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Semantic similarity influences early morphological priming in Serbian: A challenge to form-then-meaning accounts of word recognition

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Abstract

Semantically similar (e.g., coolant-COOL) primes produced greater facilitation than did form similar, semantically dissimilar (e.g., rampant-RAMP) primes when English words appeared in the forward masked primed lexical decision task (Feldman, O'Connor & Moscoso del Prado Martín, 2009). Results challenge claims that form-based semantically blind activation underlies early morphological facilitation. Some have argued that those English materials were not ideally constructed insofar as types of spelling changes to affixed stems in semantically similar and dissimilar pairs differed. The present study exploits Serbian's bialphabetism, rich morphology, and homographic (form-identical) stems to replicate early effects of semantic similarity. Further, it incorporates a within-target manipulation of prime type and of alphabet such that alphabet of prime-target pairs matched in Exp.1a and alternated in Exp.1b. Importantly, no letter or phoneme changes occurred between stems of prime and target. Results reveal significant effects of semantic similarity that are comparable with and without alphabet alternation. Semantic effects in Serbian replicate almost exactly those in English (Feldman et al., 2009) and suggest that even early in the course of processing, morphemes are units of meaning as well as form. Results fail to support models of lexical processing that postulate sequential access to the morphological form and then the semantic aspects of words.

Keywords

forward masked priming task; morpho-semantic processing; morpho-orthographic processing; semantic transparency, Serbian, morphology; Form-with-meaning accounts

Theories of word recognition differ as to whether orthographic form and meaning processes occur concurrently and interdependently or whether they occur sequentially and independently. Trivially, all models of visual recognition assume that a word's orthographic form plays a role in lexical access, so that the letters that make up a word strongly influence

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its interpretation. At issue is whether there is a stage of form processing that is isolated from semantics so that it is meaningful to claim that activation of a word form precedes activation of its meaning. If form processing is not autonomous from meaning processing then form codes can become structured by the contexts in which a word appears meaning that form and meaning are not readily isolable.

Semantic influences on word level processes have been detected in a variety of recognition tasks and similar effects arise in spoken recognition with pictures (e.g., Apfelbaum, Blumstein & McMurray, 2011) as with written words. In the visual lexical decision task, forward masked primes activate related targets more than unrelated primes do when semantic relatedness is based on forms like LGHT that are orthographically distorted words (Perea & Gomez, 2010). Even more relevant, when form overlap is equated, facilitation is greater for morphologically (FELL-FALL) than for form similar (FILL-FALL) prime-target pairs where only the former are similar in meaning (Pastizzo & Feldman, 2002: Crepaldi, Rastle, Coltheart & Nickels, 2010). Findings such as these are consistent with the cascaded activation of a word's semantics before orthographic processing terminates. The current study contrasts form-with-meaning accounts and sequential form-then-meaning accounts in the context of morphological processing.

Words are morphologically structured if they can be decomposed into multiple units (morphemes), as is the case with many words in English or in Serbian. For instance, segmentation of the affix ER from WHITER or FARMER leaves stems (WHITE and FARM) that are often, but not always, semantically similar to the original word. Other words such as CORNER or MOTHER only appear to be morphologically structured. They have a letter sequence such as ER that functions as an affix in many other words although not in these particular words. At the same time, their meaning is dissimilar to that of the words that are embedded in them (CORN or MOTH). Finally, there are words like CUTER that are composed of a stem and an affix but the stem CUTE cannot be derived simply by stripping off the ER affix because of its similarity to the homographic stem, CUT.

When words are composed of multiple morphemes, they are assumed to undergo segmentation into their constituent morphemes in the course of recognition. Accordingly in a priming task, processing of a morphologically complex (i.e., composed of multiple morphemes) prime leads to pre-activation of its stem in a morphologically related target and this produces morphological facilitation. When stimulus onset asynchronies (SOAs) are 100ms or more, it is difficult to interpret the results of priming studies in terms of a single, isolated stage of lexical processing because it is possible to use the prime to predict the target so that episodic and other strategic knowledge may contaminate lexical effects. Consequently, it is often assumed by masked priming researchers that SOAs longer than 100ms do not reveal “early” stages of processing during recognition. When forward masked primes and SOAs of 50ms or less are used, however, inter-level effects are less likely and it is generally assumed that effects arising with very brief SOAs reflect very early stages of processing.

