Journal of Experimental Psychology:
Learning, Memory, and Cognition
2008, Vol. 34, No. 3, 680–687

0278-7393/08/$12.00 DOI: 10.1037/0278-7393.34.3.680

BRIEF REPORTS

List Context Fosters Semantic Processing: Parallels Between Semantic and Morphological Facilitation When Primes Are Forward Masked

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The authors examined patterns of facilitation under forward-masked priming conditions across 3 list contexts (Experiments 1–3) that varied with respect to properties of filler trials—(a) mixed (morphological, orthographic, semantic), (b) identity, and (c) semantic—but held the relatedness proportion constant (75%). Facilitation for targets that were related morphologically to their prime occurred regardless of filler context, but facilitation for semantically related pairs occurred only in the context of identity and semantic fillers. Facilitation was absent for orthographically similar prime–target pairs in all 3 filler contexts when matching numbers of orthographically similar word–word and word–nonword prime–target pairs rendered orthographic similarity uninformative with respect to lexicality of the target. Enhanced semantic and morphological facilitation in the context of identity and semantic relative to mixed fillers support a semantically attuned, as contrasted with a purely form-based, account of early morphological processing.

Keywords: forward-masked primes, semantic priming, morphological priming, prime validity, prime recruitment

When primes are forward masked and appear for durations on the order of 50 ms or less, readers generally are unaware of their presentation. Nonetheless, various dimensions of similarity between forward-masked primes and their targets differentially influence this early phase of target recognition. Typically, it is difficult to observe semantic (e.g., *craft–ART*) facilitation when primes are forward masked and prime durations are as short as 50 ms in the lexical decision task (Forster, Mohan, & Hector, 2003; Rastle, Davis, Marslen-Wilson, & Tyler, 2000), although some have obtained it under exceptional conditions (see Bodner & Masson, 2003; Perea & Gotor, 1997). Morphological (e.g., *artist–ART*) facilitation, however, is robust and easy to detect (Forster & Azuma, 2000; Forster, Davis, Schoknecht, & Carter, 1987; Grainger, Colé, & Segui, 1991; Pastizzo & Feldman, 2002; Rastle et al., 2000). Effects when orthographically similar primes are forward masked (e.g., *artery–ART*) are inconsistent. Some have observed nonsignificant orthographic inhibition (Janack, Pastizzo, & Feldman, 2004; Pastizzo & Feldman, 2002; Pollatsek, Perea, & Binder, 1999; Sears, Hino, & Lupker, 1995), whereas others have observed facilitation (Carreiras, Perea, & Grainger, 1997; Forster & Shen, 1996; Forster & Taft, 1994). Separate from type of overlap (e.g., *artery–ART* vs. *arm–ART*), effects seem to depend on lexicality of the prime (Siakaluk, Sears, & Lupker, 2002), relative prime–target length (De Moor & Brysbaert, 2000), relative prime–target frequency (Segui & Grainger, 1990), and properties of the target's orthographic neighborhood, including number of neighbors or density (Carreiras et al., 1997; Forster et al., 1987), number of higher frequency neighbors (Perea & Lupker, 2003), and number of shared neighbors between prime and target (Davis & Lupker, 2006).

One interpretation of the failure to detect semantic facilitation when primes are forward masked and morphological facilitation is reliable is that even though both semantic associates and morphological relatives are similar in meaning, the relations are processed or represented differently in the lexicon. Thus, transfer of processing between different lexical entries for the prime and target underlies semantic facilitation, whereas morphological facilitation arises from the reactivation of a lexical representation shared among whole words (e.g., satellite entry hypothesis; Lukatela, Gligorijević, & Kostić, 1980) or among a cluster of decomposed words linked by a shared base morpheme that collectively constitute a lexical entry. Moreover, some researchers have argued that robust morphological facilitation in the absence of semantic facilitation indicates that lexical entries capture orthomorphological structure (Forster et al., 1987; Rastle, Davis, & New, 2004) and that semantic effects arise only later in the course of recognition (Giraudo & Grainger, 2001). Stated succinctly, the process of morphemic analysis has a "functional integrity that does not depend on semantic support" (Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2000, p. 1286). The logic of the present study

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The research reported in this article was supported by funds from the National Institute of Child Health and Development Grant HD-01994 to Haskins Laboratories. We would like to thank Glen Bodner and Marc Brysbaert for their comments on an earlier version of this work.

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is to introduce list-wide experimental manipulations that affect morphologically and semantically (but not orthographically) related prime–target pairs comparably and to use the outcome to argue for morphological accounts that encompass not only early analysis of form but also meaning.

