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Morphological Priming: The Role of Prime Duration, Semantic Transparency, and Affix Position

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Patterns of facilitation in three lexical decision studies reveal several properties of morphologically complex words that influence processing. In one study, effects of morphological (VOWED–VOW) similarity are contrasted with effects of either semantic (PLEDGE–VOW) or orthographic (VOWEL–VOW) similarity at two prime durations to show the distinctiveness of morphological processing. In a second study, we compare morphologically complex forms that are semantically transparent (CASUALLY–CASUALNESS) with opaque forms (CASUALTY–CASUALNESS) and show that opaque relatives are more similar to VOWEL–VOW type pairs than to transparent relatives. In the third study, we examine facilitation for complex targets (CALCULATION) preceded by prefixed (MISCALCULATE) and suffixed (CALCULATOR) relatives and show that the position of the base morpheme influences processing under cross-modal but not under purely visual presentation conditions. Taken collectively, under comparable presentation conditions, semantic transparency but not base morpheme position constrains morphological processing.

Key Words: morphological processing; cross-modal priming; morphological similarity; semantic similarity; orthographic similarity; semantic transparency; prefixed forms; suffixed forms.

In the present overview, we provide experimental evidence from three lexical decision studies conducted with English materials to elucidate several factors relevant to the processing of morphologically complex forms. In each study, the critical comparison focuses on decision latencies to targets that follow morphologically related primes differing on some dimension of morphological complexity. Morphological relatives tend to share both meaning and form. Accordingly, in the first study, we systematically differentiate between these dimensions of similarity by contrasting the effects of morphological (VOWED–VOW) similarity with effects of either semantic (PLEDGE–

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VOW) or orthographic (VOWEL–VOW) similarity. Base morphemes do not always contribute to the meaning of a complex form in a predictable manner. Therefore, in the second study, we compare the effects of morphological relatedness for derivational pairs that differ with respect to the contribution of the base morpheme to the meaning of the morphologically complex forms and contrast primes that are transparent (CASUALLY–CASUALNESS) with primes that are opaque (CASUALTY–CASUALNESS). Finally, in the third study, we ask whether the position of the base morpheme relative to its prefixes or suffixes influences recognition. Patterns of facilitation for complex targets (CALCULATION) preceded by prefixed (MISCALCULATE) and suffixed (CALCULATOR) relatives are examined across varying modality configurations of prime and target. Ultimately, each of our findings must be incorporated in an understanding of morphological processing.

DO SEMANTIC AND ORTHOGRAPHIC SIMILARITY UNDERLIE MORPHOLOGICAL RELATEDNESS?

By necessity, words formed from the same base morpheme tend to have similar meanings and similar forms. In one study, we compared morphological effects with the effects of shared meaning and shared form (Feldman, submitted). Within each experiment, we varied the type of similarity (orthographic, semantic, morphological) that primes shared with targets. By manipulating type of similarity within an experiment, we had the potential to compare the magnitudes of facilitation for various dimensions of similarity. We also varied the temporal relation (prime duration) between visual primes and visual targets. Manipulations of prime duration allowed us to probe the dynamics of activation for particular dimensions of similarity.

Critical primes were related to targets morphologically (VOWED–VOW), orthographically (VOWEL–VOW), or semantically (PLEDGE–VOW). For each of the three related primes, a separate unrelated prime was selected to match the frequency, length and morphological structure (simple, complex) of its related pairs. Target frequency was always higher than that of its prime. In addition, because degree of relatedness influences magnitude of facilitation, we matched the degree of (orthographic) overlap between morphologically related and orthographically related primes and (semantic) relatedness between morphologically related and semantically related primes.

Across both prime durations (66 and 300 ms) in the short-term priming procedure, decision latencies to targets following morphological (585 and 587 ms)[1] and semantic (592 and 604 ms) primes were reduced (facilitation) relative to their respective unrelated controls (see Table 1). Moreover, morphological facilitation was significantly greater than semantic facilitation.[2]

[1] Mean latency at 66-ms duration and 300-ms duration.

[2] Unless otherwise noted, all results are significant at $p < .05$ using both subjects and items as random variables.

