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The Nature of Lexical Representation in Visual Word Recognition

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[–] Abstract and Keywords

This chapter explores how information about words is represented for the purposes of recognizing those words when reading. A description is first given of the various architectures that have been proposed to frame our understanding of lexical processing, with an emphasis on the way they portray lexical representation. The importance of morphological structure to the nature of lexical representation is highlighted, and attention is directed to specific models that attempt to capture that structure. The model that forms the major focus of the chapter, the AUSTRAL model, is one where identification of a letter string is based on information associated with an abstract level that mediates between form and function, namely, a lemma level. The incorporation of a lemma level into the lexical processing system provides a locus for morphological structure. It captures a level of lexical representation that not only underlies both visual and spoken word recognition but is also compatible with models of word production.

Keywords: hierarchical activation, lemmas, lexical representation, models of lexical processing, morphological processing, orthographic processing

Introduction

It is easy for a literate English speaker to recognize that *cat* is a word while *lat* is not. Only the former is represented in the speaker's long-term memory for words (i.e., the mental lexicon), and access to this representation allows the speaker to differentiate between real words and pronounceable strings of letters that are nonwords (also called pseudowords, e.g., *frink*). Such a lexical decision judgment therefore provides a window into the nature of the lexical representations that are accessed when we read, and, because of this, has been adopted widely as a laboratory-based task to explore the issue of lexical representation and retrieval.

Participants in the lexical decision task are typically presented a randomly mixed series of words and nonwords and asked to press a "yes" or "no" button as quickly but as accurately as possible in response to whether the presented letter string is a word or not. Reaction times and error rates are measured. Reaction times (RTs) and error rates are measured. The RT for a word item (usually averaging around 500 ms) reflects the time it takes to access the relevant lexical information, as well as to decide that such information is sufficient to indicate that the letter string is a word. The RT for a nonword (usually longer than for a word item) reflects the amount of lexical information accessed on the basis of the letter string and the time it takes to decide that this is insufficient for a word response to be made. Different types of item are compared by including 15 or more examples of each. The two conditions making up each type vary on the factor of interest while being matched closely on as many important factors as possible (e.g., frequency of occurrence in the language in the case of real words). In the case of priming research, the same target is compared when preceded by different primes and the impact of different relationships between the prime and target can therefore be measured.

Linguists are likely to interpret the notion of lexical representation in terms of the linguistic information associated with a word (i.e., its semantic and syntactic functions). For the cognitive psychologist who is interested in how we read, however, an understanding of the nature of the functional information itself is less important than the mental representations that provide access to that information. For this reason, the issue that will be addressed in this chapter is the nature of the representation that allows identification of the word. Couched in terms of the lexical decision task, the question is what representation is accessed that allows a letter string to be identified as a particular word (or to alternatively be classified as a nonword). It is this representation that constitutes the gateway through which the incoming letter string can be associated with its functional interpretation during reading.

Models of Lexical Processing

Early Views

The notion of lexical access in visual word recognition was first explored in the late 1960s and early 1970s, with two distinct approaches being adopted.

Lexical Search

Forster (1976) outlined a model of lexical processing where all information about a word (semantic, syntactic, phonological, and orthographic) is stored in a master file that is accessed via a serial search through modality-specific peripheral access files. The orthographic access file that is used in reading is a list of words in order of their frequency of occurrence, although divided into smaller sized bins according to form-based characteristics. A visually presented word might therefore be recognized when found to match with an entry in the orthographic access file. However, Taft and Forster (1975, 1976) argued that a polymorphemic word (such as *revive, henchman*) whose stem is not a free-standing word is recognized when that stem (e.g., *vive, hench*) is accessed in the orthographic access file, with information about the whole word being subsequently extracted from the master file entry. As such, the access file includes nonwords (e.g., *vive, hench*), which means that word recognition requires access to the master file because that is the locus of information necessary to discriminate real words from nonwords.

Lexical Activation

An alternative idea that words are accessed in lexical memory via a parallel activation system was incorporated by Morton (1969, 1970) in his logogen model. The lexical entry for each word is seen as an information-collecting device (i.e., a logogen) whose activation level increases in response to relevant features being contained in the stimulus. Once enough evidence accumulates in one of the logogens for its threshold to be reached, the corresponding word becomes available for recognition and the relevant functional information associated with that word can be accessed. There are separate sets of orthographic and phonological logogens that are activated depending on the modality of the input. In addition, Morton argued for the existence of orthographic and phonological output logogens that are used for writing and speaking, respectively, although it is unclear how parallel incremental activation would work within an output system.

Lexical representations in the logogen model are the words corresponding to each logogen. However, on finding that inflected words prime recognition of their stem (e.g., *cars* primes *car*, while *card* does not), Murrell and Morton (1974) concluded that logogens actually correspond to morphemes. Since the logogen model does not specify how polymorphemic words might be represented, its notion of lexical representation is rather vague.

More Recent Approaches

The idea of serial search through lexical memory has become largely outdated, with most investigators now adopting an account that incorporates a parallel activation mechanism. Even the main proponent of lexical search has recently proposed a model that combines parallel activation with serial processing (Forster, 2012). Therefore, the nature of lexical representation will now be considered in the light of the activation frameworks that are currently most influential.

Interactive-Activation

The interactive-activation (IA) model, as first outlined by McClelland and Rumelhart (1981) and Rumelhart and McClelland (1982), elaborates upon the notion of parallel activation. Words are represented in the IA model in much the same way as in the logogen account. However, there is also a layer of activation units corresponding to individual letters that feed their activation to the word level, and a layer of activation units corresponding to visual features that feed their activation to the letter level. Thus activation passes up from features to letters to words, with activated units inhibiting competitors at the same level. As a unit increases in activation, it feeds activation back down the hierarchy so that the lower level units whose activation has been most productive at the higher level will be strengthened. From this interaction of activation throughout the system, a single word unit will eventually reach a threshold that allows the letter string to be recognized as that word.

The word units in the IA model are lexical representations in the sense that a letter string can be identified once one such unit reaches its recognition threshold. However, the term “lexical representation” need not be taken in its literal sense of “the mental portrayal of a complete word,” but can be more broadly defined as “the stored information through which a word can be recognized.” Given that the sublexical units (i.e., features and letters) are integral to the activation of word units in the IA model, it can be argued that they are also a part of the lexical representation. Thus when considering the nature of lexical representation, the breadth of its definition needs to be clear. To further our understanding of visual word recognition we will primarily be interested in the broadest definition, because the act of reading involves the whole procedure of getting from the letter string to its identification as a particular word.

