

OBSERVATIONS

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Phonology: Comment on Sebastián-Gallés (1991)**

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# Lexical Involvement in Naming Does Not Contravene Prelexical Phonology: Comment on Sebastián-Gallés (1991)

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N. Sebastián-Gallés (1991) showed lexical involvement in naming Spanish. Her results were purported to be a failure to substantiate claims for prelexical phonology that characterize Serbo-Croatian. Summaries of several experimental demonstrations of lexical involvement in naming Serbo-Croatian are used to show that such results are only interpretable consistently in a model that assumes prelexical phonology. The lexicon is accessed through assembled phonology, but assembled and lexical phonology interact in resolving a unique pronunciation when several pronunciations are assembled and in assigning stress, which is not assembled. The authors argue that lexical access need not be different in different orthographies but that the weights on connections between orthographic and phonological substructures established through covariant learning will distinguish orthographies in the rate and degree of phonological involvement in word recognition.

Sebastián-Gallés (1991) reported three experiments that show lexical involvement in the naming task using the Spanish language. Cast in the framework of how orthographic depth (cf. Liberman, Liberman, Mattingly, & Shankweiler, 1980) relates to lexical access, her results were purported to be a failure to substantiate claims for the sort of prelexical phonology that we find using the Serbo-Croatian language (e.g., Carello, Lukatela, & Turvey, 1988; Feldman & Turvey, 1983; Frost, Katz, & Bentin, 1987). Both Spanish and Serbo-Croatian are shallow orthographies; in contrast with English, for example, the relation between graphemes and phonemes is straightforward, regular, and reliable (or, in the framework outlined by Van Orden, Pennington, & Stone, 1990, the relation between orthography and phonology is more closely *single valued*). We have argued that the evidence from the shallow Serbo-Croatian orthography demands a phonological route to the lexicon; prelexical phonology is not merely an option that can be circumvented (Carello et al., 1988; Feldman, Lukatela, & Turvey, 1985; Turvey, Feldman, & Lukatela, 1984). Sebastián-Gallés, in contrast, claims that "no predictions of the prelexical hypothesis have been met" (p. 476) in her experiments with the shallow Spanish orthography. She concludes that even in shallow orthographies, the phonological access of lexicon occurs only if the visual

route is slowed: "I see no reason to think that the orthographic way has to work differently according to different orthographies" (p. 476).

We find her conclusions to be unwarranted. The predictions she tested do not follow from the model of prelexical phonology that we have described. Moreover, the data she reported parallel rather than conflict with data we reported with Serbo-Croatian. Finally, we have shown repeatedly that there is no evidence for an "orthographic way" in Serbo-Croatian; the lexicon must be accessed phonologically. Our commentary, therefore, is directed at clarifying our model of prelexical phonology with respect to the data and arguments of Sebastián-Gallés (1991): What should be expected from a model of prelexical phonology, what has been found with the shallow Serbo-Croatian orthography, and what kinds of differences in processing should be expected because of orthographic depth?

One central issue is how lexical influences on naming can occur if the name is assembled on the basis of prelexical phonology. As Sebastián-Gallés (1991) pointed out, we argued that the phonologically assembled name is automatically confirmed by activity in the lexicon (Carello et al., 1988). The automatic involvement of the lexicon is critical, given the bi-alphabetic nature of Serbo-Croatian. A single spoken language is transcribed in two partially overlapping alphabets, Roman and Cyrillic.<sup>1</sup> In the uppercase form, 11 of

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<sup>1</sup> Those who are unfamiliar with the Serbo-Croatian writing system should see Feldman and Turvey (1983) for a description of features that are relevant to the following discussion. One point should be emphasized: The fact that Serbo-Croatian is transcribed in two alphabets does not undercut the claim that it is phonologically shallow in going from script to sound. It is simply shallow in two orthographies—the letter-phoneme connections in each alphabet are few and strong. In going from sound to script, of course, all words will have two legal transcriptions. What might be considered an asymmetry in orthographic depth for reading in contrast with writing was also noted for Spanish by Sebastián-Gallés

