Participants

There were two participants. One male and one female student from the University of Belgrade were paid to participate in the experiment.

Materials

A base set of 48 HF words with simple vowels was assembled (see Appendix C). (For these materials, frequency means familiarity determined by judgments on familiarity performed by high school and university students. The corpus of familiarity judgments has been established within the Belgrade laboratory over many years.) Each word was a CVC (consonant–vowel–consonant) monosyllable written in unambiguous Roman letters (Lukatela & Turvey, 1998). A given target word (e.g., *dan* = the day) was preceded by a vowel-preserving nonword (e.g., DAF–*dan*) or by a consonant-preserving nonword (e.g., DON–*dan*), or by a nonoverlapping control nonword (e.g., KOF–*dan*). There were, therefore, three different sets of prime–target stimulus pairs for each target word. Two filler prime–target subsets were also included. The prime was written in uppercase and the target in lowercase.

Design

There were six experimental sessions, one on each of 6 successive days. In each session the participant saw 48 prime–target pairs involving one third of the targets from the base set. For example, in Session 1, the participant saw 16 prime–target stimulus pairs of the kind DAF–*dan,* 16 of the kind KET–*kit,* and 16 of the kind DEF–*jug.* The major constraint of the design was that in a given session the participant never encountered a given pair of words more than once. Other features of the design were the same as those in Experiment 7.

Procedure

The male participant was presented with primes bounded by the number sign (e.g., #DAF#–*dan*); the female participant was presented with unbounded primes (e.g., DAF–*dan*). For both participants, the mask–prime–target sequence was set to 286, 14, and 72 ms or 20, 1, and 5 refreshing cycles of the computer's monitor, respectively.

Results and Discussion

For Participant 1, the RT and error means for the targets under the three prime conditions were 537 ms and 6.9% for vowel-preserving, 530 ms and 4.5% for consonant-preserving, and 559 ms and 10.7% for the control. For Participant 2, the corresponding means were 562 ms and 4.1% for vowel-preserving, 563 ms and 3.1% for consonant-preserving, and 578 ms and 5.5% for the control.

A 3 by 3 (Group by Prime type) ANOVA on Participant 1's RTs revealed an effect of prime type, $F1$ (2, 30) = 8.27, $p < .001$ $F2$ (2, 90) = 16.28, $p < .0001$. Similarly, in the error analysis, $F1$ (2, 30) = 3.92, $p < .05$; $F2$ (2, 90) = 4.19, $p < .05$. Planned comparisons revealed that the 22-ms priming advantage of vowel-preserving primes over control primes (e.g., DAF–*dan* over KOF–*dan*) was significant, $F1$ (1, 15) = 7.7, $p < .01$; $F2$ (1, 45) = 15.53, $P < .001$. Similarly, the 29-ms priming advantage of consonant-preserving primes over control primes (e.g., DON–*dan* over KOF–*dan*) was significant, $F1$ (1, 15) = 13.66, $p < .01$, $F2$ (1, 45) = 30.32, $p < .001$. In contrast, the 7-ms priming advantage of consonant-preserving primes over vowel-preserving primes (e.g., DON–*dan* over DAF–*dan*) was not significant, $F1$ (1, 15) = 1.15, $p > .05$, $F2$ (1, 45) = 2.26, $p > .05$.

A 3 by 3 (Group by Prime type) ANOVA on Participant 2's RTs revealed an effect of prime type, $F1$ (2, 30) = 4.17, $p < .05$; $F2$ (2, 90) = 6.24, $p < .01$. Prime type was not significant in the error analysis. Planned comparisons revealed that the 16-ms priming advantage of vowel-preserving primes over control primes (e.g., DAF–*dan* over KOF–*dan*) was significant, $F1$ (1, 15) = 7.08, $p < .01$; $F2$ (1, 45) = 11.10, $p < .001$. Similarly, the 15-ms priming advantage of consonant-preserving primes over control primes (e.g., DON–*dan* over KOF–*dan*) was significant, $F1$ (1, 15) = 5.89, $p < .05$, $F2$ (1, 45) = 8.07, $p < .01$. In contrast, the 1-ms priming advantage of consonant-preserving primes over vowel-preserving primes (e.g., DON–*dan* over DAF–*dan*) was not significant, F (1, 15) < 1, $F2$ (1, 45) < 1.

