Memory & Cognition
2002, 30 (4), 629-636

Semantic aspects of morphological processing: Transparency effects in Serbian

LAURIE BETH FELDMAN
State University of New York, Albany, New York
and Haskins Laboratories, New Haven, Connecticut

DRAGANA BARAC-CIKOJA
Gallaudet College, Washington, D.C.

and

ALEKSANDAR KOSTIĆ
University of Belgrade, Belgrade, Serbia
and Haskins Laboratories, New Haven, Connecticut

We examined the contribution of semantics to morphological facilitation in the visual lexical decision task at two stimulus onset asynchronies (SOAs) with Serbian materials. Primes appeared in Roman or Cyrillic characters. Targets always were printed in Roman. When primes were presented at an SOA of 250 msec, decision latencies to verbal targets (e.g., VOLIM) showed greatest facilitation after inflectionally (e.g., VOLE) related primes, significantly less after semantically transparent derived primes (e.g., ZAVOLE), and less again after semantically opaque derived primes (e.g., PREVOLE). Latencies after semantically transparent and opaque derived target words did not differ at an SOA of 48 msec. Both were slower than after inflectionally related primes. Stated generally, effects of semantic transparency among derivationally related verb forms were evident at long SOAs, but not at short ones. Under alphabet-alternating conditions, magnitudes of facilitation were greater overall, but the pattern was similar. The outcome suggests that restricted processing time for the prime limits the contribution of semantics to morphological processing and calls into question accounts that posit a task-invariant semantic criterion for morphological decomposition within the lexicon.

For a variety of languages with an assortment of word recognition tasks, researchers have demonstrated that prior presentation of a word formed from the same base morpheme as the target (morphologically related) speeds decision latencies to the target (see Feldman, 2001, for a review). Reliable evidence of morphological facilitation indicates that a word's morphological structure influences the processes of word recognition. Because morphological relatives tend to be formed by adding an affix to a base morpheme, words that share a base morpheme tend to be similar in form and similar in meaning. However, there can be variability in the degree of similarity. For example, the meaning of some complex forms (ALLOWABLE) is fully predictable from the meanings of its components (ALLOW + ABLE), and therefore, morphological relatives such as ALLOWABLE and ALLOW are relatively close in meaning. The meaning of other relatives (e.g., ALLOWANCE) is not fully predictable from its components (ALLOW + ANCE). Words like ALLOWANCE, whose meanings cannot be derived from knowledge of the constituent morphemes, tend to be semantically opaque.

A source of debate among those who study morphology is whether morphological knowledge about complex forms is represented explicitly in the mental lexicon and whether the same characterization applies for both opaque and transparent derivations. For a decompositional account, morphologically complex words are accessed or represented in terms of their constituent morphemes (e.g., Taft & Forster, 1975), and morphological facilitation arises from multiple activations of a shared base morpheme (Marslen-Wilson, Tyler, Waksler, & Older, 1994). For a full-form account, morphologically complex words are represented as full forms (e.g., Butterworth, 1983) that are interconnected in accord with a morphological principle (Lukatela, Gligorijević, Kostić, & Turvey, 1980) so as to produce facilitation by activation along a shared pathway. When patterns of morphological facilitation differ among morphologically complex forms, depending on their semantic transparency, a possible locus is the lexical architecture. Accordingly, semantically opaque derived forms fail to produce facilitation because they are represented in the lexicon as (separate) whole units, whereas semantically transparent derived forms produce facilitation be-

This study was supported by funds from National Institutes of Child Health and Development Grant HD-01994 to Haskins Laboratories and by funds from the Faculty of Philosophy at The University of Belgrade in Serbia. We thank Matthew Pastizzo for analyzing the data. Please address correspondence to L. B. Feldman, Haskins Laboratories, 270 Crown Street, New Haven, CT 06510 (e-mail: lf503@albany.edu).

cause they can be decomposed into morphological components and the base morpheme is activated by the prime and then by the target (e.g., Marslen-Wilson et al., 1994). In essence, decomposition and, therefore, morphological facilitation apply only to transparent forms in English. In contrast to the account developed for English, Frost and his associates have asserted that because of its productive morphology, transparent and opaque morphological relatives in Hebrew are represented in the same decomposed manner and produce comparable magnitudes of facilitation (Bentin & Frost, 1995; Deutsch, Frost, & Forster, 1998; Frost, Forster, & Deutsch, 1997).

An alternative perspective posits no explicit representation of morphology and no decomposed lexical entries. Instead, it emphasizes graded similarity of form and similarity of meaning as they contribute to distributed patterns that underlie morphological facilitation (Plaut & Gonnerman, 2000; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997). To the extent that outcomes vary across languages, differences reflect the overall systematicity in the mapping between form and meaning (Plaut & Gonnerman, 2000). Universally within a language, however, inflections (e.g., ALLOWED) tend to be more systematic than transparent derivations (e.g., ALLOWABLE), which tend, in turn, to be more systematic than (even partially) opaque derivations (e.g., ALLOWANCE). Therefore, graded magnitudes of facilitation are anticipated.

