**Morphology and the mental lexicon: Three questions about *decomposition*[*]**

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## 1 Introduction

The most basic question for the study of morphology and the mental lexicon is whether or not words are *decomposed*: informally, this is the question of whether words are represented (and processed) in terms of some kind of smaller units; that is, broken down into constituent parts. Formally, what it means to represent or process a word as decomposed or not turns out to be quite complex. One of the basic lines of division in the field classifies approaches according to whether they decompose all "complex" words ("Full Decomposition"), or none ("Full Listing"), or some but not all, according to some criterion (typical of "Dual-Route" models). However, if we are correct, there are at least three senses in which an approach might be said to be decompositional or not, with the result that ongoing discussions of what appears to be a single large issue might not always be addressing the same distinction. Put slightly differently, there is no single question of decomposition. Instead, there are independent but related questions that

[*] Thanks to…

define current research. Our goal here is to identify this finer-grained set of questions, as they are the ones that should assume a central place in the study of morphological and lexical representation.

### 1.1 Morphology

A great deal of research on words and morphology in theoretical linguistics takes an architectural focus, asking questions like *Is morphology part of the syntax? Is there a "Lexicon" in which words are derived and stored?*[1] Very different answers to these questions have been developed and continue to be debated in an active literature. For the purposes of this paper, it is important to highlight two points of consensus that have emerged from what are often very distinct lines of investigation. The first is a matter of representation; the second concerns the direction that further research should take.

The representational point centers on how morphological relatedness is encoded. The consensus that has arisen in morphology theory is that morphological *features* serve this purpose. While theories might say different things about how these features are represented, there is agreement that e.g. past tense verbs like *played* are associated with a feature like [+past] that is in turn related to both phonology and semantics. The nature of these features is examined in detail in §3. For now, we note merely that the very fact that there is a consensus of this type is striking, given that it arises in approaches that otherwise differ markedly in terms of what they say about a number of other issues. Much of our discussion will thus concentrate on the role(s) features of this type play in explaining the relationships between words—a particularly important topic in

[1] For an overview of some foundational questions, and a look at morphological theories until the late 1980s, Carstairs-McCarthy (1992) is a useful source.

the light of recent approaches that deny the existence of specifically morphological representations (see below).

Concerning the second point, directions for further research, there has been a move in recent years towards increasing integration of paradigms from theoretical, experimental, quantitative, and computational paradigms. In the past, it has been possible to find analogues across these domains. For example, the idea from early work in theoretical linguistics that words that are irregular are stored in the lexicon (cf. Aronoff 1976; cp. Bloomfield 1933) resonates with the position taken in Dual-Route (or Dual Mechanism) models of the mental lexicon (e.g. Baayen et al. 1997; Bertram et al. 2000; Burani and Laudanna 1992; Caramazza et al. 1988; Frauenfelder and Schreuder 1992; Giraudo and Grainger 2001, 2003; Schreuder and Baayen 1995). More recent developments indicate a move past analogies and towards the idea that theoretical and experimental paradigms, rather than being connected indirectly or correlating with each other in certain ways, are actually different ways of looking at the same questions. According to one way of thinking about this, different options that have been identified in more "theoretical" lines of investigation are used as hypotheses to make qualitative and quantitative predictions about behavioral (and neural) responses, within a single integrated research program (for one set of views on this see Poeppel and Embick 2005, Embick and Poeppel 2015; Marantz 2005, 2013; and Goodwin Davies 2018).

These two points of consensus fit together in the following way. A number of research programs with very different starting assumptions and goals have adopted the idea from morphological theory that morphological features are necessary in the representation of words, in a way that, moreover, involves abandoning what will be called the "textbook" view of the morpheme in the discussion to come. However, the consequences of this move have not been articulated in detail.

A primary goal of this paper will thus be to show how it leads to a set of research questions that are more refined than a simple 'decomposition-or-not' dichotomy.

### 1.2 Three questions

The bulk of our discussion concentrates on the following three questions:

**(Q1) Is there *independent morphological representation?*** The first (and most fundamental) question is whether morphological features—that is, independent morphological representations—exist in the first place. As noted above, while linguistic theories have reached a sort of consensus on this question, this agreement does not extend across the broader language sciences where the mental lexicon is studied. In ways that are made precise below, this question asks, in essence, if the putative effects of morphology could instead be reduced to other types of representations, viz. semantic and phonological ones, or whether there is indeed a kind of unit that is connected to form and meaning, but represented distinctly.

**(Q2) What does it mean to store ("morphologically complex") words in memory?** A second question concerns what it could mean to store a word in memory. Some theories say, for example, that a past tense form like *played* is derived by rule and morphologically complex, consisting of the stem *play* and the past tense morpheme (orthographic) *-ed*, but that an irregular like *sang* is "simplex", i.e., and exists as an unanalyzable object in memory. As we will show, this kind of dichotomy masks several important questions that are implicated in much recent work, but which are not often posed clearly.