For Serbo-Croatian, as for English, the priming resulting from processing within the first cycle was characterized by equal influences of vowels and consonants.

EXPERIMENT 9

A final evaluation of the generalizability of the main finding was conducted in Experiment 9 using English materials similar in structure to those of the Serbo-Croatian materials of Experiment 8. Vowel and consonant graphemic complexity were equated within CVCs, all of which were regular. Further, in these English language materials, as in the Serbo-Croatian, the phoneme manipulation distinguishing prime and target excluded the initial phoneme.

Berent and Perfetti's (1995) Experiment 4 suggested that a consonantal advantage might depend on frequency. In their experiment, the benefit of consonant preserving primes was numerically greater for HF than for LF words (see their footnote 18). As implied above, the five-factor design of Experiment 7 of the present series was ill-suited to a thorough evaluation of this possible frequency influence on first-cycle processing. A strong test was permitted by the design of Experiment 9, which was restricted to the factors of group, frequency (HF versus LF), and prime type.

Participants

Twenty-seven University of Connecticut undergraduates participated in the experiment in partial fulfilment of a course requirement. A participant was randomly assigned to one of three groups (9 participants per group).

Materials

The targets consisted of one set of 48 LF simple vowel regular words and one set of 48 HF simple vowel regular words (see Appendix D). Each word was a CVC monosyllable. A given target word (e.g., *ban, bad*) was preceded by a vowel-preserving nonword (e.g., BAL–*ban*, BAK–*bad*), or by a consonant-preserving nonword (e.g., BON–*ban*, BYD–*bad*), or by a nonoverlapping control nonword (e.g., FOL–*ban*, ROK–*bad*). Therefore, for each target word there were generated three different sets of the prime–target stimulus pairs. The prime was written in uppercase and the target in lowercase. There were, in addition, two filler subsets identical to those in Experiment 1.

Design

The design was similar to that in Experiment 7. A given participant never encountered a given pair of words more than once. This was achieved by dividing the 27 participants evenly into three groups. Each participant in each group saw one third of targets from the LF simple vowel base set and one third of targets from the HF simple vowel base set, with different "thirds" for each group. Thus, each participant saw 16 prime–target stimulus pairs from each of the LF simple vowel set with vowel-preserving (e.g., BAL–*ban*), consonant-preserving (e.g., BON–*ban*), and control (e.g., FOL–*ban*) primes, as well as from the HF simple vowel set with vowel-preserving (e.g., BAK–*bad*), consonant-preserving (e.g., BYD–*bad*), and control (e.g., ROK–*bad*) primes. Other features of the design were the same as those in Experiment 7.

Procedure

The procedure was similar to that in Experiment 7 except that all primes were bounded by the number sign (e.g., #BAL#–*ban*) to equalize the visual salience of masked uppercase letters. To repeat, the mask–prime–target sequence was set to 286, 14, 72 ms or 20, 1, and 5 refreshing cycles of the computer's monitor, respectively.

Results and Discussion

The RT and error means for the targets under the three prime conditions were 572 ms and 8.0% for vowel-preserving primes, 572 ms and 7.7% for consonant-preserving primes, and 580 ms and 8.2% for control primes. A 3 by 3 by 2 (Group by Prime type by Target Frequency) ANOVA was conducted on target latencies. Target Frequency (LF = 584 ms vs. HF = 565 ms) was significant by items, $F2$ (1, 90) = 5.61, $p < .05$, and marginally significant by participants, $F1$ (2, 48) = 3.49 $p < .07$. The two-way interaction between Prime type and Frequency was significant, $F1$ (2, 96) = 7.30, $p < .001$, $F2$ (2, 180) = 7.25, $p < .001$. There were no other significant effects in the latency analysis and none in the corresponding error analysis.