the characters are shared by the two alphabets; 4 of them are pronounced differently depending on whether they are read as Roman or Cyrillic (e.g., *B* can be read as /bə/ or /və/, respectively). Two alphabets entail two sets of letters, with each set a single-valued map onto the same set of phonemes. For letter strings that contain phonologically ambiguous letters, therefore, more than one name must be assembled. BABA, for example, would give rise to four names: /baba/, /vava/, /bava/, and /vaba/. Only one phonological code can be realized, however, so processing continues for each name thus assembled. This subsequent processing, which involves the lexicon, allows a single pronunciation to emerge (Carello et al., 1988; Lukatela, Feldman, Turvey, Carello, & Katz, 1989; Lukatela, Turvey, Feldman, Carello, & Katz, 1989). In the case of BABA, activation of the lexical entry "baba" ("grandmother"), brought about by the phonological code /baba/, enhances the activation of /baba/. This operation is characteristic of the ordinary language processor; the involvement of the lexicon ensues, therefore, even when only one name is assembled (as for phonologically unique letter strings). It should be noted that bi-alphabetism is not the only rationale for lexical involvement in this shallow orthography; type and location of stress (rising or falling, short or long, first or other syllable) are not represented in the orthography and must be accessed from the lexical representation (Lukatela, Feldman, Turvey, Carello, & Katz, 1989). Thus, pronunciation assembled on the basis of prelexical phonology should reflect lexical influences.

The framework of a parallel distributed network allows the fullest articulation of this model, the most compact summary of the data on which it is based, and the richest source of predictions (Lukatela, Feldman, Turvey, Carello, & Katz, 1989; Lukatela, Turvey, Feldman, Carello, & Katz, 1989; for simulations of and predictions from the model, see Lukatela, Carello, & Turvey, 1990; Lukatela, Turvey, & Todorović, 1991). We assume successive, connected levels of letter, phoneme, and word units where connections within a level can be excitatory or inhibitory but connections between levels are excitatory only. Our investigations of Serbo-Croatian thus far suggest that this network has the following properties: (a) The letter units for the two alphabets are functionally distinct and mutually inhibitory; (b) the letter unit to phoneme unit connections, which reflect the covariation between orthography and phonology, are such that phoneme units are not duplicated (*B* and *V* are both connected to /və/); and (c) the activation of phoneme units by letter units starts a two-way interactive process between the phoneme unit level and the word unit level (the lexical involvement described earlier). Note that the phoneme units are the major activators of word units—lexical access is phonological.<sup>2</sup>

This model is grounded in a large body of data. In the following section, we summarize those data that have illustrated the automatic involvement of the lexicon in a shallow orthography (paralleling the observations of Sebastián-Gallés, 1991). This is followed by discussions of two types

of experimental manipulations that not only support prelexical phonology but directly challenge the possibility of an orthographic access code for this shallow orthography. Finally, against the backdrop of this model and these data, we describe the ways in which orthographic depth might be expected to influence visual word processing and its experimental investigation.

### Lexical Involvement in Naming in Serbo-Croatian

Sebastián-Gallés (1991) examined lexical involvement in naming Spanish because her understanding of prelexical phonology was that "lexical effects . . . ought to be expected in languages with a deep orthography but not necessarily in languages with a shallow orthography" (p. 471). She claimed that such effects are common in English, a deep orthography, but have not been found in Serbo-Croatian, a shallow orthography. Finding lexical influences on naming in the shallow Spanish orthography, therefore, was taken as evidence against prelexical phonology. Four kinds of experimental results were cited: (a) The pattern of pronunciation errors in naming pseudowords depended on how the pseudowords differed from their source words, (b) latencies to name words were correlated with their frequency of usage, (c) naming was facilitated by a semantically related prime, and (d) latencies to name words were correlated with their lexical decision times. All of these facts are consistent with a large body of experimental results in Serbo-Croatian, however, and comport with the foregoing account of prelexical phonology.

With respect to (a), the relevant Serbo-Croatian experiments on pseudoword naming exploited the shared letters of the two alphabets. Letter strings composed exclusively of these shared letters are phonologically ambiguous. They can be read as a word in one alphabet and a different word or a pseudoword in the other alphabet ("phonologically ambiguous words"), they can be read as a pseudoword in each alphabet as well as in a mix of the alphabets ("phonologically ambiguous pseudowords"), or they can be read as pseudowords in each alphabet but words if the alphabets are mixed ("virtual-word pseudowords"). Phonologically ambiguous

