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Interactive Activation Accounts of Morphological Decomposition: Finding the Trap in Mousetrap?

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Many accounts of the processing of morphologically complex words have been elaborated within the interactive activation model of word identification. Conceptually, this model adopts a ‘‘segmentation-through-recognition’’ approach to morphological decomposition, which assumes that a complex word activates representations of constituent morphemes as well as the representation of the whole word. However, a detailed consideration of the assumptions of interactive activation frameworks reveals that current implementations of the model are incapable of achieving segmentation-through-recognition. © 1999 Academic Press

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Many investigations of the processing of morphologically complex words have focused on the issue of whether the whole-word forms comprising a morphological complex are fully listed in the lexicon (e.g., Fowler, Napps, & Feldman, 1986) or whether morphologically complex words are represented in decomposed form—the root form along with a listing of its permissible affixes (e.g., Taft & Forster, 1976). A number of the articles in this special issue report research testing the validity of these alternative accounts in various different languages.

But evaluating these alternatives hinges on a much more basic issue about the processing of complex words that has received surprisingly little attention: how do the morphemic constituents of a complex word become available to the lexical processing system? This issue is perhaps most concretely illustrated by compound words (e.g., *blackbird, teaspoon*). The question that is the focus of this discussion concerns whether the lexical representations of *black* and *bird* participate in identification of *blackbird* and, if so, how—and, indeed, why—does this occur.

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MORPHEMIC CONSTITUENTS INFLUENCE COMPOUND WORD IDENTIFICATION

There are a variety of sources of evidence demonstrating that constituent morphemes influence identification of compound words, at least when they are semantically transparent (Libben, 1998; Zwitserlood, 1994). The stimulus to the present discussion was a series of experiments that confirmed earlier suggestions (Andrews, 1986) that the speed of identification of compound words is influenced by the frequency of *both* the first and the second morphemic constituents. The details of the research will be presented elsewhere (Andrews & Davis, in preparation). In the present context, the critical evidence of constituent influences on whole-word identification is the finding that low-frequency compound words were recognized more quickly when they contained a high-frequency constituent in either the first or second position than when the corresponding constituents were low frequency. Words with two high-frequency constituents (e.g., *birthday*) were identified more quickly than items in which only the first (e.g., *handcuff*) or only the second constituent (e.g., *scrapbook*) was high frequency, which were, in turn, faster than items with two low-frequency constituents (e.g., *gangplank*). These effects were obtained in experimental conditions that required participants to retrieve complete compounds rather than to base judgements on the constituents alone because compound words had to be discriminated from nonwords, including reversed compound items like *ballmoth* and associate pairs like *fastslow*. The fact that classifications of *ballmoth* items were considerably slower than those for *fastslow* items—which did not differ from compounds created from unrelated words such as *wirewife*—confirms that judgements were based on retrieval of representations of complete compound words.

Evidence like this is usually interpreted as supporting interactive activation (IA) models which assume that a compound word activates representations of both the whole compound and its constituents and that activated constituents contribute to activation of the whole compound form (Taft, 1994). Constituents that are of higher frequency than the whole compound achieve high levels of activation early in processing and increase the speed with which the detector for the complete compound reaches threshold. In principle, this provides an appealing and general account of a variety of results, demonstrating that morphological constituents contribute to identification of the whole-word forms that they contain. However, a more detailed consideration of the assumptions of IA frameworks reveals fundamental problems with their explanation of constituent effects on whole-word identification.

HOW ARE CONSTITUENTS PARSED FROM THE COMPOUND?

There are two major ways in which the components of compound words might be located in the complete word (Davis, 1999). ‘‘Segmentation-then-recognition’’ accounts assume that the constituents of complex words are determined prelexically and that access procedures operate on the predefined segments. The validity of such accounts hinges on specifying effective prelexical segmentation procedures and demonstrating their psychological validity. A number of segmentation procedures have been specified—for example, Taft’s (1979) Basic Orthographic Syllabic Structure (BOSS) and Adam’s (1979) ‘‘bigram trough’’ proposal—but there is no conclusive evidence for their psychological validity (e.g., Lima & Pollatsek, 1983; Rapp, 1992).

Interactive activation models rely on the alternative ‘‘segmentation-through-recognition’’ approach to morphological decomposition. Such approaches assume that morphological components are identified by matching them against lexical knowledge: *blackbird* is decomposed into *black* and *bird* by retrieving the lexical representations for the constituents in the course of retrieving the compound itself. There are two essential requirements for segmentation-through-recognition: (1) the system must be capable of recognizing embedded words within a longer stimulus and (2) the system must be able to process multiple words simultaneously. Conceptual descriptions of the IA model’s application to morphologically complex words assume that it possesses both of these properties. But, implementations of the model have not been extended to long complex words and a careful consideration of its assumptions reveals a number of problems that will arise when this is attempted.

RECOGNIZING EMBEDDED SEGMENTS

The original implementation of the IA model (McClelland & Rumelhart, 1981) was only developed to deal with four-letter words. The features of each letter activate position-specific abstract letter codes which, in turn, activate words containing those letters in the appropriate positions and inhibit words that do not: that is, *b* in position 1 activates all words with the first letter *b* and also inhibits all words without an initial *b*. The restriction to four-letter words was an implementational limitation that can, of course, be modified to allow an IA network to deal with a range of word lengths. Two approaches to this generalization have been implemented.

Grainger and Jacobs (1996) included separate sets of position-specific letter nodes for words of different lengths. This generalization of the model implies that word-processing is length specific: the letter detectors for four-letter words only activate nodes for four-letter words. Such a solution to the problem of dealing with words of different lengths clearly precludes recognition of embedded words—a nine-letter word like *blackbird* cannot activate *black*.