The significant Prime type by Target Frequency interaction rationalized a separate analysis of LF- and HF-target words. The 3 by 3 (Group by Prime Type) ANOVA conducted on LF-target words revealed no significant effects. A similar 3 by 3 ANOVA conducted on HF-target words found a main effect of Prime type, $F1$ (2, 96) = 7.30, $p < .001$, $F2$ (2, 180) = 7.25, $p < .001$. For HF-target words, planned comparisons proved that the 26-ms priming advantage of vowel-preserving primes over control primes (e.g., BAK–*bad* over ROK–*bad*) was significant, $F1$ (1, 24) = 9.46, $p < .01$, $F2$ (1, 45) = 13.46, $p < .001$. Similarly, the 24-ms priming advantage of consonant-preserving primes over control primes (e.g., BYD–*bad* over ROK–*bad*) was also significant, $F1$ (1, 24) = 10.68, $p < .01$, $F2$ (1, 45) = 9.73, $p < .01$. The 2-ms priming advantage of vowel-preserving primes over consonant-preserving primes (e.g., BAK–*bad* over BYD–*bad*) was not significant, $F1 < 1$, $F2 < 1$.

In sum, within the first cycle, vowel- and consonant-preserving primes matched for orthographic complexity were equally effective in respect to HF targets and equally ineffective in respect to LF targets. A reasonable conclusion is that there is no processing distinction between consonant and vowel graphemes, whatever the frequency. The frequency effect deserves a comment. That the priming was limited to HF targets raises the possibility that for very briefly exposed and masked primes the activation they induce is neither particularly strong nor long lived. Consequently, if the processing of the target is slowed, for whatever reason, then the target may fail to benefit from the prior presentation of the prime. This possibility warrants future investigation.

GENERAL DISCUSSION

The nine experiments of the present article used the three-field presentation sequence of mask–prime–target and the lexical decision task to evaluate the two-cycles model of phonology assembly (Berent & Perfetti, 1995). The experiments failed to find evidence for the central claim that only consonant graphemes are processed in the first cycle, defined operationally as a prime duration/SOA of one refresh cycle (14.3 ms).

Focal to Experiments 1–5 was the use of the monosyllabic words of English that begin with C. This set of C-initial words produces the largest number of pseudohomophones that can be constructed by changing the initial letter. The results obtained with these C-initial stimuli were contrary to expectations from the two-cycles model. They revealed that (a) a nonword prime that conveyed information about both the target's vowel and consonants was superior to a nonword prime that conveyed information only about the target's consonants and (b) two nonword primes equated for the number but not type of phonemes they shared with the target (specifically, three consonants versus two consonants and the vowel), primed equally. Experiments 1–5 also examined monosyllabic words that contained dipthongs. The results for these so-called D stimuli were also contrary to the two-cycles model: In the first cycle, nonword primes that contained dipthongs and conveyed information about all of their targets' phonology slowed lexical decision relative to nonword primes that contained monopthongs and conveyed information only about their targets' consonants.

Potential limitations on the inferences from the results of Experiments 1–5 were addressed in Experiments 6–9. Experiment 6 evaluated whether the grapheme C's phonological ambiguity was behind the consonant-preserving CLEP's inability to prime as effectively as the vowel- and consonant-preserving KLIP. Experiments 7–9 evaluated, using different stimulus subsets, whether the failure to demonstrate a consonant advantage was due to the specific class of C-initial stimuli used in Experiments 1–5. In corroboration of Experiments 1–5, the outcomes of each of these additional experiments were contrary to the predictions of the two-cycles hypothesis. Specifically, nonhomophonous consonant-preserving primes (e.g., GLEZE–*glaze,* BYD–*bad*) were not superior to nonhomophonous vowel-preserving primes (e.g., GLAME–*glaze,* BAK–*bad*).

