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Multiple dimensions of relatedness among words:

Conjoint effects of form and meaning in word recognition★

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Abstract

Words can be similar with respect to form (viz., spelling, pronunciation), meaning, or both form and meaning. In three lexical decision experiments (48 ms forward masked, 116 ms, and 250 ms SOAs), targets (e.g., FLOAT) followed prime words related by form only (e.g., COAT), meaning only (e.g., SWIM), or form and meaning (e.g., BOAT). BOAT–FLOAT and SWIM–FLOAT type pairs showed reduced target decision latencies relative to unrelated controls when primes were unmasked, but not when they were masked, and the magnitude of facilitation increased with increasing prime duration. By contrast, COAT–FLOAT type pairs produced significant inhibition at the shorter two prime durations. In all three experiments, including at the shortest SOA, (BOAT–FLOAT) pairs that shared form and meaning differed from COAT–FLOAT type pairs that shared only form. We discuss the similarity of the BOAT–FLOAT pattern to that of morphological facilitation and argue that if the same mechanism underlies both outcomes then activation of a shared morphemic representation need not underlie morphological facilitation.

Keywords

convergent morphology; forward masked priming; semantic priming

Word pairs such as TEACHER–TEACH are morphologically related. Because they share a morpheme (e.g., TEACH), they tend to be similar with respect to (orthographic and phonological) form and meaning. Similarity on multiple dimensions (viz., form and meaning) is not limited, however, to morphologically related words. Word pairs such as BOAT–FLOAT share form and meaning even though they do not share a linguistically defined morphemic unit. Many studies have investigated the effect of orthographic, phonological, semantic, or morphological relatedness on word recognition, but few have examined the conjoint effects of form and meaning in the absence of a shared morpheme on the same target. The primary goal of the present study is to examine the influence on word recognition of shared form and meaning between word pairs that do not share a morpheme. We compare BOAT–FLOAT type pairs (shared form and meaning) with SWIM–FLOAT type pairs (exclusively shared meaning) and COAT–FLOAT (exclusively shared form). We ask whether patterns of priming for morphologically unrelated (e.g., BOAT– FLOAT) pairs resemble those observed previously for morphologically related (e.g., TEACHER–TEACH) pairs.

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It is often argued that morphologically related pairs are special because they share a base morpheme (e.g., TEACH) and that activation of the base morpheme is the basis of facilitation in primed word recognition tasks. Further, the recurrence of a base morpheme introduces a degree of meaning and form similarity between prime and target that cannot be fully matched in the absence of a shared morpheme. Accordingly, for morphological relatives that have similar form and meaning, facilitation cannot be predicted simply from the sum of orthographic and semantic similarity effects (Feldman, 2000). If an analogous pattern occurs for BOAT–FLOAT type pairs and the same mechanism underlies both types of facilitation, then the implication is that the locus of morphological facilitation need not be characterized in terms of multiple activations of a morphemic representation.

The logic of the present study entails examining BOAT–FLOAT pairs at progressively longer stimulus onset asynchronies in the lexical decision task where traditional morphological facilitation has been documented as distinct from form effects or from semantic effects and asking whether the pattern of facilitation for pairs that share both semantic and form-based similarity can be accounted for by examining word pairs that share only form or only meaning. To motivate the present study, we begin by contrasting two accounts of morphological facilitation; specifically, one that posits lexical representations of morphemes and their activation (*Morpheme Activation Account*) and another that attributes morphological effects to the conjoint effects of form and semantic dimensions of similarity (*Conjoint Similarity Account*). Then we look at the available experimental literature for evidence that the conjoint effects of form and of semantics cannot be predicted from the effect of each dimension alone. Finally, we describe our study to examine the influences of shared form and meaning (in the absence of a shared morpheme) relative to word pairs that share only form or only meaning.

Morphological facilitation

There is no doubt that speakers of a language can demonstrate an appreciation of morphological structure both in producing and comprehending language, yet there is little agreement among psycholinguists as to how that knowledge might be represented. Traditional accounts posit an explicit representation of a word’s morphological structure, usually in terms of lexical entries that are decomposed into their constituent morphemes, but sometimes in terms of a morphological principle of organization among whole word entries in the mental lexicon (e.g., Stanners, Neiser, Hernon, & Hall, 1979). Alternative accounts with distributed representations focus on the degree of shared form between prime and target together with the degree of shared meaning, and emphasize the time course over which orthographic and semantic codes converge to specify a distributed pattern unique to a word (e.g., Gonnerman, Seidenberg, & Andersen, 2007; Seidenberg & Gonnerman, 2000).

One of the basic tools to probe morphological representation and processing is to examine magnitudes of facilitation in variants of the primed lexical decision and naming tasks where critical prime-target pairs are morphologically related. By one account, morphological facilitation arises because the same morpheme is activated by a prime and a target that are morphologically related (e.g., Marslen-Wilson, Tyler, Waksler, & Older, 1994). By another, whole words that are similar along a morphological dimension are interconnected and can activate each other (Lukatela, Gligorijević, Kostić, & Turvey, 1980). In principle, either the morpheme or whole word-based option could account for facilitation between words composed of a shared stem and a differing affix, at least if their meanings can be predicted from those of their respective components (semantically transparent).

Because activation in *Morpheme Activation accounts* is interpreted as either present or absent, one problem for a *Morpheme Activation* account of morphological facilitation is variation in the magnitude of facilitation between morphologically related prime-target pairs. Graded magnitudes of facilitation (with increasing similarity within a prime-target pair) are more compatible with an account where morphological effects reflect the convergence of similarity based on form and on meaning (e.g., Gonnerman, 1999; Rueckl, 2002; Rueckl & Raveh, 1999; Seidenberg & Gonnerman, 2000) than with the all-or-none activation implied by accounts of morpheme activation.

Studies that provide evidence of graded effects typically hold one dimension of similarity constant and manipulate the other. In one forward masked primed lexical decision study (Pastizzo & Feldman, 2002a), we restricted morphological relatedness to past-present tense verb pairs so that they were highly related semantically, then we systematically manipulated the magnitude of letter overlap. We observed greater facilitation for regular (e.g., *hatched–HATCH*) than for irregular (e.g., *fell–FALL*) verb pairs. Because facilitation was present for irregular as well as regular verb pairs, activation of a base morpheme proved not to be an adequate account of morphological facilitation. Facilitation for irregular as well as regular past tense-present tense morphologically related verb pairs is not restricted to the visual modality. Similar results have been observed under cross-modal presentations when primes are presented auditorily and targets are visual (Allen & Badecker, 2001; Feldman, Kostic, & Pastizzo, 2005; Gonnerman, 1999; Seidenberg & Gonnerman, 2000). Likewise, results in the long-term priming task (Rueckl, 2002; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997; Rueckl & Raveh, 1999) and in the fragment completion task (Feldman, Rueckl, Diliberto, Pastizzo, & Vellutino, 2002) have revealed magnitudes of morphological facilitation that vary with letter overlap (and thus regularity) between prime and target.