<sup>2</sup> To date, there are no data from the experimental study of Serbo-Croatian to support the notion that familiar spelling patterns are processed differently. Evidence for phonologically based access holds equally for both highly familiar and rare words (e.g., Feldman & Turvey, 1983; Lukatela & Turvey, 1987). The observation in English of a Frequency  $\times$  Regularity effect (a processing difference between exception words and regular words holds only when they are unfamiliar) has been interpreted as evidence of a strictly visually based access for familiar spelling patterns (e.g., Seidenberg, 1985). An important contrary interpretation, however, is that the interaction follows from asymptotic covariant learning in a matrix connecting orthographic and phonological subsymbols—the connection matrixes of high-frequency words are updated at a rate that compensates for the noise arising from inconsistent mappings (e.g., Van Orden et al., 1990). In short, there may well be no unequivocal evidence for a lexicon of familiar spelling patterns in English.

(1991), with the exception that only one written interpretation would be legal. In either direction, however, both of these languages are shallow compared with English.

pseudowords, which had a minimum of four possible pronunciations, were pronounced according to the alphabet of the source word from which they were derived 40%–60% of the time even when they were primed by a phonologically unique word written in the other alphabet (Lukatela, Feldman, Turvey, Carello, & Katz, 1989, Experiments 4 and 5). Virtual-word pseudowords were given a mixed (i.e., word) reading almost 40% of the time in a nonassociative context and 60% of the time in an associative context (Lukatela, Turvey, Feldman, Carello, & Katz, 1989, Experiment 5), compared with no more than 14% mixed readings when the mixing merely yielded another pseudoword (Lukatela, Feldman, Turvey, Carello, & Katz, 1989, Experiment 4). Although the Serbo-Croatian experiments differ in their details from Experiment 1 of Sebastián-Gallés (1991), they are similar in demonstrating a lexical influence on pseudoword pronunciation.

With respect to (b), Sebastián-Gallés (1991) found a significant correlation between naming latency and word frequency for Spanish words ( $r = -.298$ ) and noted that Frost et al. (1987) reported no frequency effects in naming in Serbo-Croatian. This latter observation is not entirely true. In a comparison of Hebrew, English, and Serbo-Croatian they reported that “high-frequency words were named faster than low-frequency words” and that “the interaction between frequency and language was not significant” (p. 107). What did interact with language was the pseudoword–word difference. In any event, a clear frequency<sup>3</sup> effect on naming in Serbo-Croatian has been obtained in a priming task (Lukatela & Turvey, 1990b, Experiment 7). Moreover, the case for frequency effects on naming in English is not unequivocal (Paap, Newsome, McDonald, & Schvaneveldt, 1982; Richardson, 1976; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Taraban & McClelland, 1987). Their dependence on a variety of stimulus attributes in both deep and shallow orthographies suggests that what is at issue is more subtle than simply lexical involvement (Lukatela & Turvey, 1993).

With respect to (c), Sebastián-Gallés (1991) highlighted two failures to find semantic priming of naming in Serbo-Croatian: Katz and Feldman (1983) and Frost et al. (1987). In fact, those investigators were quite circumspect about both what should be expected from a shallow orthography and the implications of their findings (e.g., Frost et al. suggested that “lexical processes in naming printed words should be more conspicuous in English than in Serbo-Croatian” [p. 105] and concluded that “in Serbo-Croatian, as in other languages, lexical involvement in naming can be manipulated” [p. 110]). They did not deny the possibility of lexical involvement of naming in a shallow orthography. Also, Sebastián-Gallés noted our conjecture, following Lupker (1984), that these failures may have been due to our colleagues’ use of semantic rather than associative priming (Carello et al., 1988). However, Carello et al. also presented results from two experiments that found associative priming of naming in Serbo-Croatian: 13 ms relative to asterisk contexts (Experiment 1) and 26 ms relative to unrelated word contexts (Experiment 3). These compare favorably with the 17-ms semantic priming effect found by Sebastián-Gallés relative to unrelated word contexts (Sebastián-Gallés, 1991, Experiment 3). In-

deed, fairly robust associative priming of naming in Serbo-Croatian is found routinely: 25–40 ms for phonologically unambiguous targets (Lukatela, Feldman, Turvey, Carello, & Katz, 1989, Experiment 6; Lukatela, Turvey, Feldman, Carello, & Katz, 1989, Experiment 5), phonologically ambiguous targets (Lukatela, Feldman, Turvey, Carello, & Katz, 1989, Experiment 6), and virtual-word targets (Lukatela, Turvey, Feldman, Carello, & Katz, 1989, Experiment 5). As Carello et al. observed, “lexical involvement in naming does not contravene prelexical phonology” (p. 193).