The particular implication of the results of Experiments 1–5, in which homophonous primes were compared with nonhomophonous primes, is that phonology is assembled rapidly for each of a letter string's orthographic subpatterns. Consonant and vowel phonologies are assembled in the same time frame. There is a further implication given in the juxtaposition of the results with the M and D stimuli from Experiments 1–5, although its exact form is unclear. One variant is that the assembly proceeds locally (at the subword level) and globally (at the word level) but that it is the phonology at the global level of assembly that plays the leading role in the visual word recognition process. Another variant is that the local assemblies are highly interdependent (mutually constraining), such that the time scale for full or global assembly is set by the most slowly evolving local assembly. The preceding implications of the present results bear on the two questions posed in the opening paragraph of the introduction.

By What Principles Are Phonological Codes Assembled from Orthographic Information?

Berent and Perfetti (1995) identified two major assumptions in the literature regarding the nature of assembled phonology, namely, linearity and domain independence. The linearity assumption is that the assembled code is a linear string of phonemes that lacks any internal structure. For any given letter string, its phonological representation can be viewed simply as a left-to-right ordered sequence of phonemes. The contrasting assumption is multilinearity—the assembled phonological representation involves multiple levels or planes of representation defined by their phonological properties. By the multilinear assumption, consonants and vowels are assigned to two different planes and are coordinated by a third, intermediate structural level (e.g., Goldsmith, 1990; Kaye, 1989; McCarthy, 1989). Berent and Perfetti translated the spatial structure of the multilinear view into a temporal sequence and a computational difference: They proposed that consonants and vowels are not processed in the same time frame and they are not processed by the same mechanism. Although the present results clearly counter Berent and Perfetti's temporal and computational interpretations, they are neutral in respect to the essential argument from autosegmental theories. The assembled phonology may well consist of levels of structural organization from the perspective of subsequent linguistic processes; it is just that those levels were not evident in the present experimental analysis of the assembling process.

The second assumption about the nature of assembled phonology is linked to the first. This assumption is that the cognitive capacity to derive phonology from print is independent of the cognitive capacities that define a reader's linguistic knowledge. In identifying this assumption, Berent and Perfetti wish to highlight the modern tendency to view the mapping from orthography to print in purely associative terms in contrast to a fairly general tendency to view linguistic knowledge in terms that refer abstractly to the forms and functions of constituent structures. Hence, a conception of the assembly process can be developed that ignores the conclusions of linguistic theory in respect to the contrasting status of vowels and consonants.

Although the present data do not reinforce the claim that assembly entails the hypothesized vowel–consonant distinction in the manner suggested by Berent and Perfetti, they do dovetail with contemporary investigations of articulatory or gestural phonology (e.g., Bowman & Goldstein, 1995; Saltzman, 1995). The standard assumption is that phonology consists of computational rules performed on symbol strings, where the symbols refer to phonological constituents typically defined by binary features. The assumption defining gestural phonology is that the phonological constituents—units of articulatory action called *gestures*—are dynamical systems expressed by equations of motion, governed by attractors, and related through coupling functions. Utterances, in this view, are organized sequences of dynamical systems. With respect to the present data, the relevant aspects of gestural phonology are the intuitions that (a) other things being equal, more complicated gestures, those defined by a combination of attractors, may take longer to equilibrate and (b) other things being equal, the time scale of equilibration of a gestural constellation will reflect the gesture that equilibrates most slowly. If the phonology that is engaged implicitly by written words reflects the dynamics of gestural phonology, then one might expect to find, at appropriate time scales of visual processing, the kinds of results we obtained for the D stimuli of the present experiments. NAIM as a prime for *name* will take longer to equilibrate than NALM as a prime for *name.* Consequently, within the first cycle, the vowel phonology will be less fully resolved for NAIM than NALM and if vowel and consonant phonology are resolved mutually, then NAIM's ability to prime will be compromised relative to NALM's ability to prime.

How Immediate Is the Expression of Phonological Codes?