**(Q3) What does it mean to be *morphologically complex,* or, are morphemes *pieces*?**

The third question concerns exactly *how* morphology is represented. For theories that posit independent morphological representations, an important question to ask is what properties these representations have. One possibility is that morphological features like [+past] are represented independently in memory, in the same way that stems like *play*, *sing*, etc. are; on this view *played* has an internal structure consisting of the two pieces [play]-[+past]. Another possibility is that morphology is not represented in this way, but instead appears as part of a representation with a stem, e.g. [play +past]; this representation has no internal hierarchical structure. These possible analyses are the subject of a long-standing debate in linguistic theory, and have surfaced in recent experimental and computational discussions as well.

Our choice to concentrate on these questions is designed to (re)direct inquiry in a way that moves past some familiar dichotomies; the most basic is that between what are classified as *Full Listing* (Butterworth 1983; Bybee 1995; Manelis and Tharp 1977; Norris and McQueen 2008) versus *Decompositional* approaches. The latter are of different types, including those with *Full* or *Obligatory Decomposition* (Fruchter and Marantz 2015; Taft and Forster 1975; Taft 1979; Taft 2004) of all complex words; versus *Dual Route* approaches (Baayen et al. 1997; Bertram et al. 2000; Frauenfelder and Schreuder 1992; Marslen-Wilson and Tyler 1998; Pinker and Ullman 2002) that posit decomposition for some words but not others, according to different criteria. Zwitserlood (2018) provides a succinct overview of these and other approaches.

While all of these ways of classifying and opposing approaches provide convenient reference points, we will be at pains to show that the refined set of questions (Q1-3) does a better

job of posing the questions that are (or should be) in focus in investigating morphological and lexical representation.

## 2 (Independent) morphological representation

What does it mean **(Q1)** to have specifically *morphological* representations?

Perhaps the most straightforward way of approaching this question is by thinking about what it means for words to be *related* to one another; for illustration, we will employ the words *play* and *played*. In one way of talking about how they are related, these two words share the "stem" (or "root") *play*; the past tense has a feature [+past] in addition to the stem. In ways that different theories specify, this feature in turn relates form (the phonology /d/) and meaning (the semantics of "past tense"). The (informal) principle assumed in this type of work is that generalizations about form and meaning can be maximized by minimizing the amount of information that has to be memorized. Based on the existence of other present/past pairs in the language like *amaze/amazed*, *blend/blended*, *rig/rigged*, etc., it can be observed that there are a number of past tense forms that look like the present form with a /d/ added; allowing for phonological devoicing, many more such pairs can be adduced (*pass/passed, buff/buffed,* etc.). Storing all of these words in memory would, according to this way of thinking, fail to account for the observation that the past tense is signaled by the addition of /d/. Seen in this way, the [+past] feature anchors or provides a locus for encoding the generalization that past tense has this particular form.

The way of talking about morphological relatedness outlined above is an accurate though partial representation of an important line of reasoning, one that we will expand on below. It is not the only way of approaching morphological relatedness, though. It could be denied, for

instance, that there is anything to be gained by minimizing the number of morphemes in memory. More relevant for our immediate purposes is the fact that given what we have considered to this point, it looks as though semantic and phonological relatedness might exhaust what there is to be said about the relatedness of words. In particular, given that *play* and *played* overlap considerably in meaning (they both relate to "playing"); and, given, moreover, that they are quite similar in form (they share most of their phonological content), why would we need an 'independent morphological representation'—i.e. a feature like [+past]? This is the question at the heart of this section: *given that phonological and semantic relatedness are independently motivated, why would specifically morphological representations be required as well?*

## 2.1 Abstraction from form and meaning

The answer to this question is that morphological features are required because **words appear to be related in ways that go beyond what can be stated in terms of simple overlap in form and meaning**.

To demonstrate this point, we will review arguments showing that, although appealingly simple, the idea that "past tense means [[<semantics of past tense>]] and is pronounced /d/" is inadequate for explaining the connections between words, even for this kind of apparently straight-forward example.

First, some further context is required. The simple view just outlined is based on the idea that morphemes connect a single form to a single meaning. It is a version of a "textbook" or classic approach to the morpheme, one that is associated with works like Hockett (1958)—see Aronoff (1976). As Aronoff discusses, the textbook morpheme requires three things: a constant form, a constant meaning, and an arbitrary link between the two. However, the reality that

emerges from morphological theory shows conclusively that form/meaning connections are much more complex than this.

To illustrate this point, it is useful to think about what this kind of morpheme would look like. Simplifying considerably, the approach to morphology presented in Lieber (1980,1992) involves morphemes ("lexical items") with the relevant properties; a past tense morpheme, for example, could be represented as in (1):

(1) [ [$_{V}$ ] **past'**, /d/]

This type of morpheme is a single object whose underlying content includes semantics (here **past'**), a phonological underlying representation /d/, and an indication of the morpheme's combinatory properties (in this case, that this affix attaches to verbs).