Analogously, researchers sometimes manipulate the degree of semantic similarity between morphologically related prime targets pairs while holding degree of form similarity constant. When we restricted morphological relatedness to primetarget pairs related by derivation that were matched for overlap of form but varied with respect to degree of semantic transparency, we observed greater facilitation for transparent (e.g., *casually–CASUALNESS*) than for opaque (e.g., *casualty–CASUALNESS*) pairs at a long but not at a short stimulus onset asynchrony (Feldman & Soltano, 1999; Feldman, Soltano, Pastizzo, & Francis, 2004). Similarly, when targets are simple (e.g., ALLOW) decision accuracy was higher after semantically transparent (e.g., ALLOWABLE) as compared to after partially transparent (e.g., ALLOWANCE) morphological primes in the decision task (Feldman & Pastizzo, 2003).

In summary, magnitudes of morphological facilitation that are comparable across gradations in semantic similarity provide evidence consistent with the claim that morphemes are explicitly represented in the lexicon and that activation of the same morpheme in prime and target accounts for facilitation. However, significant effects whose magnitude varies systematically with base morpheme allomorphy or semantic transparency are difficult to reconcile with traditional all-or-none *Morpheme Activation* accounts. Rather, they seem more compatible with an account of facilitation based on distributed patterns that arise from the degree of systematic mapping between form and meaning (Gonnerman, 1999; Gonnerman et al., 2007; Rueckl, 2002; Rueckl & Raveh, 1999; Rueckl et al., 1997; Seidenberg & Gonnerman, 2000).

A second shortcoming for *Morpheme Activation* accounts derives from comparisons of morphological representation and processing with orthographic and semantic priming effects within the same study (and preferably with the same targets). The focus here is on whether morphological facilitation can be predicted from the sum of facilitation from the orthographic and semantic dimensions of similarity (Feldman, 2000). Critical pairs shared morphological (e.g., VOWED–VOW), semantic (e.g., PROMISE–VOW) or orthographic (e.g., VOWEL–VOW) relatedness where morphological and semantic pairs were equated for ratings of semantic similarity and morphological and orthographic pairs were equated for letter overlap between prime and target. In the lexical decision task, when there was no mask and both prime and target were presented visually, morphological facilitation (VOWED–VOW) was evident over a variety of stimulus onset asynchronies (SOA) and the magnitude of morphological facilitation increased significantly with SOA. At the same time, for those same targets, effects of orthographic similarity based on initial letter overlap tended to be facilitatory or absent at the very short SOAs and to become inhibitory as SOA increased. In addition, the magnitude of facilitation due to semantic similarity (PLEDGE–VOW) tended to be slightly smaller than the morphological effect and showed a nonsignificant increase in magnitude with SOA. More relevant to the present study, when the magnitude of morphological facilitation in the decision task was compared with the sum of the effects of shared form in isolation (VOWEL–VOW) and shared semantics in isolation (PLEDGE–VOW), results indicated that the magnitude of morphological facilitation was significantly greater (overadditive) than the sum of the orthographic and the semantic effects, but only at the long SOA (250 millisecond (ms) prime duration with a 50 ms blank). At a 32 ms (unmasked) SOA by contrast, neither semantic nor orthographic effects were significant and their combined effect did not differ significantly from morphological facilitation. A similar pattern arose in the go/no go naming task and in the conventional naming task (Feldman & Prostko, 2002).

Morphological effects that are greater than the combined effects of semantic and orthographic similarity can be interpreted as evidence for the lexical representation of morphological structure within the lexicon, but this outcome also is consistent with *Conjoint Similarity* accounts given the greater similarity along each single dimension. Both an account based on activation of a shared morpheme and an account based on the conjoint effects of shared form and shared meaning could accommodate a morphological effect that is greater than the sum of facilitation for the two separate dimensions of similarity. Crucially, one domain in which the *Morpheme Activation* and the distributed *Conjoint Similarity* accounts of morphological processing make very different predictions is when prime-target pairs are similar in form and are similar in meaning but fail to share a base morpheme. Minimally, an account of facilitation whereby the benefit of morphological similarity reflects repeated activation of the same morpheme by prime and by target would require a different mechanism to account for overadditive effects of semantic and orthographic relatedness in the absence of morphological relatedness.

Concurrent influences of form and meaning

A limited number of studies (see Table 1) have investigated the conjoint influence of form and meaning in the absence of morphological relatedness on word recognition (Bergen, 2004;Damian & Martin, 1999;Rastle, Davis, Marslen-Wilson, & Tyler, 2000;Rouibah, Tiberghien, & Lupker, 1999;Starreveld & La Heij, 1995,1996). A review of the relevant literature reveals magnitudes of facilitation after primes that share form and meaning that cannot be predicted by adding the effects that arise after each dimension in isolation.

Bergen (2004) presented English prime-target pairs related only by orthographic form at word onset (DRUID–DRIP), by meaning (CORD–ROPE), or by both form and meaning (GLITTER–GLOW) in a lexical decision task. Critical prime-target pairs that shared form (+F) and meaning (+M) were further defined by the semantic consistency of their onset family (i.e., the percentage of words with the same initial consonant cluster that also shared meaning). To illustrate, Bergen reported that 39% (48/124) of the words that start with GL have a definition related to *light* or *vision*, whereas pairs such as CRONY–CROOK were unique in shared meaning relative to other words in the CR onset family. That is, the GLITTER–GLOW type items retain a more systematic mapping between form and meaning than do the CRONY–CROOK type items. Primes appeared for 150 ms followed by a 300-ms blank screen, and then the target appeared for 1000 ms. Relative to the unrelated baseline, target decision latencies were significantly reduced for GLITTER– GLOW pairs (+F+$M_{consistent}$) and for CORD–

ROPE (−F+M) pairs (59 ms and 23 ms respectively), and the difference was significant. In contrast, latencies after DRUID– DRIP (+F−M) pairs did not differ (−3 ms) from the unrelated condition. There was only negligible facilitation (7 ms) for CRONY–CROOK pairs ($+F+M_{inconsistent}$) where the rating of semantic consistency of the onset family was low. Most importantly, the magnitude of priming in the $+F+M_{consistent}$ (59 ms) condition was numerically greater than would be expected (20 ms) by adding the −F+M (23 ms) and +F−M (−3 ms) effects, although the significance of this (apparent) overadditive interaction was not reported. The outcome is consistent with the claim that, in the absence of a shared morpheme, dimensions of form and meaning similarity combine in a nonadditive and graded manner. Crucially, the numerical overadditivity resulting from the conjoint effects of form and meaning similarity in the Bergen study cannot be attributed to an explicit representation of morphological structure.