The superior priming by homophonous nonwords at the prime duration of 14 ms (relative to visually similar nonhomophonous nonwords) suggests that, even at the shortest time scales, the activation of the word knowledge required for lexical decision is initially and primarily through a word's phonology. The present results, therefore, support a strong phonological theory of visual word recognition (Frost, 1998). Correspondingly, the present results provide little support for an orthographic contribution to the activation of word knowledge over and above a phonological contribution.

Evidence for an independent orthographic contribution has been sought by Ferrand and Grainger (1992, 1994) and Grainger and Ferrand (1996). Using mask–prime–target sequences, with the prime in lowercase and the target in uppercase, they have asked questions of the kind: Is the orthographically similar pseudohomophone MERT a better prime than the orthographically dissimilar pseudohomophone MAIR for the French word *mére?* The answer has been that, at very short prime durations (about 30 ms), MERT primes and MAIR does not, with successful priming by MAIR becoming evident only at longer prime durations. As noted above, this latter pattern of results has been interpreted as evidence for an independent evolution over time of two codes for lexical access with the orthographic access code available, and the phonological access code unavailable, at the shortest time scales.

Not only do the present results counter the argument that phonological codes are not immediately available, but they also counter the independence argument. Specifically, they suggest that the priming ability of a nonword's orthography may depend on the degree to which it conveys the target's phonology. In support of this latter suggestion is Lukatela et al.'s (1998a) observation that, at a prime duration of 43 ms, PLIP was a better prime for *clip* than CLEP but a worse prime than KLIP. Further support is provided by rapid naming experiments using the mask–prime–task target presentation sequence with 60 ms prime exposure (Lukatela & Turvey, 1994b). Whereas *toad* was named faster following TOWED than following PLASM (matched to TOWED in length and frequency), the naming of *toad* following TOLD was no faster than the naming of *toad* following GAVE (matched to TOLD in length and frequency). Relatedly, the advantage of TODS–*toad* over LARM–*toad* was less than the advantage of TODE–*toad* over LAIM–*toad.*

Collectively, these experimental findings in English suggest that the observed superior priming in French of orthographically similar pseudohomophones (MERT versus MAIR as primes for *mére*) is possibly better interpreted as indicating a contribution of the number of shared letters when (and, perhaps, only when) the phonology of prime and target are identical. In this light, it is noteworthy that Grainger and Ferrand (1996, Experiment 3) found no effect of number of shared letters when the phonological overlap was partial rather than full (e.g., %ERT and %AIR rather than MERT and MAIR). As argued by Lukatela et al. (1998a), one implication of the surveyed experiments is that a more complete understanding of orthographic contributions beyond phonological contributions will require research that examines conditions of partial phonological overlap. Another implication is that conclusions about the evolution of phonological codes over time depend on the conditions of stimulus presentation. In the research reported here with computer displays, we used a spatially adjacent rather than overlapping forward mask and we used a low level of ambient light and a low level of incident light. Under these latter conditions we found evidence of phonological codes at a time scale well below that identified by prior research. Clearly, there is still a great deal to be learned about masking methodologies and masking phenomena. There are also many issues to be resolved concerning the logic of infering processing time scales from data obtained in masking experiments and from masked priming experiments in particular.

Concluding Remarks

Although our results are inconsistent with the two-cycles model of phonology assembly, they are consistent with general features of assembly assumed in a number of models such as parallel activation of many levels of orthographic–phonological correspondence (e.g., Norris, 1994; Shallice, Warrington, & McCarthy, 1983) and the representation of words as distributed pattern of activation across phonological subpatterns of several different grain sizes (e.g., Plaut et al., 1996; Seidenberg & McClelland, 1989). Our results give strong support to those models that assume a leading rather than ancillary role for phonological codes and that view the time to achieve phonological coherence as setting the lower limit on visual word recognition times as measured, for example, by naming and lexical decision latencies (e.g., Lukatela, Carello, Savić, Urošević, & Turvey, 1998b; Van Orden & Goldinger, 1994; Van Orden et al., 1990). In more general terms, the time to resolve a unique phonological code for a letter string defines the fundamental time scale of the visual word processing system.