While theories involving morphemes like (1) continue to be explored, the prevailing view in morphological theory, with roots in approaches from the 1960s and 1970s in work by Beard (1966), Matthews (1972), Aronoff (1976) and others, is that morphemes that combine syntax/semantics/form in a single item in memory as in (1) cannot account for the ways in which natural languages relate form to meaning. This idea is an important one. It continues to grow in significance as its implications have begun to have an impact on experimental and quantitative research, in approaches with very different starting points. For example, it appears both in experimental work connected to linguistic theories like Distributed Morphology (Halle & Marantz 1993), and also in work exploring learning models like Baayen et al. (2011) (see also §5). It is thus of central importance in understanding current discussions of morphology and the mental lexicon.

The conclusion drawn in theoretical works like those cited above is that the semantic and phonological facets of the morpheme must not be represented in the same primitive object. This position has come to be known as the *Separation Hypothesis*. The key role that Separation plays for present purposes is as follows: when the sound and meaning parts of the morpheme are separated from one another, it is no longer necessary that there be "one form/one meaning" as there is with the classic morpheme. In terms of the example above, it says that notions like "past tense form of the verb" need not have (i) a single sound form associated with them, nor (ii) a single semantic interpretation. Second, it provides a way of encoding the idea that there nevertheless **is** a single coherent notion of past tense verb forms. Whether regular or irregular, all past tense verb forms (*played*, *gave*, *bent*, *went* etc.) have the same distribution in the syntax of the language. It is this identity, one that is abstracted from a single phonological realization or semantic interpretation, that is accounted for with the feature [+past].

We will unpack the phonological and semantic components of the argument for Separation in turn, beginning with the former. In a typical way of implementing Separation, phonology-free morphological features like [+past] are provided with a form through a process of *phonological realization*. The details of phonological realization can be implemented in different ways, which depend to some extent on the "morphemes as pieces (or not)" question (Q3). At a very general level, the idea is that for a feature like [+past], there must be a rule or object that associates it with a phonological form. The object in (2), a *Vocabulary Item* in the terminology of Distributed Morphology, is one way of doing this (see Embick 2015 for an overview):

(2) [+past] ↔ /d/

Informally, (2) says that the feature [+past] is provided with the phonological form /d/.

Relating form to features as in (2) allows for a morphological feature to be realized in a way that is influenced by its context. So, for example, the past tense [+past] is realized as /t/ in the context of *bend*, *keep*, and several other verbs. This can be accounted for by making the realization sensitive to the verb to which the [+past] feature is attached; we show this in (3), to be interpreted as "[+past] is realized as /t/ in the context of LIST", where LIST = {*bend*, *keep*, …}:[2]

(3) [+past] ↔ /t/ /LIST _____

In a standard way of thinking about (2) and (3), there are principles of competition that ensure that the more specific (3) applies when its conditions on application are met, such that *bent* is derived (and **bended* is not); see Embick (2015) for a general discussion. Terminologically, a feature like [+past] that shows different phonological realizations in this way shows *(contextual) allomorphy*.

The discussion above shows that a morpheme's feature content is sometimes abstracted away from a particular phonological realization, such that the context in which a morphological feature appears plays a crucial role in determining its phonological form. The same types of considerations apply to semantic interpretation as well. Aronoff's (1976) arguments against the classic morpheme provide a way of thinking about this. Based on the behavior of "bound roots" in the Latinate vocabulary of English, e.g. MIT in *e-mit, o-mit, com-mit, per-mit*, etc., or CEIVE in *con-ceive, de-ceive, per-ceive* etc., Aronoff concludes that the roots in question are

[2] A comprehensive account would also address the changes to the stem vowel that is found in forms like *bent*, *kept*, and others.

morphemes that have no inherent/constant meaning, and that the traditional definition of the morpheme must therefore be abandoned or modified. In one way of looking at this, the argument is that the meanings of certain morphemes may be abstract in the same way that their phonological form is, and require crucial reference to their context. For discussion of this point, see Marantz (2013), Marantz and Myler (forthcoming), and references cited there, where (on analogy with the phonological side) the contextual interpretation of morphemes is called *allosemy.*[3]

Contextual effects can also be identified with inflectional morphology. While past tense forms are used in simple past tense contexts (*Mary laughed)*, past tense forms are also used to express non-past meanings; for example, the kind of irrealis interpretation associated with certain conditional antecedents (*If Mary laughed at the meeting tomorrow, we would be surprised*). Past tense is also used in polite contexts, e.g. *Did you want to have the cake as well?* Even if there is a way of connecting these different meanings, by e.g. abstracting a notion of 'remoteness' that is common to all, the point is the same: there is not a unique association between [+past] and a single meaning like 'past tense'.

Taken together, these observations point to the sense in which morphological representations like 'past tense' are abstractions: one and the same feature like [+past] need not have a single phonological representation, nor does it need to correlate with a single meaning.