In a second priming study, also with English materials, Rastle et al. (2000, Experiment 2) manipulated form (F) and meaning (M) in three lexical decision experiments that differed with respect to prime duration and whether or not the prime was masked. The relevant conditions were +F+M (e.g., SCREECH–SCREAM), −F+M (e.g., CELLO–VIOLIN), and +F−M (e.g., TYPHOID–TYPHOON). Form overlap for +F+M prime-target pairs included onset (e.g., FLOOD–FLOAT), rime (e.g., BRUNCH–LUNCH) and other less easily characterized aspects of form (e.g., NOSTRIL– NOSE). Results indicated that when forward masked primes were presented for 43 ms, the magnitude of facilitation (15 ms) in the FLOOD–FLOAT (+F+M) condition was greater than the sum of the −F+M (1 ms) and +F−M (−8 ms) effects. (Different targets appeared in each configuration of ±F and ±M and the individual contrasts were not significant; it is likely therefore, that the overadditive interaction was not statistically significant.) Similar results arose when primes appeared for 72 ms before the forward mask. However, when the same primes were unmasked and presented for 230 ms, the magnitude of +F+M facilitation (34 ms) was comparable to the combination of the −F+M (28 ms) and the +F−M (−1 ms) effects. At a short SOA, +F+M facilitation was numerically greater than the combined (nonsignificant) magnitudes of the −F+M and +F−M effects; however, this overadditivity was not apparent at the longer SOA. Comparisons were made across different targets in the Rastle et al. but not the Feldman study. Numerically, the Rastle et al. timevarying pattern based on the sum of the two effects is the reverse of the interaction of overadditivity and SOA reported by Feldman (2000). Therefore, before concluding that different mechanisms underlie SCREECH–SCREAM and morphological facilitation, we decided to test for overadditivity at short and long SOAs in a design where the same targets appear with each time of prime.

Time-dependent interactions of form and semantic similarity also have been observed in a picture-naming task (e.g., Damian & Martin, 1999, Experiment 3; Starreveld & La Heij, 1995, 1996) and in a semantic categorization task (Rouibah et al., 1999). The implication is that the overadditive benefit of shared form and shared meaning between prime-target pairs not only applies to morphologically related pairs, and to word-word pairs that do not share a morpheme, but to language processing in general. To reiterate, in order to preserve an argument for the special status of morphological representations when facilitation for BOAT–FLOAT and VOWED–VOW pairs are both greater than one would predict based on effects of form and effects of meaning, one could posit that different mechanisms underlie each type of facilitation. Specifically, for morphologically related pairs, nonadditivity arises at a long but not at a short SOA, but the time course for SCREECH–SCREAM type facilitation is the opposite.

The primary goal of the present study was to examine the influence on word recognition of shared form and meaning between word pairs that do not share a morpheme. We compared BOAT–FLOAT type pairs (shared form and meaning) with SWIM–FLOAT type pairs (exclusively shared meaning) and COAT–FLOAT (exclusively shared form). In the present study, the same materials appeared under a variety of presentation conditions so that we could hold constant properties of the target that can interact with magnitudes of priming. Our specific focus was potential limitations to the time course under which BOAT–FLOAT facilitation could be predicted from the sum of facilitation from the form and semantic dimensions of similarity.

Method

Participants

One hundred sixteen students participated in Experiment 1a, 81 students participated in Experiment 1b, and 73 students participated in Experiment 1c. All were recruited from the University at Albany, State University of New York Psychology Research Pool. With the exception of 4 participants in Experiment 1b and 13 participants in Experiment 1c who received $5 for their participation, participation partially fulfilled Introductory Psychology course requirements. Participants were native (monolingual) English speakers with normal or corrected-to-normal vision, and had no known reading disorders.

Materials

Fifty-two target words were selected. Each target word (e.g., FLOAT) was paired with 4 primes: (a) a rime associate (e.g., BOAT), (b) a non-rime associate (e.g., SWIM), (c) a non-associate rime (e.g., COAT), and (d) an unrelated word (e.g., SEED). All primes were matched with respect to printed frequency (Kučera & Francis, 1967), word length, onset length, body length, number of syllables, and morphological complexity (viz., all primes were monomorphemic). Primes were also approximately matched for number of orthographic neighbors (Coltheart, Davelaar, Jonasson, & Besner, 1977). See Table 2 for a summary of material attributes.

Target words were selected from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1998) to meet several constraints. Associated word pairs also rhymed (e.g., BOAT–FLOAT). From the first vowel (i.e., the nucleus) to the end of the word, rime words were orthographically and phonologically identical to one another. To maximize the potential for form-based facilitation from an unmasked prime, the lower frequency member of the word pair (e.g., FLOAT) was selected as the target when possible (Segui & Grainger, 1990). The decision to use a low frequency target resulted in a relatively stronger backward association as compared to the forward association.[1] A forward association refers to the proportion of participants who generated the target when given the prime, whereas the backward association refers to the proportion of participants who produced the prime when given the target. For example, in the prime-target pair BOAT–FLOAT, 2% of participants give the lower frequency FLOAT when cued with the higher frequency BOAT, whereas 10% of participants give the higher frequency BOAT when cued with the lower frequency FLOAT (across all items, the average forward and backward strengths were 2% and 9%, respectively).[2]

Non-rime associates were selected from the same norms to match rime associates with respect to their associative relatedness to the target. For example, BOAT and SWIM are matched with respect to their forward and backward associative strengths with the target FLOAT. Moreover,

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[1] There is a natural confound between target frequency and direction of association. Specifically, because participants are more likely to generate high as compared with low frequency words, a low frequency target is in general more likely to lead to the generation of a high frequency associate than a high frequency target is to lead to the generation of a low frequency associate.

[2] Maximal facilitation due to association or semantic similarity between prime and target derives from a strong forward association (according to spreading activation models of semantic priming); however, facilitation due to backward association is reliable in visual lexical decision tasks (see Kahan, Neely, & Forsythe, 1999, for a review).

rime associates and non-rime associates were matched with respect to strength as well as the number of shared associates (i.e., the number of words associated with both the prime and the target). Notably, there was a small (non-significant) bias for greater associative strength between SWIM and FLOAT as compared to between BOAT and FLOAT pairs.

Associatively related words (e.g., WATER–BOAT) share some type of relationship (e.g., functional), whereas semantically related words express the same concept (e.g., SHIP–BOAT). BOAT and SWIM type primes were equated statistically for their *associative* relatedness to the targets, but not necessarily for their *semantic* relatedness. Because semantic priming can occur independently of prime-target association (for a review, see Lucas, 2000), we also considered a co-occurrence statistic based on latent semantic analysis (LSA, Landauer, Foltz, & Laham, 1998). Based on that statistic, SWIM–FLOAT type pairs are indeed more similar in meaning than BOAT–FLOAT type pairs, $t(51) = 2.51$, $p < .02$. If BOAT–FLOAT facilitation is greater than SWIM–FLOAT facilitation, it cannot be attributed to greater associative or semantic relatedness.