Finally, with respect to (d), Sebastián-Gallés (1991) argued that, because a relationship between naming latency and lexical decision time indicates similarity of processing for those tasks, no such relationship would be predicted for shallow orthographies. Nonetheless, she showed that in Spanish, task latencies are correlated ( $r = .455$ ). However, we have compared lexical decision and naming under a wide variety of conditions—with phonologically ambiguous and unambiguous targets; graphemically, phonemically, associatively, grammatically, and pragmatically related and unrelated contexts; masked and unmasked targets and contexts; forward and backward masking; high- and low-frequency contexts and targets; word and pseudoword contexts and targets; and auditorally and visually presented contexts and targets. Whether or not lexical decision and naming latencies correlate depends on what is being manipulated and where in the processing its influence should arise (e.g., both lexical decision and naming are affected by associative contexts but only lexical decision is affected by grammatical contexts, Carello et al., 1988). The fact that those tasks sometimes correlate and sometimes do not is the rationale for using both tasks (Carello et al., 1988; Forster, 1979; Seidenberg, Waters, Sanders, & Langer, 1984; Stanovich & West, 1983).

On the basis of her belief that lexical involvement in the shallow Spanish orthography was inconsistent with prelexical phonology, Sebastián-Gallés (1991) suggested that a visual route to the lexicon ought to be characteristic of all orthographies. Our research with Serbo-Croatian, however, continually fails to support such an assertion. Two types of manipulations are especially germane. Both were conducted with lexical decision and naming.

### Associative Priming With Virtual-Word Pseudowords

As noted earlier, the bi-alphabetism of Serbo-Croatian allows the construction of letter strings that are phonologically ambiguous because they are composed exclusively of shared letters. Some of these letter strings are nonwords when they are read strictly as Roman letter strings and when they are read strictly as Cyrillic letter strings. A subset of them, how-

<sup>3</sup> We use experiential familiarity (Gernsbacher, 1984) rather than frequency norms, which are unavailable for Serbo-Croatian. These are subjective ratings of word familiarity provided by people from the same population as the subjects in a given experiment. Subjective ratings have been found to be highly correlated with objective frequency (Gordon, 1985) and may be preferred because of their currency (Gernsbacher, 1984).

ever, despite their actual status as nonwords, would be pronounced as words if read as a mixture of the two alphabets—that is, if some ambiguous letters in the string were read as Cyrillic while other ambiguous letters in the string were read as Roman. Consider the nonword HAPEB with three phonologically ambiguous letters *H*, *P*, and *B*, and two letters, *A* and *E*, that receive the same interpretation in both alphabets. If the letter–phoneme correspondences of both alphabets are applied to HAPEB, then one of the resulting eight phonological descriptions corresponds to a word, namely, /napev/, meaning *tune*. It comes about by assigning the phoneme /n/ to *H* by the Cyrillic alphabet, the phoneme /p/ to *P* by the Roman alphabet, and the phoneme /v/ to *B* by the Cyrillic alphabet. A nonlexical letter string that can be read as a lexical item by mixing alphabet interpretations, such as HAPEB, can be designated a virtual word. Experiments using virtual words were conducted against the backdrop of (a) the phonological ambiguity effect—phonologically ambiguous letter strings take longer to name and evaluate lexically than phonologically unambiguous letter strings—and (b) alphabetic priming—the phonological ambiguity effect is reduced by a context that specifies its alphabet as Roman or Cyrillic. The design of the lexical decision and naming experiments was the same. The target was either a virtual word such as HAPEB or its phonologically unambiguous control word NAPEV.<sup>4</sup> The target was preceded by a phonologically unambiguous context (half were Roman, half were Cyrillic) that was either associatively related or unrelated to the target (see Lukatela, Turvey, Feldman, Carello, & Katz, 1989, for details about filler words and pseudowords, and so on).

