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Visual and Associative Factors in Processing Serbo-Croatian Words

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A recent report of an association × stimulus quality interaction in Spanish was construed as support for the use of the lexical route in word recognition in a shallow orthography (Bajo, Burton, Burton, & Cañas, 1994). Because the interaction occurred against the backdrop of latencies in excess of 1 sec (and was not replicated in Bajo and co-workers' second experiment), the results must be considered equivocal. A naming experiment in Serbo-Croatian, a similarly shallow orthography which has not shown the interaction heretofore, focused on stimulus onset asynchrony (SOA) of prime and target. The interaction was absent at an SOA of 600 msec, replicating our previous results, but was reliable at an SOA of 40 msec. A second experiment in Serbo-Croatian followed Bajo and co-workers' experiments in that the task was lexical decision and the SOA was 800 msec. The experiment's primary feature was the use of phonologically ambiguous targets to enhance clean-up processes potentially responsible for the interaction. No interaction was observed in either the latency or error measures. The results are discussed in relation to dual-route theory and the phonological coherence hypothesis, and in relation to possible differences among the English, Spanish and Serbo-Croatian orthographies.

INTRODUCTION

It has long been assumed that important insights into underlying mechanisms of visual word recognition can be provided by research directed at how the visual quality of a word and the priming of an associate

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combine to affect naming (Meyer, Schvaneveldt, & Ruddy, 1975). In significant degree, experiments on the relation between stimulus quality and associative priming have been conducted against the backdrop of the additive factor methodology (Sternberg, 1969) in conjunction with the hypothesis that word recognition proceeds in stages. If visually degrading a word and priming an associate of the word affect different stages, then degradation and priming should contribute additively to the speed with which a word is named. In contrast, if the two manipulations affect the same stage, then their contribution to naming should be interactive.

A number of experiments with English materials have shown that visually degraded words show larger lexical context effects (related *vs* unrelated) than do visually intact words. This is true for both lexical decision and naming (Becker & Killion, 1977; Borowsky & Besner, 1991; Carello, Lukatela, Peter, & Turvey, 1995; Massaro, Jones, Lipscomb, & Scholz, 1978; Meyer et al., 1975); semantic (Massaro et al., 1978; Sanford, Garrod, & Boyle, 1977) and associative priming (Becker & Killion, 1977; Meyer et al., 1975); degradation accomplished with a superposed regular dot pattern (Meyer et al., 1975), checkerboard pattern (Sanford et al., 1977), 180° rotation of the target (Massaro et al., 1978), or reduced target intensity (Becker & Killion, 1977); and spoken (Massaro et al., 1978) or silently read contexts (Becker & Killion, 1977; Meyer et al., 1975). Behind the original interpretation of this interaction were the assumptions that a word's name and identity reside in its lexical entry, degradation retards the activation of a word's lexical entry by its sublexical components, and a preceding associate brings the lexical entry closer to threshold (Meyer et al., 1975). Using a horse race analogy, a slow horse (degraded) and a fast horse (non-degraded) will finish closer together the closer the finishing line is (the lower the threshold) (Neely, 1991).

Recently, the stimulus quality × associative priming interaction was examined as a potential indicator of differences in word processing as a function of orthography (e.g. Bajo, Burton, Burton, & Cañas, 1994). The idea that the interaction might be used in this way derives from Lukatela and Turvey's (1987) failure to obtain the interaction with Serbo-Croatian materials. Given the reliability of the interaction in experiments with English, Lukatela and Turvey suggested that the absence of the interaction in Serbo-Croatian might be due to the greater simplicity of its orthographic–phonological mapping. If the Serbo-Croatian lexicon is accessed primarily by phonological codes—on the so-called non-lexical route of classical dual-process theory (Coltheart, 1978)—then the effects of degradation may be limited to the pre-lexical computation stage, resulting in an additive relation between quality and association rather than an interaction. Only when the so-called lexical route (the direct visual route) is prominent in the reading of a language will the interac-

tion be observed. Applying this logic, Bajo et al. (1994) compared Spanish and English readers using the lexical decision task. Their experimental design included unrelated words as one baseline for measuring the effects of degradation and priming (by associatively related words) and asterisks as an additional baseline. The significance of the two baselines was that Lukatela and Turvey (1987) had used only an asterisks baseline and it has been conjectured that this usage could have been the source of their difficulty in obtaining a stimulus quality × associative priming interaction. In studies with English, use of an asterisk baseline leads to additivity, in contrast to use of an unrelated word baseline which leads to overadditivity (Borowsky & Besner, 1991). In their Experiment 1, Bajo et al. (1994) found that type of baseline made a difference to their English readers but not to their Spanish readers. For the readers of the deeper orthography (English), the stimulus quality × associative priming interaction was limited to the baseline of unrelated words. For the readers of the shallower (Spanish) orthography, the stimulus quality × associative priming interaction occurred equally with unrelated words and asterisks. In their second experiment, involving only Spanish subjects, Bajo et al. (1994) failed to find the interaction for either baseline in the latency data ($F < 1$ in both the subjects and items analyses). A statistically reliable interaction did show up, however, in the error data, although the differences were very small [–0.5% (related minus control) for intact and 0.5% for degraded] and in different directions for the two baselines [–1.0% (intact) *vs* 1.0% (degraded) for the unrelated baseline and 0.5% (intact) *vs* –0.5% (degraded) for the asterisks baseline]. The conclusion drawn by Bajo et al. was that word recognition in Spanish is primarily via the lexical route, suggesting, therefore, that processing in shallow orthographies is of the same kind as processing in deep orthographies.