Time- and task-varying patterns of facilitation complicate assessments of the role of semantic transparency in morphological processing and dictate that cross-task variation must be differentiated from cross-language variation. A review of the literature reveals remarkably similar findings across languages when comparisons are within a task (Feldman, Soltano, Pastizzo, & Francis, 2001). For example, results in the long-term repetition priming variant of the lexical decision task, where an average of 10 items intervened between the presentation of the prime and that of the target, failed to show an effect of semantic transparency among derivational relatives in either Hebrew (Bentin & Feldman, 1990) or English (Feldman & Stotko, 1990, cited in Feldman, 1992). That is, the magnitudes of morphological facilitation at long lags after derived primes (e.g., CREATION) that were semantically close to targets (e.g., CREATE) and those that were semantically more remote (e.g., CREATURE) did not differ. Similarly, inflections (e.g., FOLDED) and derivations (e.g., FOLDER) tended to differ in the degree of similarity they shared with the base morpheme (e.g., FOLD), but differences in long-term target facilitation failed to emerge in English (Raveh & Rueckl, 2000).

With immediate unmasked visual (Raveh, 1999) and cross-modal (Pastizzo & Feldman, 2001b) variants of the primed lexical decision task in English, facilitation was greater after inflections than after derivations. Similarly in Hebrew, effects of semantic transparency among derivationally related primes and targets arose with visual (Bentin & Feldman, 1990), as well as with cross-modal (Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2000), presentations. Conversely, however, when primes were forward masked and presented in immediate succession at very short prime durations in Hebrew, the magnitudes of facilitation after opaque and transparent primes formed from the same base morpheme as their target were comparable (Frost et al., 1997).

Even in unmasked priming contexts that typically reveal an effect of semantic transparency, stimulus onset asynchrony (SOA) is critical. In English, morphological facilitation for visual targets preceded by a semantically transparent suffixed form (e.g., ACCORDING–ACCORDANCE) and by an opaque suffixed form (e.g., ACCORDIAN–ACCORDANCE) differed significantly at an SOA of 250 msec but did not differ at an SOA of 48 msec (Feldman & Pastizzo, 2002; Feldman & Soltano, 1999; Feldman et al., 2001). Collectively, patterns of divergence between inflections and derivations and between semantically transparent and opaque morphological relatives that vary with experimental manipulations such as prime duration challenge the adequacy of a decompositional account of morphological facilitation and call into question a semantic criterion for decomposition of lexical entries into their constituent morphemes.

The implication of the foregoing is that although coordinated studies across languages are important to ascertain the generality of a lexical architecture and, in particular, the extent to which semantic transparency determines the manner in which morphologically complex words are represented (e.g., Marslen-Wilson et al., 1994), procedures are not interchangeable, and variations across tasks and SOAs within a language cannot be ignored. Accordingly, the present study extended recent work conducted by Feldman et al. (2001) to the morphologically rich language of Serbian, where extensive families of derivationally related verbs can be created by affixing a derivational prefix to a base morpheme (Bybee, 1985; Partridge, 1964). We replicated with Serbian verbs differences between inflections and derivations, as well as the interaction of SOA and semantic transparency among derivations previously documented in English. For example, the verb infinitives ZAVOLITI (to fall in love) and PRIVOLITI (to convince) are formed from the same base morpheme (VOL), as is VOLETI (to love). They necessarily differ word initially, however, because of the presence of a derivational prefix. Therefore, inflected forms of the verbs ZAVOLITI and PRIVOLITI are related to inflected forms of the verb VOLETI by derivation. To elaborate, the inflected (third person plural present tense) forms ZAVOLE and PRIVOLE are derivations of the first person singular present tense form VOLIM. It is useful to point out that, in Serbian, there are multiple prefixes (i.e., ZA, PRI, U, IZ) that can combine with verbs and that a particular prefix can enter into a relatively semantically opaque derivation when combined with one verb, but into a relatively transparent derivation when combined with another verb. In sum, the repertoire of derivational prefixes is not confounded with degree of transparency.

In Experiment 1A, visual primes and visual targets were presented in the immediate priming variant of the lexical decision task at an SOA of 250 msec. On the basis of previous work at SOAs of 250 msec or greater (Bentin & Feldman, 1990; Feldman & Raveh, in press; Feldman & Soltano, 1999; Raveh & Feldman, 1998), effects of semantic transparency among verb forms created from a common base morpheme were anticipated. The goal of Experiment 1B was to contrast the effect of transparent and opaque morphological relatives on decision latencies to visual targets when primes appeared at a 48-msec SOA. On the basis of the absence of semantic transparency effects at very short SOAs with English derivations (Feldman & Soltano, 1999) and the absence of a difference between English inflections and derivations that were matched on orthographic overlap to the target (Raveh, 1999; Raveh & Rueckl, 2000) in Serbian, we did not expect to observe differences between opaque and transparent forms under those experimental conditions that tend to be relatively insensitive to semantic dimensions of relatedness. Because they retained greater orthographic similarity, as well as semantic similarity, to the target, we anticipated that even at short SOAs, inflectional primes would produce greater facilitation than would derivational primes. This finding would be consistent with the claim that at short SOAs, form also influences the magnitude of morphological facilitation (Pastizzo & Feldman, 2001b).