TABLE 1
Differences in Target Decision Latencies (Accuracies) Following Related Primes and Their Unrelated Controls

	Prime type		
Prime duration (ms)	Morphological	Orthographic	Semantic
66	29 (−3)	18 (−7)	21 (2)
300	49 (6)	−18 (−2)	34 (2)
Long-term	28 (6)	9 (−4)	1 (2)

By contrast, target latencies following orthographically related primes were reduced at the shorter prime durations but increased (inhibition) at the longer prime durations.

In a second experiment, we compared the effects of morphological, semantic, and orthographic relatedness when subjects made decisions to both the target and its related prime and an average of 10 trials separated the presentation of prime and target. At long lags, morphologically related primes (580 ms) significantly reduced target decision latencies. Neither orthographic (610 ms) nor semantic (609 ms) primes had a significant effect on target latencies, however. That is, morphological facilitation was present under conditions in which neither semantic nor orthographic effects were significant.

The general pattern suggests that in both long and short-term priming tasks, morphological (M) effects are greater than either orthographic (O) or semantic (S) effects. The design of the present study also allowed us to ask whether morphological effects can be described in terms of the combined effects of semantic and orthographic similarity (see Rueckl & Raveh, 1999, this volume). In an additional set of analyses, we computed the sum of semantic and orthographic facilitation and compared it with the magnitude of morphological facilitation. At the shorter prime duration, M = O + S, but at the longer duration M more closely approximated S alone than the O + S combination. Stated generally, across prime durations, the dimensions of similarity did not combine in a constant manner.

By some accounts, morphological relatedness reflects conjoint similarity of form and meaning and need not be explicitly represented in the lexicon (e.g., Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997). One might have expected that the individual effects of orthography and of semantics would sum to produce an effect equivalent to that of morphology. However, in the present study, the validity of an additive approach was constrained such that whether or not the effects were additive (M = O + S) depended on prime duration. In effect, processing time for the prime constrained the additivity of semantic and orthographic effects. Evidently, the time-varying pattern must be rationalized before the data can be interpreted as evidence for or against claims about how morphology is represented.

TABLE 2
Differences in Target Decision Latencies (Accuracies) Following Unrelated and Related Primes That Differ in Semantic Transparency

SOA (ms)	Transparent	Opaque
48	19 (−1)	23 (−2)
250	24 (1)	−14 (−1)

CAN SEMANTIC SIMILARITY INFLUENCE MORPHOLOGICAL RELATEDNESS?

In the previous study, similarity of meaning reflected either the presence of a shared base morpheme or an association between whole-word forms. Among forms that share a base morpheme, the semantic transparency of the base relative to the meaning of the complex form can vary. As a result, words that are morphologically related can differ in the similarity of their meanings. We (Soltano, Feldman & Francis, in preparation) have examined the pattern of decision latencies for derivational relatives whose base morpheme was semantically transparent (CASUALLY–CASUALNESS) and for those with an opaque base (CASUALTY–CASUALNESS). Transparent and opaque relatives were determined from judgments of semantic relatedness between the meaning of the base morpheme and that of the complex form.

Results suggested that semantically transparent derivational relatives facilitated visual target decision latencies significantly more than semantically remote relatives but that the effect was constrained by visual prime duration (see Table 2). The effect of semantic similarity among morphological relatives in the short-term task was evident at durations on the order of 250 ms. Latencies following opaque (788 ms) and transparent (751 ms) derivational relatives were significantly different. At a prime duration of 48 ms, opaque and transparent relatives did not differ, however. Latencies were 733 and 737 ms respectively. In essence, morphological relatives that were semantically opaque were more similar to the VOWEL–VOW-type pairs of the previous study than to semantically transparent relatives. The implication of this finding is that for morphological relatives that share the same base morpheme, the varying contribution of the base to the meaning of the complex form can render relatives distinct. However, semantic processing of morphological constituents is temporally constrained (see also, Baayen & Schreuder, 1999, this volume).

ARE A WORD'S MORPHOLOGICAL CONSTITUENTS PROCESSED SEQUENTIALLY?

