Psychonomic Bulletin & Review
2006, 13 (5), 842-847

Cross-alphabet and cross-modal long-term priming in Serbian and English

JELENA HAVELKA
University of Kent, Canterbury, England

JEFFREY S. BOWERS
University of Bristol, Bristol, England

and

DRAGAN JANKOVIĆ
University of Belgrade, Belgrade, Serbia

In Experiments 1 and 2, we investigated long-term repetition priming effects in Serbian under cross-alphabet and cross-modal conditions. In both experiments, results followed the same pattern: significant priming in all conditions and no significant reduction in priming in the cross-modal as opposed to the cross-alphabet condition. These results are different from those obtained in English (Experiment 3), in which a modality shift led to a reduction in priming. The findings are discussed within a theoretical framework, in which long-term priming is a by-product of learning within the language system. A full list of word stimuli for all three experiments presented in this article can be found at www.psychonomic.org/archive.

Priming occurs when previous exposure to a stimulus modifies the subsequent response to a related stimulus. The duration of priming depends on the priming technique used, from milliseconds (masked priming) to minutes or hours (long-term priming). In the long-term priming paradigm, exposure to items during a study phase affects performance in the test phase. However, the test phase does not make direct reference to the previous study episode, and participants are often unaware of the connection between the two phases of the experiment.

A number of studies have obtained reliable and comparable long-term priming effects within the visual modality when the study and test words are presented in different formats, such as lowercase and uppercase in English (e.g., Bowers, 1996; but see Tenpenny, 1995), Hindi and Urdu scripts in Hindustani (Brown, Sharma, & Kirsner, 1984), hiragana and katakana in Japanese (Bowers & Michita, 1998), and Cyrillic and Roman scripts in Serbian (Feldman & Moskovljević, 1987). By contrast, changes in the modality of the study and test item (e.g., auditory presentation at study and visual at test) reduces priming, typically, by 50% or more (e.g., Bowers, 2000b; Rajaram & Roediger, 1993), suggesting that a significant component of priming is visual. This pattern of results has led a number of authors to argue that long-term priming is mediated in part by preexisting and abstract orthographic codes, and that priming reflects structural changes that affect the later processing of the repeated items (e.g., Morton, 1979). Bowers, Damian, and Havelka (2002) simulated various aspects of long-term priming within the orthographic component of Seidenberg and McClelland's (1989) distributed model of word identification, lending further support to the view that long-term priming is a by-product of learning within the word recognition system.

Although priming is reduced following modality shifts, it is rarely eliminated, suggesting a contribution from nonorthographic codes. The phonological basis of cross-modal priming is suggested by a number of findings, including the robust priming obtained between homophones (Rueckl & Mathew, 1999) and imaging studies that reveal that cross-modal priming is associated with activation in brain areas involved in processing of phonological information (e.g., Badgaiyan, Schacter, & Alpert, 1999; Schacter, Badgaiyan, & Alpert, 1999).

In summary, priming may be viewed as a by-product of learning within the language system, or, more specifically, as a result of structural changes within orthographic, and to some extent, phonological and even semantic systems (e.g., Becker, Moscovitch, Behrmann, & Joordens, 1997). Because these systems are also involved in visual word recognition, factors that influence word recognition may, hypothetically, also influence long-term priming, and vice versa.

One issue in visual word recognition research that has long been a subject of debate is the relative importance of visual versus phonological processing. According to one of the predominant visual word recognition models, the dual-route

We thank Dinkar Sharma, Clive Frankish, and Sven Mattys for their helpful suggestions during the preparation of this manuscript. We are also grateful to Vasilije Gozdenović for technical help and support in setting up these experiments. All correspondence concerning this article should be addressed to J. Havelka, Department of Psychology, University of Kent, Canterbury, Kent CT2 7NP, England (e-mail: j.havelka@kent.ac.uk).

cascaded (DRC) model (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), there are two possible mechanisms for deriving a phonological representation from print. The nonlexical route involves the application of print-to-sound conversion rules to individual graphemes to generate phonological codes. The second mechanism, the lexical route, relies on the lookup of lexical-orthographic representations, which map onto the corresponding lexical-phonological representations. Although these two routes operate in parallel, it is often assumed that recognition for the majority of words is dominated by the lexical route, whereas the phonological assembly route plays a larger role in supporting naming of low-frequency and unfamiliar words.