The goal of Experiments 1C and 1D was to contrast the effect of transparent and opaque morphological derivations on decision latencies when primes and targets were presented in different alphabets. Alphabet alternation in Serbian provided a technique to essentially eliminate from the pattern of facilitation the effect of orthographic (but not phonological) similarity between prime and target (e.g., Lukatela, Lukatela, Carello, & Turvey, 1993; Lukatela, Turvey, & Todorović, 1991) because, with the exception of about five phonemes, graphemes differ in the Roman and Cyrillic scripts. In Experiment 1C, visual primes in Cyrillic appeared for 250 msec. In Experiment 1D, visual primes in Cyrillic appeared for 48 msec.

To summarize, we exploited the productive system of derivation based on verb prefixation in Serbian and compared the magnitudes of morphological facilitation after opaque and transparent derivational primes at long and at short SOAs in the immediate priming task. Our intent was to use the pattern of morphological facilitation to determine whether a decomposed lexical representation of a word's morphological structure was restricted to semantically transparent forms. Contrasting magnitudes of facilitation for opaque and transparent forms would be compatible with the outcome reported in English with cross-modal and with long-duration visual presentations and would attest to the contribution of semantics to morphological processing. Comparable magnitudes of facilitation would be compatible with the outcome reported in Hebrew with a forward masked procedure and would imply an attenuated role of semantics. To this end, we also made use of the bialphabetic fluency of skilled readers in Serbia to reduce the orthographically based form similarity between targets and their morphologically related primes (see, e.g., Feldman & Barac-Cikoja, 1996). A secondary but related goal was to replicate differences in morphological facilitation after inflectional and derivational primes. Concurrently, we varied processing time for the prime so as to alter the potential semantic contribution to morphological processing.

METHOD

Participants

Forty-eight students participated in each experiment defined by SOA (250 and 48 msec) and by alphabet of the prime (Roman and Cyrillic). All the participants were recruited from psychology courses at the University of Belgrade. All were native speakers of Serbian, with normal or corrected-to-normal vision and no known reading disorders. No one participated individually in more than one experiment.

Materials

Morphologically complex words were selected as primes and as targets. Forty words were selected as critical targets. Primes were paired with each target to create four conditions: inflected forms of the same verb (e.g., VOLE–VOLIM), derived forms that were transparent with respect to base morpheme (e.g., ZAVOLE–VOLIM), derived forms that were opaque with respect to base morpheme (e.g., PRIVOLE–VOLIM), and unrelated but morphologically complex forms (e.g., ŠTAMPAJU–VOLIM). Accordingly, the repeated base morpheme appeared word medially in prefixed derivational primes (e.g., ZAVOLE, PRIVOLE), but word initially in targets and in inflectional primes (e.g., VOLIM, VOLE).

All related primes shared the base morpheme (e.g., VOL) with the target. Targets were first person singular (e.g., + IM, +AM) and primes were third person plural (e.g., + E, AJU) affixed forms. In the transparent morphological condition, meaning was also shared between the full forms of the prime and the target. In the opaque morphological condition, prime and target shared the base morpheme, but the full forms were not similar in meaning. An informal rating study by native speakers ($n = 10$) was conducted to assess which of the derivationally related primes was more closely related to the target, and all items had at least 70% agreement. Unrelated primes were matched for person, number, and tense to the related primes and did not overlap orthographically with the target.

In addition, 40 morphologically complex pseudoword targets were created and presented. They were formed by changing one or two letters in a verbal base morpheme other than those of the word targets. The proportions of primes that were paired with pseudowords mimicked that of word primes. To reduce the proportion of related trials, filler trials in which the prime and the target did not match on form or meaning were introduced. The inclusion of 40 filler word–word trials and 40 filler word–pseudoword trials reduced the relatedness proportion for word–word trials to about 38%. Filler primes did not share phonology, orthography, or meaning with their targets.

Procedure and Design

We constructed four experimental lists, each containing 160 trials. Both prime and target letter strings appeared in the Roman alphabet in Experiments 1A and 1B. Primes were presented in Cyrillic, and targets were presented in Roman, in Experiments 1C and 1D. Primes were counterbalanced across the four lists so that each list included all types of primes. If a particular target appeared with a particular prime on one experimental list, its paired prime was different on the other three lists. No target was repeated within an experimental list.

In all experiments, a trial consisted of a fixation point (+) presented in the center of the computer monitor for 250 msec. Then a prime appeared for 250 msec (Experiments 1A and 1C) or for 48 msec

(Experiments 1B and 1D) in the same location, after which the target appeared alone one line below where the prime had been. The target remained on the screen until the participant made a lexical decision response or until 1,500 msec had elapsed. A 1,000-msec intertrial interval followed each trial. Responses were registered on a generic keyboard. The participants pressed the *L* key for word responses and the *A* key for nonword responses, and latencies were measured from the onset of the target. Each session began with 16 practice trials to familiarize the participant with the task.

RESULTS AND DISCUSSION

Incorrect keypresses and outliers (defined as a standard deviation of three or more from each participant's mean) were classified as errors. Outliers constituted about 1% of the responses. No data were deleted because of high item error rates or high participant error rates. A total of four prime–target pairs were eliminated from the critical item set because they were incorrectly spelled in one or more conditions. By eliminating the 4 items from all four lists across experiments and SOAs, we standardized the set of targets. Mean response times, accuracies, and difference scores based on the remaining 36 items are reported in Table 1.

In general, target latencies were faster after a morphological relative than after an unrelated prime, and the magnitude of facilitation varied with type of relatedness. Unless otherwise indicated, all effects were significant at the $p < .05$ level. We present the results of analyses on each combination of SOA, along with planned comparisons. Although alphabet and SOA were manipulated between participants, items did repeat. Therefore, we also include a combined analysis across SOA and alphabet.