Morpheme constituents vary in their contribution to the overall meaning of the complex forms and compounds in which they are found. For example, morphologically related words can be semantically transparent, as in *FIXABLE–FIX*, or semantically opaque, as in *FIXTURE–FIX*. The absence of an effect of semantic transparency on the magnitude of morphological facilitation when forward-masked morphological constituents serve as primes has been interpreted as support for a lexical representation of morphology devoid of semantics. For example, comparable facilitation after compounds (Shoolman & Andrews, 2003) that are transparent (*BOOKSHOP–BOOK*) and partially opaque (*JAYWALK–WALK*), or pseudocompounds (*HAMMOCK–HAM*), attest to lexical processes that purportedly depend on orthographic but not semantic properties of morphemic units (Rastle & Davis, 2003). As noted by Shoolman and Andrews (2003), however, facilitation following compound primes and frequency effects following inflected forms such as *MOONS* that have high frequency base morphemes but a rare combination of base morpheme and affix (Taft, 2004) tend to appear when rejection is easy but are more difficult to detect when rejection is difficult. More specifically, nonword compounds consisting of illegal combinations of word constituents and nonwords composed of true base morphemes affixed with incompatible inflectional morphemes (e.g., *MIRTHS*) were slower to reject than inflected variants of nonexistent bases such as *MILPHS* (Taft, 2004).

In addition to frequency and combination of constituents in nonwords, list composition can alter outcomes when primes are forward masked in the lexical decision task. One well-investigated factor is relatedness proportion (RP), or number of related trials among all word–word (prime–target) pairs (Bodner & Masson, 2003; Neely, Keefe, & Ross, 1989). With the introduction of identical prime–target trials and a necessarily concomitant increase in the proportion of semantically related trials from .25 to .75 (because identical primes and targets are always semantically related), Bodner and Masson (2003; Experiment 2) reported that the magnitude of semantic facilitation increased from 11 ms to 35 ms. At an RP of .75, not only was the magnitude of facilitation numerically greater than when the RP was .25, but the effect of forward-masked semantic facilitation became statistically significant (when number of participants was the random variable). Similar but numerically attenuated effects emerged when filler items were semantically related (Experiment 1). Magnitudes in the high and low RP were 24 ms and 14 ms, respectively. Although the introduction of identity trials necessarily raises the average strength of prime–target semantic relatedness relative to semantically related trials, we interpreted the comparability of patterns across filler types as evidence that the effect is not specific to semantic processing of the prime. In fact, more recent studies suggest that enhanced effects with increases in the proportion of related trials are not specific to linguistic processing (e.g., Bodner & Dypvik, 2005; Bodner & Masson, 2004).

There are several accounts of why increasing the proportion of identity trials can enhance semantic facilitation in a paradigm that purportedly eliminates strategic priming processes. Some emphasize the flexibility of early prime processing. According to Bodner and Masson (Bodner & Masson, 2003; Masson & Bodner, 2003), a high RP enhances the cue validity of the prime and the extent to which processing operations on the prime are appropriate for and can be transferred to the upcoming target. Because readers tend not to be aware of the prime and because facilitation did not decrease when data from readers with partial prime awareness were eliminated, processing of the prime cannot entail conscious control. Although automatic, prime recruitment is flexible in that it can change depending on the overall validity with which attributes of the prime correlate with attributes of the target. At the same time that increased prime recruitment benefits responses after related primes, especially at higher RPs, responses can be less accurate or slower on invalid (unrelated) trials (Bodner, Masson, & Richard, 2006).

A second account focuses on shifts in the experiment-wide response criteria that depend on list context (Lupker, Brown, & Colombo, 1997). In this framework, the RP effect is a type of blocking effect (Mozer, Kinoshita, & Davis, 2004), and the introduction of many identical or semantically related prime–target trials serves to make the task easier and to alter overall performance by inducing subjects to set the criterion to respond in a manner that benefits both related and unrelated trials. However, in a more variable and less pure list context, due to pressures of latency homogenization (Lupker, Kinoshita, Coltheart, & Taylor, 2003), difficult responses tend to benefit whereas easy responses remain unchanged.

Although prime recruitment and criterion accounts appear to differ with respect to whether RP affects processes of lexical access or a somewhat later criterion-setting stage, they can be differentiated from accounts of facilitation from a masked prime in the lexical decision task that emphasize not only the automaticity, but also the invariant processes of lexical entry opening (Forster, 1998; Forster & Davis, 1984; Forster, Mohan, & Hector, 2003). Opening a lexical entry for the target in the course of processing the prime produces savings (viz., facilitation) when processing the target. Time to open a lexical entry purportedly does not vary, regardless of the word's frequency. By the entry opening account, facilitation when primes are forward masked arises only for word targets and should be constant across varying properties of the target and the list context in which it appears.