In the lexical decision task, an associatively related context speeded up acceptance of control words but slowed down rejections of virtual words. The number of errors on virtual words was quite high: 59.5% were accepted as words in related contexts, 42.1% were accepted in unrelated contexts (compared with 7% for ordinary associatively primed, phonologically ambiguous pseudowords that give rise to a comparable number of phonological codes, e.g., Lukatela, Feldman, Turvey, Carello, & Katz, 1989, Experiment 1). In the naming task an associatively related context speeded up responses to both control words and virtual words. The mixed alphabet reading that yielded the word pronunciation /napev/ occurred 60.5% with related contexts, 39.6% with unrelated contexts (compared with no more than 14% and 11% mixed readings for standard pseudowords, e.g., Lukatela, Feldman, Turvey, Carello, & Katz, 1989, Experiments 4 and 5).

The large error rate in lexical decision, the number of word readings in naming, and the existence of associative priming in both tasks suggest that virtual-word pseudowords activate lexical entries in the following way. As noted, the letter unit–phoneme unit connections of Serbo-Croatian would activate eight access codes for the phonologically ambiguous letter string HAPEB: /hareb/, /nareb/, /hapeb/, /napeb/, /harev/, /narev/, /hapev/, and /napev/. The last of these would activate the word unit “napev” (meaning *tune*) with which it shares all five phonemes. This activation at the word unit level is fed back to the phoneme unit level, enhancing the activation of /n/, /p/, and /v/ in their respective positions which, on the one hand, increases the tendency to pronounce HAPEB as

/napev/ and, on the other hand, further enhances the dominance of the word unit “napev” leading to difficulty in rejecting it as a word. Preceding HAPEB with the associate MELODIJA (*melody*) lowers the threshold of the word unit, facilitating its activation by the phoneme units which, in turn, receive more feedback (relative to an unrelated context). Thus, activity at the word unit level speeds lexical decision, and activity at the phoneme unit level hastens naming.

Note that in both lexical decision and naming, the extent of lexical access is only possible if there is a prelexical phonological code. Pseudowords that are created by changing one letter in a word share  $n - 1$  letters and  $n - 1$  phonemes with a lexical item; pseudowords that are virtual words share  $n - 1$  letters and  $n$  phonemes with a lexical item. Graphemically, the two kinds of pseudowords are equally similar to a lexical item. The large difference in lexical decision errors and mixed names must arise because of the phonemic similarity. Let us now turn to a direct comparison of phonemic and graphemic similarity.

#### Phonemic Priming With High- and Low-Frequency Targets

A number of experiments have addressed the issue of whether the visual processing of a target is influenced by its phonemic similarity to a context. In English, the challenge has been to disentangle phonemic similarity from graphemic similarity. This challenge is easily met by the bialphabetic nature of Serbo-Croatian—graphemic dissimilarity is brought about by writing the context and target in different alphabets. For example, whereas the Cyrillic–Cyrillic context–target pair ЛИДЕР–ЛИКЕР /lider–liker/ is phonemically and graphemically similar, the Roman–Cyrillic LIDER–ЛИКЕР /lider–liker/ is the same word–word pair rendered phonemically similar but graphemically dissimilar. The same target can also be preceded by the Cyrillic БУКАЧ or the Roman БУКАĆ (both /bukatch/), that are phonemically and graphemically dissimilar to it. (All of the contexts and targets described in this section are phonologically unique—they have only one pronunciation.) In both lexical decision and naming, phonemic similarity mattered, graphemic similarity did not, and they did not interact (Lukatela & Turvey, 1990b, Experiments 1 and 5). The effect of phonemic similarity was not uniform in the two tasks, however. It speeded naming, regardless of target familiarity or lexicality, and speeded lexical decision to pseudowords and less familiar words. However, phonemic similarity slowed lexical decision to highly familiar words (Lukatela & Turvey, 1990b, Experiments 4 and 7).

The existence of phonemic similarity effects suggest that when a letter string appears, it activates the appropriate letter units which, in turn, activate the appropriate phoneme units

<sup>4</sup> See Lukatela, Turvey, Feldman, Carello, and Katz (1989) for details of how the appearance of a single phonologically unique letter (such as the Roman *N* and *V*) inhibits the other-alphabet interpretation of phonologically ambiguous letters (such as *P*).