APPENDIX A

The M Stimulus Materials

Each row identifies, in order, the homophonic prime, the orthographic and consonantal–phonemic control prime, the different–initial–letter and different–initial–phoneme prime, and the corresponding target. In all appendixes, the stimuli are reported in the order of presentation.

1. KLIP, CLEP, PLIP, CLIP
2. KORD, CYRD, PORD, CORD
3. KREAM, CROAM, FREAM, CREAM
4. KRISP, CRASP, TRISP, CRISP
5. KLERK, CLORK, PLERK, CLERK
6. KLOCK, CLECK, SLOCK, CLOCK
7. KREEK, CROEK, PREEK, CREEK
8. KATCH, COTCH, RATCH, CATCH
9. KARD, CIRD, PARD, CARD
10. KRUST, CROST, DRUST, CRUST
11. KLUE, CLOE, PLUE, CLUE

12. KLING, CLONG, PLING, CLING
13. KLAM, CLOM, FLAM, CLAM
14. KANS, CYNS, ZANS, CANS
15. KASH, COSH, YASH, CASH
16. KLASS, CLOSS, BLASS, CLASS
17. KLAP, CLOP, BLAP, CLAP
18. KROSS, CRUSS, TROSS, CROSS
19. KRUSH, CRESH, DRUSH, CRUSH
20. KUBS, CIBS, BUBS, CUBS
21. KLAN, CLIN, SLAN, CLAN
22. KARS, CORS, YARS, CARS
23. KRAFT, CRIFT, PRAFT, CRAFT
24. KRAM, CRIM, WRAM, CRAM
25. KLOT, CLAT, FLOT, CLOT
26. KRAMP, CROMP, BRAMP, CRAMP
27. KRAB, CROB, FRAB, CRAB
28. KART, CORT, YART, CART
29. KRACK, CRYCK, DRACK, CRACK
30. KLUMP, CLIMP, FLUMP, CLUMP
31. KRASH, CRISH, PRASH, CRASH
32. KLIFF, CLOFF, SLIFF, CLIFF
33. KORK, CARK, NORK, CORK
34. KULT, CALT, YULT, CULT
35. KREED, CROED, TREED, CREED
36. KROP, CREP, WROP, CROP
37. KLICK, CLECK, PLICK, CLICK
38. KAMP, CUMP, ZAMP, CAMP
39. KORN, CURN, NORN, CORN
40. KLOG, CLEG, PLOG, CLOG
41. KATS, CYTS, YATS, CATS
42. KLUB, CLEB, FLUB, CLUB
43. KRAP, CRIP, DRAP, CRAP
44. KUTS, CITS, VUTS, CUTS
45. KUPS, CIPS, NUPS, CUPS
46. KRIB, CROB, FRIB, CRIB
47. KAST, CUST, YAST, CAST
48. KREST, CROST, FREST, CREST

APPENDIX B

The D Stimulus Materials

Each row identifies, in order, the homophonic prime, the orthographic and consonantal-phonemic control prime, and the corresponding target.