Traditionally, models of visual recognition assume that word form guides lexical access. The controversy regarding an early role for semantics derives from a subset of morphological priming studies in which the prime and target always “appear” to be morphologically related; yet may or may not share meaning. In these priming tasks, it is common to report greater facilitation for semantically similar (whiter-WHITE) than for semantically dissimilar (corner-CORN)[1] prime-target pairs when at least 100ms separates

[1]Semantically dissimilar pairs do not qualify as morphologically opaque relatives because they are formed from different, albeit homographic, morphemes.

prime and target onsets in the lexical decision task (e.g., Marslen-Wilson, Tyler, Waksler, Older, 1994; Feldman, & Soltano, 1999). Crucially at shorter SOAs, fewer studies report significantly greater facilitation for semantically similar than for dissimilar pairs; either with (farmer-FARM vs. corner-CORN) or without (pledge-VOW vs. scrape-VOW) shared form. Rastle, Davis and New (2004) failed to detect a difference between semantically similar and dissimilar pairs that shared form. Rastle and Davis (2008) summarize other studies that replicate their null effect. They interpret the absence of an effect of semantic similarity in the presence of a form effect as evidence that masked and brief prime presentations tap into form-based processing where morpho-orthographic but not morpho-semantic properties of the stem govern morphological facilitation (for a second perspective see Rueckl & Aicher, 2008).

Morpho-orthographic refers to effects that arise from the frequent repetition of the orthographic properties of a morpheme (i.e., “act” appears in many words), and morpho-semantic refers to the meaning of a stem that persists despite variation in context (i.e., an “actor” is someone who acts; an “action” is the outcome of an act). In essence in a morpho-orthographic process, morphemes are units of form but not of meaning. Elsewhere, we have termed this a form-then-meaning account. Feldman, O'Connor, and Moscoso del Prado Martín (2009) conducted a meta-analysis of Rastle and Davis's (2008) morphological priming review. Their results raise the possibility of semantic contributions to a purportedly morpho-orthographic stage insofar as facilitation is significantly greater for semantically similar than for dissimilar pairs. The present study provides further documentation of semantic influences concurrent with early formed-based processing, this time in Serbian, a language that features a shallow writing system in each of its two alphabets, along with a rich morphology.

Evidence that the degree of similarity between the meanings of morphologically complex primes and their stems influences magnitudes of facilitation under masked primed presentation conditions in the lexical decision task does not derive from a single experiment or a single meta-analysis. Across a range of SOAs (32, 50, 67, 87, 100) in English, responses following semantically similar primes were faster than after dissimilar primes matched for degree of form overlap. Similar results arose with both native (Feldman, Moscoso del Prado Martín, & O'Connor, 2011) and nonnative speakers (Diependaele, Duñabeitia, & Keuleers, 2011). These findings with different materials replicate Feldman et al. (2009) insofar as semantically similar pairs produced greater facilitation than did semantically dissimilar pairs. Davis and Rastle (2010) claim that it is “logically possible” for facilitation to reflect both morpho-orthographic and morpho-semantic processing in a single experiment, but that these effects are independent in that they arise in different brain regions or in different time windows. They allow for the possibility that when primes are forward masked, semantic similarity and morpho-orthographic structure might separately contribute to facilitation. Crucially, they fail to grant the possibility that effects of semantic and form similarity are interdependent and inform each other early in the course of a single recognition process. For them, early processing is semantically blind and when semantic effects appear to arise, they argue that methodological deviations pertaining to stimulus construction are likely to have produced them (e.g., Feldman et al., 2009). More specifically, Davis and Rastle (2010) focus on patterns of orthographic alternations between the semantically similar and dissimilar materials and contend that the dissimilar condition included many prime-target pairs whose orthographic changes were non-systematic and arbitrary according to criteria promulgated by McCormick, Rastle, & Davis (2008).

We seek to replicate the much-contested semantic influences on early morphological processing, this time in Serbian a language written in two alphabets, Roman and Cyrillic. Serbian readers are generally fluent in both alphabets. Together with its shallow writing system and consistent grapheme to phoneme mappings in each of its two alphabets, Serbian features a rich morphology and many homographic stems. At long lags, when items intervene between prime and target, magnitudes of morphological facilitation are comparable whether prime and target are visually similar (because the shared morpheme is written in the same alphabet) or are less similar because alphabet alternates between prime and target (Feldman, & Moskovljević, 1987). In the present study we compare facilitation after semantically similar ("raved-RAVE") and dissimilar ("raven-RAVE") prime-target pairs that appear to have form-identical stems when the affix (viz., ED) or possible affix (viz., EN) is removed. Thus, affixes like ED or EN function to disambiguate form-identical (or homographic) stems like RAV(E) as either RAVED or RAVEN. One consequence is that only when they are semantically similar are targets morphological relatives of the prime. The dissimilar primes in the present study could be pseudo-affixed forms of homographic stems like "raven-RAVE" or affixed forms of a homographic stem like "cuter-CUT".