To test whether BOAT–FLOAT facilitation is in part due to form priming, non-associate rime primes (e.g., COAT) were included. Non-associate rime primes were matched to associate rime primes (e.g., BOAT) for orthographic and phonological similarity. Orthographic overlap based on the metric by Rastle et al. (2000) did not differ for BOAT–FLOAT and COAT–FLOAT type pairs. However, +F+M overlap was significantly higher, $t = 1.86$, $p = .03$, 1-tailed, than that in the Rastle et al. (2000) study. Lastly, unrelated primes constituted the baseline condition against which to assess the magnitude of facilitation for the 3 critical prime conditions (i.e., rime associate, non-rime associate, and non-associate rime). Unrelated primes (e.g., SEED) were selected to be maximally dissimilar to targets (e.g., FLOAT) on semantic, orthographic, and phonological dimensions of relatedness.

Twenty-six unrelated prime-target pairs (e.g., PULSE–GRAZE) served as fillers. They were introduced to reduce the proportion of related trials. Filler primes and targets mimicked critical primes and targets with respect to frequency, letter length, and number of syllables. To mimic the word-word pairs, 78 word-nonword pairs were created. Specifically, 26 or 1/3 of the pairs were orthographically and phonologically similar (e.g., START–GLART) and the remaining 52 pairs were unrelated (e.g., MILD–CRUSP).

Design

The materials were counterbalanced such that each participant responded to 78 word targets: 13 BOAT–FLOAT type pairs, 13 SWIM–FLOAT type pairs, 13 COAT–FLOAT type pairs, 13 SEED–FLOAT type pairs, and 26 unrelated filler pairs. Stated alternatively, 1/3 of the critical pairs were semantically related, 1/3 were orthographically/phonologically related, and 1/6 of the pairs shared both form and meaning (BOAT–FLOAT). The 26 unrelated word-word filler pairs as well as the 78 word-nonword pairs were not counterbalanced, and did not vary from list to list.

Participants were randomly assigned to 1 of 4 experimental lists with the constraint that an equal number of participants saw each list. Each list consisted of a total of 156 trials (78 word targets, 78 nonword targets). Lists were counter-balanced such that each of the 52 critical word targets appeared only once per list, but across lists, each critical word target was paired once with each of the 4 prime types. Within each experimental list, each prime condition was equally represented (but) with different critical targets. Prime type was a repeated factor by participants as well as by items (viz., target words).

Procedure

Participants were tested individually on a Power Macintosh 6100/60AV computer. Items were presented in a different random order for each participant using Psy-Scope 1.2.4 software. The same set of 6 practice trials preceded each of the experimental lists. On each trial, the experimental sequence consisted of a 450-ms fixation “+,” a 50-ms blank, a 250-ms (Experiment 1a) or 116-ms (Experiment 1b) prime, and finally a target. Primes and targets were presented in 18 point, lowercase Courier font. The target appeared one line below the prime immediately after prime offset, and remained visible until participants responded or 3000 ms had elapsed. The procedure for Experiment 1c was identical to Experiments 1a and 1b with the following modifications. On each trial, the experimental sequence consisted of a 450-ms fixation “+,” a 50-ms blank, a 500-ms mask “####” (matched in length to the prime), a 48-ms prime, and finally an uppercase target until participants respond or 3000 ms had elapsed. Crucially, all stimuli were left-justified on the same line at the same central location on the screen.

Participants made a lexical decision response to each target on a PsyScope button box by pressing the left button (with their left index finger) for nonwords and the right button (with their right index finger) for words. Response latency was measured from the onset of the target until button press, and accuracy was recorded automatically. Reaction times at or beyond the 3000-ms timeout were treated as errors. No reaction time or accuracy feedback was given; however, accuracy feedback was given on the practice trials. There was a 1000-ms inter-trial interval.

Results and Discussion

Experiment 1a (250-ms prime duration)

Data from six participants were removed because their accuracy rates were less than 70% in the unrelated word-target condition. Using the same criteria, data from 1 target (viz., VET) were also removed from the analyses. Reaction times that were more extreme than 2 standard deviations from each participant’s mean reaction time to critical word targets were replaced with the cutoff value (4.4% of participant, and 4.6% of item scores were replaced). Nonword-target trials and word-target filler trials were excluded from the analyses. For this and all subsequent analyses, mean decision latencies and accuracy rates were entered into separate 2 (± form) × 2 (± meaning) analyses of variance (ANOVAs) with participants (F_1) and items (F_2) treated as random effects. When primes were presented for 250 ms, target (e.g., FLOAT) decision latencies were fastest after BOAT type primes, and next fastest after SWIM type primes; however, latencies were comparable after COAT and SEED type primes. Differences among accuracy rates were small, but mimicked the pattern observed with the latency data. Latency and accuracy data appear in Table 3.

Latency measure—The main effect of form was not significant in the analyses by-participants or by-items, F_1 (1,109) = 1.83, *MSE* = 4,132, $p < .18$; F_2 (1,50) < 1. Overall, target decision latencies after orthographically/phonologically similar primes (690 ms) did not differ from those after formally dissimilar primes (698 ms). The main effect of meaning was significant, F_1 (1,109) = 32.59, *MSE* = 3,235, $p = .000$; F_2 (1,50) = 18.82, *MSE* = 3,192, $p = .000$. Latencies were faster after semantically related (678 ms) as compared to after semantically unrelated (709 ms) primes. Crucially, there was a significant overadditive interaction between form and meaning, F_1 (1,109) = 9.41, *MSE* = 2,392, $p = .003$; F_2 (1,50) = 3.60, *MSE* = 3,542, $p = .06$, such that +F+M facilitation was greater than the sum of the −F+M and +F−M effects.

Planned comparisons in this and all subsequent analyses were calculated with the error term specific to each comparison (functionally equivalent to t-tests).[3] The 95% confidence interval from the analysis by-participants is indicated for each difference score (i.e., unrelated target decision latency minus related latency). Relative to after unrelated primes (e.g., SEED), target latencies were significantly reduced after BOAT (39 ± 15 ms), $F_1(1,109) = 25.62$, $MSE = 6{,}611$, $p = .000$; $F_2(1,50) = 16.53$, $MSE = 5{,}111$, $p = .000$, and after SWIM (17 ± 14 ms), $F_1(1,109) = 5.79$, $MSE = 5{,}268$, $p = .018$; $F_2(1,50) = 3.61$, $MSE = 4{,}842$, $p = .063$, but not after COAT (−6 ± 16 ms) ($F_S < 1$) type items. Importantly, latencies after BOAT type primes differed significantly from those after SWIM type primes (23 ± 14 ms), $F_1(1,109) = 9.66$, $MSE = 5{,}806$, $p = .002$; $F_2(1,50) = 4.90$, $MSE = 5{,}130$, $p = .031$, as well as after COAT type primes (45 ± 15 ms), F_1 (1,109) = 37.64, $MSE = 5{,}987$, $p = .000$; F_2 (1,50) = 14.86, $MSE = 8{,}626$, $p = .000$. Finally, +F+M (e.g., BOAT–FLOAT) facilitation was significant and greater than the −F+M (e.g., SWIM–FLOAT) and +F−M (e.g., COAT–FLOAT) effects.