Experiments 1–3

Our goal in the present study was to examine magnitudes of orthographic, morphological, and semantic forward-masked facilitation for one set of targets when we maintained the proportion of related prime target pairs at .75 but varied list context. Fillers were mixed in Experiment 1 and included equal numbers of morphologically (e.g., *frosty–FROST*), orthographically (e.g., *antic–ANT*), and semantically related pairs (e.g., *noisy–LOUD*). Experiment 2 included only identity fillers (e.g., *ant–ANT*), and Experiment 3 included only semantically related pairs (*bug–ANT*). As a result, semantic but not orthographic validity of the prime as an index of target lexicality was lower in Experiment 1 than in Experiments 2 or 3. In Experiment 1, two thirds of filler pairs shared orthographic and two thirds shared semantic similarity, whereas in Experiment 2 all fillers were identical and therefore shared full orthographic and semantic (as well as morphological) similarity. Semantic primes are less similar to targets (by accounts based on co-occurrence, feature sharing, association, or category membership) than are identity primes with themselves; therefore, overall semantic similarity was reduced in Experiment 3 relative to Experiment 2. Collectively, altering the nature of the filler word pairs allowed us to vary dimension-specific validity of the prime. Notably, in the present study, prime–target orthographic similarity was uninformative about lexical status of the target because proportions of orthographically similar pairs were matched across word–nonword and word–word pairs. In effect, the introduction of identity or semantic fillers when orthographic similarity was uninformative with respect to target lexicality served as an experiment-wide semantic manipulation. Our focus was whether facilitation after the three critical prime types—morphological (M), orthographic (O), and semantic (S)—changed as a function of list-induced variation in validity of the prime and whether changes in magnitudes were comparable across prime types.

Facilitation that varied depending on properties of the filler context would indicate that over and above RP (which was constant at 75%), processing of forward-masked primes in the lexical decision task is sensitive to list-induced variation in the prime–target relation. If variation in the composition of filler trials slowed responses overall, the outcome would invite an account based on shifts in criterion to respond "word." Augmented facilitation in the absence of prolonged unrelated responses is accommodated more easily by accounts that emphasize prime validity. Although both accounts can handle magnitudes of M, O, and S facilitation that increase uniformly across list contexts, interactions of list context with prime type depending on whether pairs do (M, S) or do not (O) share semantics invite an account that incorporates dimension-specific validity of the prime. Further, variation in degree of prime–target semantic similarity should enhance facilitation more in the context of identity compared with semantically related fillers. From the perspective of morphological processing, of particular interest would be changes in facilitation for morphological and semantic, but not orthographic, prime–target types across list contexts, as this outcome would provide a challenge to claims for the independence of morphological from semantic processing early in the course of recognition.

Method

Participants

Eighty-two students participated in Experiment 1, 79 participated in Experiment 2, and 71 participated in Experiment 3. All were from the State University of New York at Albany, participated in partial fulfillment of the course requirements for Introduction to Psychology, were monolingual English speakers with no known reading or speech disorders, and had normal or corrected-to-normal vision.

Materials

The critical items for Experiments 1–3 consisted of 54 sets of word pairs used in Feldman (2000). Word pairs were orthographically related (*artery–ART*), morphologically related (*artist–ART*), or semantically related (*craft–ART*). Nested within each of the orthographic and morphologically related prime words were all of the letters that composed the matching target word. For orthographic pairs all overlapping letters were contiguous (e.g., *badger–BADGE, paint–PAIN*). Semantic similarity for the semantic and morphologically related primes was rated (7-point scale) in a prior study (see Feldman, 2000) and primes were matched. Analogously, form similarity based on number of letters shared with the target was matched for orthographic and morphological primes. This ensured that the semantic and morphologically related primes were equated on ratings of semantic similarity with the target and that orthographic and morphological primes were matched on orthographic overlap with the target. Each target had three unrelated prime words paired with it, one that was matched on frequency and length to each of three related prime words (e.g., *avenue–ART, review–ART, sheep–ART*). See Table 1 for a description of mean frequencies and lengths for each prime type.

Fifty-four of the 108 nonword targets were paired with word primes and appeared in Experiments 1–3. The structure of the word–nonword pairs mimicked the critical word–word pairs and therefore shared either orthographic/morphologic structure (*cancer–CANCE*), or was unrelated in form (*shake–BREE*).

Fifty-four word–word filler items that were orthographically, morphologically, or semantically related also appeared in Experi-

Table 1
Properties of Critical Stimuli in Experiments 1 and 2

Prime type	Related prime	Unrelated prime	Target word
Orthographic	*artery*	*avenue*	*ART*
Frequency[a] (*SD*)	20.3 (34.0)	20.3 (34.0)	107 (160.0)
Length (*SD*)	5.8 (1.1)	5.8 (1.1)	3.7 (0.6)
Relatedness ratings (*SD*)[b]	1.7 (0.81)		
Morphological	*artist*	*review*	*ART*
Frequency (*SD*)	25.2 (50.0)	25.2 (51.0)	
Length (*SD*)	5.8 (1.1	5.8 (1.1)	
Relatedness ratings (*SD*)	5.9 (0.81)		
Semantic	*craft*	*sheep*	*ART*
Frequency (*SD*)	33.6 (71.0)	33.4 (71.0)	
Length (*SD*)	5.3 (1.1)	5.3 (1.1)	
Relatedness ratings (*SD*)	5.7 (0.94)		
	Filler Items 1		
Orthographic	*antic*		*ANT*
Frequency (*SD*)	11.6 (13.0)		59 (91.0)
Length (*SD*)	5.3 (0.67)		3.4 (0.5)
Morphological	*baker*		*BAKE*
Frequency (*SD*)	10.9 (14.0)		38 (82.0)
Length (*SD*)	5.4 (0.49)		4.3 (0.5)
Semantic	*shrimp*		*CRAB*
Frequency (*SD*)	12.8 (14.0)		49 (54.0)
Length (*SD*)	5.1 (0.9)		4.8 (1.1)
	Filler Items 2		
Identity	*ant*		*ANT*
Frequency (*SD*)			48 (79.0)
Length (*SD*)			4.2 (0.9)
	Filler Items 3		
Semantic	*bug*		*ANT*
Frequency (*SD*)			60 (70.0)
Length (*SD*)			4 (1.0)