Importantly, the CUTER-CUT example in English violates the preserved phonology constraint whereas all prime-target pairs in the Serbian materials maintained the spelling and pronunciation of the shared portion. Consistent form within a pair is important because a small proportion of the materials in the Feldman et al. (2009, 2010) experiments with English materials included primes and targets with alternations in the spelling or pronunciation of the stem. Examples of this are the dissimilar pairs "cabbage-CAB", "cavity-CAVE", and "palatable-PALACE". Feldman et al. (2009, 2010) did match the number of these spelling changes between their semantically dissimilar and similar conditions, however. Examples of such changes in the similar condition include "palatial-PALACE", "striding-STRIDE", and "batter-BAT". Obviously, materials that do not introduce spelling changes between the similar and dissimilar conditions are preferable.

Finally, alphabet of prime and target was manipulated (Roman primes and targets in Expt. 1a; Cyrillic primes and Roman targets in Expt. 1b) so as to reduce orthographic similarity between prime and target. If effects of semantic similarity arise when prime and target are in different alphabets and if effects are comparable to pairs with no alphabet change then morphological facilitation would be less likely to derive from repetition of orthographic structure between prime and target. Also noteworthy is that, across participants, the same target appeared with the semantically similar and dissimilar prime so that target properties would not be confounded between the similar and dissimilar conditions. Feldman and colleagues used different targets between the similar and dissimilar conditions in earlier work (Feldman et al., 2009), but incorporated a within-target design in later experiments (Feldman et al., 2010). Both presented English materials and contained many instances of spelling changes between prime and target. To anticipate, results replicate, in Serbian, the early effects of semantics on facilitation when spelling and pronunciation changes between prime and target that can occur in English were absent.

Method

Participants

One hundred fifteen students from the Faculty of Philosophy at the University of Belgrade participated in partial fulfillment of the introductory psychology course requirements. All were native speakers of Serbian with no known reading or speech disorders and normal or corrected-to-normal vision. The national curriculum dictates that all students learn both the Roman and Cyrillic scripts in elementary school, with a one year lag in favor of Cyrillic. None participated in both experiments.

Materials

Sixty nominative singular nouns or infinitive verbs were selected as critical word targets. Three prime types (similar, dissimilar, unrelated) appeared with each target across counterbalancing lists. The appendix comprises the targets, their English translations, the three primes for each target, and their parse into stem and affix. Unrelated primes were formed from a semantically and orthographically different stem than their target. In the other two conditions, form similarity was equated. In the semantically similar condition, the meaning of the target (e.g., RAT meaning *war*; GLAD meaning *hunger*) was preserved in the affixed prime (e.g., RATOVI *war* nom pl; GLADAN meaning *hungry*) so that members of a pair (RATOVI-RAT; GLADAN-GLAD) were morphologically related by inflection or by derivation. In the semantically dissimilar condition, some primes were morphologically simple (e.g., RATAR, meaning *peasant; GLADAK* meaning *smooth*) but ended with a letter sequence (e.g., AR, AK) that functions as an affix in other words. Other semantically dissimilar primes were morphologically complex and were formed from stems that were homographic with the target. Both morphologically simple and complex affixed words appeared as unrelated primes so as to mimic the two related prime types, and these primes contained minimal letter overlap with their targets.

Items in the different prime types were matched on frequency (using frequency counts extracted from Kostić, 1999) and word length in letters (see Table 1). Experimental lists that contain a high proportion of identical (ID) prime-target filler trials (e.g., *papir-PAPIR*) produce semantic facilitation even when primes are forward masked (Bodner & Masson, 2003). Moreover, the inclusion of form-similar word-word ID and word-nonword quasi-ID trials to create a relatedness proportion of 75% significantly boosts semantic and morphological but not orthographic facilitation (Feldman & Basnight-Brown, 2008). Therefore in the present study, as in Feldman et al. (2009), we introduced many ID filler trials and concomitant listwise semantic similarity so as to maximize morphological facilitation and the potential to detect an interaction with semantic similarity. Finally, like the word-word pairs, two thirds of the word-nonword pairs were orthographically similar and one third was not. By maintaining the same ratio of form similar and dissimilar pairs, form similarity did not predict lexicality of the target (cf., Rastle et al., 2004).