Parallel Distributed Processing

Like the IA approach, the parallel distributed processing (PDP) model is a connectionist framework. However, while the former represents words as localist (i.e., specified) lexical units, the latter captures lexical information within patterns of activation distributed across sets of “hidden” units that mediate among the orthographic, phonological, and semantic levels of representation (e.g., Harm & Seidenberg, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989). As such, there is no explicit representation of the whole word (i.e., no lexical entry per se), only a pattern of connection weights that has been settled upon through repeated experience with the letter string. Since representations in the PDP model are common to more than one word and also participate in the processing of nonwords, it can be said that lexical representations do not exist (cf. Seidenberg & McClelland, 1989, p. 560).

However, in a general sense, there must be some type of lexical representation within the PDP system given that it is possible to discriminate words from nonwords. Lexical decision judgments are made by comparing the orthographic input with the orthographic output that is generated by the hidden units on the basis of that input. This provides a measure of orthographic familiarity because the more the system encounters a letter string, the more accurately the weights within the hidden units will settle on a pattern that reflects the orthographic form of that letter string. Since a nonword has never been previously encountered, the pattern of activation generated in the hidden units will be a less accurate reflection of the orthographic input, and, if this match between input and output falls below some criterial level, a nonword classification can be made. Within such an account, then, it is the settled pattern of activation within the hidden units that is equivalent to a lexical representation. While the representation of a word may be distributed across a number of units that overlap with the distribution of units representing other words in the vocabulary, the pattern of weighted activation is nevertheless unique and therefore functions as a lexical representation.

Within the PDP framework, a pattern of connection weights becomes more stable the more an orthographic form is systematically associated with an output, either phonological or semantic. So, systematic sublexical relationships that exist between print and sound are captured within the hidden units that mediate between the orthographic and phonological levels (e.g., the fact that ‹EE› is typically pronounced /i:/), while systematic sublexical relationships that exist between print and meaning are captured within the hidden units that mediate between the orthographic and semantic levels. In fact, the only sublexical systematicity between print and meaning is at the level of the morpheme and, as such, the hidden units mediating between orthography and semantics must reflect morphemic rather than submorphemic information (e.g., Gonnerman, Seidenberg, & Andersen, 2007; Rueckl & Raveh, 1999). Given the similar lack of submorphemic systematicity between phonology and semantics, it is parsimonious to amalgamate the hidden units that mediate between orthography and meaning with those that mediate between phonology and meaning, and that is what Gonnerman et al. (2007) propose.

The PDP approach, regardless of its specific computational implementation, is impressive in the way it simulates known data by capturing the statistical relationships that exist between the orthographic, phonological, and semantic domains. However, the model can be seen more as a facsimile of human reading performance than providing an understanding of it. The PDP explanation for how we read is essentially that the presented letter string sets up a pattern of neural activity that corresponds to a pattern that was previously acquired in response to that letter string. Such an account is therefore not very instructive and, accordingly, the PDP approach has not proven very successful over the years in generating new research into the reading process. For this reason, many have sought a more revealing approach to the question of lexical representation and the processes involved in reading words. This typically involves the adoption of the IA framework where the localist description gives a clearer picture of what the units that are involved in the processing of the word represent. A description of one such approach follows.

The AUSTRAL Model

The model to be outlined here in greater detail was introduced in Taft (1991) and developed further in Taft (2006). It adopts the IA framework, but replaces the word level with a level of representation that provides a link between function (semantic, syntactic, pragmatic, etc.) and form regardless of the modality of input which, as such, incorporates information about morphemic structure. Taft (2006) refers to this as the lemma level following the lead of Baayen, Dijkstra, and Schreuder (1997) who adopted the notion from the production literature (cf. Kempen & Huijbers, 1983; Roelofs, 1992). The inclusion of such a level of representation makes it the localist equivalent of the PDP model of Gonnerman et al. (2007) inasmuch as meaning is linked to both orthographic and phonological form via the same set of units that capture morphemic information.

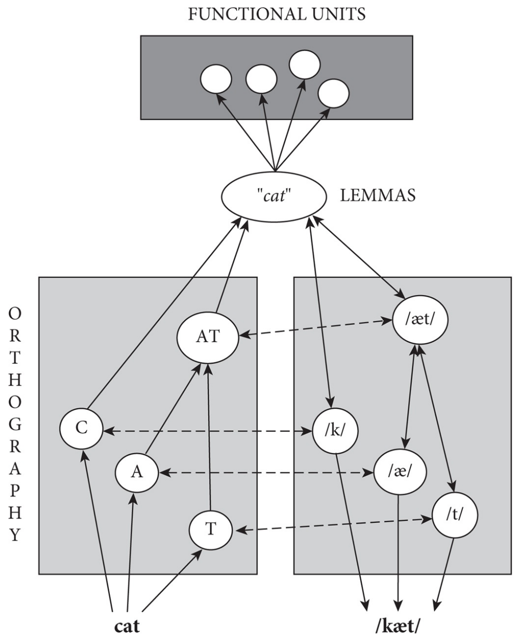

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Figure 1 : Example of how *cat* is represented in the AUSTRAL model.

Figure 1 depicts a version of this model, which will be referred to as AUSTRAL for reasons to be given shortly. The figure illustrates the way in which the word *cat* is both recognized and pronounced when visually presented, and depicts the lexical representation in its broadest sense. That is, it describes the representations required to access the word during reading. Representational units at the form level are sublexically based, while units at the function level represent componential semantic and syntactic features and any other information relevant to the word. A lemma can be seen then as the unit that brings these components together. So, the lemma for “cat” represents the union of the graphemes *c, a*, and *t* (in that order) and the phonemes /k/, /æ/, and /t/ with the notion of a countable concrete noun that has the semantic features relevant to the concept of “cat.”

Although neutral with regard to the way in which the functional information might be represented, the AUSTRAL model specifies the nature of the sublexical form units. In particular, there has been strong evidence that consonantal onsets are treated separately from the rest of the syllable when reading monosyllabic English words (e.g., Andrews & Scarratt, 1998; Taraban & McClelland, 1987; Treiman & Chafetz, 1987). The rest of the syllable is referred to as the *body* of the word (or orthographic *rime*), and is composed of a vowel plus consonantal coda if there is one (e.g., *str* is the onset of *street*, and *eet* is its body, comprising vowel *ee* and coda *t*). Thus the sublexical units of the AUSTRAL model form a hierarchy whereby grapheme units activate body units (e.g., the graphemes A and T activate the body AT), and the lemma is then activated through the combination of the onset and body. It is this “activation using structurally tiered representations and lemmas” that characterizes the model and creates the acronym AUSTRAL.[1]

By incorporating structurally tiered orthographic representations linked to phonological units of a corresponding structure, the AUSTRAL model embodies lexical and sublexical information in a different way from dual-route models of reading aloud such as DRC (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) and CDP++ (e.g., Perry, Ziegler, & Zorzi, 2010), where lexical and sublexical information are processed through different pathways. Like the PDP model, AUSTRAL pronounces nonwords via the same units through which words are named, except that nonwords lack the support that words receive from the lemma level. Taft (1991, 2006) discusses the way in which AUSTRAL readily explains why regular words (e.g., *pink*) are named with a shorter latency than irregular words (e.g., *pint*) and why regular words with a body that is inconsistently pronounced (e.g., *hint*) also show slower naming latencies. However, the focus of this chapter is not on the generation of sound from print but on the identification of visually presented words. So discussion will now be restricted to the way in which a visually presented letter string is represented for the purposes of recognition during reading.