[a] Frequencies are in parts per million.
[b] Range = 7 (*high*) to 1 (*low*).

ment 1. These included 18 pairs of each type (*antic–ANT, baker–BAKE, shrimp–CRAB*). In Experiment 2, all fillers consisted of identity (ID) trials.[1] In Experiment 3, all fillers were semantically related (*bug–ANT*). The remaining 54 nonword targets (from the 108 total) were paired with word primes. Their structure paralleled closely that of the filler word–word pairs. In Experiment 2, the filler word–nonword pairs retained the *cancer–CANCE*, *vintage–VINT* structure, and items were re-paired in Experiment 3 to eliminate orthographic similarity.

Design

Six lists, each containing 216 prime–target pairs, were created. The targets appeared once per list, and prime–target pairings differed across lists. Of the 54 critical pairs, each participant saw 9 that were related orthographically, 9 morphologically, 9 semantically, and 9 for each of their respective unrelated controls (see the appendix for a list of critical stimuli). Within each list, no target words repeated. Both prime type (M, O, S) and relatedness (related or frequency-controlled unrelated) were manipulated within-subjects. All pairings for filler items and nonwords stayed the same in each list within an experiment.

In Experiment 1, fillers were distributed over morphological, orthographic, and semantic dimensions so that 18/54 of fillers as well as 36/54 of critical items (viz., M, O) shared form, and 36/54 of fillers as well as 18/54 of critical items (viz., M, S) shared some meaning. Collectively, in Experiment 1, 50% of all pairs shared form, 50% of all pairs shared meaning, and 25% shared both dimensions. In Experiment 2, all fillers were ID trials, and thus they shared morphological as well as orthographic and semantic similarity. Consequently, 72/108 of items (67%) shared form, an equal proportion shared meaning, and 63/108 (or 58%) shared both. In Experiment 3, all fillers were semantically related trials so that 18/108 (17%) of items shared form, 72/108 (67%) shared varying degrees of meaning, and 9/108 (8%) shared both.

The relatedness proportion in each experiment was .75. Both critical and filler prime–target pairs contributed to the overall relatedness proportion. The calculation included 25% each of morphological, orthographic, and semantic dimensions of relatedness in Experiment 1 and 8% each of pairs that shared morphological, orthographic, and semantic dimensions of relatedness, as well as 50% of pairs that were identical or semantically related in Experiments 2 and 3.

Procedure

Each trial began with a 500 ms fixation (+) that appeared in the middle of the screen. An interstimulus interval (ISI) of 50 ms occurred before the forward mask (#####) appeared for 450 ms. The number of # symbols that appeared in the forward mask was matched to the length of the particular prime word for that trial. Therefore, mask length changed with each trial. The prime word, in lowercase letters, replaced the mask and appeared for 50 ms. The target word, in capital letters, replaced the prime in the same position and was visible until the participant made a response or for a maximum of 3,000 ms. The intertrial interval was 1,000 ms.

Items were presented on a G3 Macintosh computer in 16-point font in black ink on a white background. A different random order of items appeared for each participant. Participants made a lexical decision for each target on a PsyScope button box by pressing the right button (green) for words and the left button (red) for nonwords.

Results

Separate analyses of variance (ANOVAs) were conducted on the latency and the error rate data with participants (F_1) and items (F_2) as random variables. Reaction times more extreme than three standard deviations from the participant's mean were treated as outliers and deleted (< 3%). We report all effects significant at $p < .10$ or stronger, as well as confidence intervals (± 1 *SD*) for each planned comparison. A summary of mean reaction times and error rate data appears in Table 2. Data from participants and items that fell below the 60% accuracy criterion were removed from the analyses. This eliminated data from two participants and one item (*SILL*).

Experiment 1

The results with latency as a dependent measure failed to reveal a fully significant interaction between prime type (orthographic, morphological, and semantic) and relatedness, F_1 (2, 158) = 2.62, $p = .08$. Planned comparisons showed significant facilitation (+25 ms ± 12) for morphologically related word pairs—F_1 (1, 158) = 5.55, $p = .02$; F_2 (1, 104) = 3.48, $p = .065$—and nonsignificant inhibition after both orthographically (−4 ms ± 10) and semantically (−5 ms ± 12) related primes. These results replicate prior results at very short stimulus onset asynchronies when the same targets recurred with orthographic, morphological, and semantic prime types (Feldman, 2000). Planned comparisons on the nonword data revealed that response latencies to nonword targets preceded by an orthographically similar prime word were faster, $t(76) = 6.67$, $p < .001$, and more accurate, $t(76) = 2.896$, $p < .01$, than those preceded by a word that differed in form. Evidently, orthographic similarity in the absence of shared meaning biased a nonword response.