Design

Prime type was manipulated within participants and alphabet was manipulated between participants (i.e., in Exp. 1a participants viewed both prime and target in the Roman alphabet, whereas in Exp. 1b participants saw a Cyrillic prime followed by a Roman target). Across participants, all targets were preceded by semantically similar, dissimilar and unrelated primes equally often and, with the exception of one oversight, no target was repeated within a session. In addition to the 60 critical items described above, 30 word-word pairs were included as filler trials. All of the word-word filler pairs had identical primes and targets (i.e., “identity” trials). One half included an affix and thus were complex. Each participant responded to 90 word target trials of which 70 were similar in form. To parallel the word-word pairs, 70 of the word-nonword pairs contained the nonword target's form plus a frequent letter sequence as the ending on the prime (e.g., PITAK; PIT; PRAZAN-PRAZ) and 20 shared no letters in the same position (TORBICA-KIMEL).

Procedure

The task was presented on a PC compatible computer running Superlab 2 software. Each trial began with a 500ms fixation mark (+) that appeared in the middle of the screen. An ISI of 50ms occurred before the forward mask (number of # signs matched to prime length) that lasted 450ms. The prime then appeared in lowercase letters for 50ms and replaced the mask.

The target was printed in uppercase letters and replaced the prime in the same position. Targets were visible for 3000ms or until response. The inter-trial interval was 1000ms.

Items were presented in black 16-point Helvetica font (Cyrillic or Roman) on a white background. A different random order of prime-target pairs appeared for each participant. Participants made a lexical decision for each target by pressing the right button (green) for words and the left button (red) for nonwords. Participants responded to 12 practice trials before the experimental session, and the composition of the practice stimuli mirrored that of the stimuli in the main experiment.

Results

Overall mean accuracy rates for each subject and each item on critical trials were computed. All participants had error rates lower than 30% and hence no participant's data were discarded. Experiment 1b was conducted after the completion of Experiment 1a. Both experiments were collapsed together into two single analyses (one for the RTs and another for errors). RT analyses include only correct responses. One item, “PAR”, appeared twice in each session of Experiment 1b due to a programming error and was deleted from all analyses.

Median correct reaction times (henceforth RTs) were 714ms, 674ms, and 689ms for unrelated, similar and dissimilar conditions respectively. In order to approximate the preconditions of a Gaussian linear model (i.e., normality and homoscedasticity), the correct RTs where transformed using the changed sign reciprocal transform of the RT in seconds (i.e., -1000/RT). This transformation was chosen by maximum-likelihood estimates of the best Box-Cox transformation for the particular regression models (Box & Cox, 1964). Linear mixed effect models (cf., Baayen, Davidson, & Bates, 2008) were fitted to the transformed RTs with a fixed effect of prime type (similar, dissimilar, unrelated; coded as contrasts in relation to the unrelated condition, which was mapped into the intercept) and random effects of target and participant. The significance of the fixed effect coefficients was evaluated by sampling 10,000 instances of the model using a Markov-Chain Monte Carlo technique. Neither an effect of alphabet (mixed vs. Roman) nor the interaction of alphabet by prime type was significant so they were not retained in the final model. In order to explicitly test the contrast between semantically similar and semantically dissimilar pairs, an additional (separate) model was fit, including only the data points in these two conditions. Both LME models were subjected to model criticism by examining the distribution of the model residuals using quantile-quantile plots against a theoretical standard normal. Evaluations showed that the residuals within both models were almost exactly normally distributed, with just two possible outlier trials that deviated from normality. Refitting the models excluding these points did not modify the results. Further, we fitted additional models considering the possibility of mixed-effect interactions between either subject or target item identity and the experimental condition. Model comparison (both using chi-squared log-likelihood tests and the Bayesian Information Criterion) indicated that neither of these interactions sufficiently improved the model so as to justify its inclusion into the final model. The largest absolute value correlation between the fixed effects in the final model was 0.51.[2]

The upper panel of Table 2 summarizes the significant fixed effects of the RT models. To summarize, unrelated trials were slower than both dissimilar and similar trials (reversing the reciprocal transformation one can estimate the effect sizes to be 25ms for the dissimilar vs.

[2]Notice that the correlations between fixed effects are not a crucial issue in orthogonal designs such as this one. We nevertheless report them to adhere to reporting standards.

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unrelated and about 40ms for similar vs. unrelated). In this restricted model (restricted to include only those factors that were significant), the correlation between the fixed effects was 0.19. The bottom of Table 2 reports the explicit comparison between the similar and dissimilar pairs, which was also significant (as one would expect, back-transformation from the reciprocal scale revealed that this difference was 15ms).