1. NAIM, NALM, NAME
2. ROAP, ROSP, ROPE
3. BAIK, BAWK, BAKE
4. RANE, RANS, RAIN
5. WATE, WATH, WAIT
6. TOAN, TOON, TONE
7. JOAK, JONK, JOKE
8. FALE, FALS, FAIL
9. OTES, OTRS, OATS
10. FAIT, FANT, FATE
11. RORE, RORT, ROAR
12. FAIK, FASK, FAKE
13. BLAID, BLARD, BLADE
14. STOAV, STOOV, STOVE
15. SAIF, SARF, SAFE
16. FRAIM, FRALM, FRAME
17. HOAM, HORM, HOME
18. LAIT, LANT, LATE
19. BOAN, BOON, BONE
20. POAL, PORL, POLE
21. RAIK, RWAK, RAKE
22. FOME, FOMP, FOAM
23. GOTE, GOTS, GOAT
24. RALE, RALD, RAIL
25. FAIM, FALM, FAME
26. MOAD, MOND, MODE
27. GANE, GAND, GAIN
28. DAIT, DAST, DATE
29. VOAT, VONT, VOTE
30. SAIM, SARM, SAME
31. TRANE, TRANT, TRAIN
32. TAIK, TARK, TAKE
33. GAIM, GALM, GAME
34. BOTE, BOTS, BOAT
35. SOKE, SOKL, SOAK
36. HAIT, HANT, HATE
37. ROAL, ROTL, ROLE
38. GOLE, GOLK, GOAL
39. STOAN, STORN, STONE
40. TRAID, TRALD, TRADE
41. LAIK, LASK, LAKE
42. HOAL, HORL, HOLE
43. TAIP, TASP, TAPE
44. GRAID, GRALD, GRADE
45. RAIT, RAST, RATE
46. HOAP, HOSP, HOPE
47. SOPE, SOPT, SOAP
48. MAIT, MANT, MATE

APPENDIX C

The Serbo-Croatian Stimulus Materials in Experiment 8

Each row identifies, in order, the vowel-preserving prime, the consonant-preserving prime, the control prime, and the corresponding target.

1. DAF, DON, KOF, DAN
2. NOG, NUJ, MUG, NOJ
3. KIG, KET, SEG, KIT
4. LEN, LOD, RON, LED
5. NIR, NEZ, DER, NIZ
6. RAG, RID, NIG, RAD
7. RON, RUG, DUN, ROG
8. SIG, SON, TOG, SIN
9. TOL, TIN, RIL, TON
10. VOF, VUZ, TUF, VOZ
11. ZIG, ZED, JEG, ZID
12. DUF, DAG, ZAF, DUG
13. GAN, GIS, RIN, GAS
14. JUF, JEG, DEF, JUG

15. LAM, LUV, GUM, LAV
16. MEL, MID, RIL, MED
17. ZON, ZAV, TAN, ZOV
18. VIL, VAD, RAL, VID
19. DIT, DEV, FAS, DIV
20. SUL, SID, MIL, SUD
21. SIF, SOR, GOF, SIR
22. RON, REV, DEN, ROV
23. NOD, NES, VED, NOS
24. LUF, LOK, NOF, LUK
25. KUL, KEM, TEL, KUM
26. DIZ, DEM, MEZ, DIM
27. LOD, LUJ, FUD, LOJ
28. JOS, JUD, LUS, JOD
29. LEF, LOK, TOF, LEK
30. LIT, LAM, NAT, LIM
31. MAZ, MUJ, FUZ, MAJ
32. RAL, REK, DEL, RAK
33. REG, RUD, ZUG, RED
34. LON, LAZ, RAN, LOZ
35. ROF, RUK, NUF, ROK
36. LOR, LUV, NUR, LOV
37. MAD, MOK, SOD, MAK
38. ROS, REJ, VES, ROJ
39. SAR, SOT, JOR, SAT
40. RIN, ROS, ZON, RIS
41. VUD, VOK, NOD, VUK
42. ZEM, ZAT, GAM, ZET
43. TEZ, TAG, RAZ, TEG
44. SOG, SIM, VIG, SOM
45. VER, VAZ, MAR, VEZ
46. RAZ, ROT, GOZ, RAT
47. LOD, LUM, ZUD, LOM
48. RAV, REM, VEV, RAM

APPENDIX D

The Stimulus Materials in Experiment 9

Each row identifies, in order, the vowel-preserving prime, the consonant-preserving prime, the control prime, and the corresponding target. LF targets are 1–48, whereas HF targets are 49–96.