The ANOVA on the accuracy data revealed a significant interaction (by participants only) between relatedness and prime type, F_1 (2, 158) = 4.46, $p = .05$, such that accuracy increased nonsignificantly after semantic primes, F_1 (2, 158) = 3.37, $p = .06$, and morphological primes, F_1 (1, 158) = 1.59, and decreased nonsignificantly after orthographic primes. To summarize, only morphological facilitation with the latency measure was fully reliable with forward-masked primes and fillers that included M, O, and S pairs.

Experiment 2

In Experiment 2 with ID fillers, ANOVAs on reaction time data revealed a main effect of relatedness, $F_1(1, 76) = 14.99$, $p < .0002$; $F_2(1, 52) = 3.68$ $p < .06$, and of prime type, $F_1(2, 152) = 4.98$, $p = .008$; $F_2(2, 104) = 5.40$, $p < .006$. Most important, the interaction between relatedness and prime type was significant, $F_1(2, 152) = 7.27$, $p = .001$; $F_2(2, 104) = 7.09$, $p = .002$.

[1] All primes were words. Therefore, identity word pairs were identical, whereas identity word–nonword pairs actually differed by a letter or two. Manipulations in the degree of overlap for identity pairs does not alter the outcome, however (M. Brysbaert, personal communication, July 2007).

Table 2
Mean Reaction Times in ms (and Percentage Accuracies) for Experiments 1-3

Variable	Prime type	Related	Unrelated	Effect
Experiment 1				
Critical items	Orthographic	674 (90)	670 (93)	−4 (−3)
	Morphological	649 (94)	674 (92)	25* (2)
	Semantic	664 (93)	658 (91)	−6 (2)
Filler items	Orthographic	646 (93)		
	Morphological	621 (99)		
	Semantic	638 (98)		
Nonword	Orthographic NW	809 (88)	835 (89)	26* (−1)
Experiment 2				
Critical items	Orthographic	667 (88)	668 (93)	1 (−5*)
	Morphological	618 (94)	671 (93)	53* (2)
	Semantic	649 (95)	672 (92)	23* (3)
Filler items	Identity pairs	593 (98)		
Nonword	Orthographic NW	786 (91)	830 (89)	44* (−2)
Experiment 3				
Critical items	Orthographic	693 (90)	689 (93)	−4 (−3*)
	Morphological	650 (94)	686 (94)	36* (0)
	Semantic	667 (97)	682 (92)	15 (5*)
Filler items	Semantic pairs	655 (95)		
Nonword	Orthographic NW	838 (88)	871 (87)	34* (−1)

Note. NW = nonword.
* $p < .05$.

Planned comparisons on the magnitudes of facilitation for each prime type revealed significant facilitation for the morphologically (+53 ms ± 9) and semantically (+23 ms ± 11) related word pairs, respectively: $F_1(1, 152) = 30.07$, $p = .0001$; $F_2(1, 104) = 16.35$, $p = .0001$; and $F_1(1, 152) = 5.88$, $p = .02$. Inhibition after orthographic primes was not significant, $F_1 < .5$; $F_2 < 1.5$. Consistent with the outcome from Experiment 1, the nonword data from Experiment 2 indicated that response latencies to orthographically related word–nonword pairs were faster, $t(79) = 5.209$, $p < .001$, than to word–nonword pairs that differed in form.

The ANOVA on the accuracy data revealed a main effect of prime type, $F_1(2, 152) = 6.65$, $p < .002$; $F_2(2, 104) = 6.78$, $p < .002$. The interaction between relatedness and prime type was significant, $F_1(2, 152) = 9.18$, $p = .0002$; $F_2(2, 104) = 9.21$, $p < .0002$. Relatedness tended to increase accuracy for semantically related prime target pairs—$F_1(1, 152) = 3.16$, $p = .07$; $F_2(1, 104) = 2.87$, $p = .10$—and decrease accuracy for orthographically related pairs, $F_1(1, 152) = 15.06$, $p = .002$; $F_2(1, 104) = 15.12$, $p = .0002$.

Experiment 3

The ANOVAs on reaction time data with semantic fillers revealed marginal effects of relatedness, $F_1(1, 64) = 3.88$, $p < .053$; $F_2(1, 51) = 3.43$, $p < .07$; of prime type, $F_1(2, 128) = 2.43$, $p = .09$; $F_2(2, 102) = 1.34$; and the interaction between relatedness and prime type that was significant by participants, $F_1(2, 128) = 3.82$, $p = .03$; $F_2(2, 102) = 1.70$.