Accuracy data were analyzed using logistic mixed-effect model regression. As with RT, neither the effect of alphabet change nor its interaction with the effect of prime type reached significance. Thus, both were dropped from the models. Similarly, model comparisons failed to provide evidence of mixed effect interactions between prime type and subject or item identity. The maximum absolute value of the correlation between fixed effects in this model was 0.50. As can be seen in the top panel of Table 3, the similar trials elicited significantly fewer errors than unrelated trials (about 2.1% more), whereas no significant difference arose between dissimilar and unrelated trials. The maximum absolute value of the correlation between fixed effects in this model was 0.50. The bottom panel of Table 2 shows a model whose results confirm that the difference in the number of errors between unrelated and similar trials was significantly smaller (about 2.8%) than between unrelated and dissimilar trials. The correlation between the fixed effects in this model was 0.27.

Discussion

In summary, semantically similar primes produced greater facilitation than did semantically dissimilar primes in the forward masked priming task in Serbian. This difference was not due to differing orthographic similarity between prime and target induced by using a single or multiple alphabets. In addition, it was not influenced by contributions of orthographic similarity being greater for the similar primes, because form similarity was equated between semantically similar and dissimilar pairs. Although semantic similarity effects tend to be small numerically, results of the present study in inflectionally-rich Serbian, like those of Feldman et al. (2009) in relatively impoverished English, show very early effects of semantics under conditions that are purported to foster morpho-orthographic but not morpho-semantic processing. In this respect, both studies confirm statistically a pattern that is present in the literature as a whole, albeit not uniformly significant in individual studies. Futhermore, even the estimated magnitude of the effect is consistent with the magnitude reported by Feldman et. al. (2009) for English.

The novel contribution of the present study is to demonstrate effects of semantic similarity when primes are forward masked and briefly presented and when the same targets are paired with semantically similar and dissimilar primes. This replication makes it implausible that uncontrolled properties of dissimilar targets were responsible for effects of transparency in Feldman et al.'s earlier study, as had been hypothesized by Davis and Rastle (2010).

A secondary novel finding is that any reduction of shared orthographic form due to manipulations of prime-target alphabet did not significantly reduce the effect of semantic transparency (13ms vs.16ms). If one assumed that early morphological priming is caused by form overlap, then one might have expected facilitation to be greater when the alphabet did not change from prime to target. However, cross alphabets comparisons failed to support any explicit role of orthographic form.

Letter sequences that behaved in a semantically systematic manner in prime and target were easier and faster to categorize as words than those that were inconsistent. Similar and dissimilar primes shared orthographically-defined stems and differed only with respect to affixes. Therefore it is unlikely that the mechanism that underlies morphological facilitation entails that the stem of a morphologically complex or pseudocomplex prime, decomposed and isolated from its affix, preactivates the target (Rastle et al., 2004). Rather, differences between similar and dissimilar primes could only arise when stem processing is not independent of affix processing. This outcome in a priming paradigm complements reported interactions of affix and stem processes in single word recognition (e.g., Baayen, Milin, Filipović Durdević, Hendrix, & Marelli, 2011). Evidently, even at very brief SOAs, morphological processing is not restricted to form-based segmentation –i.e., traditional "affix-stripping"- of the stem from the whole word. Rather, it makes contact with a stem's combinatorial behavior, defined with respect to the morpheme or word contexts in which it appears.

Here and elsewhere, it is often asserted that the masked priming paradigm taps "early" phases of processing because primes appear very briefly and participants are not consciously aware of them. Demarcating early from late processing in this priming task only is compelling, however, if the recognition system stops processing the prime when the target appears. If prime and target can be processed concurrently then a distinction between early and late processes is more difficult to defend. Nonetheless, with brief SOAs and masked primes, we have demonstrated a semantic influence on what others have claimed is a purely form-based stage of processing. We prefer to characterize semantic and morphological influences on orthographic structure in terms of long term usage patterns for stems and words across varied contexts and assume that words that appear in similar contexts are similar in meaning. For example, FARMER and FARM co-occur more systematically than do words with equal letter overlap such as CORNER and CORN and this alters orthographic processing. Thus in the present experiments and others, semantic similarity allows semantically similar primes (e.g., farmer-FARM) to benefit target processing in a way that dissimilar primes (e.g., corner-CORN) cannot. We acknowledge, nonetheless, that other accounts of semantics may handle our data as well. More contentious is whether some variant of a model with separate orthographic and semantic levels and cascaded activation between them constitutes a viable option. Results of the present study, although limited to a single SOA in a single language, reveal cascaded activation of a word's semantics before orthographic processing terminates. With respect to morphological processing, what is certain is that results are consistent with claims (e.g., Moscoso del Prado Martín, 2007; Plaut & Gonnerman, 2000) that morphemes are units of meaning and units of form so that morpho-orthographic and morpho-semantic processes are not independent and sequential. Our results are also are consistent with neurophysiological evidence showing near-simultaneous access to the orthographic and semantic aspects of the "neural assembly" that is associated to a word (e.g., Pulvermüller, 1999). In conclusion, results contribute to a growing literature challenging the universality of the form-then-meaning assumption within models of "early" word recognition.