[3] Aronoff, and others following him in the tradition of *lexeme-based* morphology, speak of the situation as one in which individual lexemes like *emit* have meanings, even though their constituent parts do not. This approach differs in interesting ways from one in which morphemes are assigned interpretations by virtue of the morphemes that appear in their context, as is suggested later in the main text. The differences between these approaches do not detract from the point on which they agree, which is that morphemes have an identity that is abstracted from particular/consistent meanings.

On this point, it is important to note that identical forms are realized for a given verb in the different meanings that have been identified:

(4) Mary talked/left/spoke/sang/went to the beach yesterday.

(5) If Mary talked/left/spoke/sang/went to the beach tomorrow…

In other words, the fact that the same form of a verb is found with past tense and (certain) irrealis meanings is not an accident. Rather, it calls for an abstract identity that underlies a set of disparate contextually-determined phonological and semantic realizations; and this is what [+past] provides.

For reasons that have been introduced above, the feature [+past], though abstract from the point of view of form and meaning, plays a definite role in the grammar: it determines the distribution of the verb forms that we call "past tense". In this way, it is directly connected to the syntax of the language, since this is the part of the grammar that governs where past tense forms do and do not surface. Crucially, though, the syntactic distribution of past tense forms is independent of how those forms are realized phonologically. The abstraction inherent in [+past] thus provides a way of connecting regular and irregular verbs, which are often treated in very different ways. The important point is that (abstracting away from irrelevant effects of lexical meaning), regular and irregular verb forms are identical in terms of their clausal syntactic distribution. This is a clear reason for treating both of them as involving a [+past] tense feature; although how they relate to this feature is contentious, as we will see in §3.[4]

[4] On this theme, see Pinker and Ullman (2002:457), who state that "classical theories of generative phonology and their descendants … generate irregular forms by affixing an abstract morpheme to the stem … to account for the fact that most

## 2.2 Independent morphology in lexical processing/representation

The primary challenge for investigating the role of morphological features in lexical processing and representation is disentangling different types of relatedness between words. In particular, any given indication of relatedness that is detected in an experiment could be phonological or semantic in nature, not specifically morphological. The basic question to be addressed thus concerns how can it be determined what type(s) of representations are driving observed effects. The question is particularly poignant given different movements that seek to eliminate morphological representations (see Baayen et al. 2011; Gonnerman et al. 2007; Milin et al. 2017; Plaut and Gonnerman 2000; Raveh 2002; Seidenberg and Gonnerman 2000, and related work). Despite differences in starting assumptions and implementations, these approaches share the idea that putatively morphological effects can be reduced to relatedness in form and meaning, and do not require morphological representations beyond these.

The question of how to distinguish phonological, semantic, and (hypothesized) morphological relatedness manifests itself clearly in morphological priming paradigms, which are in principle designed to probe morphological processing and representation. It is well established that priming paradigms are sensitive to semantic and phonological relatedness between words. For instance, words that are related semantically, such as *cat* and *dog*, or *carrot* and *vegetable*, typically facilitate each other in associative priming paradigms (see Neely 2012

irregular forms are not completely arbitrary but fall into families displaying patterns…". This is not an accurate way of describing the motivation for features like [+past], as we have shown here. For the question of how irregular forms might be realized (in terms of storage or not) see §4.

for an overview). Similarly, words like *fog* and *dog* are related phonologically by virtue of rhyming, a shared phonological property that produces significant facilitation in priming paradigms. Other phonological relationships have detectable effects as well; for example, *gray* and *grape* are related phonologically in that the former is a substring of the latter (e.g., Wilder, Goodwin Davies, and Embick 2019). These and other relations may produce facilitation or inhibition in priming paradigms, in ways that relate to the predictions of models of lexical activation and access. For immediate purposes, what is important is the fact that many morphologically related words (e.g., *frogs* and *frog,* or *teacher* and *teach*) are also phonologically and semantically related. This raises the question of when facilitation and other findings can be interpreted as purely morphological effects, since the effects could also be due to phonological or semantic priming (or an interaction between the two); see e.g. Feldman (2000) and Gonnerman et al. (2007).

With these kinds of concerns in mind, various means have been proposed to attempt to rule out semantic or phonological factors in attempts to detect morphological relatedness. Primed lexical decision experiments typically include control conditions containing pairs of items that are similar semantically (e.g. *hit* → *kick*) or phonologically (orthographically, in visual presentation) but which are not morphologically related (e.g. *bail* → *boil*). Such conditions are then used to compare effect sizes for the different types of relatedness; in this case, to examine whether morphological relatedness in pairs like *came* → *come* can be shown to be distinct from semantic and phonological relatedness. A different way in which this issue has been addressed is by examining morphological priming effects for complex words that lack either a close phonological relation (as in English irregular past tense words like *taught* with respect to *teach*), or by employing rhyme prime to probe whether monomorphemic targets behave differently from

targets with affixes (e.g. *dough* → *code* vs. *dough* → *snowed*; Bacovcin, Goodwin Davies, Wilder, and Embick 2017). On the semantic side, a growing literature asks whether morphological relatedness can be detected in words that do not share a semantic relation to their stem (see e.g. Marslen-Wilson et al. 1994; Smolka et al. 2014; Stockall & Marantz 2006; Creemers et al. 2020).