Issues of interpretation aside, recent experiments with Serbo-Croatian have produced the opposite outcome, extending Lukatela and Turvey's original observation of no interaction with an asterisk baseline in a lexical decision task into the experimental setting of an unrelated word baseline and a naming task. In two experiments, the latency difference between naming following an associated prime and naming following a non-associated prime was not magnified by degrading the target (Carello et al., 1995). The main effects on naming latency of associative priming and stimulus degradation were reliable, but their relation was additive not interactive. There were no reliable effects in the analysis of naming errors. In the same study, Carello et al. included an experiment with native readers of English. The experiment used the same computerised stimuli presentation and the same stimulus parameters as Carello and coworkers' Serbo-Croatian experiments. The outcome was in agreement

with the standard finding for English; namely, a reliable stimulus quality × associative priming interaction.

Clearly, in view of the ambiguity in Bajo and co-workers' experiments and the clear negative outcome in Carello and co-workers' experiments, the question of a stimulus quality × associative priming interaction in shallow orthographies remains open. In the present paper, we continue the investigations of Carello et al. (1995) regarding the interaction between stimulus quality and associative priming in the naming of Serbo-Croatian words.

EXPERIMENT 1

One unexplored possibility for the previous failed attempts to demonstrate the interaction is that the stimulus onset asynchrony (SOA) in the Serbo-Croatian experiments was outside the time scale needed to demonstrate the interaction. In Carello and co-workers' (1995) experiments, the SOA was 600 msec. A reasonable assumption is that the temporal lag of target onset relative to prime onset is an important determinant of priming and its interactions (Carello et al., 1995; Lukatela, Lukatela, Carello, & Turvey, 1993). Experiments that have manipulated the SOA and the strength of the prime–target association have found that the priming effects on naming are apparent by 150 msec (the briefest SOA evaluated), increase to an asymptotic level that depends on the association strength, and do so at a rate that is independent of association strength (Lorch, 1982). Other experiments have shown that the onset of associative priming occurs well before 150 msec, with pronounced effects present at an SOA $\leqslant$ 50 msec (Lukatela & Turvey, 1994a), and that the build up of activation due to the prime is a continuous process (Yantis & Meyer, 1988). In the present experiment, we compared the effects of stimulus quality and associative priming at an SOA of 600 msec with their effects at an SOA of 40 msec. Although no interaction should occur at the longer SOA, given prior results, it may well occur at the (very much) shorter SOA.

The experiment addressed an additional issue involving stimulus quality; namely, do stimulus quality and frequency effects interact or are they additive? Important predictions follow from the hypotheses, advanced by Besner and Smith (1992), that (1) stimulus quality affects the orthographic input lexicon, the one accessed directly by the visual or lexical route, and (2) frequency is coded within the orthographic lexicon's connections to the semantic memory and the phonological output lexicon. Given these hypotheses, frequency should add to degradation's influence on word naming in contrast to association, which should interact with

degradation. The non-additivity of association and stimulus quality follows from the two-way interaction between the orthographic lexicon and semantic memory such that to prime semantic memory is to prime the site of stimulus quality effects—the orthographic lexicon (Besner & Smith, 1992). The upshot is that, for word naming, there ought to be different dependencies of stimulus quality on frequency and context. This prediction has been verified for English (Borowsky & Besner, 1991; Carello et al., 1995) but has not been verified for Serbo-Croatian (Carello et al., 1995).

Methods

Subjects. Fifty-four high-school seniors from the Fifth Belgrade Gymnasium were paid for their participation in the experiment. They were assigned at random to one of the two SOA groups—S (short) and L (long)—according to their appearance at the laboratory.