Accuracy measure—When collapsed over levels of meaning, the main effect of form was not significant in the analyses by-participants or by-items ($F_S < 1$) with the accuracy measure. Overall, target accuracy after orthographically/phonologically similar primes (94.5%) did not differ from that after formally dissimilar primes (94.4%). However, the main effect of meaning was significant, F_1 (1,109) = 16.05, $MSE = .003$, $p = .000$; F_2 (1,50) = 13.96, $MSE = .002$, $p = .000$. Accuracy was higher after semantically related (95.6%) as compared to after semantically unrelated (93.3%) primes. The interaction between the effects of form and meaning was not reliable with the accuracy measure ($F_S < 1$).

Although the interaction was not significant, planned comparisons revealed that relative to after unrelated primes (e.g., SEED), target accuracy was significantly higher after BOAT (2.3% ± 1.5%), $F_1(1,109) = 9.73$, $MSE = .006$, $p = .002$; $F_2(1,50) = 9.52$, $MSE = .003$, $p = .003$, and after SWIM (1.8% ± 1.8%), $F_1(1,109) = 4.17$, $MSE = .009$, $p < .05$; $F_2(1,50) = 5.00$, $MSE = .003$, $p = .03$, but not after COAT type primes (0.4% ± 1.8%) ($F_S < 1$). Accuracy after BOAT type primes did not differ from that after SWIM type primes (0.5% ± 1.6%) but was significantly higher than after COAT type primes (2.7% ± 1.5%), $F_1(1,109) = 11.97$, $MSE = .007$, $p = .001$; F_2 (1,50) = 8.86, $MSE = .004$, $p = .004$.

Semantic consistency in rime families—For words that share onset form and meaning (e.g., GLOW, GLARE, GLIMMER, GLISTEN), Bergen (2004) made a distinction between prime-target pairs that have a consistent semantic family and those that have an inconsistent semantic family where semantic consistency reflected the proportion of family members whose meaning overlapped with that of the target. Bergen (2004) reported reliable facilitation for primes and targets (e.g., GLITTER–GLOW) that shared onset form and meaning and belonged to a semantically consistent family but not for pairs (e.g., CRONY–CROOK) that shared form and meaning but were from inconsistent families. Latent semantic analysis (LSA, Landauer et al., 1998) of the Bergen materials revealed that GLITTER–GLOW type items co-occurred in written texts almost twice more often than CRONY–CROOK pairs (0.23 vs. 0.12), which suggested that GLITTER–GLOW type pairs have a stronger semantic relationship between prime and target. The materials in the current study allow for an effect of the semantic consistency independent of the semantic relatedness between prime and target (see Feldman & Pastizzo, 2003).

If the magnitude of facilitation in rime families (e.g., BOAT, BLOAT, COAT, FLOAT, GOAT, MOAT) is sensitive to the degree of regularity in the mapping between form and meaning defined over a group of words, then facilitation should be greater for prime-target pairs with a more rather than less consistent family. To compute the semantic consistency of a rime family in the present study, we first computed rime family size for each target word. On average, the

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[3] Keppel (1991) recommended that "the safest strategy is to construct separate error terms for *all* comparisons" (p. 356).

critical targets had a family size of 12 (*range* = 3 to 22, *SD* = 5) rime words. Inspection of a target's rime family revealed that some words (e.g., BOAT, LSA = 0.35) were more semantically related to the target (e.g., FLOAT) than others (e.g., GOAT, LSA = 0.05). Relatedness between a rime family member and the target was operationally defined by its co-occurrence value from LSA. LSA co-occurrence values revealed that families varied with respect to the number of words that were highly related to the target word. For each target, rime members with a co-occurrence value greater than the average co-occurrence for that rime family were considered highly related to the target. Across targets, the number of highly related rime members varied from 1 to 17 (*M* = 7.4, *SD* = 4.0).

To determine whether facilitation for BOAT–FLOAT type items varied as a function of the number of highly related rime members, targets were divided into thirds so that the top- (i.e., consistent families) and bottom- (i.e., inconsistent families) thirds could be compared. Inconsistent families contained an average of 3.2 highly related rime members ranged (*N* = 17, *range* = 1 to 5, *SD* = 1.3), and consistent families had an average of 12.1 highly related members (*N* = 16, *range* = 10 to 17, *SD* = 2.4). In contrast to the Bergen (2004) study, inconsistent and consistent families were matched with respect to the semantic relatedness between prime and target. Accordingly, any difference in facilitation for items from inconsistent and consistent families cannot be due to differences in semantic relatedness between primes and targets, but instead can be attributed to semantic similarity defined over a group of words in conjunction with the size of the group.

BOAT–FLOAT facilitation was significant for consistent (56 ± 41 ms), $t(15) = 2.61$, $p = .02$, 2-tailed, but not for inconsistent families (29 ± 34 ms), $t(16) = 1.61$, $p < .13$, 2-tailed. When controlling for rime family size, a univariate analysis of covariance revealed a significant effect of consistency, $F\,(1,30) = 4.18$, $MSE = 6{,}005$, $p = .05$, such that facilitation was greater as the number of related forms increased. The difference suggests that not only can shared form and meaning facilitate target recognition in a way that cannot be predicted by simply adding the two dimensions of relatedness, but also that the magnitude of facilitation between prime and target seems to be related to the number of words within a rime family that share meaning as well as form.

Experiment 1b (116-ms prime duration)

Data from one participant were removed because accuracy rate was less than 70% in the critical unrelated word-target condition as were data from the target VET. Reaction times that were more extreme than 2 standard deviations from each participant's mean reaction time to critical word targets were replaced with the cutoff value (4.5% of participant, and 5.1% of item scores were replaced). Compared with Experiment 1a (250-ms SOA), on average, target decision latencies were 29 ms slower, but accuracy rates were 2% higher. Target (e.g., FLOAT) decision latencies were fastest after BOAT type primes, and next fastest after SWIM type primes; however, latencies after COAT were slower than after SEED type primes. Accuracy rates were lower after COAT, but did not differ after BOAT, SWIM, and SEED type primes. Latency and accuracy data appear in Table 4.