Information about the whole word is found at the lemma level, which potentially makes it the locus of lexical representation in its narrowest sense. That is, words can potentially be discriminated from nonwords at the lemma level because only words have developed a unit linking form with function. However, this is not entirely true because, as will be explained later, there are real words that might not be represented by a lemma and there are also nonwords that might be. To elucidate, we need to consider how morphological structure is represented in the lexical processing system (see also Hyönä, this volume). As will be seen, the way in which morphemically complex words are processed is central to our understanding of lexical representation.

Morphological Processing

A morpheme is usually defined as the smallest unit of form associated with a semantic or syntactic function. Given that a lemma is a unit that encapsulates the association between form and function, it follows that the lemma level captures morphemic structure and drives the processing of morphemically complex words (e.g., *cats, unfriendly, daydream*). How are such polymorphemic words recognized?

Obligatory Decomposition in the AUSTRAL Model

In accord with its notion that the form level represents components of the whole word, the AUSTRAL model has all polymorphemic letter strings being decomposed into their apparent morphemes for recognition to take place (e.g., *un, friend*, and *ly*). This idea of obligatory decomposition has been around since Taft and Forster (1975), and has been supported in more recent times by research using the masked priming paradigm. As overviewed by Rastle and Davis (2008), many experiments have shown not only that the masked presentation of a transparently derived word (e.g., *hunter*) facilitates subsequent recognition of its stem (*hunt*), but that the same is true of a pseudoderived word (e.g., *corner-corn*). Because no facilitation is reported when the prime does not include a putative suffix (e.g., *turnip-turn*), it is concluded that a pseudoderived word is blindly decomposed into its apparent morphemes (e.g., *corn* and *er*). Only at a later stage is this analysis overturned so that the pseudoderived word is correctly treated as a monomorphemic word. How then is a polymorphemic word recognized after the form representations of its component morphemes are accessed? Taft (2003, 2004) and Taft and Nguyen-Hoan (2010) argued that the lemmas for each of the component morphemes are activated via their form representations and then there are two possible ways in which the whole word might be recognized.

First, if the function of the polymorphemic word is entirely transparent with respect to the function of its component morphemes, as is typically the case for regularly inflected words (e.g., *cats, jumped, eating*), the whole word can be recognized purely on the basis of the functional information associated with each morpheme lemma. The stem and the affix each have their own lemma. For example, once it is known what a *cat* is and that the suffix *s* can denote the plural of a countable noun, everything that is known about the word *cats* can be determined. So, as in a printed dictionary, there is no need for a whole-word representation to exist in the mental lexicon, because it would be redundant. These are the types of real words referred to earlier that would not be represented at the lemma level in the model, but that can nonetheless be recognized on the basis of functional information.

Second, and in contrast to words whose morphological composition is entirely transparent, a polymorphemic word that has any semantic or grammatical function that cannot be determined on the basis of its component morphemes must be represented by a whole-word lemma to provide a link to that idiosyncratic information. For example, there needs to be a lemma for *friendly* to associate it with the functional knowledge that it means more than just "characteristic of a friend." Similarly, the present participle of *meet* (as in *I am meeting her for the first time*) is entirely understandable from the combination of the functions associated with the stem and affix lemmas and, hence, does not require a lemma, but there does need to be a whole-word lemma for *meeting* when used as a gerund (as in *we'll hold a meeting tonight*) in order to understand that it specifically means "an assembly of people for the purposes of discussion." Taft (2003, 2004) and Taft and Nguyen-Hoan (2010) propose that such a whole-word lemma is activated via the lemmas for its component morphemes, creating a hierarchy of lemmas from monomorphemic to polymorphemic.

Support for the existence of such a hierarchy of lemmas is presented by Taft and Nguyen-Hoan (2010) from a masked priming experiment with ambiguous targets (e.g., *stick* meaning either "a twig" or "adhere"). The results showed that when asked to provide the meaning of the target, participants were biased by the meaning suggested by a prime that was an affixed version of the target. For example, more participants gave the "adhere" meaning of *stick* (as opposed to the "twig" meaning) when preceded by the masked prime *sticky* than when preceded by an unrelated word. Moreover, there was no such bias when the prime was only semantically related to that meaning without being a morphological variant of the target (e.g., the word *glue*). This lack of a bias toward the "adhere" meaning of *stick* when *glue* was the prime indicates that the observed bias to the "adhere" meaning when *sticky* was the prime could not have arisen solely at the semantic level. Neither could its locus be the form level because, logically, the two versions of a homograph are not differentiated at that level, being identical in form. It was therefore concluded that the locus of meaning bias must have been a level that mediates between form and semantics, namely, the lemma level. So, the lemma for *sticky* is activated via the lemma for only one version of *stick* (i.e., the "adhere" version) and, when *sticky* is presented as the prime, that version remains active when the target arrives, hence biasing the response.

Bound Morphemes

If morphemes are represented at the lemma level because they capture the correlation between form and function, this should be equally true whether the morpheme is free or bound, that is, whether or not it can stand as a word in its own right. Affixes are the typical bound morphemes (e.g, *un, y, ing*), but some stems are also bound. For example, *venge* cannot stand on its own as a word, yet it occurs in *revenge, avenge, vengeful*, and *vengeance*, which clearly have overlapping meanings. Therefore, it is argued (see Taft, 2003) that *venge* develops a lemma to capture this form-meaning correlation, through which the whole-word lemmas for *revenge, avenge*, and so on are activated.

With nonwords existing at the lemma level (i.e., when they are bound morphemes), it cannot be the case that lexical decision responses are made purely on the basis of there being a lemma corresponding to the presented letter string. While classifying a bound stem as a nonword is certainly difficult (e.g., Taft, 1994; Taft & Forster, 1975), it is nevertheless possible to do so, and the AUSTRAL model needs to explain how. The simplest explanation is that there is information linked to the bound-stem lemma that stipulates that it cannot be used as a word in its own right; information that would be particularly important when it comes to production. It might be the case that this information takes the form of a further level that represents lexical concepts, as has been proposed in relation to speech production (e.g., Levelt, Roelofs, & Meyer, 1999). That is, only free-standing words, be they monomorphemic or polymorphemic, correspond to holistic concepts. Bound morphemes do not and can, therefore, be rejected as words on that basis.