Experiment 1A

The overall one-way analysis of variance (ANOVA) on the data at the 250-msec SOA when the prime and the target appeared in Roman characters revealed that the effect of prime type was significant with both the latency measure [$F_1(3,141) = 15.53, MS_e = 1,924; F_2(3,105) = 13.11, MS_e = 2,367$] and the accuracy measure [$F_1(3,141) = 3.68, MS_e = 0.005; F_2(3,105) = 2.46, MS_e = 0.003, p < .07$].

Planned comparisons revealed that decision latencies to targets that followed inflected primes (620 msec) and transparent primes (649 msec) were significantly faster than those that followed unrelated primes [674 msec; $F_1(1,141) = 35.96, MS_e = 1,924; F_2(1,105) = 30.19, MS_e = 2,367$; and $F_1(1,141) = 7.33, MS_e = 1,924; F_2(1,105) = 5.62, MS_e = 2,367$, respectively]. Moreover, latencies after opaque primes and unrelated primes (3 msec) did not differ ($F_s < 1$). Most important, latencies to targets that followed transparent derived primes (649 msec) were significantly reduced relative to those after opaque derived primes [671 msec; $F_1(1,141) = 6.02, MS_e = 1,924; F_2(1,105) = 4.80, MS_e = 2,367$]. Finally, decision latencies after inflected and transparent derived primes differed [$F_1(1,141) = 10.82, MS_e = 1,924; F_2(1,105) = 9.75, MS_e = 2,367$]. Facilitation (unrelated minus related) after transparent and opaque primes is plotted in Figure 1, panel A.

Experiment 1B

The overall one-way ANOVA on the latency data at the 48-msec SOA when the prime and the target appeared in Roman characters also revealed an effect of prime type [$F_1(3,141) = 11.75, MS_e = 1,976; F_2(3,105) = 11.96, MS_e = 1,769$]. The effect of prime type was significant with the accuracy measure as well [$F_1(3,141) = 2.93, MS_e = 0.003; F_2(3,105) = 2.58, MS_e = 0.002, p < .06$].

Planned comparisons revealed that decision latencies to targets that followed inflected primes (677 msec) were significantly reduced relative to those that followed unrelated primes [728 msec; $F_1(1,141) = 31.86, MS_e = 1,976; F_2(1,105) = 32.52, MS_e = 1,769$]. The difference between transparent and unrelated primes just missed significance [713 msec; $F_1(1,141) = 2.87, MS_e = 1,976, p < .09; F_2(1,105) = 2.76, MS_e = 1,769, p < .10$]. In addition, latency differences after opaque primes and unrelated primes were not significant (13 msec; $F_1 = 1.93; F_2 = 2.14; p < .20$). In contrast to the 250-msec SOA outcome, latencies

Table 1
Mean Decision Latencies (RTs, With *SD*s) and Percentages Correct

	250-msec SOA				48-msec SOA			
	RT				RT			
Prime Type	*M*	*SD*	% Correct	Facilitation	*M*	*SD*	% Correct	Faciliation
				Roman–Roman				
Unrelated	674	91	94		728	117	97	
Inflection	620	80	94	54*	677	112	98	51*
Derivation transparent	649	91	97	25*	713	117	95	15
Derivation opaque	671	91	94	3	715	106	96	13
				Cyrillic–Roman				
Unrelated	660	91	93		710	93	91	
Inflection	603	80	97	57*	655	91	99	55*
Derivation transparent	621	90	97	39*	676	78	97	34*
Derivation opaque	639	83	96	21*	679	73	97	31*

Note—The prime–target pairs for the prime types were ŠTAMPAJU–VOLIM for the unrelated, VOLE–VOLIM for the inflection, PRIVOLE–VOLIM for the derivation transparent, and ZAVOLE–VOLIM for the derivation opaque. *Significantly different from the unrelated condition by subject and by items.

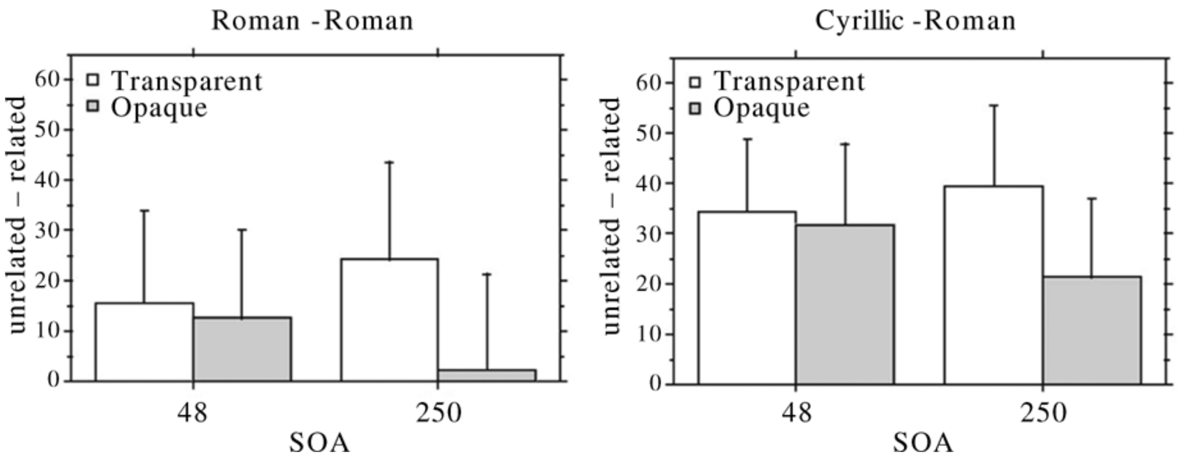

Figure 1. Facilitation as a function of prime type and stimulus onset asynchrony (SOA). Panel A shows the data for Roman primes and Roman targets; panel B shows the data for Cyrillic primes and Roman targets. Error bars represent the 95% confidence interval.