Latency measure—The main effect of form was not significant in the analysis by-participants, but was marginally significant in the analysis by-items, $F_1\,(1,79) < 1$; $F_2\,(1,50) = 2.50$, $MSE = 2{,}851$, $p = .12$. Overall, target decision latencies after orthographically/phonologically similar (726 ms) and dissimilar primes (719 ms) did not differ. The main effect of meaning was significant, $F_1\,(1,79) = 16.84$, $MSE = 2{,}625$, $p = .000$; $F_2\,(1,50) = 9.71$, $MSE = 3{,}972$, $p = .003$. Latencies were faster after semantically related (711 ms) as compared to semantically unrelated (734 ms) primes. Crucially, again there was a significant overadditive interaction between the effects of form and meaning, $F_1\,(1,79) = 6.74$, $MSE = 3{,}091$, $p = .011$;

F_2 (1,50) = 6.63, *MSE* = 3,132, p =.013, such that +F+M facilitation was greater than the sum of the −F+M and +F−M effects.

Planned comparisons revealed that relative to the baseline condition (e.g., SEED–FLOAT), target latencies were significantly reduced (in the participant analysis) after BOAT (17 ± 15 ms), F_1(1,79) = 4.71, *MSE* = 4,721, p =.033; F_2(1,50) = 2.07, *MSE* = 6,057, p <.16, but not after SWIM type primes (7 ± 14 ms), F_1(1,79) = 1; F_2(1,50) < 1; conversely, latencies were significantly inhibited after COAT type primes (−23 ± 19 ms), F_1(1,79) = 5.89, *MSE* = 7,168, p =.018; F_2(1,50) = 9.69, *MSE* = 5,391, p =.003. Latencies after BOAT type primes did not differ from those after SWIM type primes (9 ± 18 ms), F_1(1,79) = 1; F_2(1,50) < 1; however, latencies after BOAT type primes did differ significantly from those after COAT type primes (40 ± 19 ms), F_1(1,79) = 17.48, *MSE* = 7,194, p =.000; F_2(1,50) = 15.70, *MSE* = 7,388, p =. 000.

The absence of reliable semantic facilitation at a 116-ms SOA was unexpected. Feldman (2000) obtained reliable semantic facilitation with a 300- as well as a 116-ms SOA (33 and 30 ms, respectively). The reduced magnitudes of semantic facilitation in the present study (250-ms SOA: 17 ms; 116-ms SOA: 7 ms) suggest that the semantic overlap between prime and target pairs was weaker in the present study (e.g., SWIM–FLOAT) compared to in the Feldman (2000) study (e.g., PLEDGE–VOW). In contrast to the null effect after semantic primes in the present study, form inhibition was significant.

Accuracy measure—The main effect of form was significant in the analysis by-participants but was marginal in the analysis by-items, F_1 (1,79) = 4.33, *MSE* =.005, p <.05; F_2 (1,50) = 3.26, *MSE* =.004, p <.08. Overall, target decision accuracy after orthographically/ phonologically similar primes (94.7%) was lower than that after formally dissimilar primes (96.3%). The main effect of meaning was significant, F_1 (1,79) = 8.89, *MSE* =.003, p =.004; F_2 (1,50) = 4.99, *MSE* =.004, p =.03, such that accuracy was higher after semantically related (96.4%) than after semantically unrelated (94.6%) primes. The interaction between the effects of form and meaning was not reliable with the accuracy measure, F_1 (1,79) < 1; F_2 (1,50) = 1.

Although the interaction was not significant, planned comparisons revealed that relative to after unrelated primes (e.g., SEED), target accuracy was worse after COAT type primes (−2.2% ± 2.1%), F_1(1,79) = 4.23, *MSE* =.009, p =.043; F_2(1,50) = 3.38, *MSE* =.007, p =.072. Accuracy after BOAT type primes did not differ from that after SWIM type primes (1.0% ± 1.7%), F_1(1,79) = 1.4; F_2(1,50) = 1.2. Accuracy after BOAT type primes was, however, higher than after COAT type primes (2.4% ± 1.7%), F_1 (1,79) = 7.78, *MSE* =.006, p =.007; F_2 (1,50) = 5.25, *MSE* =.006, p =.026.

Semantic consistency in rime families—Consistent with the outcome for Experiment 1a (250-ms prime duration), when primes appeared for 116 ms, BOAT–FLOAT facilitation was again significant for consistent (47 ± 36 ms), t(15) = 2.43, p <.03, 2-tailed, but not for inconsistent families (12 ± 34 ms), t(16) = 0.67, p =.51, 2-tailed. In contrast to Experiment 1a, when we controlled for rime family size, a univariate analysis of covariance failed to reveal a significant effect of family consistency, F (1,30) < 1. Apparently, the influence of semantically related family members on the magnitude of BOAT–FLOAT facilitation takes time to emerge as the family consistency effect was reliable only at a relatively long prime duration (viz., 250 ms).

Experiment 1c (48-ms duration forward masked prime)

Data from the target, VET, were once again removed from the analyses and latencies were more extreme than 2 standard deviations were replaced with the cutoff value (4.9% of participant, and 5.0% of item scores were replaced). In forward masked priming, target (e.g., FLOAT) decision latencies were slowest after COAT type primes, and equivalent after BOAT, SWIM, and SEED type primes. Differences among accuracy rates were small, but mimicked the pattern observed with the latency data. Data appear in Table 5.

Latency measure—The main effect of form was significant in the analysis by-participants but was marginal in the analysis by-items, $F_1(1,72) = 4.69$, $MSE = 1{,}913$, $p = .034$; $F_2(1,50) = 2.48$, $MSE = 1{,}723$, $p = .12$. Overall, target decision latencies after orthographically/phonologically similar primes (656 ms) were slower than after formally dissimilar primes (645 ms). The main effect of meaning was significant, $F_1(1,72) = 4.32$, $MSE = 1{,}708$, $p = .041$; $F_2(1,50) = 5.66$, $MSE = 1{,}600$, $p = .021$. Latencies were faster after semantically related (645 ms) than after semantically unrelated (655 ms) primes. Most importantly, the overadditive interaction between the effects of form and meaning was significant, $F_1(1,72) = 4.95$, $MSE = 2{,}328$, $p = .029$; $F_2(1,50) = 7.18$, $MSE = 1{,}415$, $p = .01$, such that +F+M priming was greater than the sum of the −F+M and +F−M effects.

Planned comparisons revealed that relative to the baseline condition (e.g., SEED–FLOAT), target latencies were significantly inhibited after COAT type primes (−24 ± 13 ms), $F_1(1,72) = 14.17$, $MSE = 2{,}883$, $p = .000$; $F_2(1,50) = 6.51$, $MSE = 4{,}238$, $p = .014$. Latencies after BOAT type primes were not inhibited. Stated alternatively, latencies after BOAT type primes that share semantics as well as form with the target did differ significantly from those after COAT type primes that shared only form (23 ± 15 ms), $F_1(1,72) = 9.26$, $MSE = 4{,}034$, $p = .003$; $F_2(1,50) = 11.33$, $MSE = 3{,}390$, $p = .001$. At the same time, latencies after BOAT type primes did not differ from those after SWIM type primes or after unrelated controls. In essence, under forward masked presentation conditions, semantic facilitation[4] was absent and form inhibition was significant. Most importantly, the significant interaction between the effects of form and meaning (such that BOAT–FLOAT priming differed from COAT–FLOAT priming) indicated that under forward masked presentation conditions where effects of semantic similarity failed to arise, the inhibitory effect of similarity due to form was offset by similarity due to meaning.