Another possibility is that lemmas vary in some way as a function of the form-meaning correlation that they capture. A systematic relationship between form and function is likely to be most obvious when the form retains its meaning within a variety of contexts, because the constancy of the relationship contrasts with the variability of the linguistic information surrounding it. As such, a real word will have a stronger correlation than will a bound morpheme. Although a bound morpheme might recur in several different contexts (i.e., with different affixes attached), these will be fewer than the number of contexts in which a real word can recur (i.e., all the sentences in which that word is encountered). Therefore, there might be a threshold of correlation above which the letter string is classified as a word. Of course, if such an argument were to be pursued, the mechanism by which a lemma is able to vary on the basis of form-meaning correlation would need greater specification.

Morphological Decomposition in Other Models

While other word recognition models that focus on morphological processing also incorporate the notion of a lemma level, they differ from AUSTRAL in a number of ways.

Schreuder and Baayen (1995)

As in AUSTRAL, Schreuder and Baayen (1995) propose the separation of access representations from lemmas (which, prior to Baayen et al., 1997, were labeled as “concepts”; see also Taft, 1991). However, according to Schreuder and Baayen (1995), on-line decomposition only occurs at the earliest stages of acquiring a new polymorphemic word. Otherwise, polymorphemic words are identified through a whole-word access representation that activates either a lemma corresponding to the whole polymorphemic word or lemmas corresponding to its component morphemes, depending on how transparently related those morphemes are to the whole word. Therefore, apart from newly experienced polymorphemic words, the only decomposition that occurs in the model of Schreuder and Baayen (1995) is at the lemma level after whole-word access, and only for some words.

However, such a notion of postlexical activation of constituent morphemes (as also proposed by Burani & Caramazza, 1987, and Giraudo & Grainger, 2000, 2001) fails to explain the pseudoderived masked priming (e.g., *corner* priming *corn*) that was described earlier (see Rastle & Davis, 2008). That is, according to this account, at no point in its recognition is *corner* ever decomposed into *corn* and *er*, because its whole-word access representation only activates a whole-word lemma. Therefore, there is no reason for the processing of *corner* to influence the processing of *corn* other than through orthographic overlap, in which case *turnip* should equally prime *turn*. For this reason, other models have incorporated early morphological decomposition based purely on form in order to tap into a so-called *morpho-orthographic level* of representation.

Diependaele, Sandra, and Grainger (2009)

The model proposed by Diependaele, Sandra, and Grainger (2009) has two levels based on form; the morpho-orthographic level where *hunter* is represented by *hunt* and *er*, and the lexical form level where all words are represented, including *hunter, hunt*, and *corner*. Lexical form representations for polymorphemic words are activated both via the decompositional pathway that is mediated by the relevant morpho-orthographic units (e.g., *hunt* and *er*), and directly from the letter string without mediation. It is through the former pathway that *corner* will prime *corn*, since the lexical form of *corn* will be preactivated via its morpho-orthographic unit that is inadvertently activated when *corner* is blindly decomposed. The difference between the processing of a pseudoderived and truly derived word is that the lexical form of such words (e.g., *hunter, corner*) receives activation from the morpho-orthographic level when it has a true stem (e.g., *hunt*), but not when it has a pseudostem (e.g., *corn*).[2] Links between the morpho-orthographic level and lexical form level arise from feedback from a higher *morpho-semantic level* where words are represented as morpheme units (such that the lexical form unit for *hunter* activates the morpho-semantic units for *hunt* and *er*, but the lexical form unit for *corner* does not activate semantic units for *corn* and *er*). As such, the morpho-semantic units function as morpheme-based lemmas, with information about the whole polymorphemic word only being found at the lexical form level. Therefore, the model incorporates both a prelexical decomposition pathway (i.e., based on sublexical information) and a postlexical decomposition pathway (i.e., based on lexically stored information), with lexical decision centering on the existence of an intermediate lexical form representation. However, if a word can be recognized through direct access to the whole lexical form, what is the purpose of prelexical decomposition? If it somehow makes access to the lexical form of a complex word easier than whole-word access, what then is the purpose of postlexical decomposition?

Crepaldi, Rastle, Coltheart, and Nickels (2010)

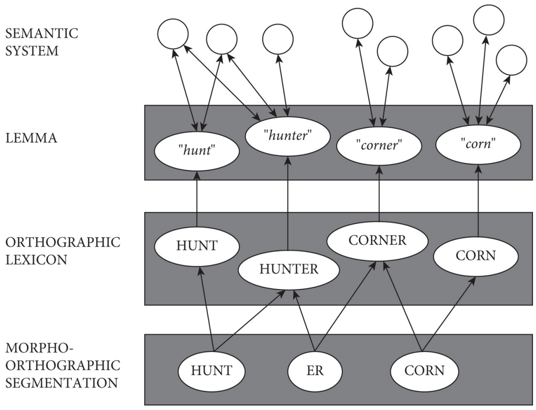

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Figure 2 : The representation of derived and pseudoderived words according to Crepaldi, Rastle, Coltheart, and Nickels (2010).

Diependaele et al. (2009) differentiate the early processing of truly derived and pseudoderived words in order to capture the apparent fact that masked priming is stronger for the former than the latter. In contrast, Crepaldi, Rastle, Coltheart, and Nickels (2010) maintain that the magnitude of masked priming is not significantly different for truly derived and pseudoderived words, though only the former generate priming when unmasked and, therefore, the two types of words are only distinguished at a late semantic stage. According to Crepaldi et al. (2010), morpho-orthographic representations are activated via obligatory decomposition and these, in turn, combine to activate the form representation for the whole word (at a level referred to as the *orthographic lexicon*). While such a decompositional pathway also features in the Diependaele et al. (2009) account, Crepaldi et al. (2010) specify that activation of the whole-word form is mediated by the component morphemes regardless of semantic transparency. As seen in Figure 2, the morpho-orthographic representations *CORN* and *ER* activate the orthographic lexical unit for *CORNER* in exactly the same way that the morpho-orthographic representations *HUNT* and *ER* activate the orthographic lexical unit for *HUNTER*.

According to Crepaldi et al. (2010), activation from the orthographic lexicon passes to a lemma level and then on to the semantic system. However, unlike AUSTRAL, derivationally related words do not share a lemma. This means that the relationship between the lemmas for *corner* and *corn* is exactly the same as that for *hunter* and *hunt*. It is only in the semantic system that the two types of words differ, because the latter have overlapping semantic features and the former do not. The purpose of the lemma level in the Crepaldi et al. (2010) account is solely to capture the relationship between inflectionally related words, where such words share a lemma regardless of whether the inflection is regular (e.g., *cats* and *cat*) or irregular (e.g., *fall* and *fell)*.