Some authors have suggested that the relative dominance of lexical versus prelexical phonology in word recognition is a function of the nature of a language's writing system (e.g., Frost & Katz, 1989; Frost, Katz, & Bentin, 1987; Ziegler, Perry, & Coltheart, 2003). For example, languages like English and French have a set of rules for converting graphemes to phonemes, and vice versa, but still admit a significant number of irregular spelling patterns that do not follow those rules. This type of orthography is usually referred to as a *deep* orthography. In contrast, languages like Spanish or Italian always follow a set of fixed rules in reading and writing, and their orthographies are usually referred to as *transparent* or *regular*. The balance between lexical and nonlexical processing seems to be language specific, with word reading in a transparent orthography relying on nonlexical processing more than reading in a deep orthography. According to Ziegler et al. (2003), these cross-language differences can be accounted for by variations in lexical and nonlexical processing speeds across orthographies.

An extreme case of a transparent orthography is Serbian, in which each individual letter corresponds to an individual phoneme, and vice versa. Furthermore, the Serbian language can be written in two different alphabets, Roman and Cyrillic, and their graphemes map onto the same set of phonemes. Children in Serbia learn Cyrillic in the first grade and Roman in the second grade, and skilled adult readers of Serbian are equally competent in reading and writing in both alphabets. It has been argued that reading in Serbian usually proceeds with reference to prelexical phonology[1] (e.g., Lukatela, Lukatela, Carello, & Turvey, 1999). If transparency of a given orthography affects the relative dominance and speed of the lexical and nonlexical processes in word recognition, it may affect the pattern of long-term priming as well. In English, abstract lexical-orthographic codes are presumed to play an important role in reading, so long-term priming for written English words is abstract, modality specific, and sensitive to frequency and morphological structure (see Bowers, 2000a). This is consistent with a close connection between orthographic representations and priming. By contrast, if Serbian is largely read by sublexical grapheme–phoneme mappings, there should be no basis for supporting this abstract, modality-specific priming. The study most relevant to this issue was carried out by Feldman and Moskovljević (1987), who reported significant and comparable priming between the visually unrelated Roman and Cyrillic scripts, much like priming between uppercase and lowercase words in English; but the authors did not include a cross-modal comparison. Accordingly, it is not clear whether or not these priming effects were mediated mostly by abstract orthographic codes, as in English, or whether phonological codes significantly contribute to the priming effects.

In the present study, we attempted to explore the role of balance between lexical and nonlexical processing in constraining long-term priming by contrasting within- and cross-modal priming in Serbian. If the transparent nature of its orthography is irrelevant to this process, priming in Serbian should mirror the standard result obtained in English—that is, significant cross-script, but reduced cross-modal priming. By contrast, if the nature of orthography is a relevant factor, with word identification in Serbian relying more heavily on nonlexical processing, any advantages of modality-specific over cross-modal word priming should be reduced or eliminated.

EXPERIMENTS 1A AND 1B

The first experiment tested whether or not long-term priming effects can be obtained between the two different Serbian alphabets (Cyrillic and Roman), and whether or not this effect is larger than it would be in a cross-modal priming condition.

Method

Participants. As part of a course requirement, 40 students from the University of Belgrade participated in Experiment 1A, and another 36 took part in Experiment 1B. All participants were native speakers of Serbian and equally fluent in both alphabets.

Stimuli. The same set of 60 words was used in both experiments. All words were two-syllable five-letter Serbian nouns consisting of unique and common letters[2] with a mean frequency of 61 per million (Kostić, 2001). For the lexical decision task in the test phase of the experiment, 60 five-letter pronounceable nonwords were generated. An additional set of 8 words and 8 nonwords was used in practice trials for the lexical decision task.

Design and Procedure. Experiments 1A and 1B included priming condition as a within-group factor with four levels: identity priming, cross-alphabet priming, cross-modal priming, and baseline. The dependent variables were response time and accuracy in the lexical decision task.