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Appendix

Appendix

Critical prime and target stimuli presented in the present study

Target			Similar Prime		Dissimilar Prime		Unrelated Prime	
Whole Word	Stem + Affix	Translation	Whole Word	Stem + Affix	Whole Word	Stem + Affix	Whole Word	Stem + Affix
CAR	car	tzar	carem	car-em	carina	carin-a	kvaka	kvak-a
ČIN	čin	rank	činom	čin-om	činima	čini-ma	veslo	vesl-o
CRV	crv	worm	crvom	crv-om	crven	crven-0	ovca	ovc-a
ČVOR	čvor	knot	čvorovi	čvor-ovi	čvorak	čvorak-0	tigar	tigar-0
DAN	dan	day	danu	dan-u	danak	danak-0	čoban	čoban-0
DOB*	dob*	age	dobom	dob-om	dobar	dobar-0	hladan	hlad-an
DRUG	drug	friend	drugovi	drug-ovi	drugima	drug-ima	pramac	pramac-0
GAS	gas	gas	gasovi	gas-ovi	gasim	gasi-m	levak	levak-0
GLAD	glad	hunger	gladan	glad-an	gladak	glad-ak	stablo	stablo-0
GRB	grb	coat of arms	grbovi	grb-ovi	grbav	grb-av	detlić	detlić-0
GRM	grm	bush	grmu	grm-u	grmi	grmi-0	dleto	dlet-o
HRAM	hram	temple	hramu	hram-u	hramati	hrama-ti	pismo	pism-o
IZNOS	iznos	amount	iznosom	iznos-om	iznosim	iznos-im	javor	javor-0
JAVITI	javi-ti	to call up	javim	javi-m	javan	javan-0	palata	palat-a
KANTA	kant-a	bucket	kantu	kant-u	kantar	kantar-0	kruška	krušk-a
KIP	kip	statue	kipovi	kip-ovi	kipim	kip-im	jabuka	jabuk-a
KLAS*	klas*	blade of wheat	klasje	klas-je	klase	klas-e	pepeo	pepeo-0
KLIP	klip	piston	klipu	klip-u	klipan	klipan-0	maska	mask-a
KLJUČ	ključ	key	ključem	ključ-em	ključati	ključa-ti	miris	miris-0
LAVA	lav-a	lava	lavi	lav-i	lavovi	lav-ovi	kofer	kofer-0
LOZ*	loz*	lottery ticket	lozovi	loz-ovi	loze	loz-e	bič	bič-0
MALJ	malj	hammer	maljem	malj-em	malje	malj-e	ograda	ograd-a
MRK*	mrk*	dark	mrkom	mrk-om	mrkva	mrkv-a	crep	crep-0
MUTITI	muti-ti	to muddy, to smear	mutim	muti-m	mutav	mut-av	pevanje	peva-nje
MUZA	muz-a	muse	muzom	muz-om	muzem	muze-m	limun	limun-0
NARAV	narav	temper	naravi	narav-i	naravno	narav-no	lovor	lovor-0
NASTAVA	nastav-a	lectures	nastavu	natav-u	nastavak	nastav-ak	maslac	maslac-0
NOS	nos	nose	nosem	nos-em	nosim	nosi-m	pena	pen-a
ODELO	odel-o	suit	odel-om	odel-om	odeliti	odeli-ti	glas	glas-0
ORGAN	organ	organ	organ-i	organ-i	organista	organi-sta	prolaz	prolaz-0
PAR*	par*	pair	par-ovi	par-ovi	pare	par-e	stadion	stadion-0
PITATI	pita-ti	to ask	pita-m	pita-m	pitu	pit-u	sumrak	sumrak-0
PLAVITI	plavi-ti	to flood	plavi-š	plavi-š	plavom	plav-om	lanac	lanac-0
POJATA*	pojat-a*	hut	pojat-om	pojat-om	pojati	poja-ti	rovac	rovac-0
POKORA	pokor-a	penance	pokor-u	pokor-u	pokoran	pokor-an	lakom	lakom-0
POMOR	pomor	apocalypse	pomo-ru	pomor-u	pomorac	pomor-ac	ohol	ohol-0
POREDITI	poredi-ti	to compare	poredi-m	poredi-m	poredak	pored-ak	krigla	krigl-a
POSADA	posad-a	crew	posad-u	posad-u	posadim	posadi-m	ogledalo	ogledal-o
POSTAVA	postav-a	lining	postav-u	postav-u	postavim	postavi-m	razum	razum-0
POSUDA	posud-a	vessel	posud-om	posud-om	posudim	posudi-m	biser	biser-0