Irregularly Inflected Words and Whole-Word Form Representation

The major motivation for Crepaldi et al. (2010) to include an orthographic lexicon in their model is to capture the fact that real inflected words (e.g., *jumped*) can be distinguished from nonwords composed of a real stem and affix (e.g., *falled, sheeps*). The latter have no representation in the orthographic lexicon, while real inflected words do. Irregularly inflected words (e.g., *fell, taught, sheep, teeth*) are not decomposed at the form level, but activate the lemma for their stem, and this is true in AUSTRAL as well (see also Allen & Badecker, 2002). Presentation of either *fell* or *fall* will directly activate the lemma for *fall*. According to AUSTRAL, the former will also activate the lemma corresponding to the past tense just as the suffix *ed* would (see Taft, 2003), because otherwise there would be no way to distinguish *fell* from *fall*. With words being identified on the basis of information associated with the lemmas in the AUSTRAL model, what stops *falled* from being recognized as a word, given that it will activate lemmas that can be combined on the basis of functional information (e.g., *fall* is a verb that can take the past tense)?

The way the AUSTRAL model can handle this is by simply having the lemma for the stem being explicitly associated with information stipulating that the word does not follow regular inflectional patterns. That is, a "yes" response could ultimately be avoided if *falled* were presented because, after decomposition, information associated with the lemma for *fall* would specify that its past tense is actually *fell* or, more generally, that the regular inflection *ed* is not appropriate for this word. So, against the claim of Crepaldi et al. (2010), it is possible for the AUSTRAL model to distinguish all words and nonwords without the need for a form-based lexicon that includes all possible words, including inflected ones.

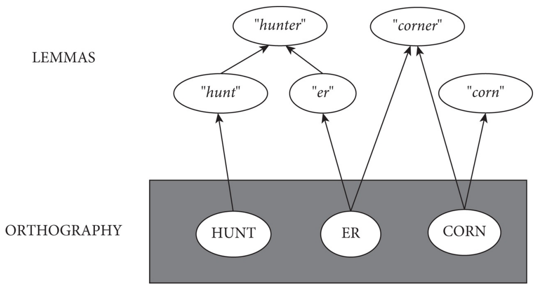
However, there is a further issue in relation to irregularly inflected words that has implications for the nature of form-based representations. In the description of the AUSTRAL model as presented here and in Taft (1991, 2006), the subsyllabic units of onset and body are depicted as the highest level of form representation. At other times, though, the model has been presented with whole-word form representations, at least when the words are monosyllabic (e.g., Taft, 2003, 2004; Taft & Nguyen-Hoan, 2010). In other words, whether or not the highest level of form representation corresponds to the whole word has been an open-ended aspect of the model. However, the proposed account of irregular word processing seems to necessitate the existence of a whole-word form representation, or at least a whole-syllable representation. The only way in which an irregularly inflected word can activate a lemma associated with its relevant syntactic function (e.g., the past-tense lemma when *fell* is presented or the plural lemma when *teeth* is presented) is if there is a whole-word form representation that can be linked to that lemma. It is the whole-word form *FELL* that is associated with the past-tense lemma, rather than either its onset *F* or its body *ELL*. If it were the body *ELL* that activated the past-tense lemma, this would happen not only when *fell* was presented, but when any other word that contains *ell* was presented, such as *yell* or *spell*. Obviously, it would be inappropriate to activate information about the past tense when the word is not actually a past-tense verb. Therefore, in a localist model such as AUSTRAL it seems necessary to allow for whole-word form representations, even if not for all words (i.e., not for regularly affixed words, or possibly even polysyllabic words; see section “Representation of Polysyllabic Words”).

Graded Effects of Morphological Relatedness

There is a further aspect of morphological structure that is informative with regard to lexical representation. The transparency of whether there is a derivational relationship between an affixed word and its stem is not an all-or-none property of those words. It is clear that *hunter* and *hunt* are derivationally related (i.e., a hunter is “someone who hunts”), while *corner* and *corn* are not. However, many cases show a partial relationship, such as *archer* and *arch* where the shape of the latter is captured in the bow used by the former, or *hearty* and *heart* where a metaphorical sense of the latter seems to be contained in the former (as it also is in *heartfelt* and *wholehearted*). Speakers are sensitive to such a gradation in derivational transparency both when asked to rate semantic relatedness and in the degree of facilitation of lexical decision responses when the stem is preceded by an unmasked version of the complex word that contains it (e.g., Gonnerman et al., 2007). How is such a continuum of transparency to be incorporated into models of lexical processing?

Gonnerman et al. (2007) argue that the transparency continuum is expected within a PDP model because hidden units statistically capture the relationship between form and meaning, and the more transparently related two words are in both form and meaning, the greater the overlap in their pattern of activation within those hidden units. This overlap provides the basis for a gradation in priming in line with derivational transparency. According to such an account, there is no need for a morpho-orthographic stage in which letter combinations that correspond to affixes are blindly stripped, because patterns of activation corresponding to different morphological structures are entirely encapsulated within the hidden units. Gonnerman et al. (2007) support such a claim by drawing on an unpublished masked priming study by Gonnerman and Plaut (2000) where pseudoaffixed words failed to prime their pseudostems (e.g., *corner* not priming *corn*). However, more recent research has clearly shown masked priming for all levels of transparency including pseudoderivations (e.g., Marslen-Wilson, Bozic, & Randall, 2008; Rastle & Davis, 2008), an outcome that seems incompatible with the PDP account as it stands (though see Rueckl & Aicher, 2008, for speculation as to how it might come about). The masked priming observed for pseudoderived words seems most readily explained by the existence of a stage of decomposition that is blind to semantic factors, namely, a morpho-orthographic stage.

Can a graded effect of transparency in ratings and unmasked priming be handled within a model that also includes morpho-orthographic processing? Certainly, the Crepaldi et al. (2010) account has no problem incorporating the idea of graded feedback from the semantic level depending on the relationship between the complex word and its stem. Such feedback is the only source of differentiation between transparently and opaquely derived words, and comes into play when the complex word is more fully processed (as in the unmasked priming paradigm).



Click to view larger

Figure 3 : The AUSTRAL representation of derived and pseudoderived words.

The idea of graded effects of transparency is more of an issue for the AUSTRAL account. As depicted in Figure 3, Taft and Nguyen-Hoan (2010) suppose that a transparently derived word (e.g., *hunter*) is activated through the lemma for its stem (*hunt*), whereas a pseudoderived word (e.g., *corner*) and its pseudostem (*corn*) compete with each other at the lemma level. The greater the opportunity for the inhibitory impact of competition to come into play, the greater its counteracting impact on the morpho-orthographic facilitation that occurs at the form level. Therefore, under unmasked conditions, pseudoderived words will show no facilitation, unlike transparent words where priming is generated at both the form and lemma levels. With such a qualitative difference between the representations of the two types of words, though, how can partially related words (e.g., *archer* and *arch*) show a graded effect of priming in the unmasked priming paradigm?