which, in turn, activate (in proportion to the amount of overlap) all word units that contain those phonemes. The activation sets off inhibition at the word unit level (cf. Grainger & Segui, 1990), with the amount of inhibition felt by any given unit proportional to its frequency (see, e.g., Grossberg's [1982] principle of self-modulation). A phonemically similar, low-frequency target that appears against this background of activity will encounter primed phoneme units and not much inhibition at the word unit level. Lexical decision, which is viewed as a signal-detection evaluation of the activity level of word units, should be speeded relative to a target that must be processed through a phoneme unit level that has not been primed. Similarly for pseudowords, the appropriate phoneme units are primed, and there is no word unit level inhibition. However, the specific word units for high-frequency targets will have been inhibited by a phonemically similar context, resulting in a slowing of lexical decision. Naming, in contrast, is based on the states of the phoneme units, some of which are boosted, to greater or lesser degree, by the downward activation from the word level (Lukatela et al., 1990). Inhibition of a particular word unit, against the backdrop of summed activation at the word level, is effectively lost in the downward activation to the phoneme level; it does not diminish the activation already at that level. Consequently, naming high-frequency words, low-frequency words, and pseudowords should all be facilitated by a phonemically similar context.

The idea that inhibition at the word unit level is in proportion to a word's frequency and has less effect on naming than lexical decision is supported by a manipulation of context lexicality. Both phonemically similar pseudoword-word pairs and phonemically similar word-word pairs show facilitation of naming. However, whereas the former showed facilitation for lexical decision as well, the latter showed inhibition (Lukatela et al., 1990). Once again, the direction of the effect on naming does not change because inhibition at the word level does not diminish the activation states of the relevant units on which naming is based (the phoneme units); it simply boosts them less. In contrast, the direction of the effect on lexical decision reverses because inhibition brought about by a word context diminishes the activation state of the relevant unit on which lexical decision is based—the word unit. (As an aside, these last experiments obliterated the possibility of graphemic similarity not only by writing contexts and targets in different alphabets but also in different cases: Contexts were lowercase, targets were uppercase. Thus, the similarity of the word-word pair *pasus*–*ПАСУЈБ* /*pasus*–*pasulj*/ is defined strictly at the phoneme level.)

The model of data obtained with Serbo-Croatian clarifies what is to be expected from prelexical phonology: a level of phoneme units below a level of word units with naming dependent on the states of phoneme units and lexical decision dependent on the states of word units. Prelexical phonology is responsible for accessing the lexicon. The interaction between the phoneme unit level and the word unit level is responsible for lexical influences on naming. However, lexical effects that depend on inhibition of a specific word unit will not affect naming because the activation that is fed back to the phoneme unit level is the summed effect of all phono-

logically similar word units, with the contribution of the particular primed target embedded in that summed influence.

In summary, the lexicon is accessed phonologically by speakers and readers of Serbo-Croatian. One concern from Sebastián-Gallés (1991) remains. How does orthographic depth influence visual-word processing?

### Orthographic Depth and Lexical Access

Sebastián-Gallés (1991) championed the sort of dual-process theory that originated with Coltheart (1978). Briefly, a direct visual code is independent of and faster than a derived phonemic code (Seidenberg, 1985; Seidenberg & McClelland, 1989). In a shallow orthography, Sebastián-Gallés argued, "very regular grapheme-to-phoneme translation routines" (p. 476) might be sufficiently fast that phonological access of the lexicon could appear in select circumstances:

although only in the case of words that are difficult to locate in the orthographic lexicon, for example, in very low frequency words or in densely populated neighborhoods in which the lexical retrieval process may take so long as to lag behind the prelexical processing. (p. 476)

The data described in the preceding section belie the canard that prelexical phonology only appears when processing is slowed (see also Van Orden et al., 1990, for a pointed critique of what they term the delayed phonology hypothesis). The thoroughness of the graphemic controls in the phonemic priming experiments bear repeating. The word-word pair *ПАСУС*–*ПАСУЈБ* is identical to the word-word pair *pasus*–*ПАСУЈБ* in meaning, associative relatedness, number of letters, and so on. The target is facilitated in both contexts and to the same extent even though one adds graphemic similarity to phonemic similarity. Only phonemic relatedness matters.