## 3 Morphological complexity/Storage of words

What does it mean **(Q2)** to store a (morphologically complex) word in memory?

Questions about storage have a complex history in linguistic theories of morphology. In a tradition that is often associated with Chomsky (1970), many such proposals arise in theories of the *Lexicon*, a component of grammar whose contents, organization, and very existence are investigated and debated in a complex literature.[5] Our focus in this section is on what it would mean for *morphologically complex* words to be **stored**. This is an important topic in morphological theory. Early proposals by Aronoff (1976:43) rely crucially on the idea that at least some morphologically complex words (namely, those that are irregular in any way) are listed in the Lexicon. While Aronoff (1976) is interested in derivational morphology (e.g. *-ity* derivatives like *curiosity* versus *-ness* forms like *curiousness*), the same kind of reasoning about irregularity has been extended to inflectional morphology. For example, familiar versions of the Dual-Route approach to modelling the English past tense hold that irregulars are "stored", unlike regulars, which are "computed by rule". What precisely this means, though, is not at all obvious;

[5] Some additional difficulties arise due to the many different ways in which the terms *Lexicon, lexical*, etc. are used; see Aronoff (1994) and Embick (2015) for discussion.

what might be stored (and how storage relates to composition of complex objects) is a complex matter, one that takes on special importance in the light of the Separation Hypothesis.

### 3.1 Storage and separation

As a starting point, note that storage in memory is typically posited as an alternative to something that is referred to as *computation by rule*. To see what it might mean to store a complex word, then, it is useful to begin with the question of which aspects of a word's representation might be rule-governed in a relevant way. Illustrating with the English past tense again, the previous section motivates features like [+past], so that past tense verbs consist of the verb (here capitalized to indicate a degree of abstraction, for reasons that will become clear below) and a past tense feature: e.g. [PLAY +past]. As described in §2, [+past] is realized as the "regular" past tense exponent /d/ to produce *played*.

There are two things happening in this example that could be understood as being done "by rule". The first **(R(ule)1**) is the process that **combines** PLAY and [+past]. In standard ways of talking about this relation, the rule is combinatoric, in the sense that it combines two independent objects into a complex representation. The second thing **(R(ule)2)** that is involved here is the process that **realizes** the [+past] feature, in this example as /d/. This could be effected by a morphological rule, or something similar like the Vocabulary Item [+past] ↔ /d/ employed in the previous section. The form /d/ is the regular realization of [+past], so this behavior is also rule-governed in the relevant sense.

With these distinctions at hand, it is clear that treating some words as stored and not derived by rule could amount to denying for those words the application of either one of (R1) and (R2), or both, as we will now show.

### 3.1.1 Storing complex objects and their forms

For the purposes of this section we will adopt a sort of operational definition of *morphological complexity* that says that a word is morphologically complex when it consists of more than one grammatical element; e.g. two "stems", like in compounds (e.g. *blackberry*), or a stem and a morphological feature like [+past], and so on. It is then possible to consider what it means to store a morphologically complex word in memory in a way that denies both (R1) and (R2). Pinker and Ullman's (2002) "words and rules" approach takes this stance with respect to (R1)/(R2). Their view is that with irregulars, speakers "memorize a complex word outright rather than parsing it into a stem and an affix" (Pinker and Ullman 2002:456). For regular past tense verbs, a stem like *play* is associated with a feature [+past] that is combined with it by an affixation rule (as in (R1)) that produces *play-ed.* In notation like that used above, the output of this rule is a word [$_V$ play –ed, +past], a verb that appears in past tense syntactic contexts. On the other hand, irregular past tense verbs like *gave* are stored in the lexicon "as a whole", i.e. as [$_V$ gave +past]. This approach denies (R1) for *gave*, since this word is stored in memory with the [+past] feature, not combined with it. With respect to (R2), there is also nothing rule-like that produces the irregular past tense from the stem; rather, *gave* is a suppletive stem, along the lines of *go/went.*

### 3.1.2 Storing stem forms

(R1) and (R2) are independent and thus need not be denied or accepted together. One approach that appears in the literature rejects (R2) for certain words but retains (R1). In this kind of approach, complex objects like [GIVE +past] are created by combining two separate elements, GIVE and [+past]. In the realization of this representation, though, there is a difference from

what happens with regulars. In particular, *gave* is a special "stem" in memory that realizes both [GIVE] and [+past]; in the notation used above, this would involve an item [GIVE +past] ↔ *gave*. This is essentially the approach of Anderson (1992); but it could in principle be implemented in any number of realizational approaches, with differences in implementation of stem suppletion that could potentially be investigated further.[6] In this type of analysis, irregular **forms** like *gave* are stored in memory—they are thus not related (morpho)phonologically to the form realized in *give*. However, what is stored in memory is not a complex object; the form *gave* is simplex, and realized in the complex object [GIVE +past].