One way to capture this within the AUSTRAL framework would be to propose that lemmas that are activated via the same form representation are always linked, but with weightings that range from zero through to a strongly positive value, depending on feedback based on their semantic overlap. So, the lemmas for *corn* and *corner* are linked, but with a minimal weighting. When *corner* is presented as the prime, the lemma for *corn* will be activated, but will send negligible activation to the lemma for *corner* which is activated directly from the form level. In turn, the lemma for *corner* will provide negligible support to the lemma for *corn*, which effectively places the two lemmas in competition with each other. In contrast, the lemma for *hunt* will send positive activation to the lemma for *hunter* and vice versa, as will the lemmas for *arch* and *archer*, but to a lesser degree. When the prime is unmasked, there will be sufficient opportunity for the impact of the relationship between the two lemmas to modulate the effect of priming. In this way, the graded effect of partial transparency in the unmasked priming task can be handled within the AUSTRAL model.

With reference to Figure 3, the inclusion of a weighted link between the lemmas for a complex word and those for its component morphemes would mean that there is an additional link between the lemma for *corn* and that for *corner*. However, being so weak, it would lose out to the pathway that links the *corner* lemma directly to the form units *CORN* and *ER*. If conceptualized in this way—namely, as a competition between a direct form-to-lemma link and a mediated lemma link—the same should hold for all complex words, including truly derived words. That is, not only is the lemma for *hunter* linked to the lemma for *hunt*, but it also receives direct activation from the form units for *HUNT* and *ER*. In this case, however, the positive linkage between lemmas makes it a more effective pathway than the direct link from the form level and, therefore, recognition of the transparently derived word will typically be based on the mediated pathway.

The idea of competing pathways has been previously proposed in relation to morphological processing (e.g., Baayen et al., 1997; Bertram, Schreuder, & Baayen, 2000; Colé, Beauvillain, & Segui, 1989; Diependaele et al., 2009; Niswander, Pollatsek, & Rayner, 2000). In those accounts, though, the two possible pathways correspond to decomposition versus whole-word access. In contrast, form-based decomposition always occurs in AUSTRAL. It is only after decomposition that access to the whole-word representation might follow two competing pathways: one direct from the form-based components and one via the lemmas corresponding to those components. Thus flexibility can be introduced into the AUSTRAL model, with the overlap in semantic features determining which postdecompositional pathway is stronger.

Relationship Between Reception and Production

The models described in relation to the reading process address the lexical mechanisms involved in getting from print to meaning, and similar mechanisms are likely to underlie the recognition of spoken words once phonetic variation is taken into account. It would also make sense to propose that the same lexical mechanisms are involved in speech production, although running in the reverse direction. In fact, AUSTRAL owes much to the models of speech production proposed by Dell (1986) and by Levelt et al. (1999). The Dell (1989) model has a level of morpheme representation (equivalent to the lowest level of the lemma hierarchy in AUSTRAL) above which is a word level that includes derivationally complex words (potentially equivalent to the higher level of the lemma hierarchy in AUSTRAL), but does not include inflected words which are instead activated through the functionally-determined combination of the stem and affix, as in AUSTRAL. Furthermore, the highest level of form representation in the Dell model comprises syllables which, in turn, activate their component onsets and rimes prior to activating their phonemes. This is the same as the form level of the AUSTRAL model in reverse, albeit phonologically based rather than orthographic.

The existence of a lemma level is a major feature of the WEAVER++ model of Levelt et al. (1999), but there is also a separate level that represents lexical concepts. The production of a word begins with activation of a semantically-based concept which, in turn, activates a lemma. The lemma is seen as a link to syntactic information about the word. In reception models such as AUSTRAL, little emphasis has been placed on this distinction between semantic and syntactic information. The reason for this is that when passing from the form level to the function level (as is the case in word recognition), the lemma provides direct links to both syntax and meaning and their order of activation is immaterial. As such, the distinction between the locus of lexical semantics and lexical syntax may be critical for speech production, but has little impact on lexical processing in reading.

Future Directions

Impact of Derivational Transparency in Masked Priming

The equivalence of masked priming for truly derived and pseudoderived words would seem to be critical for the Crepaldi et al. (2010) model, since the two types of words are treated in exactly the same way throughout much of their processing. However, variable results have been observed with regard to this issue. Although Rastle and Davis (2008) concluded from their overview of such research that there is no difference in priming between transparently derived and pseudoderived words, a statistical meta-analysis indicates that priming might be greater for the former than for the latter (cf. Feldman, O'Connor, & Moscoso del Prado Martín, 2009; Taft & Nguyen-Hoan, 2010; but see Davis & Rastle, 2010). If this is indeed the case, it would be hard to maintain the Crepaldi et al. (2010) account. Therefore, it is important to establish whether a genuine difference between transparent and pseudoderived priming can be found under masked conditions. The AUSTRAL account is flexible with regard to this question because whether or not priming is greater for transparently derived than pseudoderived words will depend on whether competition in the latter case has the opportunity to come into play.

Dual Pathways from Form to Lemma

According to the modification to the AUSTRAL account whereby graded effects of transparency arise from the differential use of mediated and direct links, there should also be graded effects in the impact of stem frequency on complex word recognition. If lemma activation is influenced by word frequency, recognition of a derived word will be influenced not only by its own frequency of occurrence but also by the frequency of its stem, if recognition is mediated through the lemma for that stem. The impact of stem frequency has been well documented (e.g., Baayen et al., 1997; Bertram, et al., 2000; Colé et al., 1989; Niswander et al., 2000; Taft, 1979b, 2004; Taft & Ardasinski, 2006), so it would make sense to examine further whether the strength of this effect varies as a function of transparency. It should do so if semantic transparency determines which of the competing pathway succeeds, because only lemma mediation will be influenced by stem frequency. The Crepaldi et al. (2010) model would expect stem frequency effects regardless of transparency because access to the whole-word representation is the same for all types of words.