to targets that followed transparent primes (713 msec) and opaque primes (716 msec) did not differ ($F_s < 1$). Finally, decision latencies after inflected and transparent derived primes differed [$F_1(1,141) = 15.60$, $MS_e = 1,976$; $F_2(1,105) = 19.33$, $MS_e = 1,769$].

Experiment 1C

The overall one-way ANOVA on the Cyrillic prime latency data at an SOA of 250 msec revealed a significant effect of prime type [$F_1(3,141) = 20.43$, $MS_e = 1,423$; $F_2(3,105) = 9.96$, $MS_e = 2,208$]. Prime type was also significant [$F_1(3,141) = 4.27$, $MS_e = 0.004$; $F_2(3,105) = 2.95$, $MS_e = 0.004$] with the accuracy measure.

Planned comparisons revealed that decision latencies to targets that followed inflected primes and transparent primes (621 msec) were significantly faster than those to targets that followed unrelated primes [660 msec; $F_1(1,141) = 55.57$, $MS_e = 1,423$; $F_2(1,105) = 26.01$, $MS_e = 2,208$; and $F_1(1,141) = 26.38$, $MS_e = 1,423$; $F_2(1,105) = 14.10$, $MS_e = 2,208$, respectively]. Moreover, in Experiment 1C, latencies after opaque primes were faster than those after unrelated primes [$F_1(1,141) = 7.63$, $MS_e = 1,423$; $F_2(1,105) = 3.29$, $MS_e = 2,208$, $p < .07$]. Most important, latencies to targets that followed transparent derived primes (621 msec) were reduced relative to those that followed opaque derived primes [639 msec; $F_1(1,141) = 5.63$, $MS_e = 1,423$; $F_2(1,105) = 3.77$, $MS_e = 2,208$]. Finally, target latencies after inflected and transparent derivations differed only in the analysis by participants [$F_1(1,141) = 5.38$, $MS_e = 1,423$; $F_2(1,105) = 1.81$, $MS_e = 2,208$, $p < .20$].

Experiment 1D

The overall one-way ANOVA on the latency data at an SOA of 48 msec revealed an effect of (Cyrillic) prime type [$F_1(3,141) = 16.19$, $MS_e = 1,531$; $F_2(3,105) = 10.24$, $MS_e = 2,605$]. The effect of prime type also was significant with the accuracy measure [$F_1(3,141) = 12.77$, $MS_e = 0.005$; $F_2(3,105) = 9.77$, $MS_e = 0.002$].

Planned comparisons revealed that decision latencies to targets that followed unrelated primes (710 msec) were significantly slower than those that followed either inflected primes [655 msec; $F_1(1,141) = 47.50$, $MS_e = 1,531$; $F_2(1,105) = 30.21$, $MS_e = 2,605$] or transparent primes [676 msec; $F_1(1,141) = 18.56$, $MS_e = 1,531$; $F_2(1,105) = 10.56$, $MS_e = 2,605$]. Latencies after opaque primes and unrelated primes also differed [$F_1(1,141) = 15.70$, $MS_e = 1,531$; $F_2(1,105) = 10.66$, $MS_e = 2,605$]. Finally, latencies to targets after transparent primes (676 msec) and opaque derived primes (679 msec) did not differ at the short SOA ($F_s < 1$). However, target latencies after inflected and transparent derivations did [$F_1(1,141) = 6.68$, $MS_e = 1,531$; $F_2(1,105) = 5.04$, $MS_e = 2,605$].

Combined Analyses

Because decision latencies after opaque and transparent primes were our focus and because inflected prime facilitation did not vary over SOA, difference scores (unrelated minus related) for target latencies after opaque and transparent primes in Experiments 1 A–1D were computed and combined into one analysis. The main effect of alphabet was significant [$F_1(1,188) = 5.38$, $MS_e = 5,835$; $F_2(1,35) = 5.41$, $MS_e = 5,305$], as was the main effect of transparency [$F_1(1,188) = 10.43$, $MS_e = 1,205$; $F_2(1,35) = 4.53$, $MS_e = 2,332$]. Accordingly, the alphabet-alternating condition produced greater magnitudes of facilitation than did the pure Roman condition, and the magnitude of facilitation was reduced after opaque, relative to transparent, morphological relatives. Most important, transparency did not interact significantly with alphabet ($F_s < 1$) but did interact with SOA [$F_1(1,188) = 5.99$, $MS_e = 1,205$; $F_2(1,35) = 8.38$, $MS_e = 1,079$]. Stated succinctly, consistent with the planned comparisons individually reported in Experiments 1A–1D, whether opaque and transparent primes differentially affected target decision latencies depended on SOA. Finally, because it did not interact with alphabet ($F_s < 1$), the interaction of transparency and SOA was present in the Roman–Roman alphabet condition, as well as in the Cyrillic–Roman alphabet condition.