Target			Similar Prime		Dissimilar Prime		Unrelated Prime	
Whole Word	Stem + Affix	Translation	Whole Word	Stem + Affix	Whole Word	Stem + Affix	Whole Word	Stem + Affix
POTEZ	potez	stroke	potez-om	potez-om	potezati	poteza-ti	safir	safir-0
POVOD	povod	cause, motive	povod-u	povod-u	povodac	povod-ac	uzlet	uzlet-0
PRAVA	prav-a	straight line	prav-oj	prav-oj	pravite	pravi-te	zamor	zamor-0
PRAZNIK*	praznik*	holiday	praznik-u	praznik-u	praznina	praznina	kolač	kolač-0
PROJEKT	projekt	project	projekt-u	projekt-u	projektor	projektor-0	sestra	sestr-a
PROTEZA	protez-a	artificial limb	protez-u	protez-u	protezati	proteza-ti	kafana	kafan-a
PUST*	pust*	wasted, deserted	pustom	pust-om	pustim	pusti-m	brat	brat-0
RANA	ran-a	wound	ranama	ran-ama	ranog	ran-og	čizma	čizm-a
RAT	rat	war	ratovi	rat-ovi	ratar	rat-ar	kanal	kanal-0
RAZRED	razred	class	razredu	razred-u	razrediti	razredi-ti	balvan	balvan-0
RED	red	order	redom	red-om	redak	redak	prsten	prsten-0
REP	rep	tail	repom	rep-om	repama	rep-ama	film	film-0
REZ	rez	cut	rezom	rez-om	rezak	rez-ak	korpa	korpk-a
ROD	rod	gender	rodovi	rod-ovi	rodama	rod-ama	bulka	bulk-a
RUM	rum	rum	rumom	rum-om	rumen	rumen-0	plaža	plaž-a
RUŽ	ruž	lipstick	ružem	ruž-em	ružama	ruž-ama	žamor	žamor-0
SIT	sit	fed up	sitog	sit-og	sitan	sitan-0	buka	buk-a
STAJA*	staj-a*	barn	stajama	staj-ama	stajati	staja-ti	malina	malin-a
TON	ton	tone	tonovi	ton-ovi	tonem	tone-m	konopac	konopac-0
VRAT	vrat	neck	vratu	vrat-u	vratima	vrat-ima	domar	dom-ar-0

References

Apfelbaum KS, Blumstein SE, McMurray B. Semantic priming is affected by real-time phonological competition: Evidence for continuous cascading systems. Psychonomic Bulletin & Review. 2011:141–149. DOI 10.3758/s13423-010-0039-8. [PubMed: 21327343]

Baayen RH, Davidson DJ, Bates DM. Mixed-effects modeling with crossed random effects for subjects and items. Journal of Memory and Language. 2008; 59:390–412.

Baayen RH, Milin P, Filipović Durdević D, Hendrix P, Marelli M. An amorphous model for morphological processing in visual comprehension based on naive discriminative learning. Psychological Review. 2011; 118:438–481. [PubMed: 21744979]

Bodner GE, Masson MEJ. Beyond spreading activation: An influence of relatedness proportion on masked semantic priming. Psychonomic Bulletin & Review. 2003; 10:645–652. [PubMed: 14620359]

Box GEP, Cox DR. An analysis of transformations (with discussion). Journal of the Royal Statistical Society B. 1964; 26:211–252.

Crepaldi D, Rastle K, Coltheart M, Nickels L. 'Fell' primes 'fall', but does 'bell' prime 'ball'? Masked priming with irregularly inflected primes. Journal of Memory and Language. 2010; 63:83–99.

Davis MH, Rastle K. Form and meaning in early morphological processing: Comment on Feldman, O'Connor and Moscoso del Prado Martín. Psychonomic Bulletin & Review. 2010; 17:749–755. [PubMed: 21037177]

Diependaele K, Duñabeitia J, Keuleers E. Fast morphological effects in first and second language word recognition. Journal of Memory and Language. 2011; 64:344–358.

Feldman LB, Basnight-Brown DB. List context fosters semantic processing: Parallels between semantic and morphological facilitation when primes are forward masked. Journal of Experimental Psychology: Learning, Memory and Cognition. 2008; 34:680–687.