Materials. Associated pairs were generated by the population from which the subjects were drawn. A column of 196 isolated test words was printed on response sheets that were distributed among 34 students in a class. For each word, the students were requested to write down the first five words that came to mind (that is, to identify the given word's associates). They were urged to respond quickly and to make no corrections. From the completed response sheets, a list of 160 related prime–target pairs was created, with the prime the highest occurring (strongest) associate for the target, and with all but three words conforming to the standard stress pattern (emphasis on the first syllable) (see Carello et al., 1995). The target words from these related pairs were printed on other response sheets that were presented to another class of 28 different students for familiarity evaluation, on a scale from 1 to 5. The evaluated test words were arranged in descending order of familiarity. From the completed response sheets, a basic list of 40 high-familiarity and 40 low-familiarity associatively related prime word–target word pairs were selected. An appropriate re-pairing of those primes and targets yielded 40 high-familiarity and 40 low-familiarity non-related prime word–target word pairs. [All targets were words that contained no phonologically ambiguous letters; that is, those letters common to the Cyrillic and Roman alphabets which refer to different phonemes. Furthermore, all target words were of the consonant–vowel–consonant–vowel type or of the vowel–consonant–vowel–consonant type and most of them (80%) were 4–5 letters in length and bi-syllabic. The remainder were mono- or trisyllabic]. Thus, subjects in the present experiment encountered 50%

associatively related stimulus pairs, as compared to the 25% encountered by subjects in the study by Bajo et al. (1994).

Procedure. Each subject was seated in front of an Apple IIe computer in a dimly lit room. A fixation point was centred on the screen. On each trial, the subject heard a brief warning signal after which the prime appeared above the fixation point for 40 msec (Group S) or 500 msec (Group L). After an inter-stimulus interval (ISI) of 0 msec (Group S) or 100 msec (Group L), the target appeared below the fixation point for 1400 msec. A target duration of 500 msec and an ISI of 100 msec were used so as to duplicate the conditions of Carello et al. (1995), who failed to produce a reliable stimulus quality × associative priming interaction. The target was degraded on half the trials by a random arrangement of 72 dots, a degradation procedure that in previous experiments produced a degradation effect of less than 100 msec (Carello et al., 1995). The subjects were instructed to name the target as rapidly as possible. They were told that silently reading the upper word (the prime) might make them more accurate in reading aloud the lower word (the target). To ensure that the subjects were reading the primes, a computer message occasionally (approximately 5% of the trials) requested that they report the prime orally after the target word was named. Naming latencies were measured from the onset of the target. If the response latency was longer than 1400 msec, a message appeared on the screen requesting that the subject respond more quickly. The inter-trial interval was 2500 msec. The experimental sequence was preceded by a practice sequence of 40 different stimulus pairs. The whole session lasted about 20 min.

Design. Stimulus onset asynchrony was a between-subjects variable; prime, stimulus quality and familiarity were within-subject variables. A given subject never encountered a given prime–target pair more than once. Among the word targets, there were eight (2 × 2 × 2) stimulus types (prime × stimulus quality × target familiarity) and every subject was presented with 10 word pairs from each of the eight types. The experimental sequence was divided into four sublists, with a brief rest after each sublist. Stimulus types were ordered pseudorandomly within each sublist.

Results and Discussion

Minimum and maximum acceptable latencies were set at ± 2 standard deviations. The context × stimulus quality means are shown in Table 1. A 2 (prime) × 2 (stimulus quality) × 2 (familiarity) × 2 (SOA) analysis of variance with subjects (F_1) and items (F_2) as random factors was

TABLE 1
Mean (± SD) Naming Latencies (L, msec) and Error Rates (ER, %) as a Function of Stimulus Onset Asynchrony (SOA, msec) for the Data of Experiment 1

		Context			
		Associated		*Unrelated*	
SOA	*Stimulus Quality*	*L*	*ER*	*L*	*ER*
600	Intact	508 ± 62	1.8 ± 4.2	516 ± 67	3.4 ± 6.4
	Degraded	535 ± 69	3.6 ± 6.4	547 ± 71	3.9 ± 6.0
40	Intact	617 ± 60	2.5 ± 5.4	616 ± 65	0.9 ± 2.9
	Degraded	666 ± 70	4.6 ± 6.3	697 ± 59	4.6 ± 7.4

performed on the naming latencies. Three main effects were significant: prime [$F_1(1,54) = 38.45$, $P < 0.001$, $F_2(1,78) = 19.53$, $P < 0.001$] with primed targets being named faster (581 msec) than non-primed targets (594 msec); stimulus quality [$F_1(1,54) = 179.12$, $P < 0.001$, $F_2(1,78) = 152.44$, $P < 0.001$], with degraded targets taking longer to name (611 msec) than intact targets (564 msec); and SOA [$F_1(1,54) = 57.94$, $P < 0.001$, $F_2(1,78) = 927.24$, $P < 0.001$], with naming slower at the shorter SOA (649 *vs* 527 msec). Familiarity did not reach significance (Fs < 1; high familiarity = 587 msec, low familiarity = 588 msec). The prime × stimulus quality interaction was significant [$F_1(1,54) = 15.81$, $P < 0.001$, $F_2(1,78) = 12.57$, $P < 0.001$], as was stimulus quality × SOA [$F_1(1,54) = 26.55$, $P < 0.001$, $F_2(1,78) = 22.55$, $P < 0.001$] and prime × stimulus quality × SOA [$F_1(1,54) = 9.81$, $P < 0.003$, $F_2(1,78) = 5.23$, $P < 0.02$]. The error analysis showed only an effect of stimulus quality [$F_1(1,54) = 13.87$, $P < 0.001$, $F_2(1,78) = 10.94$, $P < 0.001$], with more errors on degraded targets (4.2%) than on intact targets (2.1%).