Collectively, the evidence obtained on Serbo-Croatian from many different paradigms can be coherently interpreted in terms of prelexical phonology; it resists coherent interpretation in terms of direct (visual) access (e.g., Lukatela & Turvey, 1990b; Lukatela, Turvey, Feldman, Carello, & Katz, 1989). To the extent that evidence from other languages is less straightforward with respect to the role of assembled phonology, can one nonetheless maintain a single theory of language processing? How are we to understand the contribution of orthographic depth? The connectionist model outlined in the preceding section is such a theory. Rather than dispensing with the phoneme unit level for English as is often done (e.g., McClelland & Rumelhart, 1981), we have argued that the distinctiveness of its contribution can vary across languages (Lukatela et al., 1990). Consistent with the orthographic depth hypothesis, this difference derives from the relative consistency of orthographic substructure-phonological substructure correspondences, which are represented in the strength and number of connections established through covariant learning (Lewicki, 1986; Van Orden, 1987; Van Orden et al., 1990). Let us elaborate. In most languages, if not all, an invariant mapping is most closely approximated between orthographic structure and phonological structure—between word spellings and word

names. Less consistent are the mappings of orthography to word meanings and to the syntactic functions of words. In contemporary dynamical terms, a consequence of approximating single valuedness is that resonance or self-consistency is achieved rapidly within the connective matrix that binds (the processing units) of the mapped-between structures (Grossberg & Stone, 1986; Van Orden et al., 1990). To the degree that a mapping deviates from single valuedness, the time course of achieving resonance will be slower, or the final-state stability will be less, or both. Thus, although many activations of linguistic substructures by orthographic substructures may occur concurrently in word recognition, it is the phonological activation that stabilizes earliest, providing a basis for stabilizing the other patterns of linguistic activation (Van Orden et al., 1990). On this latter understanding, orthographic depth would translate as the rate at which the essential phonological codes stabilize and the extent of their stabilizing influence on other linguistic codes.

It should be emphasized that, in addition to providing linguistic conditions likely to lead to considerable phonemic involvement, the Serbo-Croatian writing system provides a particularly salubrious setting for demonstrating prelexical phonology (see discussions by Lukatela et al., 1990; Lukatela & Turvey, 1990a). As intimated earlier, we suspect that prelexical phonology is characteristic of all languages, but we also suspect that languages are not alike in the opportunities that they provide experimentally for revealing prelexical phonology. Recent evidence from a variety of novel tasks strongly indicates that lexical access in English is also phonological, with some arguing that it is, perhaps, primarily so (Lukatela & Turvey, 1991, 1993; Van Orden, 1987; Van Orden, Johnston, & Hale, 1988; Van Orden et al., 1990). Naming target words following a context that is a pseudohomophone of an associate of the target is faster than if the context is merely graphemically similar to an associate of the target (Lukatela & Turvey, 1991, Experiments 3 and 4). That is, associative priming occurs for TAYBLE-CHAIR but not for TARBLE-CHAIR. Identification of target words whose processing is interrupted by backward masking with pseudowords (that are themselves degraded by a subsequent pattern mask to preclude strategic guessing about target-mask relationships) is more successful if the masking pseudowords are phonologically related to the targets (Naish, 1980; Perfetti & Bell, 1991; Perfetti, Bell, & Delaney, 1988). The implication is that prelexical phonological processing of the target that is insufficiently complete for purposes of lexical access, can be boosted by a subsequent stimulus with shared phonological dimensions. (This homophonous masking result, strongly indicative of automatic prelexical phonology, has been replicated in Serbo-Croatian; Lukatela & Turvey, 1990a). Semantic categorization of target words is more likely to be in error if the target is a homophone of a category member than if it is a spelling control (Van Orden et al., 1988). That is, "rows" is categorized as a flower more often than "robs" is.

We suspect that data from cross-language comparisons will reflect both the experimental setting and orthographic depth. Complete methodological parallels between Serbo-Croatian and English are not always possible. Homophones,

for example, do not exist in Serbo-Croatian; mixed alphabets do not exist in English. However, to the extent that systematic parallels can be achieved, residual differences may be taken to indicate influences of covariant learning. These influences ought to be manifest under certain conditions but not under others—in particular, conditions that rely most directly on the connective matrix and associated weights linking orthographic and phonological substructures. Because naming depends primarily on the states of phoneme units, whereas lexical decision depends crucially on the states of word units, cross-language differences may be more apparent in naming. However, given that (a) the word unit level is activated by the phoneme unit level and (b) word unit level activation is fed back to the phoneme unit level, determining the locus of a particular effect requires careful disentangling. The upshot is that the influence of orthographic depth on the processing of written language cannot be assessed on the basis of limited data sets with single manipulations. Rather, the complexity of the issues demands systematic experiments informed by simulations that embody hypothesized differences in the connections between orthographic and phonological substructures.

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