Feldman, LB.; Moscoso del Prado Martín, F.; O'Connor, PA. Must analysis of meaning follow analysis of form? A time course analysis.. 2011. Ms revised for publication

Feldman LB, Moskovljević J. Repetition priming is not purely episodic in origin. Journal of Experimental Psychology: Learning, Memory and Cognition. 1987; 13:573–581.

Feldman LB, O'Connor PA, Moscoso del Prado Martín F. Early morphological processing is morpho-semantic and not simply morpho-orthographic: A violation of form-then-meaning accounts of word recognition. Psychonomic Bulletin & Review. 2009; 16:684–691. [PubMed: 19648453]

Feldman LB, Soltano EG. Morphological priming: The role of prime duration, semantic transparency and affix position. Brain and Language. 1999; 68:33–39. doi:10.1006/brln.1999.2077. [PubMed: 10433736]

Kostic, Dj. *Frekvencijski recnik savremenog srpskog jezika* (“Frequency dictionary of contemporary Serbian language”).. Institute for Experimental Phonetics and Speech Pathology & Laboratory of Experimental Psychology, University of Belgrade; Serbia: 1999. Availablefrom: http://www.serbian-corpus.edu.rs

Marslen-Wilson W, Tyler LK, Waksler R, Older L. Morphology and meaning in the English mental lexicon. Psychological Review. 1994; 101:3–33. doi: 10.1037/0033-295X.101.1.3.

McCormick SF, Rastle K, Davis MJ. Is there a ‘fete’ in ‘fetish’? Effects of orthographic opacity on morpho-orthographic segmentation in visual word recognition. Journal of Memory and Language. 2008; 58:307–326.

Moscoso del Prado Martín F. Co-Occurrence and the effect of inflectional paradigms. Lingua e Linguaggio, V1.2. 2007:247–262.

Pastizzo MJ, Feldman LB. Discrepancies between orthographic and unrelated baselines in masked priming undermine a decompositional account of morphological facilitation. Journal of Experimental Psychology: Learning, Memory and Cognition. 2002; 28:244–249.

Plaut DC, Gonnerman LM. Are non-semantic morphological effects incompatible with a distributed connectionist approach to lexical processing? Language and Cognitive Processes. 2000; 15:445–485.

Perea M, Gomez P. Does LGHT prime DARK? Masked associative priming with addition neighbors. Memory and Cognition. 2010; 38:513–518.

Pulvermüller F. Words in the Brain's Language. Behavioral and Brain Sciences. 1999; 22:253–336. [PubMed: 11301524]

Rastle K, Davis MH. Morphological decomposition based on the analysis of orthography. Language and Cognitive Processes. 2008; 23:942–971.

Rastle K, Davis MH, New B. The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. Psychonomic Bulletin & Review. 2004; 11:1090–1098. [PubMed: 15875981]

Rueckl JG, Aicher KA. Are CORNER and BROTHER morphologically complex? Not in the long term. Language and Cognitive Processes. 2008; 23:972–1001. [PubMed: 22933828]

Table 1

Mean (standard deviation) log frequency and length for the critical primes and targets used in the current study.

Attribute	Prime Type – Semantic Relation			Target
	Similar	Dissimilar	Unrelated	
Length	5.9 (0.9)	6.1 (1.3)	5.3 (0.9)	4.5 (1.4)
Log Frequency	0.79 (0.51)	0.96 (0.78)	0.79 (0.06)	1.76 (0.74)

Table 2

Results of linear mixed effects modeling for reaction times (RT) and error rates (ERR) comparing the semantically similar (Sim) and dissimilar (Dis) conditions to each other and to the unrelated (UR) condition across experiments 1a and 1b

Overall Model RT	Estimate	MCMC Mean Estimate	HPD 95% CI	*p*(MCMC)
Intercept (UR)	-1.3987	-1.3992	[-1.4343, -1.3605]	.0001
Sim vs. UR	-0.0837	-0.0837	[-0.1000, -0.0679]	.0001
Dis vs. UR	-0.0515	-0.0516	[-0.0685, -0.0360]	.0001
Sim vs. Dis Intercept (Sim)	1.4823	-1.4834	[-1.5212, -1.4450]	.0001
Sim vs. Dis	0.0315	0.0313	[0.0147, 0.0475]	.0001

Overall Model ERR	Estimate	Standard Error	*z* Value	Pr(>|z)
Intercept (UR)	2.4785	0.21093	11.751	.0001
Sim vs. UR	0.3315	0.10551	3.142	.0017
Dis vs. UR	-0.1069	0.09977	-1.072	.2839
Sim vs. Dis Intercept (Sim)	2.8347	0.2223	12.749	.0001
Sim vs. Dis	-0.4384	0.1031	-4.253	.0001