Given that prime × stimulus quality interacted with SOA in the latency analysis, separate analyses were conducted for each SOA. For the 600 msec SOA, only the main effects of prime [$F_1(1,27) = 25.29$, $P < 0.001$, $F_2(1,78) = 8.70$, $P < 0.001$] and stimulus quality [$F_1(1,27) = 52.25$, $P < 0.001$, $F_2(1,78) = 79.92$, $P < 0.001$] were significant. Prime × stimulus quality was not significant (Fs < 1). For an SOA of 40 msec, the two main effects and their interaction were significant [prime: $F_1(1,27) = 17.88$, $P < 0.001$, $F_2(1,78) = 11.32$, $P < 0.001$; stimulus quality: $F_1(1,27) = 127.10$, $P < 0.001$, $F_2(1,78) = 84.02$, $P < 0.001$; prime × stimulus quality: $F_1(1,27) = 17.60$, $P < 0.001$, $F_2(1,78) = 10.14$, $P < 0.002$].

In summary, a reliable stimulus quality × associative priming interaction was found at an SOA of 40 msec but not at an SOA of 600 msec.

The absence of the interaction at the 600 msec SOA replicates two previous experiments on naming Serbo-Croatian words using the same SOA, the same type of baseline and the same degree of degradation (Carello et al., 1995). The presence of the interaction at an SOA of 40 msec is a new finding and provides corroborating evidence from Serbo-Croatian of Bajo and co-workers' (1994) observation that the interaction is not limited to deep orthographies, contrary to the conjecture by Lukatela and Turvey (1987). Furthermore, the present experiment corroborates the results of Bajo et al. (1994) and Carello et al. (1995) in demonstrating that the interaction is not dependent on baseline (cf. Borowsky & Besner, 1991). In the present experiment, the baseline was provided by non-associated words at both SOAs but the interaction was found only at the shorter SOA.

An important theory addressing the stimulus quality × association interaction is that of Besner and Smith (1992). This theory addresses both of the interactions between stimulus quality and the lexicon—the stimulus quality × association interaction and the stimulus quality × frequency interaction—and it does so, as noted in the Introduction, via contrasting predictions. These predictions have been confirmed previously in English (Borowsky & Besner, 1991; Carello et al., 1995). It is possible that the present experiment, with Serbo-Croatian materials, has provided additional confirmatory evidence: At an SOA of 40 msec, quality and frequency were additive, whereas quality and association were non-additive. The cautionary attitude is mandated by the failure to obtain a main effect of frequency (defined by the familiarity measures provided by an equivalent group of subjects).

As noted, the motivation for Bajo and co-workers' (1994) study was the conjecture by Lukatela and Turvey (1987) that the interaction observed frequently in English between associative priming and stimulus quality is less probable in shallower orthographies because of the hypothesised greater dependency in such orthographies on assembled phonology. Degradation affects the time required to assemble a word's phonology from its orthography, but once the phonological code is assembled, activation of lexical entries and articulatory routines proceeds unhindered. A number of recent developments mandate that this conjecture, derived from the logic of classical dual-route theory (Coltheart, 1978), be substantially modified. Foremost is the growing understanding that, regardless of the writing system, phonological codes rather than orthographic codes play the leading role in visual word recognition. For example, there is now considerable evidence that phonology is an early source of constraint on the visual recognition of English words (e.g. Lukatela & Turvey, 1994a, 1994b; Perfetti & Bell, 1991; Perfetti, Bell, & Delaney, 1988; Peter & Turvey, 1994; Van Orden, 1987; Van Orden,

Johnston, & Hale, 1988), and that it may well be the primary constraint (Lukatela & Turvey, 1991, 1993, 1994a, 1994b; see reviews by Carello, Turvey, & Lukatela, 1992; Van Orden & Goldinger, 1994; Van Orden, Pennington, & Stone, 1990).[1]

The understanding that phonological codes play the leading role in visual word recognition is expressed through the *phonological coherence hypothesis*. The various processes that eventuate in a pronunciation of a letter string, or in a decision about its lexical status, or a judgement about its semantic category, rely on the initial achievement of a coherent phonological code (Van Orden & Goldinger, 1994; Van Orden et al., 1990). The flows of activation between lower orthographic substructures and higher phonological substructures equilibrate (reach resonance, attain coherence) sooner than the orthographic–semantic and phonological–semantic flows of activation and provide the foundation for these higher-level equilibrations. That phonological–semantic resonance should precede orthographic–semantic resonance is argued for on grounds of covariant learning and self-consistency by Van Orden and colleagues (Stone & Van Orden, 1994; Van Orden & Goldinger, 1994; Van Orden et al., 1990). A type of spelling check/clean-up process can be readily identified with this slowest resonance. Essentially, once sufficient resolution has been achieved in the semantic space through phonological–semantic resonance, then orthographic–semantic resonance can evolve with the consequence of further resolution at the semantic level and global coherence of the entire network (Smolensky, 1986; Stone & Van Orden, 1994; Van Orden & Goldinger, 1994; Van Orden et al., 1990). Orthographic–semantic resonance acts to filter competing phonologically activated semantic states, reinforcing that semantic state which comports with the word's orthographic structure.