In the study phase, 45 words were randomly presented to participants. Each word was shown for 2 sec, with a 2-sec intertrial interval. Fifteen words were presented in the Cyrillic alphabet, 15 in Roman; 15 were presented as spoken words, and 15 words were not presented, thus providing a baseline. Four experimental files were created and words were counterbalanced across four conditions. Participants were randomly assigned to one of the four experimental files. Participants were instructed to read aloud visually presented words and to repeat aloud spoken words while wearing a headset through which words were spoken. They were told that they were participating in a naming task.

Immediately after study came the test phase of the experiment, consisting of a lexical decision task in which all 60 words and 60 nonwords were presented in a randomized order in only one of the alphabets (Cyrillic in Experiment 1A and Roman in Experiment 1B). The lexical decision task began with a practice set in which participants were instructed to press the right mouse button if the stimulus was a word and the left button if it was a nonword. Before presentation of each stimulus, a cross was displayed in the center of the screen as the warning sign for 500 msec. Response time was measured as the time between the onset of the stimulus and the buttonpress, after which the stimulus disappeared from the screen. The intertrial interval was 1,500 msec.

Results and Discussion

Lexical decision latencies and error rates for all conditions of Experiments 1A and 1B are presented in Table 1. Response times 2.5 standard deviations above or below the participant's mean for each condition (1.4% and 1.2% of the data in Experiments 1A and 1B) and 2.5 standard deviations above or below mean for a given stimulus and priming condition (1.2% and 1.1% in Experiments 1A and 1B) were excluded.

The data were analyzed in a one-factor design with study–test condition as a within-group factor in the analyses by participants (F_1) and by stimuli (F_2). The main effect of the study–test condition for the response times was significant for both Experiment 1A [$F_1(3,117) = 10.49$, $MS_e = 1{,}103.3$, $p < .01$; $F_2(3,177) = 6.96$, $MS_e = 1{,}728.2$, $p < .01$] and Experiment 1B [$F_1(3,105) = 6.01$, $MS_e = 1{,}173.5$, $p < .01$; $F_2(3,177) = 12.19$, $MS_e = 1{,}319.8$, $p < .01$]. In both experiments, Tukey HSD post hoc tests revealed significant priming in all conditions in comparison with the baseline (all ps $< .01$), but the differences between the identity, cross-alphabet and cross-modal priming conditions were not significant (all ps $<$ .49). An additional set of planned comparisons was conducted for identity versus cross-alphabet, identity versus cross-modal, and cross-alphabet versus cross-modal priming effects, and in both experiments the differences did not approach significance at the $p < .05$ level.

In the analysis of error rates, the main effect of the study–test condition approached significance in Experiment 1A [$F_1(3,117) = 3.9$, $MS_e = 0.002$, $p < .01$; $F_2(3,117) = 2.29$, $MS_e = 0.003$, $p < .08$], with more errors in the baseline condition than in the priming conditions. This effect did not approach significance in Experiment 1B. Accordingly, the RT and error data show no indication of a speed–accuracy trade-off.

In both Experiments 1A and 1B, a significant amount of long-term priming was observed to be equivalent in the cross-alphabet and cross-modal conditions. This result contrasts with established modality-specific effects obtained in English, in which priming is typically reduced by half and often more (e.g., Rajaram & Roediger, 1993).

It is important to note that previous research has shown that the amount of long-term priming depends on word frequency, with greater priming for lower frequency words (e.g., Bowers, 2000b; Forster & Davis, 1984). Word stimuli in the present experiment had a mean frequency of 61 occurrences per million (Kostić, 2001), which could be considered relatively high. Since the amount of repetition priming in the present experiments is relatively small (around 30 msec), this may have obscured any differences between cross-modal and cross-alphabet priming.[3] In order to discount this possibility, another experiment was conducted, using low-frequency words.