### 3.1.3 Accepting (R1); maximizing (R2)

The approaches considered immediately above all posit that "storage as a whole" is a property of at least some morphologically complex words. They thus stand in contrast to theories that employ (R1) across the board and maintain (R2) to the fullest extent possible, which often bear the label *Full Decomposition* (e.g. Stockall and Marantz 2006). For this type of approach, the (R1) properties are those outlined in the first part of §3.1.2: all past tense verbs, whether regular or irregular in form, involve the composition of the verb with the feature [+past]: [PLAY +past], [GIVE +past], and so on. It is with respect to (R2) that more needs to be said. If (R2) is accepted as much as possible (see below), it is not the case that e.g. *gave* is a suppletive allomorph of *give*. Instead, there are (morpho)phonological rules that produce the stem change seen in *gave*, so that *give* and *gave* share a phonological underlying representation.

An approach of this type must nevertheless put some limits on (R2): there are some cases—the extremes of form/meaning unpredictability—where storage is required. These involve

[6] For example, rather than treating *sang* as realizing both [SING] and [+past], it could be treated as a contextual allomorph for SING that is realized in the context of [+past]; see Embick (2010b, 2015) for discussion.

the phenomenon of (stem) suppletion, which cannot be treated morphophonologically. So, for example, the verb *go* and its past tense *went* are suppletive alternants, such that *went* is inserted when GO combines with [+past]. What about alternations that share some segmental material, but less than e.g. *give*/*gave*—*bring/brought*, for example, or *think/thought*; are these related morphophonological like *give/gave*, or suppletively like *go/went*? This question is a complex one with a long history. It is, importantly, one where it appears that convergence between different lines of research is required; i.e., one where experimental investigation grounded in distinctions made in the theoretical domain are required; see Embick (2010b) and Embick and Poeppel (2015) for some discussion.

### 3.2 Detecting storage in morphological processing/representation

Theories that apply (R1) across the board and maximize (R2) are at one limit of the decomposition versus storage divide; the other limit is theories that posit that all words are memorized (i.e., Full Listing). Many (psycho)linguistic approaches adopt an intermediate position, according to which particular criteria determine whether a word is stored or derived. Perhaps the most prevalent type of approach is one in which words that are regular are derived by rule, whereas rules that are irregular are stored (see Zwitserlood 2018 for a recent overview).[7] The notions of *regular* and

[7] Additional criteria that have been suggested for the storage-or-not dichotomy include frequency and productivity. It has, for instance, been proposed that high-frequency regular forms are stored, on a par with irregular forms (Stemberger and MacWhinney 1988), or that words with a low surface frequency and high-frequency constituents may be processed through a parsing route (Burani and Laudanna 1992; Chialant and Caramazza 1995; Laudanna and Burani 1995). In a similar vein, the Morphological Race Model posits that besides semantic and phonological regularity, morphological productivity plays a role in deciding which words are stored (the "direct route") and which are derived (the "parsing route"). In this model, productive forms

*irregular* that are required here have manifestations in both form and meaning, and can be defined in different ways. For the form side, regulars are typically identified as having default or productive morphology, while irregulars show unpredictable allomorphy, or unproductive forms. On the meaning side, regulars have meanings that are semantically transparent, or predictable from their parts, or compositionally derived, while irregulars have unpredictable or special meanings. For reasons of space, we will concentrate here on the form side, since this is where most of the work related to (R1)/(R2) has been done.[8]

The interpretation of experimental evidence related to the storage-or-not question often proceeds along lines that must be reconsidered if the (R1)/(R2) distinction is taken into account. A typical kind of reasoning is based on experiments that examine relatedness between regulars and irregulars and their stems, where prior findings have identified some ways in which regulars and irregulars behave differently, and some in which they behave the same. Many experimental studies, both behavioral and neurolinguistic, have reported that regulars and irregulars differ in at least some ways (see e.g., Stanners et al. 1979; Kempley and Morton 1982; Napps 1989; Marslen-Wilson 1999; Allen and Badecker 2002; Pastizzo and Feldman 2002). In contrast, some later work that combines priming with magnetoencephalography (MEG) or electroencephalography (EEG)

(to a first approximation, those that are generalized to new forms, consider e.g. the verbs *google*/*googled*) are parsed while unproductive forms are stored (Baayen 1992; Frauenfelder & Schreuder 1992).