Within the framework of the phonological coherence hypothesis, the stimulus quality × association interaction is a phenomenon connected with orthographic–semantic resonance. When the quality of activation at the orthographic level is poor, augmented activation at the semantic level provides significant compensation. This interpretation of the site of the interaction is similar to the original interpretation offered by Meyer et al. (1975). The important difference, however, is with respect to the status of the orthographic–semantic connections: they function to clean up processes generated over the connections involving the phonological level. Presumably, the more important this clean-up is to the linguistic task

[1]The same conclusions might be drawn for other orthographies whose phonetic precision is less than that of Serbo-Croatian but more than that of English (see, for example, Ferrand & Grainger, 1992; Ziegler & Jacobs, 1995).

(naming, lexical decision) in any given orthography, then the more pronounced and the more temporally extensive the interaction between visual and semantic factors should be. On the basis of some such reason as the preceding, it might be expected that the association × stimulus quality interaction would occur more generally in English than in Spanish and Serbo-Croatian. English would be more dependent on clean-up processes than these other languages because of the greater bottom-up and top-down inconsistencies (Stone, Van Hoy, & Van Orden, in press) of its writing system.

In summary, Experiment 1 corroborates and adds to the research of Bajo et al. (1994) in demonstrating an association × stimulus quality interaction in a shallow orthography, with a nonword baseline, and under degradation conditions that preserved the normal range of response latencies. At the same time, the results of Experiment 1 underline the possibility, first suggested by Lukatela and Turvey (1987), that the interaction may be orthography-dependent.

EXPERIMENT 2

Experiment 2 addressed the conjecture above that the interaction of visual and associative factors should be more pronounced and temporally extensive the more essential is the clean-up process by orthographic–semantic connections, regardless of the orthography. The experiment used Serbo-Croatian targets that are phonologically ambiguous (bottom-up inconsistent) and a lexical decision task with an SOA of 800 msec. The task and the SOA were the same as used by Bajo et al. (1994).

Although each of the two alphabets of Serbo-Croatian (i.e. Roman and Cyrillic) is phonetically precise, the common usage of both orthographies (as is the case in Belgrade) can lead to a special form of ambiguity. The two alphabets share 11 upper-case letters, seven of which are common (i.e. they receive the same phonetic interpretation in the two alphabets) and four of which are ambiguous (i.e. they have one phonetic interpretation in Cyrillic and a different phonetic interpretation in Roman). Words that happen to be composed of at least one ambiguous letter with no alphabetically unique letters (i.e. the remainder are common or ambiguous or a combination) are phonologically ambiguous. For example, BETAP by its Cyrillic reading (/vetar/) means "the wind", but by its Roman reading (/betap/) it is not a word. VETAR is necessarily Roman (V and R are unique to that alphabet) and, therefore, phonologically unambiguous (/vetar/). Phonologically ambiguous letter strings that are words in Roman but nonwords in Cyrillic also exist, as do those that are words in both alphabets. A number of experiments have demonstrated

that both lexical decision and naming are slowed for phonologically ambiguous letter strings relative to their phonologically unique counterparts (where the counterpart is, in fact, the same word and, therefore, controlled for meaning, frequency, etc.; see summaries by Lukatela & Turvey, 1990, 1991). In addition, phonological ambiguity has been found to exaggerate the associative priming effect (Lukatela et al., 1989).

In Experiment 2, the use of target stimuli that are phonologically ambiguous produced a special contrast with Experiment 1. Because of the bottom-up inconsistency of the targets, the time taken to achieve a single coherent phonological code will be prolonged. Arriving at a code befitting a lexical representation will require clean-up processes. Accordingly, there should be a greater dependency on orthographic–semantic resonance and, by the arguments advanced above, greater likelihood of an enhanced associative priming by degradation. The other major contrast with Experiment 1 was the use of the lexical decision task. Although the interaction of stimulus quality and association has been shown reliably in English in both naming and lexical decision tasks (as summarised in the Introduction), it is nonetheless reasonable to assume that the effect may be more easily found in a task that relies more heavily on the activation of lexical forms. Lukatela and Turvey (1987) had used lexical decision but with an asterisk baseline. The present experiment provided the necessary extension of this earlier work in that the baseline was provided by non-associated words.

Methods

Subjects. Fifty-six high-school juniors from the Fifth Belgrade Gymnasium were paid for their participation in the experiment. They were assigned at random to one of four counterbalancing groups according to their appearance at the laboratory.