Table 1
Mean Response Times (in Milliseconds) and Proportion of Errors in Experiments 1A and 1B

	Response Time			Errors		
Study–Test Condition	*M*	*SD*	Priming	*M*	*SD*	Priming
Experiment 1A						
Cyrillic–Cyrillic	584	65	37	.02	.03	.02
Roman–Cyrillic	588	61	33	.02	.03	.02
Spoken–Cyrillic	595	70	26	.02	.03	.02
Nonstudied–Cyrillic	621	59	–	.04	.04	–
Experiment 1B						
Roman–Roman	602	68	25	.04	.05	.02
Cyrillic–Roman	593	62	34	.03	.04	.02
Spoken–Roman	600	68	27	.04	.06	.01
Nonstudied–Roman	627	70	–	.05	.05	–

EXPERIMENTS 2A AND 2B

The aim of the present experiment was to replicate with the new set of stimuli the results observed in Experiments 1A and 1B. In the present experiment, we used low-frequency words with a mean frequency of 4.5 per million (Kostić, 2001).

Method

Participants. As part of a course requirement, 40 students from the University of Belgrade participated in Experiment 2A and 40 students in Experiment 2B. The same selection criterion as in Experiments 1A and 1B was applied. None of the students had taken part in the previous two experiments.

Stimuli and Design. Sixty low-frequency words were used in this experiment. Again, all words were two-syllable five-letter Serbian nouns consisting only of unique and common letters. A new set of 60 five-letter pronounceable nonwords was generated and an additional set of 8 words and 8 nonwords was used in practice trials for the lexical decision task.

Procedure. The procedure was identical to that in the previous experiments for both the study and the test phases. In the test phase, all stimuli were presented in the Cyrillic alphabet in Experiment 2A and in the Roman alphabet in Experiment 2B.

Results and Discussion

The lexical decision latencies, standard deviations, and error rates for all conditions of Experiments 2A and 2B are presented in Table 2. Response times 2.5 standard deviations above or below the participant's mean for each condition (1.6% and 1% of the data in Experiments 2A and 2B) and 2.5 standard deviations above or below mean for a given stimulus and priming condition (1.2% and 1.2% in Experiments 2A and 2B) were excluded. Two items with high error rates (over 30%) were excluded from analysis in Experiment 2A and three such items in Experiment 2B.

The data were analyzed as a one-factor design with study–test condition as a within-group factor in the analysis by participants and by stimuli. The main effect of the study–test condition for the response times was again significant for both Experiment 2A [$F_1(3,117) = 29.89$, $MS_e = 1{,}566.8$, $p < .01$; $F_2(3,171) = 32.01$, $MS_e = 2{,}033.9$, $p < .01$] and Experiment 2B [$F_1(3,117) = 20.2$, $MS_e = 1{,}565.8$, $p < .01$; $F_2(3,168) = 25.14$, $MS_e = 1{,}774.3$, $p < .01$]. Again, a Tukey HSD post hoc test re-

Table 2
Mean Response Times (in Milliseconds) and Proportion of Errors in Experiments 2A and 2B

Study–Test Condition	Response Time			Errors		
	M	*SD*	Priming	*M*	*SD*	Priming
Experiment 2A						
Cyrillic–Cyrillic	628	61	76	.03	.05	.08
Roman–Cyrillic	640	70	64	.03	.04	.08
Spoken–Cyrillic	640	53	64	.05	.06	.06
Nonstudied–Cyrillic	704	85	–	.11	.07	–
Experiment 2B						
Roman–Roman	666	80	61	.04	.04	.11
Cyrillic–Roman	671	88	56	.03	.05	.12
Spoken–Roman	679	79	48	.06	.05	.09
Nonstudied–Roman	727	92	–	.15	.09	–

vealed significant priming in all priming conditions (all *p*s $< .01$), but the differences between the identity, cross-alphabet, and cross-modal priming conditions were not significant (all *p*s $< .43$). The same set of planned comparisons was conducted as in the previous experiments and none approached significance at the $p < .05$ level.

In the analysis of error rates, there was a significant main effect of study–test condition in both Experiment 2A [$F_1(3,117) = 18.68$, $MS_e = 0.002$, $p < .01$; $F_2(3,171) = 10.01$, $MS_e = 0.005$, $p < .01$] and Experiment 2B [$F_1(1,117) = 33.35$, $MS_e = 0.002$, $p < .01$; $F_2(3,168) = 20.93$, $MS_e = 0.009$, $p < .01$], with more errors in the baseline condition than in the priming conditions. The Tukey HSD post hoc test revealed no difference between priming conditions in error rates (all *p*s $< .41$).