Planned comparisons revealed significant F_1 facilitation for the morphologically (+36 ms ± 13) but not for semantically (+15 ms ± 11) related word pairs, respectively: $F_1(1, 128) = 11.95$, $p = .0007$; $F_2(1, 102) = 4.62$, $p = .03$; and $F_1(1, 128) = 2.37$, $p = .12$; $F_2(1, 102) = 2.69$, $p = .10$. Facilitation after orthographic primes was not significant ($F_s < .2$). Consistent with the outcome from Experiments 1 and 2, the nonword data from Experiment 3 indicated that response latencies to orthographically related word–nonword pairs were faster, $t(71) = 4.31$, $p < .001$, than to word–nonword pairs that differed in form.

The ANOVA on the accuracy data revealed a main effect of prime type, $F_1(2, 140) = 11.08$, $p < .0001$; $F_2(2, 102) = 4.82$, $p < .01$. The interaction between relatedness and prime type was significant, $F_1(2, 140) = 7.11$, $p = .001$; $F_2(2, 102) = 4.49$, $p < .02$. Relatedness increased accuracy for semantically related prime target pairs, $F_1(1, 140) = 6.44$, $p = .02$; $F_2(1, 102) = 6.43$, $p = .02$, and decreased accuracy for orthographically related pairs, $F_1(1, 140) = 7.66$, $p = .007$; $F_2(1, 102) = 2.76$, $p = .10$.

Experiments 1–3 Combined

An analysis of morphological and semantic facilitation across the three experiments revealed a marginal effect of filler type in the analysis with participants as a random factor, $F_1(2, 219) = 2.72$, $p = .07$; $F_2(1, 102) = 1.92$, $p = .15$. Specifically, magnitudes were greater with ID than with mixed fillers, $F_1(1, 219) = 5.42$, $p = .02$; $F_2(1, 51) = 3.68$, $p = .06$. Facilitation with semantic fillers was nonsignificantly reduced relative to ID fillers. Most important, although morphological facilitation was marginally greater than semantic facilitation, $F_1(1, 219) = 10.88$, $p = .001$; $F_2(1, 51) = 3.45$, $p = .07$, there was no suggestion of an interaction across mixed, ID, and semantic filler contexts. Means were 25 ± 12, 53 ± 9, 36 ± 13 for morphological primes and −5 ± 12, 23 ± 11, 15 ± 11 for semantic primes, respectively. Stated succinctly, magnitudes of morphological and semantic facilitation increased equivalently in the context of identity relative to mixed fillers (Experiment 3 vs. Experiment 1) and effects were not significantly different in the context of semantic fillers (Experiment 3 vs. Experiment

2). Finally, unrelated baseline latencies did not vary significantly across experiments defined by filler type (Fs < 1).

Discussion

Experiments 1–3 differed with respect to list context, whereas critical items and RP stayed the same. Results demonstrated that properties of filler items can alter the magnitude of facilitation when primes are masked and purportedly unavailable to conscious processing.[2] When filler items included pairs that shared morphological, orthographic, or semantic similarity, we documented significant facilitation to decision latencies for prime–target pairs that were related by morphology, but not for pairs that shared either form or meaning. This outcome replicates previous reports that morphological, but not semantic, facilitation is robust in the forward-masked lexical decision task (Frost, Forster, & Deutsch, 1997). In contrast, when all filler items consisted of identity pairs that were not only morphologically related, but also semantically related, prime–target pairs produced significant facilitation. Semantic facilitation with forward-masked primes in the context of identity trials that is significant only when participants is the random variable is consistent with the findings of Bodner and colleagues (Bodner & Masson, 2003; Bodner et al., 2006). Finally, magnitudes of morphological and semantic facilitation with semantically related filler items were intermediate between mixed and identity fillers. In brief, in the forward-masked lexical decision task at a relatedness proportion of .75, we documented robust morphological and more tenuous semantic facilitation, as well as an absence of orthographic facilitation. In fact, orthographic similarity in the context of semantic as well as identity fillers benefited nonword targets. Orthographic facilitation for nonwords is noteworthy in that nonwords have no lexical entries to be opened.

List-context induced increases in facilitation when relatedness proportion was constant provide new evidence for the flexibility of processing under forward-masked presentation conditions. Neither this outcome nor facilitation for nonword targets is consistent with accounts that posit an invariant style of opening lexical entries. In addition, analyses of the unrelated latencies for critical trials failed to reveal systematic changes in unrelated baseline latencies across Experiments 1–2 that are essential to a criterion-based account, and numerical differences across Experiments 2–3 incorrectly predict greater facilitation in the latter. More generally, the outcome could be consistent with an account that focuses on a shift in criterion if different criteria for related and unrelated trials could be motivated. However, it is crucial that facilitation did not increase uniformly for all three dimensions of relatedness. This outcome is more consistent with an account that focuses on validity of the prime and processing operations that can transfer to target from prime than with criteria that are set experiment-wide. To reiterate, magnitudes of morphological and semantic facilitation varied across filler contexts. By contrast, not only did orthographic relatedness fail to reduce latencies in any experiment, but also accuracy for orthographically related word pairs decreased after related as contrasted with unrelated primes. The introduction of identity trials that failed to influence all dimensions of prime–target relatedness in the same manner demonstrates a dimension-specific validity of the prime that benefits judgments of target lexicality. Further, insofar as attenuated facilitation with semantic relative to identity fillers can be attributed to reduced semantic similarity for associates as compared to identical repetitions, results also are consistent with an interpretation based on graded semantic validity.