In summary, whether alphabet alternated so as to reduce the orthographic similarity between primes and targets presented at an SOA of 250 msec or whether it remained consistent, target decision latencies after semantically transparent and opaque morphological relatives differed significantly. Latencies after transparent and opaque primes did not differ at the shorter SOA of 48 msec, however. Finally, facilitation after inflected primes was significant at both SOAs, and its magnitude remained virtually unchanged.

Although the transparent and the opaque derivational primes differed with respect to semantic transparency and similarity of meaning, repetition of the base morpheme (e.g., VOL) and the inflectional suffix (e.g., E) along with variation of only the prefix (e.g., PRI, ZA) guaranteed that the primes were matched for orthographic overlap with the target (e.g., VOLIM). Therefore, differences between transparent and opaque derivational primes in the present outcome are consistent with claims that effects of orthographic similarity are inadequate to account for patterns of morphological facilitation (Feldman & Moskovljević, 1987). Nevertheless, it is possible that abstract form similarity may interact with semantic similarity under particular temporal configurations of prime and target. In fact, because form facilitation arises at short SOAs (e.g., Drews & Zwitserlood, 1995; Feldman, 2001), we suspect that the SOA-invariant facilitation after inflected primes reflects the contributions of (abstract) form in conjunction with high semantic similarity.

GENERAL DISCUSSION

In the present study, we compared decision latencies after inflectionally and derivationally related primes and differences among derivations that varied along a dimension of semantic transparency. Inflections and derivations differed in the degree of form, as well as semantic similarity, that they shared with the target. Transparent and opaque derived primes differed only along a semantic dimension. Our study in Serbian complements previous primed visual lexical decision studies in English and in Hebrew, because derivations were formed by the addition of a derivational prefix to the base and because primes and targets were always verbal formations. By tracking the magnitude of morphological facilitation after transparent and opaque primes across SOAs within the unmasked lexical decision task, we were able to explore the time course over which effects of semantic transparency emerged in morphological processing. In our experiments, visual primes preceded visual targets at SOAs of 48 or 250 msec. From the work in English, we knew that effects of semantic transparency were variable over this range of SOAs (Feldman & Soltano, 1999; Feldman et al., 2001). Consistent with earlier findings in English, we observed that in the morphologically rich language of Serbian, the effect of semantic transparency among derivations formed by prefixation was evident at the longer, but not at the shorter, prime duration.

We introduced an alphabet manipulation between prime and target to reduce their orthographic similarity. Interestingly, the pattern of facilitation across experiments revealed an effect of alphabet such that the overall magnitude of morphological facilitation was greater by about 30 msec when the prime and the target were presented in different alphabets than when the alphabet was consistent. To our knowledge, this is the first report that in immediate unmasked priming, the magnitude of facilitation in Serbian increased with alphabet alternation and the consequent reduction in similarity between prime and target. A possible interpretation is that orthographic inhibition attenuates morphological facilitation when prime and target look similar, as in the pure alphabet condition. For phonologically ambiguous Serbian targets with masked primes in a naming task at SOAs of 550 msec or greater, same-alphabet contexts tended to facilitate naming more than different-alphabet contexts did, presumably because alphabet consistency helped to resolve phonological ambiguity in the target (e.g., Lukatela et al., 1993; see also Lukatela et al., 1991). Perhaps more relevant, for phonologically unambiguous Serbian targets presented at an SOA of 700 msec, decision latencies in same-alphabet contexts were about 20 msec faster than those in different-alphabet contexts (Lukatela, Feldman, Turvey, Carello, & Katz, 1989). Of course, the presence of phonologically ambiguous words and longer SOAs may limit the applicability of those findings. In the present study, by contrast, alphabet alternation between prime and target benefited decision latencies. Because we manipulated alphabet between participants and because the effect of alphabet did not interact with prime type, SOA, or the interaction of prime type and SOA, we do not interpret the outcome further.

The results of our experiments were strikingly similar despite the manipulation of alphabet for the prime. In both the consistent-alphabet (Experiments 1A and 1B) and the alternating-alphabet (Experiments 1C and 1D) contexts, the magnitude of facilitation following semantically transparent primes was reduced relative to inflectional primes and the relative difference did not change over SOA. Inflectional primes differed from the target only with respect to an inflectional suffix (i.e., E vs. IM). Therefore, these words were similar to the target both in form and in meaning. Greater overall (phonological and orthographic, as well as semantic) similarity is typical for inflections relative to even transparent derivations. We suggest that the greater combined similarity of form and meaning could account for augmented facilitation after inflectionally related, relative to derivationally related, primes in immediate priming.

The interaction of SOA and semantic transparency for derivations likewise dominated the outcomes of the experiments. Planned comparisons indicated that the difference between opaque and transparent derivational primes was significant at the 250-msec SOA but was absent at the shorter SOA. The pattern in Serbian replicated that reported by Feldman et al. (2001) in English. Like associative facilitation that increases with SOA (Lorch, 1982; Raveh, 1999), Feldman and her colleagues claimed that the semantic contribution to processing among morphological relatives progresses over time, so that differences between opaque and transparent forms become greater as SOA increases. In the present study, significant facilitation after inflectionally related primes accompanied the SOA × transparency interaction, thereby rendering implausible an interpretation based on lack of power to detect differences at the 48-msec SOA.