Accuracy measure—The main effect of form on target decision accuracy was not significant nor was the main effect of meaning or their interaction, $F_S < 1$.

General Discussion

Results of the present study provide evidence that prime-target pairs that share both form and meaning benefit relative to those word pairs that only share a single dimension of relatedness. Moreover, the magnitude of the BOAT–FLOAT effect was greater than what would be predicted by a linear combination of the SWIM–FLOAT and COAT–FLOAT effects. This overadditive interaction of form and meaning was replicated in visual lexical decision priming experiments with prime durations of 250 ms and 116 ms as well as when primes were forward masked and presented for 48 ms.

Results of the present study fail to demonstrate that true morphological and BOAT–FLOAT facilitation can be distinguished by their time course. We replicated overadditive effects at three SOAs in the present study. A direct comparison between the present experiment and Rastle et al. (2000) requires extreme caution because the style of prime-target form overlap varied across studies. Nonetheless, it is evident that the inhibitory orthographic contribution to nonadditivity was more robust in the present study. One consideration is that we used rime overlap whereas Rastle et al. incorporated variable styles of overlap. Rime overlap may capture

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[4] Semantic masked priming has been demonstrated, however, under presentation conditions (e.g., Abrams & Greenwald, 2000; Abrams, Klinger, & Greenwald, 2002; Bodner & Masson, 2003; Brown & Besner, 2002) that differed in some respect from those typically employed by Forster and colleagues (see Forster, 1999).

a more salient and stable aspect of orthographic-phonological form than does position varying overlap (Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welt, 1995). At a short SOA with a mask we observed form-based inhibition, but Rastle et al. did not. More important, even at very short SOAs, effects of orthographic neighbors become more inhibitory as target neighborhood increases (Davis & Lupker, 2006). Targets in the present study averaged 5.6 neighbors whereas depending on type of prime, those in (Rastle et al., 2000) varied between 1.3 and 3.3.

Statistical regularity

We documented previously that the magnitude of morphological facilitation can vary according to the systematicity of the mapping between form and meaning across a family of morphologically related words that extends beyond a particular prime and its target (Feldman & Pastizzo, 2003). Although morphologically related words exemplify systematic mappings between form and meaning particularly well, following Bergen (2004), we demonstrated in the present study that systematicity in the mapping between form and meaning also extends to morphologically unrelated words (e.g., LIGHT–BRIGHT). Feldman and Pastizzo (2003) demonstrated that after covarying for semantic relatedness between prime and target, the difference in target decision latencies after transparent (ALLOWABLE–ALLOW) and partially transparent (ALLOWANCE–ALLOW) morphologically-related primes correlated positively with the transparent family size (i.e., the number of semantically transparent morphological relatives) of a stem. In fact, a similar relation between statistical regularity and the magnitude of forward masked morphological facilitation was reported for prefixes depending on their reliability as prefixes as contrasted with pseudoprefixes (Chateau, Knudsen, & Jared, 2002). In the present study, we extend the finding that while LIGHT and BRIGHT are similar in meaning as well as form, because there exist semantically less consistent IGHT forms (e.g., FIGHT), facilitation varies with respect to the semantic consistency within a family of words that share form. In summary, one factor that influences the magnitude of facilitation is the systematicity of the mapping between form and meaning, a regularity that extends beyond a particular prime and its target. A similar relation arises when prime-target pairs share a morpheme (Feldman & Pastizzo, 2003) and, in the present study, when they do not. This outcome can be interpreted as further evidence that a common mechanism may underlie processing for shared form and shared meaning in the presence or in the absence of a shared morpheme.

Overall, magnitudes of both morphological and semantic facilitation tend to increase as SOA increases. By contrast, effects of orthographic similarity tend to be inhibitory and to decrease with SOA. In the present study, at a short SOA, BOAT–FLOAT type pairs resemble SWIM–FLOAT type pairs in that neither shows the inhibition evident for COAT–FLOAT type pairs. At the 250 ms SOA, BOAT–FLOAT pairs resemble SWIM–FLOAT pairs in that both show facilitation that COAT–FLOAT pairs do not. The BOAT–FLOAT effect is not purely semantic because whenever semantic effects are present BOAT–FLOAT pairs are faster than SWIM–FLOAT type pairs. The BOAT–FLOAT effect is not purely form based because whether or not form effects are present BOAT–FLOAT pairs are faster than COAT–FLOAT type pairs. Evidently, processing of BOAT–FLOAT type pairs is subject to influences that cannot be detected by restricting one’s focus to significant magnitudes of facilitation and cannot be predicted by combining effects of form and effects of meaning in a linear manner.

Conjoint accounts of morphological processing

In distributed models, words are represented as patterns of activation distributed over units of form and units of meaning and priming reflects similar patterns of semantic, orthographic, and/or phonological activation for prime and target (e.g., Gonnerman et al., 2007; Seidenberg & McClelland, 1989). Degree of form and meaning overlap between prime and target can influence the magnitude of facilitation; further, effects combine and not necessarily in a linear manner. In addition, systematicity at the level of form and meaning tends to be more complex and to take longer to resolve than does systematicity at the level of orthographic (and phonological) form(s) so that form effects tend to emerge earlier than form and meaning effects. Finally, the principle of division of labor (Harm & Seidenberg, 2004) predicts that effects of semantic similarity on recognition will depend on the status of orthographic and phonological form processing and whether it has stabilized or is still ongoing. These principles anticipate overadditive and even more complex nonlinear interactions based on the contributions of form and meaning and when they arise whether or not a morpheme is present.

To motivate the present study, we argued that if a similar nonadditive advantage accrues for morphologically related words such as VOWED–VOW and for pairs such as BOAT–FLOAT, then the basis of morphological facilitation may not be activation of a shared morpheme in prime and target. In essence, we opposed a localized *Morpheme Activation* account based on the repeated activation of a morphological structure shared by prime and target with an account based on distributed representations where morphological effects emerge from *Conjoint Similarity* effects of form and meaning. We acknowledge that other classes of models that include morphological representations have the potential to account for some our findings. For example, within an interactive activation framework with representations for morphemes, at the 48-ms SOA, SWIM–FLOAT effects would fail to arise because primes cannot activate targets when form similarity is absent. COAT–FLOAT inhibition would arise because of competition among orthographic representations that mismatch semantically. Finally, orthographic-level inhibition for BOAT–FLOAT type pairs could be offset by excitatory activation that feeds back from shared semantic representations. Within this framework, however, at the long SOA when 33% of targets have a semantically related prime and form similarity is uninformative about the lexicality of the target, it is unclear how a very weak inhibitory effect of form similarity would combine with a significant facilitatory effect of semantic similarity to produce facilitation for BOAT–FLOAT type pairs that is stronger than for SWIM–FLOAT type pairs.