Representation of Polysyllabic Words

It can be seen from Figure 3 that AUSTRAL breaks down monomorphemic words like *corner* into subunits at the form level. While it is possible that this only happens when the structure of the word is morphologically complex in its appearance, it is more parsimonious to assume that all polysyllabic words are similarly broken down, even if, unlike *CORN* and *ER*, each of the form-based subunits is not associated with its own lemma. For example, the lemma for *walrus* might be activated directly from orthographic units representing the meaningless syllables *WAL* and *RUS* (see e.g., Taft & Krebs-Lazendic, 2013). Where does the syllable boundary fall in cases that are potentially ambiguous in this regard? For example, *sermon* could be orthographically broken down into *ser* and *mon* in correspondence to the way it is pronounced, or, alternatively, the informativeness of its first subunit might be increased by breaking it down into *serm* and *on*, maximizing the coda of the first syllable. The latter analysis has been proposed by Taft (1979a, 1987), Taft and Kougious (2004), and Taft and Krebs-Lazendic (2013), with the maximized first syllable (e.g., *serm*) being referred to as the Basic Orthographic Syllabic Structure (or BOSS); though such an idea has by no means found wide support (see e.g., Katz & Baldasare, 1983; Lima & Pollatsek, 1983; Perry, 2013).

If all polysyllabic words are represented at the form level as subunits that correspond to the maximal coda analysis, a word like *turnip* will be represented at that level as *TURN* and *IP*. As such, it might be expected that *turnip* will facilitate responses to *turn* in the masked priming paradigm despite the fact that *ip* does not have the appearance of a morpheme. The fact that such an orthographic condition has not shown masked priming effects in previous studies is addressed by Taft and Nguyen-Hoan (2010). They point out that the items used in that condition have actually been a mixture of cases where the target is the BOSS (as in *turnip-turn, brothel-broth*) and where it is not (as in *freeze-free, shunt-shun*). Therefore, it has not yet been shown that masked priming is absent when the target is specifically the BOSS of the prime (as in *turnip-turn*) and this is something that future research could pursue.

Conclusions

The purpose of this chapter has been to explore how models of visual word recognition envisage the way in which words are represented in lexical memory. As a working definition, lexical representation was taken to embrace all information required to establish that a presented letter string corresponds to a known word. If such a word has a representation that a nonword cannot have, then access to this representation should be sufficient to recognize the letter string as a word and, indeed, as that particular word. For this reason, a number of models (e.g., Crepaldi et al., 2010; Diependaele et al., 2009; Schreuder & Baayen, 1995) incorporate form-based representations for every known word, no matter what type of word it is, and this provides the basis for discriminating real words from nonwords. Nevertheless, in some accounts when the whole-word representation corresponds to a polymorphemic word, it is accessed via form representations for its component morphemes (e.g., Crepaldi et al., 2010), or at least it can be (e.g., Diependaele et al., 2009).

In contrast, the AUSTRAL model highlighted in this chapter has a form level that only represents single syllables, whether these create a whole word (e.g., the *hunt* of *hunter* or the *corn* of *corner*) or not (e.g., *er*). The recognition of a letter string as a particular word therefore takes place at a level beyond that of form. The lemma level mediates between form and function and brings together the syllables represented at the form level. Moreover, lemmas are hierarchically structured whereby a derivationally complex word (e.g., *hunter*) has its own lemma activated via the lemmas for its component morphemes (*hunt* and *er*). The lemma level therefore provides the primary locus of lexical representation, though with certain caveats attached.

One caveat is that any affixed word whose meaning is entirely predictable from its components (e.g., *jumped, cats*) is not actually represented at the lemma level, but rather is recognizable through the combination of higher level functional information associated with the lemma for each of its morphemes (i.e., semantic, syntactic, and/or idiosyncratic features of the morpheme). When a word activates such combinable functions, but has an exceptional form (e.g., *fell, teeth*), information about its distinctive characteristics can also be found at the higher functional level. This prevents a regularization of the irregular word (e.g, *falled, tooths*) from being accepted as a word.

Second, the lemma level includes representations of bound morphemes (e.g., *venge, er*) which, by definition, are not words in their own right. Therefore, there needs to be some way of discriminating such morphemes from real words. Suggestions for achieving this can be given in terms of specific information stored at the higher functional level, the existence of a concept level, or differing degrees of form-function correlation captured at the lemma level.

We see then that the lexical representations involved in reading can be conceptualized in a number of different ways ranging from orthographic units corresponding to the whole word through to patterns of activation within a distributed set of units that mediate between form and function. The account favored in this chapter, AUSTRAL, is one where information about a word is associated with a localist unit that mediates between form and function (i.e., a lemma), while being activated through sublexical units at the form level. Such an account provides a concrete framework for helping understand the processes involved in reading all types of words, both in terms of retrieving their meaning and in generating their pronunciation. An understanding of the recognition of polymorphemic words is thus not just a niche topic within the domain of lexical processing but has important implications for the conceptualization of the whole lexical processing system.

References

Allen, M., & Badecker, W. (2002). Inflectional regularity: Probing the nature of lexical representation in a cross-modal priming task. *Journal of Memory and Language*, *44*, 705–722.

Andrews, S., & Scarratt, D. R. (1998). Rule and analogy mechanisms in reading nonwords: Hough Dou peapel rede gnew wirds? *Journal of Experimental Psychology: Human Perception and Performance*, *24*, 1052–1086.

Baayen, R. H., Dijkstra, T., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual route model. *Journal of Memory and Language, 37*, 94–117.

Bertram, R., Schreuder, R, & Baayen, R. H. (2000). The balance of storage and computation in morphological processing: The role of word formation type, affixal homophony, and productivity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 489–511.

Burani, C., & Caramazza, A. (1987). Representation and processing of derived words. *Language and Cognitive Processes, 2*, 217–227.

Colé, P., Beauvillain, C., & Segui, J. (1989). On the representation and processing of prefixed and suffixed derived words: A differential frequency effect. *Journal of Memory and Language, 28*, 1–13.

Coltheart, M., Rastle, K., Perry, C., Langdon, R. & Ziegler, J. (2001). DRC: A Dual Route Cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108*, 204–256.

Crepaldi, D., Rastle, K., Coltheart, M., & Nickels, L. (2010). “Fell” primes “fall,” but does “bell” prime “ball”? Masked priming with irregularly-inflected primes. *Journal of Memory and Language*, *63*, 83–99.

Davis, M. H., & Rastle, K. (2010). Form and meaning in early morphological processing: Comment on Feldman, O’Connor, and Moscoso del Prado Martin (2009). *Psychonomic Bulletin & Review*, *17*, 749–755.

Dell, G. S. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review, 93*, 283–321.

Diependaele, K., Sandra, D., & Grainger, J. (2009) Semantic transparency and masked morphological priming: The case of prefixed words. *Memory & Cognition*, *37*, 895–908.

Feldman, L. B., O’Connor, P. A., & Moscoso del Prado Martín, F. (2009). Early morphological processing is morpho-semantic and not simply morpho-orthographic: An exception to form-then-meaning accounts of word recognition. *Psychonomic Bulletin & Review*, *16*, 684–691.

Forster, K. I. (1976). Accessing the mental lexicon. In E. C. J. Walker & R. J. Wales (Eds.), *New approaches to language mechanisms* (pp. 257–287). Amsterdam: North-Holland.