Materials. A basic set of 28 phonologically ambiguous Cyrillic (PAC) and 28 phonologically ambiguous Roman (PAR) words was selected (the same set as used by Lukatela et al., 1993, experiment 2). These are defined as letter strings that contain one or more ambiguous letters and no unique letters. A PAC is a word by its Cyrillic reading and a nonword by its Roman reading. A PAR is a word by its Roman reading and a nonword by its Cyrillic reading. All words were of the CVCV or VCVC type. As such, all letter strings were orthographically and phonotactically legal by both readings and easily pronounceable in both readings. Most (80%) were 4–5 letters in length and bisyllabic. The remainder were mono- or trisyllabic.

The list of 56 words was presented to 53 students (25 university undergraduates and 28 high-school seniors). For each word in the list, the students were asked to write the first five words that came to mind. The 168 (first-, second- and third-order) associates thus produced were presented to another group of 32 subjects from the same population who again were asked to write the first five words that came to mind. Response sheets from both tasks were inspected for symmetrical associates regardless of rank differences (e.g. first-order and third-order, third-order and second-order, etc.) and these were used as associatively related primes. For 7 of the original 56 target words, no reliable associates were produced. In those cases, related contexts were chosen to be semantically related.

A corresponding set of 56 phonologically ambiguous pseudowords was created by changing one consonant in each of the phonologically ambiguous words. Ambiguous letters were substituted for ambiguous letters and common letters were substituted for common letters. All letter strings were orthographically and phonotactically legal.

Thirty-two phonologically unique word and 32 phonologically unique pseudoword targets were added as fillers. These fillers were not included in the subsequent analyses.

Procedure and Design. The procedure and design were the same as for the long SOA condition of Experiment 1 with the exceptions that the prime duration was extended to 700 msec and the subjects had to perform a lexical decision on the target in a prime–target sequence rather than simply name the target. All variables were within-subject.

Results and Discussion

The mean reaction times for each condition are shown in Fig. 1. Because of the selection restrictions on the stimuli—the phonologically ambiguous set was nearly exhaustive—an items analysis was inappropriate. All analyses treated only subjects as a random effect. In a 2 (association) × 2 (stimulus quality) ANOVA on acceptance latencies, the two main effects were significant: association [$F(1,55) = 155.92$, $P < 0.001$; related primes = 838 msec and unrelated primes = 926 msec] and stimulus quality [$F(1,55) = 184.35$, $P < 0.001$], with degraded targets taking longer to accept (945 msec) than intact targets (819 msec). The association × stimulus quality interaction did not reach significance [$F(1,55) = 2.33$, $P = 0.13$]. These observations were corroborated in the analysis of errors: association [$F(1,55) = 70.63$, $P < 0.001$; associated = 8.86%, non-associated = 22.07%], stimulus quality [$F(1,55) = 23.58$, $P < 0.001$; degraded = 18.49%, intact = 12.44%] and association × stimulus quality ($F < 1$).

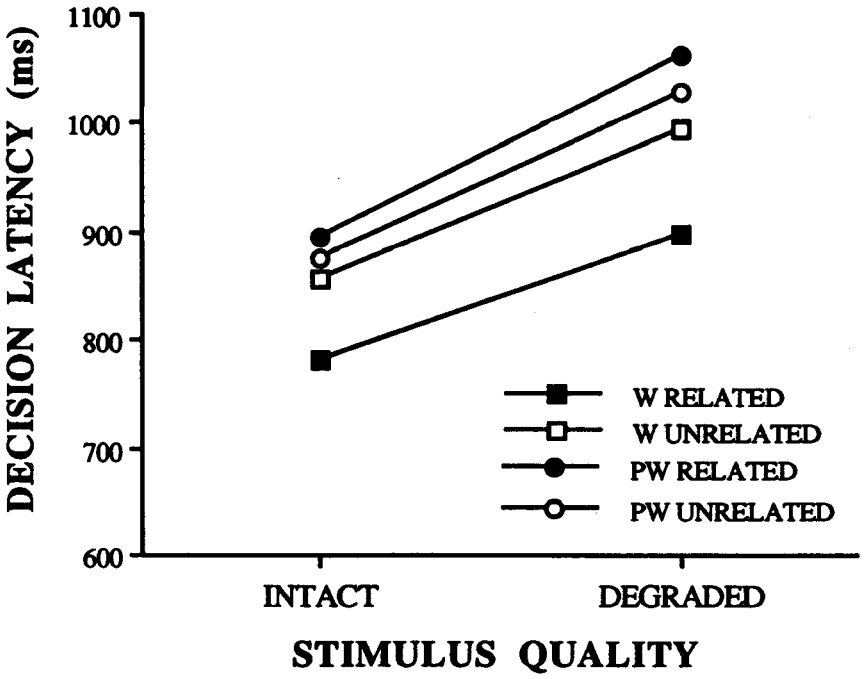

FIG. 1. Mean latencies for words (W) and pseudowords (PW) as a function of association and degradation in Experiment 2.