In summary, those who investigate morphological processing wrestle with whether or not morphological relatedness can be understood as the combined effect of form and meaning (e.g., Beauvillain & Segui, 1992; Bybee, 1985; Feldman, 2000; Napps, 1989; Rastle et al., 2000; Stolz & Feldman, 1995). To the extent that the same mechanism underlies facilitation for BOAT–FLOAT and for VOWED–VOW type items, the implication of the findings of the present study is that morphological relatedness need not be represented explicitly in the mental lexicon (e.g., Gonnerman, 1999; Rueckl et al., 1997; Rueckl, 2002; Rueckl & Raveh, 1999). Moreover, results provide further evidence that the strength of the mapping between form and meaning, as indexed by the number and status of words in a family, influences the magnitude of facilitation both when prime and target are morphologically unrelated (e.g., Bergen, 2004) and when prime and target share a morphemic unit (e.g., Pastizzo & Feldman, 2002a; Pastizzo & Feldman, 2002b). In conclusion, results of the present study call into question the necessity of describing morphological facilitation with reference to an explicitly represented linguistic unit.

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Table 1

The Effect of Multiple Dimensions of Relatedness Between Target Items and Prime(s) or Cue(s) on the Magnitude of Priming

				Dimensions				
Study	**Exp**	**SOA (ms)**	**Task**	**Meaning**	**Form**	**Form & Meaning**	**Form + Meaning**	**Interaction**
Bergen, 2004	1	450	Lexical Decision	23	−3	59	20	+39^
Rastle et al., 2000	2	43	Lexical Decision	1	−8	15	−7	+22^
	2	72	Lexical Decision	0	−14	4	−14	+18^
	2	230	Lexical Decision	28	−1	34	27	+7^
Damian & Martin, 1999	3	−150	Picture Naming	−32	5	−9	−27	+16★
	3	0	Picture Naming	−31	19	26	−12	+38★★
	3	150	Picture Naming	−6	45	37	39	−2
Rouibah et al., 1999	2	147/399	Semantic Categorization	39	35	61	74	−13★
	3	147/399	Rhyme Detection	42	45	60	87	−27★★

^ no report of statistical evaluation;

★★ p <.05 by-participants and by-items;

★ p <.05 by-participants or by-items

Table 2

Mean (SD) Attributes of Primes and Targets for each Stimulus Set (n = 52)

	Prime Type				
	−F+M	**+F−M**	**+F+M**	**−F−M**	**Target**
	SWIM	**COAT**	**BOAT**	**SEED**	**FLOAT**
Printed frequency	70.4 (95.7)	74.2 (99.6)	87.8 (158.2)	76.3 (95.6)	26.4 (55.5)
Word length	4.5 (0.9)	4.3 (0.9)	4.3 (0.9)	4.4 (0.7)	4.5 (0.9)
Onset length	1.4 (0.7)	1.3 (0.6)	1.3 (0.6)	1.3 (0.6)	1.5 (0.6)
Body length	3.1 (1.0)	3.0 (0.8)	3.0 (0.8)	3.2 (0.7)	3.0 (0.8)
# of syllables	1.2 (0.5)	1.1 (0.2)	1.1 (0.3)	1.1 (0.2)	1.1 (0.2)
# of orthographic neighbors	5.2 (3.8)	7.0 (4.7)	7.3 (5.0)	6.2 (4.6)	5.6 (4.2)
P-T orthographic overlap	0.01 (0.00)	0.70 (0.10)	0.71 (0.10)	0.01 (0.01)	–
P-T LSA	0.33 (0.18)	0.12 (0.09)	0.26 (0.20)	0.09 (0.07)	–

Table 3

Mean Target Decision Latencies (SD) and Accuracy Rates (SD) for Experiment 1a (250-ms prime duration)

	Prime condition					
	−F−M	**−F+M**	**+F−M**	**+F+M**		
	SEED	**SWIM**	**COAT**	**BOAT**		
	FLOAT	**FLOAT**	**FLOAT**	**FLOAT**	**BOAT vs. COAT**	**BOAT vs. SWIM**
By-participants						
Latency	706 (111)	690 (114)	712 (118)	667 (100)		
Priming		17★★	−6	39★★	45★★	**23★★**
Accuracy	93 (7)	95 (6)	93 (8)	96 (6)		
Priming		2★★	0	2★★	3★★	**1**
By-items						
Latency	709 (85)	691 (81)	719 (98)	669 (77)		
Priming		19★	−9	41★★	50★★	**22★★**
Accuracy	94 (8)	95 (8)	93 (9)	96 (6)		
Priming		2★★	0	2★★	3★★	**1**

★★ $p < 0.05$

★ $p < 0.10$

Table 4

Mean Target Decision Latencies (SD) and Accuracy Rates (SD) for Experiment 1b (116-ms prime duration)

	Prime condition					
	−F−M	**−F+M**	**+F−M**	**+F+M**		
	SEED	**SWIM**	**COAT**	**BOAT**		
	FLOAT	**FLOAT**	**FLOAT**	**FLOAT**	**BOAT vs. COAT**	**BOAT vs. SWIM**
By-participants						
Latency	723 (168)	716 (164)	746 (148)	706 (147)		
Priming		7	−23★★	17★★	40★★	**10**
Accuracy	96 (6)	97 (6)	93 (8)	96 (6)		
Priming		1	−2★★	0	3★★	**−1**
By-items						
Latency	724 (85)	717 (86)	756 (99)	708 (81)		
Priming		7	−32★★	16	48★★	**9**
Accuracy	96 (8)	97 (6)	94 (9)	96 (7)		
Priming		1	−2★	0	2★★	**−1**

★★ $p < 0.05$

★ $p < 0.10$

Table 5

Mean Target Decision Latencies (SD) and Accuracy Rates (SD) for Experiment 1c (48-ms forward masked prime)

	Prime condition					
	−F−M	**−F+M**	**+F−M**	**+F+M**		
	SEED	**SWIM**	**COAT**	**BOAT**		
	FLOAT	**FLOAT**	**FLOAT**	**FLOAT**	**BOAT vs. COAT**	**BOAT vs. SWIM**
By-participants						
Latency	643 (101)	646 (100)	667 (112)	644 (120)		
Priming		−3	−24★★	−1	23★★	**2**
Accuracy	95 (7)	95 (8)	94 (8)	95 (5)		
Priming		0	−1	0	1	**0**
By-items						
Latency	649 (66)	649 (70)	672 (74)	644 (62)		
Priming		−1	−23★★	4	28★★	**5**
Accuracy	95 (7)	95 (9)	94 (6)	95 (7)		
Priming		0	−1	0	1	**0**

★★ $p < 0.05$

★ $p < 0.10$