There are two methods by which to assess morphological effects in the literature, and it is interesting to note that, in the present study, reliance on one in isolation leads to an incomplete characterization of the role of semantic transparency. The traditional method focuses on the difference between target latencies after related and unrelated primes and is subject to potential problems associated with the construction of the unrelated baseline. For example, Frost et al. (1997) relied on an orthographically similar prime, whereas Feldman et al. (2001) and Marslen-Wilson et al. (1994) preferred a dissimilar prime. Crucially, however, there is evidence that when morphological relatives were similar in form and matched in length (e.g., FELL–FALL), evaluations of facilitation relative to orthographic and unrelated baselines differed (Feldman & Pastizzo, 2002; Pastizzo & Feldman, 2001a). Assessed against an unrelated prime, when both the prime and the target were presented in Roman at a 250-msec SOA, in the present study we observed that opaque primes had no effect (3 msec) on target decision latencies but that transparent primes produced significant morphological facilitation (25 msec). When primes were in Cyrillic and targets were in Roman, we observed that opaque primes produced facilitation (21 msec) on target decision, as did transparent primes (39 msec), and that both were significant.

In a study whose focus is semantic transparency, essential information derives from a direct comparison of target decision latencies after opaque and transparent primes. One advantage of this approach is that potential confounds related to the nature of the unrelated control can be avoided. When we compared target latencies after opaque and transparent primes directly, results replicated across alphabet environments. That is, the effect of transparency did not interact with alphabet of the prime, although it did interact with SOA. Evidently, a focus restricted to whether a morphologically related prime produced facilitation that meets the criterion for statistical significance fails to capture the overall pattern. Across alphabet contexts in Serbian, the effect of semantic transparency, as assessed by a significant difference in target decision latencies after opaque and transparent derived primes, was present at the long SOA but absent at the short SOA.

For a decompositional account, it is often argued that lexical representations for morphologically complex words are decomposed into their constituent morphemes and that morphological facilitation reflects the repeated activation of a morpheme in prime and target. Consequently, when transparent and opaque primes reduce decision latencies for a morphologically related target in a similar way, it is sometimes argued that decomposition is not sensitive to semantic similarity among relatives. In particular, on the basis of results with a forward masked priming task, Deutsch et al. (1998) have proposed a model of the (Hebrew) lexicon in which "all words derived from the same root are clustered via a shared representation of the root morpheme." Moreover, "this organization is independent of semantic factors" (p. 1250). Conversely, when transparent, but not opaque, derivations produce morphological facilitation, some have argued that all morphologically complex words may not be represented in the same manner within the lexicon. For example, on the basis of the outcome of a cross-modal priming task, Marslen-Wilson et al. (1994) have claimed that, in English, only those derivations that are semantically transparent are decomposed with respect to their constituents.

The interaction of SOA and transparency in the present study challenges the adequacy of a decompositional account of morphological facilitation. On the basis of patterns of facilitation across alphabets at a long SOA, one would claim that, as in English, only inflections and semantically transparent derivations are reliably decomposed. By contrast, on the basis of patterns of facilitation across alphabets at a short SOA, one would claim that, as in Hebrew, not only inflections, but also all derivations are decomposed. Stated generally, time-varying effects of semantic transparency highlight the shortcomings of simply interpreting significant morphological facilitation at a single SOA as evidence of a static lexical architecture. To elaborate, that degree of semantic similarity can influence the pattern of morphological facilitation only at a long SOA is difficult to reconcile with a semantic criterion for decomposition of lexical entries into their constituent morphemes.

An account that emphasizes similarity of form and of meaning as they contribute to word recognition and, by way of distributed patterns, of morphological activation (Plaut & Gonnerman, 2000; Rueckl et al., 1997) may be more compatible with graded magnitudes of facilitation. Accordingly, in the present study, because (inflected and) transparent derived forms are related in form and in meaning, they produce facilitation, but because opaque forms are similar in form but less reliable semantically, their effect on a target depends on the relative sensitivity of the particular experimental procedure to meaning. In essence, the critical interaction of transparency and SOA reflects the differential contributions of semantic similarity to performance in lexical decision with changes in processing time for the prime. The present findings complement another recent finding as well: Effects of semantic transparency among morphological relatives appear to be systematically graded across targets, depending on the productivity or family size of their base morphemes (Feldman & Pastizzo, 2002; Feldman et al., 2001).

In the present study, we demonstrated that the influence of semantic transparency on morphological facilitation varies over SOA in Serbian, a language with a highly productive morphology. Moreover, the finding is not restricted to visual primes and targets presented in the same alphabet. In essence, by manipulating SOA, we have replicated the contrasting patterns of transparency reported with masked primes in Hebrew and with cross-modal presentations in English. In conclusion, time- and task-varying patterns within a language call into question claims that languages differ with respect to a semantic criterion for morphological decomposition.

REFERENCES

Bentin, S., & Feldman, L. B. (1990). The contribution of morphological and semantic relatedness to repetition priming at short and long lags: Evidence from Hebrew. *Quarterly Journal of Experimental Psychology*, **42A**, 693-711.