In a final study, we compared target facilitation following prefixed and suffixed primes formed from the same base as the target (Feldman & Lar-

TABLE 3
Differences in Target Decision Latencies (Accuracies) Following Prefixed, Suffixed, and Simple Primes Relative to an Unrelated Control

	Prime type		
Presentation modality	Prefixed	Suffixed	Simple
Auditory–visual	20 (7)	−1 (4)	34 (0)
Visual–auditory	56 (−1)	−28 (−1)	44 (0)
Visual–visual	22 (1)	22 (1)	34 (0)

abee, revised). Differences in the pattern of facilitation would provide evidence that another aspect of internal structure, the linear organization of a word's morphemic components constrains processing. We presented complex targets (CALCULATION) that were immediately preceded by morphologically related primes that included a prefix (MIS in MISCALCULATE) or a suffix (OR in CALCULATOR) that was absent in the target. A base-alone condition (CALCULATE) and an unrelated condition (OBEDIENTLY) were also included for each target. Thirty percent of the primes that preceded word targets shared a base morpheme with the target. In one experiment, primes were auditory and targets were visual. In a second, primes were visual (250 ms SOA) and targets were auditory (presented at prime offset). In a third, both primes and targets were visual (250 ms SOA). In each, primes and targets were presented in immediate succession.

Latencies to suffixed targets following simple, prefixed, and suffixed primes interacted with presentation modality. Difference scores are reported in Table 3. Facilitation was evident following prefixed and simple morphological relatives. That is, all modality configurations of MISCALCULATE–CALCULATION and CALCULATE–CALCULATION pairs produced facilitation. The effect of suffixed primes varied with modality, however. When both primes and targets were presented visually, CALCULATOR–CALCULATION pairs produced facilitation that was significant and numerically equivalent to that following prefixed primes. Under visual prime–auditory target presentation conditions, CALCULATOR–CALCULATION pairs produced inhibition that was significant only in the analysis by subjects. Finally, under auditory prime–visual target cross-modal presentation conditions, neither facilitation nor inhibition to targets was evident for CALCULATOR–CALCULATION pairs. The last outcome replicated that of Marslen-Wilson and his colleagues (Marslen-Wilson, Tyler, Waksler, & Olds, 1994).

The failure to find facilitation among suffixed relatives purportedly reflects suffix suppression (Marslen-Wilson et al., 1994). The account assumes sequential processing of the base and then the suffix of the prime. (For prefixed forms, suppression does not arise because the prefix is processed before the base.) Facilitation due to repetition of the base and suffix inhibition among

nonpresented but appropriate suffixes then offset each other to yield a null effect. These conditions are met as long as the prime is presented auditorily (Marslen-Wilson, Zhou, & Ford, 1996).

In the present study, the failure to find facilitation between morphological relatives was restricted to two suffixed forms presented under cross-modal presentation conditions. Critically, the magnitude of the difference between MISCALCULATE–CALCULATION and CALCULATOR–CALCULATION pairs interacted with the modality configuration of prime and target. Planned comparisons confirmed that differences in target decision latencies following prefixed and suffixed primes were greatest for auditory targets preceded by visual primes, marginal for visual targets preceded by auditory primes, and nonexistent when both targets and primes were presented visually. Stated generally, target modality appears to constrain the difference between prefixed and suffixed forms.

In conclusion, differences in target recognition following prefixed and suffixed primes are tied to modality of presentation. In particular, modality of the target appears to be associated with the differences between affixed forms. Whether this pattern is potentially compatible with a suffix suppression mechanism must await further theorizing.

CONCLUSIONS

In the first study, we demonstrated that morphological facilitation cannot be either an orthographic or a semantic effect (see also Stolz & Feldman, 1995) but that morphological processing may reflect a more complex and time-varying pattern of activation that is sensitive to both orthographic and semantic similarity. In the second study, among words formed from the same base morpheme, semantic transparency of the base was critical at the longer, but not at the shorter, prime duration. By implication, accounts of the relation between base morphemes and whole-word forms in word recognition must be temporally as well as semantically constrained. Finally, differences between prefixed and suffixed forms in a morphological priming task arose only under cross-modal presentation conditions such that modality-related processing of the target was associated with the differences between affixed forms. In summary, morphological processing is constrained by the time course of activation of constituents, by the semantics of constituents, and by sequential processing which may, in fact, reflect presentation modality. Moreover, the same (i.e., visual) presentation conditions that produce an effect of semantic transparency give rise to equivalent morphological facilitation following prefixed and suffixed forms.

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