Thus, in Experiments 2A and 2B we replicated the findings of Experiments 1A and 1B in showing that long-term priming in cross-alphabet and cross-modal conditions is equivalent in magnitude even under conditions of greater priming, due to the inclusion of low-frequency words.

EXPERIMENT 3

The aim of Experiment 3 was to confirm that the equivalent amount of priming in cross-alphabet and cross-modal conditions was indeed due to the transparent nature of Serbian orthography rather than to the procedure used in the experiments presented so far. It is possible that engaging in the naming responses during the study phase may have enhanced phonological processes and thus diluted differences between cross-modal and cross-alphabetic priming effects. In order to address this potential criticism, we have collected data in English replicating the procedure used to collect data in Serbian.

Method

Participants. As part of a course requirement, 40 students from the University of Kent participated in Experiment 3. All participants were native speakers of English.

Stimuli and Design. Sixty low-frequency English words were used in this experiment. They were five-letter words with mean frequency of 4.5 per million (CELEX Lexical Database, 1995), the same length and frequency as for Serbian words used in Experiments 2A and 2B. A set of 60 five-letter nonwords pronounceable in English was generated, and an additional set of 8 words and 8 nonwords was used for the practice trials for the lexical decision task.

Procedure. The present experiment followed the procedure used in the previous experiments. The only difference was that in the study phase the cross-alphabet condition was replaced with a cross-case condition (uppercase in the study phase and lowercase in the test phase). All stimuli in the test phase were presented in lowercase letters.

Results and Discussion

The lexical decision latencies, standard deviations, and error rates for all conditions of Experiment 3 are presented in Table 3. The trimming procedure was the same as in the previous experiments (1% of the data was excluded from the analysis by participants and 1.1% from the analysis by stimuli).

The data were analyzed in a one-factor design, with study–test condition as a within-group factor in the analysis by participants and by stimuli. The main effect of the study–test condition for the response times was significant [$F_1(3,117) = 31.38$, $MS_e = 1{,}169$, $p < .01$; $F_2(3,171) = 38.33$, $MS_e = 1{,}837$, $p < .01$]. The Tukey HSD post hoc test revealed significant priming in all conditions in comparison with the baseline in both analyses (all *p*s $< .01$), but this time the differences between (1) cross-modal and cross-case and (2) cross-modal and identity priming conditions were also significant (all *p*s $< .01$). The differences between cross-case and identity priming conditions were not significant ($p_1 < .73$, $p_2 < .91$).

In the analysis of error rates, there was a significant main effect of the study–test condition [$F_1(3,117) = 6.69$, $MS_e = 0.004$, $p < .01$; $F_2(3,171) = 6.98$, $MS_e = 0.006$, $p < .01$]. The Tukey HSD post hoc test revealed significant differences between identity priming and the three other conditions ($p < .01$), whereas the differences in error rates between cross-case, cross-modal, and baseline conditions were not significant (all *p*s $< .1$).

Therefore, Experiment 3 replicated established modality-specific priming effects in English and confirms that the absence of difference between cross-modal and within-modality priming in Serbian is due to the nature of Serbian orthography rather than to the experimental procedure used in our experiments.[4]

GENERAL DISCUSSION

In two experiments carried out in Serbian, we found significant cross-modal priming. Furthermore, the amount of priming was equivalent in cross-modal and cross-alphabet

Table 3
Mean Response Times (in Milliseconds) and Proportion of Errors in Experiment 3

Study–Test Condition	Response Time			Errors		
	M	*SD*	Priming	*M*	*SD*	Priming
Lowercase–lowercase	604	77	68	.04	.07	.06
Uppercase–lowercase	612	84	60	.07	.09	.03
Spoken–lowercase	635	89	37	.09	.06	.01
Nonstudied–lowercase	672	101	–	.10	.07	–

conditions. This contrasts with the standard finding in English, replicated in Experiment 3, where priming is dramatically reduced following modality shift but unaffected by a change in appearance. The failure to observe a reduction in priming following modality shift suggests that lexical-orthographic codes are not the main mediators of long-term priming in Serbian, as is commonly argued in models of long-term priming in English.