Bentin, S., & Frost, R. (1995). Morphological factors in visual word identification in Hebrew. In L. B. Feldman (Ed.), *Morphological aspects of language processing*. (pp. 271-292). Hillsdale, NJ: Erlbaum.

Butterworth, B. (1983). Lexical representation. In B. Butterworth (Ed.), *Language production* (Vol. 2, pp. 257-294). San Diego: Academic Press.

Bybee, J. H. (1985). *Morphology*. Amsterdam: John Benjamins.

Deutsch, A., Frost, R., & Forster, K. (1998). Verbs and nouns are organized and accessed differently in the mental lexicon: Evidence from Hebrew. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **24**, 1238-1255.

Drews, E., & Zwitserlood, P. (1995). Morphological and orthographic similarity in visual word recognition. *Journal of Experimental Psychology: Human Perception & Performance*, **21**, 1098-1116.

Feldman, L. B. (1992). Morphological relationships revealed through the repetition priming task. In M. Noonan, P. Downing, & S. Lima (Eds.), *Linguistics and literacy* (pp. 239-254). Amsterdam: John Benjamins.

Feldman, L. B. (2001). Are morphological effects distinguishable from the effects of shared meaning and shared form? *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **26**, 1431-1444.

Feldman, L. B., & Barac-Cikoja, D. (1996). Serbo-Croatian: A biscriptal language. In P. T. Daniels & W. Bright (Eds.), *The world's writing systems* (pp. 769-772). New York: Oxford University Press.

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

Feldman, L. B., & Pastizzo, M. J. (2002). *Graded semantic compositionality alters morphological facilitation*. Manuscript submitted for publication.

Feldman, L. B., & Raveh, M. (in press). Semantic aspects of morphological processing. In J. Shimron (Ed.), *Language processing and language acquisition in languages with root-based morphology*. Amsterdam: John Benjamins.

Feldman, L. B., & Soltano, E. G. (1999). Morphological priming: The role of prime duration, semantic transparency and affix position. *Brain & Language*, **60**, 33-39.

Feldman, L. B., Soltano, E. G., Pastizzo, M., & Francis, S. (2001). *When does semantic transparency influence morphological processing?* Manuscript submitted for publication.

Frost, R., Deutsch, A., Gilboa, O., Tannenbaum, M., & Marslen-Wilson, W. (2000). Morphological priming: Dissociation of phonological, semantic, and morphological factors. *Memory & Cognition*, **28**, 1277-1288.

Frost, R., Forster, K., & Deutsch, A. (1997). What can we learn from the morphology of Hebrew? A masked-priming investigation of morphological representation. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **23**, 829-856.

Lorch, R. (1982). Priming and search processes in semantic memory: A test of three models of spreading activation. *Journal of Verbal Learning & Verbal Behavior*, **21**, 468-492.

Lukatela, G., Feldman, L. B., Turvey, M. T., Carello, C., & Katz, L. (1989). Context effects in bi-alphabetical word perception. *Journal of Memory & Language*, **28**, 214-236.

Lukatela, G., Gligorijević, B., Kostić, A., & Turvey, M. T. (1980). Representation of inflected nouns in the internal lexicon. *Memory & Cognition*, **8**, 415-423.

Lukatela, G., Lukatela, K., Carello, C., & Turvey, M. T. (1993). Reduction in alphabet priming with delay and degradation. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **19**, 1094-1100.

Lukatela, G., Turvey, M. T., & Todorović, D. (1991). Is alphabet biasing in bialphabetic word perception automatic and prelexical? *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **17**, 653-663.

Marslen-Wilson, W., Tyler, L., Waksler, R., & Older, L. (1994). Morphology and meaning in the English mental lexicon. *Psychological Review*, **101**, 3-33.

Partridge, M. (1964). *Serbo-Croatian practical grammar and reader*. Belgrade: University of Belgrade Press.

Pastizzo, M. J., & Feldman, L. B. (2001a). Discrepancies between orthographic and unrelated baselines in masked priming undermine a decompositional account of morphological facilitation. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **28**, 244-249.

Pastizzo, M. J., & Feldman, L. B. (2001b). Does prime modality influence morphological processing? *Brain & Language*, **81**, 28-41.

Plaut, D. C., & Gonnerman, L. M. (2000). Are non-semantic morphological effects incompatible with a distributed connectionist approach to lexical processing? *Language & Cognitive Processes*, **15**, 445-486.

Raveh, M. (1999). *The contribution of frequency and semantic similarity to morphological processing*. Unpublished doctoral dissertation, University of Connecticut.

Raveh, M., & Feldman, L. B. (1998, September). *The contribution of morphological relatives and affix position to morphological processing*. Paper presented at the X Congress of the European Society for Cognitive Psychology, Jerusalem.

Raveh, M., & Rueckl, J. (2000). Equivalent effects of inflected and derived primes: Long-term morphological priming in fragment completion and lexical decision. *Journal of Memory & Language*, **42**, 103-119.

Rueckl, J. G., Mikolinski, M., Raveh, M., Miner, C. S., & Mars, F. (1997). Morphological priming, connectionist networks, and masked fragment completion. *Journal of Memory & Language*, **36**, 382-405.

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning & Verbal Behavior*, **14**, 638-647.

(Manuscript received June 23, 2000;
revision accepted for publication February 15, 2002.)