1. BAL, BON, FOL, BAN
2. DAS, DED, MES, DAD
3. FIL, FEX, SEB, FIX
4. GAK, GOP, YOK, GAP
5. HAK, HOM, DOK, HAM
6. JAN, JOM, ZON, JAM
7. KIG, KED, TEG, KID
8. LAF, LOD, MOF, LAD
9. LOS, LIG, NIS, LOG
10. MUT, MED, KET, MUD
11. NED, NYT, KAD, NET
12. PAF, PON, SOF, PAN
13. DER, DYN, GAR, DEN
14. RAD, ROM, ZOD, RAM
15. RUP, REB, HEP, RUB
16. SIM, SEN, PEM, SIN
17. BAP, BOT, ROF, BAT
18. DIT, DAG, JAT, DIG
19. FOS, FUX, MUN, FOX
20. HIB, HAP, SAB, HIP
21. JAS, JOR, MOS, JAR
22. KIK, KAT, NAR, KIT
23. LAT, LEP, GEZ, LAP
24. LIB, LUD, TUF, LID
25. MUV, MEM, DEV, MUM
26. PAG, PYT, FYG, PAT
27. PIK, POG, VOZ, PIG
28. RAK, RIT, JIL, RAT
29. PUF, PAB, VAG, PUB
30. RIN, REM, NEF, RIM
31. TAK, TYP, KEM, TAP
32. TUD, TYB, ZES, TUB
33. FAM, FYN, WAS, FAN
34. HUP, HET, MEV, HUT
35. YEP, JAT, RON, JET
36. LIN, LEP, VEN, LIP
37. LIK, LAT, WAK, LIT
38. MOX, ZOL, MIX
39. PEM, PYN, ZYB, PEN
40. POL, PYP, DAL, POP
41. PIM, PON, SOM, PIN
42. ROK, RYD, SYL, ROD
43. RUV, REG, FEV, RUG
44. BEV, BYG, FYV, BEG
45. WIL, WEG, REL, WIG
46. TIK, TEP, YEK, TIP
47. WIK, WOT, ROZ, WIT
48. POB, PYT, NYK, POT
49. BAK, BYD, ROK, BAD
50. DOK, DEG, MED, DOG
51. HIN, HOL, WOL, HIM
52. GAV, GOS, TOV, GAS
53. HAF, HYT, TEF, HAT
54. JOP, JAB, KAP, JOB
55. BEL, BYT, MYL, BET
56. MAS, MOD, LOS, MAD
57. REN, RUD, SAN, RED
58. SAN, SID, KON, SAD
59. TAZ, TOX, MOZ, TAX
60. VAM, VON, DOM, VAN
61. PUD, PYT, MUD, PUT
62. YEP, YOT, VOP, YET
63. BAZ, BYG, LYK, BAG
64. FAF, FOT, GOS, FAT
65. FIP, FET, VEP, FIT
66. GEP, GYT, VAP, GET
67. HIL, HET, ZEL, HIT
68. LEF, LIG, KIF, LEG
69. MAZ, MON, YOF, MAN
70. RUK, RYN, VEK, RUN
71. BOF, BAB, SAF, BOB
72. TEM, TYN, LYP, TEN
73. WEP, WYT, KAR, WET

74. BAF, BOR, VOF, BAR
75. FUM, FON, YEM, FUN
76. GOZ, GID, HIZ, GOD
77. HOF, HYT, MYF, HOT
78. LEM, LOD, BOM, LED
79. MEP, MOT, KOS, MET
80. SEP, SUT, TOR, SET
81. BEK, BOD, LOK, BED
82. GUB, GAN, VAB, GUN
83. LOD, LAT, ZAD, LOT
84. SEZ, SYX, TYV, SEX
85. SIZ, SUX, TUZ, SIX
86. BUZ, BES, KEZ, BUS
87. LEP, LYT, YAP, LET
88. MAK, MYP, RYF, MAP
89. SUT, SEN, VET, SUN
90. TOF, TUP, KUT, TOP
91. WIF, WEN, TEZ, WIN
92. BIL, BOT, ROL, BIT
93. BOZ, BAX, SAL, BOX
94. SID, SUT, HUD, SIT
95. SOM, SYN, HYP, SON
96. FET, FOD, KOT, FED

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