One of the key features of Roman and Cyrillic alphabets in Serbian is that the mappings between graphemes and phonemes are completely consistent in both directions, whereas in English these mappings are far less regular. As noted above, a number of theorists have argued that the consistency of these mappings modulates the nature of the processes involved in word identification in different languages, with phonological assembly playing a more dominant role in languages with transparent orthographies than in those with deep orthographies. Contrasting long-term priming results reported in English and Serbian appears to support our assumption that the long-term priming is influenced by factors that affect visual word recognition—in this case, regularity of orthography. These results support both the assumption that phonological assembly plays the key role in reading in Serbian (Lukatela et al., 1999) and the proposition that speed of lexical and nonlexical processing varies across orthographies as a function of their regularity (Ziegler et al., 2003).

In light of these results, it seems that the mechanism behind long-term repetition priming involves structural changes within the language system in general, rather than primarily within the lexical-orthographic system. In a language such as English, where lexical-orthographic codes play a dominant role in visual word recognition, long-term priming will be substantially affected by those representations. This will lead to significantly larger priming effects for stimuli presented within the visual modality than for stimuli presented across the visual and auditory modalities. On the other hand, in a language such as Serbian, where word recognition relies on phonological assembly to a greater extent, long-term priming will be primarily mediated via phonological representations, leading to an equal amount of priming regardless of the modality of the study and test items.

REFERENCES

Badgaiyan, R. D., Schacter, D. L., & Alpert, N. M. (1999). Auditory priming within and across modalities: Evidence from positron emission tomography. *Journal of Cognitive Neuroscience*, **11**, 337-348.

Becker, S., Moscovitch, M., Behrmann, M., & Joordens, S. (1997). Long-term semantic priming: A computational account and empirical evidence. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **23**, 1059-1082.

Bowers, J. S. (1996). Different perceptual codes support priming for words and pseudowords: Was Morton right all along? *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **22**, 1336-1353.

Bowers, J. S. (2000a). In defense of abstractionist theories of repetition priming and word identification. *Psychonomic Bulletin & Review*, **7**, 83-99.

Bowers, J. S. (2000b). The modality-specific and -nonspecific components of long-term priming are frequency sensitive. *Memory & Cognition*, **28**, 406-414.

Bowers, J. S., Damian, M. F., & Havelka, J. (2002). Can distributed orthographic knowledge support word-specific long-term priming? Apparently so. *Journal of Memory & Language*, **46**, 24-38.

Bowers, J. S., & Michita, Y. (1998). An investigation into the structure and acquisition of orthographic knowledge: Evidence from cross-script Kanji–Hiragana priming. *Psychonomic Bulletin & Review*, **5**, 259-264.

Brown, H., Sharma, N. K., & Kirsner, K. (1984). The role of script and phonology in lexical representation. *Quarterly Journal of Experimental Psychology*, **36A**, 491-505.

CELEX Lexical Database, Release 2 (1995). Nijmegen: Max Planck Institute for Psycholinguistics, Centre for Lexical Information.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, **108**, 204-256.

Feldman, L. B., & Moskovljević, J. (1987). Repetition priming is not purely episodic in origin. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **13**, 573-581.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **10**, 680-698.

Frost, R., & Katz, L. (1989). Orthographic depth and the interaction of visual and auditory processing in word recognition. *Memory & Cognition*, **17**, 302-310.

Frost, R., Katz, L., & Bentin, S. (1987). Strategies for visual word recognition and orthographical depth: A multilingual comparison. *Journal of Experimental Psychology: Human Perception & Performance*, **13**, 104-115.

Kostić, D. (2001). *Quantitative description of Serbian language structure: Corpus of Serbian language*. Belgrade: University of Belgrade, Institute for Experimental Phonetics and Speech Pathology and Laboratory for Experimental Psychology.

Lukatela, G., Lukatela, K., Carello, C., & Turvey, M. T. (1999). Effects of frequency and phonological ambiguity on naming Serbo-Croatian words. *European Journal of Cognitive Psychology*, **11**, 1-16.

Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen model. In P. A. Kolers, M. E. Wrolstad, & H. Bouma (Eds.), *Processing of visible language* (Vol. X, pp. 259-268). New York: Plenum.