The analysis of pseudoword rejection latencies complemented the preceding. Again, the main effect of association was significant [$F(1,55) = 13.27$, $P < 0.001$], with targets following unrelated primes eliciting faster responses (951 msec) than targets following related primes (977 msec), indicating that pseudowords were harder to reject in a context related to their source word (e.g. Kinoshita, Taft, & Taplan, 1985). The main effect of stimulus quality was also significant [$F(1,55) = 315.45$, $P < 0.001$], with degraded targets taking longer to reject (1044 msec) than intact targets (885 msec). The association × stimulus quality interaction was non-significant [$F(1,55) = 1.72$, $P > 0.05$]. In the error analysis, association [$F(1,55) = 8.14$, $P < 0.007$; primed = 7.33%, non-primed = 4.91%] and stimulus quality [$F(1,55) = 51.62$, $P < 0.001$; degraded = 9.0%, intact = 4.0%] were significant, but association × stimulus quality was not [$F(1,55) = 2.08$, $P > 0.05$].

The conditions of Experiment 2 were intended to enhance the stimulus quality × association interaction: (1) targets were phonologically ambiguous, thereby imposing a greater responsibility on hypothesised clean-up

processes occurring over orthographic-to-semantic connections; (2) degradation had a large effect on errors (8% on intact targets, almost 14% on degraded targets) and the overall degradation effect was substantial (143 msec); and (3) the overall associative priming effect was substantial (87 msec). Despite these apparently favourable outcomes of the main experimental manipulations, additivity rather than non-additivity characterised the relation between stimulus quality and association—the sought-after interaction was unreliable in both the latencies and errors analyses. In consequence, the results of Experiment 2 provide little support for the hypothesis that the interaction is more probable when targets demand greater involvement of orthographic–semantic clean-up processes. At a more concrete level, the results of Experiment 2 reinforce the impression that the stimulus quality × association interaction is difficult to obtain in Serbo-Croatian. It has been suggested that Lukatela and Turvey's (1987) failure to find the interaction in their lexical decision experiment may have been due to the use of a constant non-linguistic stimulus as the unrelated prime (Borowsky & Besner, 1991). Given that Experiment 2 similarly failed to find the interaction, with the lexical decision task and with unrelated word primes providing the baseline, the reason for the additivity of quality and association observed by Lukatela and Turvey (1987) must be sought elsewhere than in baseline variations.

GENERAL DISCUSSION

Despite the successful demonstration of a stimulus quality × association interaction at the shorter time scale of Experiment 1, the continued failure to demonstrate the interaction at the longer time scale of Experiments 1 and 2, and in two different tasks, reinforces the impression that association and stimulus quality do not always interact (Carello et al., 1995). A recent re-examination of the stimulus quality × association interaction in English provides further reinforcement. When items were strongly associated and the proportion of related pairs was high (50%), the interaction was significant at both a long (800 msec) and a relatively short (200 msec) SOA (Stolz & Neely, 1995). When the items were weakly associated, the interaction disappeared at 200 msec even with a high proportion of related pairs. It is noteworthy that in both present experiments, the proportion of word pairs with an associative relation was high (50%) and the association was strong, suggesting that failures to obtain the interaction may not be due to precisely the same factors in English and Serbo-Croatian.

A re-evaluation is needed of the idea, present in both Lukatela and Turvey (1987) and Bajo et al. (1994), that the stimulus quality × associa-

tion interaction might be informative about the differential use of lexical and non-lexical processing routes. For a variety of reasons, the original dual-route theory (Coltheart, 1978) has been supplanted by the dual-route cascaded processing theory (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart & Rastle, 1994). The revised version acknowledges that processing on the non-lexical route may be commensurate in speed with processing on the lexical route (see also Paap, Noel, & Johansen, 1992) and assumes bidirectional linkages between the two routes. Although the assembling of phonology on the non-lexical route is a left-to-right, grapheme-to-phoneme conversion procedure, this serial process can nevertheless deliver its product at a speed sufficient for the phonology of a nonword backward mask to influence the identification of the letters composing a target word (Coltheart & Rastle, 1994), thus accommodating the phonological effects on visual letter processing observed at brief SOAs by Perfetti and others (e.g. Perfetti, Zhang, & Berent, 1992). The features of fast assembled phonology and bidirectionality mean that the revised dual-route model differs markedly from the original model. The hypotheses of delayed phonology and bypass are now rejected and the hypothesis of independent routes has been substantially diluted if not abandoned altogether (see Van Orden et al., 1990, for a detailed discussion of these component hypotheses of the classical theory). Of particular relevance to present concerns is the observation that bidirectionality undercuts the rationale for claims that one can use effects of associative priming and word frequency, and overadditive effects of associative priming and stimulus quality, as evidence for the use of the lexical route (Baluch & Besner, 1991; Sebastián-Gallés, 1991; Tabossi & Laghi, 1992). On the revised dual-route model of Coltheart et al. (1993) and Coltheart and Rastle (1994), similar effects would be expected from processing on the non-lexical route. That is, the model no longer seems to provide the theoretical basis needed for inferring that experimental evidence of lexical effects is evidence against lexical access by phonological codes (see Carello, Lukatela, & Turvey, 1994).