In summary, morphological and semantic facilitation benefited comparably from the introduction of identity trials, and results with semantic trials were weaker but similar. This outcome fails to provide support for the claim that morphological facilitation under forward-masked presentation conditions reflects the functional integrity or otherwise privileged representation of morphemes, including independence from semantic processing. In the present study, the percentage of orthographically related pairs did not differ for word–word and word–nonword pairs, so that form similarity was not a valid predictor of a target's lexical status. Conversely, effects of prime–target meaning similarity were informative about lexicality. Collectively, matching of word–word and word–nonword trials on orthographic similarity in conjunction with the introduction of identity fillers that shared both orthography and semantics functioned to enhance the dimension-specific (viz., semantic) validity of the prime and fostered a transfer of semantic processing between prime and target.

To conclude, morphological facilitation was greater than semantic facilitation and both increased comparably when identity fillers replaced mixed fillers. Augmented effects in the context of identity trials demonstrate the sensitivity of morphological, as well as semantic, facilitation to enhanced semantic computation and fail to support claims for qualitatively different sources of facilitation or for orthomorphological representations that are independent from semantics at early stages of processing. Effects of list context that foster semantic processing of a forward-masked prime in the lexical decision task seem more compatible with accounts of morphological processing that accommodate effects of semantic similarity even early in processing.

[2] Because awareness of a prime was not monitored for each participant, in a supplemental experiment we presented semantic and unrelated trials in the context of identity fillers to a new sample from the same population and analyzed magnitudes of semantic facilitation as a function of prime "awareness" based on elicited self-report ("Did you see anything after the pattern mask?") after the experimental task. Magnitudes were nonsignificantly larger for those ($N = 20$) for whom the prime was not visible than for those ($N = 24$) for whom anything was visible (21 vs. 13 ms, respectively).

References

Bodner, G. E., & Dypvik, A. T. (2005). Masked priming of number judgments depends on prime validity and task. *Memory & Cognition, 33,* 29–47.

Bodner, G. E., & Masson, M. E. J. (2003). Beyond spreading activation: An influence of relatedness proportion on masked semantic priming. *Psychonomic Bulletin and Review, 10,* 645–652.

Bodner, G. E., & Masson, M. E. J. (2004). Beyond binary judgments: Prime validity modulates masked repetition priming in the naming task. *Memory & Cognition, 32,* 1–11.

Bodner, G. E., Masson, M. E. J., & Richard, N. T. (2006). Repetition proportion biases masked priming of lexical decisions. *Memory & Cognition, 34,* 1298–1311.

Carreiras, M., Perea, M., & Grainger, J. (1997). Effects of orthographic neighborhood in visual word recognition: Cross-task comparisons. *Jour-*

nal of Experimental Psychology: Learning, Memory, and Cognition, 23, 857–871.

Davis, C. J., & Lupker, S. J. (2006). Masked inhibitory priming in English: Evidence for lexical inhibition. *Journal of Experimental Psychology: Human Perception and Performance, 32,* 668–687.

De Moor, W., & Brysbaert, M. (2000). Neighborhood-frequency effects when primes and targets are of different lengths. *Psychological Research, 63,* 159–162.

Feldman, L. B. (2000). Are morphological effects distinguishable from the effects of shared meaning and shared form? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(6), 1431–1444.

Forster, K. I. (1998). The pros and cons of masked priming. *Journal of Psycholinguistic Research, 27,* 203–233.

Forster, K. I., & Azuma, T. (2000). Masked priming for prefixed words with bound stems: Does *submit* prime *permit*? *Language and Cognitive Processes, 15,* 539–561.

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

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation. *Quarterly Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 829–856.

Forster, K. I., Mohan, K., & Hector, J. (2003). The mechanics of masked priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 3–37). New York: Psychology Press.

Forster, K. I., & Shen, D. (1996). No enemies in the neighborhood: Absence of inhibitory neighborhood effects in lexical decision and semantic categorization. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 696–713.

Forster, K. I., & Taft, M. (1994). Bodies, antibodies, and neighborhood density effects in masked form priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 844–863.

Frost, R., Deutsch, A., Gilboa, O., Tannenbaum, M., & Marslen-Wilson, W. (2000). Morphological priming: Dissociation of phonological, semantic and morphological facts. *Memory & Cognition, 28* (8), 1277–1288.

Frost, R., Forster, K. I., & 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, and Cognition, 23*(4), 829–856.

Giraudo, H., & Grainger, J. (2001). Priming complex words: Evidence for supralexical representation of morphology. *Psychonomic Bulletin & Review, 8,* 127–131.