Rajaram, S., & Roediger, H. L., III (1993). Direct comparison of four implicit memory tests. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **19**, 765-776.

Rueckl, J. G., & Mathew, S. (1999). Implicit memory for phonological processes in visual stem completion. *Memory & Cognition*, **27**, 1-11.

Schacter, D. L., Badgaiyan, R. D., & Alpert, N. M. (1999). Visual word stem completion priming within and across modalities: A PET study. *NeuroReport*, **10**, 2061-2065.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, **96**, 523-568.

Tenpenny, P. L. (1995). Abstractionist versus episodic theories of repetition priming and word identification. *Psychonomic Bulletin & Review*, **2**, 339-363.

Ziegler, J. C., Perry, C., & Coltheart, M. (2003). Speed of lexical and nonlexical processing in French: The case of the regularity effect. *Psychonomic Bulletin & Review*, **10**, 947-953.

NOTES

1. Some aspects of phonology in Serbian, such as stress, have to be derived postlexically.

2. In the Roman and Cyrillic alphabets, three types of letters can be distinguished: unique letters that belong to only one of the alphabets and provide readers with two graphemic interpretations for the same phoneme, one for each alphabet; common letters that are shared by the two alphabets and map into the same phonemes in both and therefore have a single graphemic and phonemic interpretation, regardless of the alphabet; and ambiguous letters that have the same graphemic form in both alphabets but map to different phonemes in the respective alphabet. Therefore, words that consist of common and ambiguous letters are phonologically bivalent; that is, they can be pronounced in one way if read as Cyrillic and in a different way if read as Roman. Previous research has

demonstrated that response times and error rates are higher for phonologically ambivalent words than for phonologically unique words (e.g., Lukatela et al., 1999). In order to avoid potential confusion with this effect, none of the stimuli used in the present experiment was phonologically bivalent.

3. The amount of priming obtained in experiments presented here is smaller than priming obtained by Feldman and Moskovljević, who report 90 msec priming in repetition and cross-alphabet priming condition (Feldman & Moskovljević 1987, Experiment 1). It is possible that methodological differences between these studies have influenced the size of the priming effect. Firstly, in our experiments only words repeated between study and test phase, whereas in their study, both words and nonwords repeated. More importantly, in our experiments, there was a 5- to 10-min lag between presentations of the item in the study and in the test phase, whereas in their study, both prime and target were presented in the same session with the average lag of 10 items, which, according to the description of the experimental procedure, was about 30 sec. This time, the lag difference is likely to have influenced the difference in the observed amount of priming.

4. To test this qualitative difference in the pattern of priming between Experiment 3 (English) and Experiments 2A and 2B (Serbian), a 2×3 ANOVA was conducted using the size of priming effect as a dependent variable. Language (English vs. Serbian) and type of priming (repetition, same modality, and cross-modal) were treated as between-group independent variables. The size of the priming effect for Serbian was collapsed across test conditions in Experiments 2A and 2B. This analysis revealed a significant interaction between the language and the type of priming [$F(2,156) = 3.32$, $MS_e = 676.41$, $p < .04$]. The Tukey HSD post hoc test confirms significant differences between cross-modal priming and the other two priming conditions (all ps $< .01$) for English, whereas for Serbian there were no significant differences in the amount of priming between the three conditions.

ARCHIVED MATERIALS

The following materials [and links] associated with this article may be accessed through the Psychonomic Society's Norms, Stimuli, and Data archive, http://www.psychonomic.org/archive.

To access these files [or links], search the archive for this article using the journal name (*Psychonomic Bulletin & Review*), the first author's name (Havelka), and the publication year (2006).

File: Havelka-2006.zip

Description: The compressed archive file contains two files:

File1.ext, containing Havelka_PBR_2006_stimuli.doc—Word file containing lists of stimuli used in Havelka, Bowers, & Janković (2006).

File2.ext, containing Havelka_PBR_2006_stimuli.pdf—PDF file containing lists of stimuli used in Havelka, Bowers, & Janković (2006).

Author's e-mail address: j.havelka@kent.ac.uk

(Manuscript received November 30, 2004;
revision accepted for publication January 17, 2006.)