We suggested above that, from the perspective of the phonological coherence hypothesis, an interaction of association and stimulus quality might be read as a measure of the significance of orthographic–semantic resonance in resolving phonologically activated lexical representations. To the extent that a number of phonological codes arise from a given orthographic code (bottom-up inconsistency) and/or a number of orthographic codes satisfy a given phonological code (top-down inconsistency), the significance of orthographic–semantic resonance *qua* clean-up will be magnified. Because languages differ in the aforementioned consistencies, they may similarly differ in the degree of clean-up required. We suggested that the more temporally extended the clean-up process, the more likely it

is that the effect of associative priming will be enhanced by poor stimulus quality. Accordingly, English may reveal the interaction more readily than Serbo-Croatian and, for much the same reason, Spanish may reveal the interaction more readily than Serbo-Croatian but less readily than English. Although the Spanish and Serbo-Croatian orthographies are approximately equal in the consistency of the mapping from spelling to pronunciation, with a potential advantage for the Spanish orthography given its specification of stress, they differ in the consistency of the mapping from pronunciation to spelling.[2] Serbo-Croatian words are more top-down consistent, on average, than Spanish words. Consequently, activity in Spanish word recognition involving the phonological level could benefit from clean-up due to orthographic–semantic processes more so than the corresponding activity in Serbo-Croatian word recognition. The upshot would be a greater probability of finding an association × stimulus quality interaction at various SOAs in Spanish than in Serbo-Croatian. Unfortunately, the results of the present Experiment 2 do not lend support to the hypothesis that ambiguity in the mapping between orthographic and phonological codes facilitates the interaction. An additive effect was found for Serbo-Croatian target stimuli whose orthographic structures gave rise to more than one phonological code.

If the contrast between the results of Bajo and co-workers' (1994) experiments and the results of the present Experiment 2 is not due to differences in orthography, then the reason for the contrast must be sought within the experimental methodologies. In the research of Bajo et al. (1994), response latencies were prolonged excessively by degradation. In their experiment 1, for example, lexical decisions to degraded word targets took 1286 msec on average, compared with an average latency of 776 msec for intact word targets—a degradation effect of 510 msec. For degraded nonword targets, mean latencies on the order of 2653 msec

[2]Like Serbo-Croatian, Spanish has a relatively straightforward mapping between orthography and phonology. Unlike Serbo-Croatian, there are some context-dependencies in the pronunciation of a few letters (e.g. C and G are hardened or softened by the following letter, H is silent except when part of a diphthong, U is silent between G and E). But these context-dependencies are strictly predictable. Moreover, unlike Serbo-Croatian, stress patterns that deviate from the standard are marked in the orthography with an accent. On balance, therefore, Serbo-Croatian and Spanish are reasonably equivalent in the ease with which one can get from script to sound. The mapping from phonology to orthography, however, is not equivalent in the two languages. Serbo-Croatian is again one to one (in each of its alphabets) but Spanish has many ambiguities (e.g. in South American Spanish, /be/ is written BE or VE, /he/ is JE or GE, /ka/ is KA or CA, /se/ is SE, CE, XE or ZE, /ya/ is YA or LLA, /mas/ can be MAS or MÁS). A letter string such as CESE can be read only as /sese/, whereas the utterance /sese/ can be transcribed in 16 different ways (by permuting the four letters that yield the /s/ sound when followed by E).

were observed. Latencies of such magnitudes suggest that the experiment was not tapping the fast-acting, automatic processes assumed to typify fluent word recognition, but rather amplified the involvement of post-lexical, strategic processes. In the present Experiment 2, the retarding effect of degradation was 143 msec and in the long SOA condition of Experiment 1 degradation lengthened response times by less than 30 msec. These degradation effects compare favourably with those of Carello et al. (1995), where degraded English words were named only 53 msec slower than intact English words. In Carello and co-workers' (1995) study, the stimulus quality × associative priming interaction was reliable. Additionally we note that, in the present Experiment 2, the mean decision latency for degraded nonword targets was 1044 msec. In sum, one possible reason for the success of Bajo et al. in finding an interaction at an SOA of 800 msec and the failure to find the interaction at comparable SOAs in the present experiments may have been that the longer time scale of responding induced by Bajo and co-workers' method of degradation encouraged strategic processes largely absent in the present experiments. This possibility may be worth pursuing in future research. For the time being, however, we note that, taken together, the present study and that of Bajo et al. provide evidence that there are conditions under which associative priming effects in shallow orthographies can be influenced by stimulus quality in the manner previously demonstrated for associative priming effects in deep orthographies.

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