[8] On the meaning side, a number of studies look for difference between words that are semantically unpredictable, which are called *opaque*, versus words whose meanings appear to be *transparent*: that is, derived predictably from the meaning of their parts. A number of studies report stem-priming from both transparent and opaque derivatives; see Smolka et al. (2009, 2014, 2019) and Creemers et al. (2020) for recent examples. One line of the literature hypothesizes that there are cross-linguistic differences in such effects, i.e., that opaque forms do not prime in some languages (see Günther, Smolka, and Marelli 2019 and references cited there). However, it is possible that differences are due to how *opaque* is defined across studies (see Creemers et al. 2020).

shows that both regular (*dated*) and irregular (*gave*) allomorphs of a verb (*date, give*) prime their stem (Stockall & Marantz 2006; Morris & Stockall 2012). Relatedly, but focusing only on irregular forms, Crepaldi et al. (2010) also find facilitation for irregular verb pairs (*fell* → *fall*) compared to orthographically matched (*full* → *fall*) and unrelated controls (*hope* → *fall*) in a series of masked priming experiments.

When differences between regulars and irregulars are found, this is often taken to be evidence for Dual-Route accounts for inflection. However, the idea that there are differences between regulars and irregulars does not require that particular implementation of the difference. Even Full Decompositional models of the mental lexicon have to posit *some* difference between formations that have irregularities associated with them and those that do not, since irregulars require a type of listed information (Embick and Marantz 2005). Moving past the idea that any regular/irregular distinction requires a Dual-Route model, we will conclude this section by looking at the question of how differences/similarities in the representation and processing of regulars and irregulars can be approached in terms of the (R1)/(R2) distinction. The gist of this part of the discussion is that similarity or difference between these two types of words depends on what types of representations and relatedness a particular experiment is probing.

The idea we put forward is that in light of the (R1)/(R2) distinction, arguments in either direction (different or similar behavior) must be examined at a finer grain. Suppose that regulars and irregulars are found to differ in some way. Is that evidence relating to (R1) for them being associated with the feature [+past] in different ways (by rule with *dated*, but stored with *gave*)? Or is it evidence related to (R2) that the ways in which their phonological forms are related differs? In the other direction, where it looks like regulars and irregulars are both related to their stems, the same kinds of questions can be asked. If regulars and irregulars both prime their roots, is this

evidence (R1) that both *dated* and *gave* are related to a structure [Root +past], such that the present and past tense forms share a morphological representation, i.e. a shared stem GIVE or PLAY? Or is it evidence (R2) that *gave* is derived (morpho)phonologically from *give*, i.e. like *played* is from *play*? To make matters more complex, the effects of **both** (R1) and (R2) types of relatedness might be found in experimental paradigms that are standardly employed.

The key question for further work in this area is thus how to distinguish the relative contributions of the (R1) and (R2) types of relatedness experimentally.

## 4 Representing morphology

What does it mean **(Q3)** to be *morphologically comp*lex, or to say that morphemes are *pieces*?

In §2 we looked at the question of morphological features. While many approaches agree that such features are required, there continues to be substantial disagreement as to how they are represented. The question at issue is whether features like [+past] are represented as *pieces*—so that they are similar to stems like PLAY, SING, etc. (at least to this extent). Terminologically, theories that represent morphological features as pieces are called *piece-based* (or *morpheme-based*, since the pieces are often called *morphemes*). The opposing type of approach is referred to as *pieceless* or *amorphous*. In the latter type of approach, there are features like [+past], but they are not represented like stems are. The primary point of contrast is that in a piece-based theory, words have internal hierarchical structure, as they are built out of a number of pieces; in a pieceless theory, on the other hand, words relate multiple features, but these are not arranged in a hierarchical structure.

### 4.1 Morphology with/without pieces

The debate between these two positions has a long and complex history. We will look at recent representatives of these views here. Beginning with the pieceless point of view, perhaps the most well-developed example is Anderson's (1992) 'Amorphous morphology' (cp. Matthews 1972; for a look at related approaches in this tradition see Blevins 2016). For purposes of illustration, let us take the Latin verb *lauda:vera:mus* 'we had praised'. In terms of morphological features, this verb has an aspect feature [+perf] (= 'perfective'), a tense feature [+past], and agreement features [+1,-2] (= 'first person'), [+pl] (= 'plural').[9] In Anderson's approach, the rules that realize morphological features operate on representations without internal structure, like the one shown in (6):

(6) Amorphous representation

$$\begin{bmatrix} +1 \\ -2 \\ +pl \\ +past \\ +perf \\ LAUD \end{bmatrix}$$

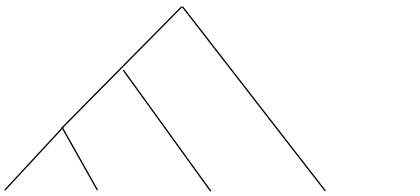
*Word-formation rules* apply to this matrix to rewrite the stem *lauda:* phonologically, to produce the end result *lauda:vera:mus*. These rules are string rewriting rules, so that, for example, the one realizing the [+perf] feature would be stated as something like /X/[+perf] → /Xve/. Further assumptions are needed in order to ensure that these rules apply in the correct order. For our purposes, the important thing to note is that this approach does have independent morphological features, but these are not packaged as pieces. Rather, they appear in matrices like (6) and are

[9] This verb also belongs to Conjugation class I (with "theme-vowel" *a:*) which we put to the side here.

referred to by rules that effect phonological changes to the stem. Importantly, neither features like [+perf] or its exponent /ve/ are pieces on a par with the stem in this approach.