Grainger, J., Colé, P., & Segui, J. (1991). Masked morphological priming in visual word recognition. *Journal of Memory and Language, 30,* 370–384.

Janack, J., Pastizzo, M. J., & Feldman, L. B. (2004). When orthographic neighbors fail to facilitate. *Brain and Language, 90,* 441–452.

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

Lupker, S. J., Brown, P., & Colombo, L. (1997). Strategic control in a naming task: Changing routes or deadlines? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 570–590.

Lupker, S. J., Kinoshita, S., Coltheart, M., & Taylor, T. E. (2003). Mixing costs and mixing benefits in naming words, pictures and sums. *Journal of Memory, and Language, 49,* 556–575.

Masson, M. E. J., & Bodner, G. E. (2003). A retrospective view of masked priming: Toward a unified account of masked and long-term repetition priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 57–94). New York: Psychology Press.

Mozer, M. C., Kinoshita, S., & Davis, C. (2004). Control of response initiation: Mechanisms of adaptation to recent experience. *Proceedings of the Twenty-Sixth Annual Conference of the Cognitive Science Society* (pp. 981–986). Hillsdale, NJ: Erlbaum.

Neely, J. H., Keefe, D. E., & Ross, K. L. (1989). Semantic priming in the lexical decision task: Roles of prospective prime-generated expectancies and retrospective semantic matching. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 1003–1019.

Pastizzo, M. J., & Feldman, L. B. (2002). Discrepancies between orthographic and unrelated baselines in masked priming undermine a decompositional account of morphological facilitation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 244–249.

Perea, M., & Gotor, A. (1997). Associative and semantic priming effects occur at very short SOAs in lexical decision and naming. *Cognition, 62,* 223–240.

Perea, M., & Lupker, S. J. (2003). Transposed-letter confusability effects in masked form priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 97–120). New York: Psychology Press.

Pollatsek, A., Perea, M., & Binder, K. S. (1999). The effect of "neighborhood size" in reading and lexical decision. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 1142–1158.

Rastle, K., & Davis, M. H. (2003). Reading morphologically complex words: Some thoughts from masked priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 279–308). New York: Psychology Press.

Rastle, K., Davis, M. H., Marslen-Wilson, W. D., & Tyler, L. K. (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language and Cognitive Processes, 15,* 507–537.

Rastle, K., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review, 11,* 1090–1098.

Sears, C. R., Hino, Y., & Lupker, J. (1995). Neighborhood size and neighborhood frequency effects in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 876–900.

Segui, J., & Grainger, J. (1990). Priming word recognition with orthographic neighbors: Effects of relative prime target frequency. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 65–76.

Shoolman, N., & Andrews, S. (2003). Racehorses, reindeer, and sparrows. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 241–278). New York: Psychology Press.

Siakaluk, P. D., Sears, C. R., & Lupker, S. J. (2002). Orthographic neighborhood effects in lexical decision: The effects of nonword orthographic neighborhood size. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 661–681.

Taft, M. (2004). Morphological decomposition and the reverse base frequency effect. *The Quarterly Journal of Experimental Psychology, 57,* 745–765.

Appendix

Targets and Their Related Primes

Orthographic	Morphological	Semantic	Target
artery	artist	craft	art
badger	badges	emblem	badge
banner	banned	prohibit	ban
belly	bells	chime	bell
billion	billing	invoice	bill
bitter	bitten	chewed	bit
bowl	bows	ribbon	bow
caper	capes	cloak	cape
card	cars	auto	car
clamor	clams	oyster	clam
dental	dented	scratch	dent
diet	dies	expire	die
dragons	dragged	tow	drag
easel	eased	comfort	ease
examples	examines	quiz	exam
factory	facts	truth	fact
flown	flows	stream	flow
gully	gulls	pelican	gull
halter	halted	cease	halt
humble	hummed	buzz	hum
irony	irons	steam	iron
jacket	jacked	lever	jack
joint	joins	unite	join
lawn	laws	rule	law
lesson	lessen	fewer	less
lettuce	letting	allow	let
liver	lived	exist	live
markets	marking	check	mark
missile	missing	skip	miss
needle	needed	want	need
paddle	padded	cushion	pad
paint	pains	hurt	pain
pawn	paws	claw	paw
pickets	picking	choose	pick
pigment	piggish	hog	pig
pity	pits	crater	pit
planets	planned	scheme	plan
raven	raves	rant	rave
robins	robber	steal	rob
rubbish	rubbing	massage	rub
rustic	rusted	corrode	rust
saddles	sadder	sorrow	sad
scandal	scanner	peruse	scan
seem	seen	look	see
shovel	shoved	nudge	shove
shuttle	shutter	lock	shut
silly	sills	ledge	sill
skillet	skilled	talent	skill
stunt	stuns	daze	stun
trickle	tricked	deceive	trick
turnips	turning	twist	turn
vowel	vowed	pledge	vow
wager	wages	salary	wage
warm	wars	battle	war

Received November 25, 2006
Revision received October 22, 2007
Accepted November 12, 2007 ■