Forster, K. I. (2012). A parallel activation model with a sequential twist. In J. S. Adelman (Ed.), *Visual Word Recognition Volume 1: Models and Methods, Orthography and Phonology* (pp. 52–69). Hove, UK: Psychology

Press.

Giraudo, H., & Grainger, J. (2000). Prime word frequency in masked morphological and orthographic priming. *Language and Cognitive Processes*, *15*, 421–444.

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

Gonnerman, L., & Plaut, D. C. (2000). Semantic and morphological effects in masked priming (2000). Department of Psychology. Paper 350. **http://repository.cmu.edu/psychology/350**.

Gonnerman, L. M., Seidenberg, M. S., & Andersen, E. S. (2007). Graded semantic and phonological similarity effects in priming: Evidence for a distributed connectionist approach to morphology. *Journal of Experimental Psychology: General*, *136*, 323–345.

Harm, M. W., & Seidenberg, M. S. (2004). Computing the meanings of words in reading: Cooperative division of labor between visual and phonological processes. *Psychological Review*, *111*, 662–720.

Katz, L., & Baldasare, J. (1983). Syllable coding in printed-word recognition by children and adults. *Journal of Educational Psychology*, *75*, 245–256.

Kempen, G., & Huijbers, P. (1983). The lexicalization process in sentence production and naming: Indirect election of words. *Cognition*, *14*, 185–209.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*, 1–38.

Lima, S. D., & Pollatsek, A. (1983). Lexical access via an orthographic code? The Basic Orthographic Syllabic (BOSS) reconsidered. *Journal of Verbal Learning and Verbal Behavior, 22*, 310–332.

Marslen-Wilson, W., Bozic, M., & Randall, B. (2008). Early decomposition in visual word recognition: Dissociating morphology, form, and meaning. *Language and Cognitive Processes*, *23*, 394–421.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88*, 375–407.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review, 76*, 165–178.

Morton, J. (1970). A functional model of memory. In D. A. Norman (Ed.), *Models of human memory* (pp. 203–254). New York: Academic Press.

Murrell, G. A., & Morton, J. (1974). Word recognition and morphemic structure. *Journal of Experimental Psychology*, *102*, 963–968.

Niswander, E., Pollatsek, A., & Rayner, K. (2000). The processing of derived and inflected suffixed words during reading. *Language and Cognitive Processes*, *15*, 389–420.

Perry, C. (2013). Graphemic parsing and the basic orthographic syllable structure. *Language and Cognitive Processes*, *28*, 355–376.

Perry, C., Ziegler, J. C., & Zorzi, M. (2010). Beyond single syllables: Large-scale modeling of reading aloud with the Connectionist Dual Process (CDP++) model. *Cognitive Psychology, 61*, 106–151.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103*, 56–115.

Rastle, K., & Davis, M. H. (2008). Morphological decomposition based on the analysis of orthography. *Language and Cognitive Processes*, *23*, 942–971.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition, 42*, 107–142.

Rueckl, J. G., & Aicher, K. A. (2008). Are Corner and Brother morphologically complex? Not in the long term. *Language and Cognitive Processes*, *23*, 972–1001.

Rueckl, J. G., & Raveh, M. (1999). The influence of morphological regularities on the dynamics of a connectionist network. *Brain and Language, 68*, 110–117

Rumelhart, D. E., & McClelland, J. L. (1982). An interactive activation model of context effects in letter perception: Part 2. *Psychological Review, 89*, 60–94.

Schreuder, R., & Baayen, R. H. (1995). Modeling morphological processing. In L. B. Feldman (Ed.), *Morphological aspects of language processing* (pp. 131–154). Hillsdale, NJ: Lawrence Erlbaum Associates.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96*, 523–568.

Taft, M. (1979a). Lexical access via an orthographic code: The Basic Orthographic Syllabic Structure (BOSS). *Journal of Verbal Learning and Verbal Behavior*, *18*, 21–39.

Taft, M. (1979b). Recognition of affixed words and the word frequency effect. *Memory & Cognition, 7*, 263–272.

Taft, M. (1987). Morphographic processing. The BOSS re-emerges. In M. Coltheart (Ed.), *Attention and performance, XII* (pp. 265–279). London: Lawrence Erlbaum Associates.

Taft, M. (1991). *Reading and the mental lexicon*. Hove, UK: Lawrence Erlbaum Associates.

Taft, M. (1994). Interactive-activation as a framework for understanding morphological processing. *Language and Cognitive Processes, 9*, 271–294.

Taft, M. (2003). Morphological representation as a correlation between form and meaning. In E. Assink, & D. Sandra (Eds.), *Reading complex words* (pp. 113–137). Amsterdam: Kluwer.

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

Taft, M. (2006). A localist-cum-distributed (LCD) framework for lexical processing. In S.M. Andrews, *From inkmarks to ideas: Current issues in lexical processing* (pp. 76–94). Hove, UK: Psychology Press.

Taft, M., & Ardasinski, S. (2006). Obligatory decomposition in reading prefixed words. *The Mental Lexicon*, *1*, 183–199.

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior*, *14*, 638–647.

Taft, M., & Forster, K. I. (1976). Lexical storage and retrieval of polymorphemic and polysyllabic words. *Journal of Verbal Learning and Verbal Behavior*, *15*, 607–620.

Taft, M., & Kougious, P. (2004). The processing of morpheme-like units in monomorphemic words. *Brain and Language*, *90*, 9–16

Taft, M., & Krebs-Lazendic, L. (2013). The role of orthographic syllable structure in assigning letters to their position in visual word recognition. *Journal of Memory and Language*, *68*, 85–97.

Taft, M., & Nguyen-Hoan, M. (2010). A sticky stick: The locus of morphological representation in the lexicon. *Language and Cognitive Processes*, *25*, 277–296.

Taraban, R., & McClelland, J. L. (1987). Conspiracy effects in word pronunciation. *Journal of Memory and Language, 26*, 608–631.

Treiman, R., & Chafetz, J. (1987). Are there onset- and rime-like units in printed words? In M. Coltheart (Ed.), *Attention and Performance, XII* (pp. 281–298). London: Lawrence Erlbaum Associates.

Notes:

([1]) In Taft (2006) the model was referred to as *localist-cum-distributed* (LCD). The reason for abandoning this term is that most models actually include a combination of localist and distributed characteristics, even if one dominates the other. For example, the input units of PDP models are typically localist, representing specified letters or letter groupings, while the letter units of the IA model can be seen as being distributed in the sense that more than one word is activated through the same set of units.

([2]) In fact, Diependaele et al. (2009) do not explicitly state that the lexical form *corner* is not activated through the morpho-orthographic unit *corn*. However, this seems a sensible conclusion based on the description they give.

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