Coltheart, Curtis, Atkins, and Haller (1993) adopted a different approach in the IA component of their Dual Route Cascade model. This implementation includes a single set of position-specific letter input nodes that are activated by words of all lengths: a four-letter word activates positions 1, 2, 3, and 4; a five-letter word activates positions 1, 2, 3, 4, and 5 and so on. This approach allows *black* to be activated by *blackbird*, but it introduces other problems. First, it permits activation of the first constituent but not the second because *bird* in positions 6, 7, 8, and 9 will not activate *bird,* which requires input from *b, i, r,* and *d* in positions 1, 2, 3, and 4.[1]

Thus, one general characteristic of the IA framework that prevents recognition of embedded words is its assumption of position-specific letter codes. Recognition of embedded segments requires position invariance: *bird* must be coded in such a way that its node can be activated regardless of where it occurs in the stimulus. This is not possible if letter nodes are position specific.

Interactive activation has a more general problem in recognizing embedded words because the degree of activation of a word node depends on both the number of letters it shares with the input in the correct position and on the number of mismatching letters. That is, even if the letter-coding assumptions allow *black* to be activated by the initial letters of *blackbird, blackbird* will always suppress *black* because it receives 9 units of letter-word excitation compared with the 5 received by *black* and because *black* also receives 4 units of letter-word inhibition from the mismatching letters in later positions. Thus, in addition to position-invariance, recognition of embedded words requires context invariance so that a stimulus can activate its detector regardless of surrounding context. Interactive activation has neither of these properties and is therefore incapable of using segmentation-through-recognition to locate embedded words.

SIMULTANEOUS PROCESSING OF MULTIPLE WORDS

Interactive activation also fails to satisfy the second requirement for segmentation-through-recognition. There are two senses in which this strategy requires simultaneous processing of multiple words. First, recognizing both constituents of a compound word requires that the network allow simultaneous activation of both constituents so that compounds can be distinguished from sequences of separate words—e.g., *blackbird* must be interpreted differently than *black bird.* Second, accurate identification of a morphologically complex word may require consideration of more than one parsing of the item—for example, to recognize *cartwheel* or *bushfire* it is necessary, in some sense, to reject *car* and *bus* as initial constituents in favor of *cart* and *bush.* Interactive activation frameworks are not capable of simultaneous processing in either of these senses.

Such models assume that an input activates all word nodes to which it is

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[1] *Bird* could be activated by *blackbird* if words were ‘‘lined up’’ from the final rather than the initial letter position, but this would preclude recognition of initial constituents.

sufficiently similar. Selection of the correct word node from among these activated candidates is achieved through lateral inhibition among word nodes. More strongly activated nodes inhibit those with weaker activation until a word node achieves threshold activation and is identified. This ‘‘winner takes all’’ approach to selecting between coactivated word nodes allows only one word to be identified with a single stimulus input. That is, even if *black, bird,* and *blackbird* were all activated by the stimulus, the activated nodes would then compete for identification to yield a single output. As described above, *blackbird* would be predicted to win, although this would depend on the relative frequency of the different word nodes. Moreover, competition from the activated constituents should delay identification of the complete compound by increasing the time required for the compound node to win the competition with its activated constituents. In fact, high-frequency constituents facilitate the speed of compound identification (Taft & Forster, 1976; Andrews & Davis, in preparation). The problems arising from the competitive selection mechanism cannot be solved by simply reducing the strength of the word-level lateral inhibition parameter because that would disrupt the network’s ability to suppress the activation of words that are orthographically similar to the compound or its constituents—*blank, bind, blackboard,* and so on.

A possible solution to the simultaneous recognition problem would be to allow for ‘‘chunks’’ of the input pattern to be identified sequentially and then combined at some higher level. However, this creates problems for items like *cartwheel* because there would be no means of recovering *cart* once the higher frequency constituent *car* had been identified and, indeed, no necessary means of retrieving *wheel* from *twheel* to determine that such a resegmentation was appropriate.

CONCLUSIONS

Unfortunately, space constraints prevent us from elaborating on solutions to these limitations of IA (Andrews & Davis, in preparation; Davis, 1999) and this discussion has therefore been entirely negative. Nevertheless, it is important to draw attention to the IA model’s limitations because they are relevant to many accounts of morphological processing, not only of compound words but also of affixed forms. Both full-listing and decomposition accounts of morphological influences on word identification assume that the morphological subcomponents of long words are in some sense extracted from the complete stimulus to allow activation of either root forms or a cluster of whole-word forms. But, as we have tried to make explicit, the IA model that is most often invoked as the theoretical framework for such accounts does not, in fact, allow the segmentation-through-recognition mechanism that is fundamental to explaining much of the apparent evidence of morphological decomposition. Without a clear specification of how the morphological constituents of complex words are segmented from whole-word forms, we should be wary about assuming that studies of morphological processing provide insight into lexical organization. It is possible that a valid specification of how segmentation is achieved will reveal that at least some of the effects of morphological constituents on word identification are a reflection of the segmentation mechanism itself rather than of the organization of lexical knowledge.

There is a more general implication of the issues we have discussed that is particularly important in this current era of computational modeling. Some current computational models provide an account of how lexical knowledge is acquired (e.g., Seidenberg & McClelland, 1989). However, the nature of the knowledge that the models learn depends crucially on their assumptions about the form of the information on which the learning algorithms operate. As our discussion of IA demonstrates, there are a number of implications that follow from apparently innocuous assumptions about how words are ‘‘fed to’’ the lexical system—for example, from the assumption that words are treated as collections of position-specified letters. Until we have more comprehensive evidence about precisely how visual patterns are treated in the early stages of identification, we should be cautious in drawing conclusions about the form and organization of lexical knowledge on the basis of investigations of morphological influences on visual word identification.

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