On the other side of things from the amorphous view are piece-based theories that accept Separation; Distributed Morphology (Halle and Marantz 1993 and subsequent work) is of this type. In this approach, *lauda:vera:mus* consists of a number of distinct morphemes that are arranged in a hierarchical structure of the type typically depicted with tree diagrams like (7):

(7) Morphemes as pieces in a hierarchical structure




Morphological features are (parts of) objects in memory (called *functional morphemes* to distinguish them from the *lexical* vocabulary of stems or *roots*) that are combined into larger structures like the one seen in (7). More precisely, these morphemes are the terminals of syntactic trees, trees in which affixation operations produce internally-structured "words" like the one diagrammed in (7).

Morphologically complex words thus contain multiple discrete morphemes in a hierarchical structure. This approach shares with the amorphous one the idea that morphological features are crucial. It also shares the property of adopting Separation: the morphemes in (7) are abstract in the sense that they do not possess phonological representations—these are added to them with Vocabulary Items like (8) (recall the discussion in §2).

(8) [+1,-2,+pl] ↔ -mus

[+perf] ↔ -ve

…

However, this approach differs from an Amorphous one in two related ways. The first is that it treats functional morphemes, which are composed of morphological features, as pieces in the sense described above. A second difference concerns the realization of features. In the amorphous approach, the material introduced by word formation rules has no independent representation; apparent pieces like *-ve*, *-mus*, etc. are simply the phonological by-products of the word formation rules. On the other hand, Vocabulary Items like those in (8) are represented as objects in memory. Both of these differences are relevant to interpreting experimental results, as we will see below.

The debate between piece-based and pieceless views in theoretical morphology continues to this day. With respect to the approaches cited above, Halle and Marantz (1993) devote considerable attention to comparing the predictions of amorphous and piece-based views in the domain of *blocking effects* (cf. Aronoff 1976 and Embick and Marantz 2008; also Embick 2015 for discussion). Another related line of work argues that pieceless theories of morphology are not able to account for different types of *locality conditions* that appear to restrict possible interactions among features in morphological realization (see Embick 2010a, 2016 and references cited there).

Both amorphous and piece-based theories continue to be explored. One issue that arises in making direct comparisons is a difference in research focus. By and large, research programs concentrating on connections with syntax have tended towards the piece-based view, while

research concentrating on more specifically morphological issues (cf. Aronoff's 1994 'morphology by itself', and related work) have tended to adopt amorphous representations.

### 4.2 Experimental directions

A small but focused literature has taken the pieces-or-not debate into the experimental domain. Here it is important to distinguish between *derivational* morphology and *inflectional* morphology, since it is with the latter that most current discussion is associated. In Anderson's (1992) approach, for example, the word formation rules for derivation have different properties from those that create inflected words, such that the former are arguably more piece-like than the latter.[10]

A number of studies address the question of whether derivational affixes are represented in a similar way to stems through priming experiments. For example, VanWagenen (2005) finds facilitation for words which share a derivational affix (e.g. *dark<u>ness</u>* → *happi<u>ness</u>*) relative to phonological (*har<u>ness</u>* → *happi<u>ness</u>*) and semantic controls (*joy* → *happi<u>ness</u>*) in a visual primed lexical decision study. In a cross-modal primed lexical decision task, Marslen-Wilson et al. (1996) report facilitation for derivational prefixes (e.g. *<u>re</u>arrange* → *<u>re</u>think*) and suffixes (e.g. *tough<u>ness</u>* → *dark<u>ness</u>*), and Duñabeitia et al. (2008) show derivational affix priming in Spanish (e.g. *breve<u>dad</u>* 'brevity' → *igual<u>dad</u>* 'equality') in a masked visual priming paradigm. As will be discussed in more detail for inflectional morphology below, it is important in interpreting such findings to be clear about what exactly is being primed. The facilitation that is found between two words that share a derivational affix (such as *-ness* in *dark<u>ness</u>* → *happi<u>ness</u>*) could, for

[10] On this theme, see Borer (2013) for another perspective on how the derivation/inflection split relates to the pieces versus processes issue.

instance, be driven by a feature [+N], by the phonological form of the affix /nəs/, by the semantics of 'abstract noun', or by a combination of these factors. Since this issue does not seem to have attracted much attention in the study of derivational morphology, we focus on this in more detail in our discussion of inflectional affix priming.

For inflectional morphology, the most controversial topic, some initial forays into this part of the morpheme debate have emerged recently, although results are mixed.[11] For instance, VanWagenen and Pertsova (2014) find priming effects for a range verbal inflectional affixes, but no significant effects for several nominal inflectional affixes in Russian. For a group of four inflectional and derivational affixes in Polish (perfective prefixes: *s-*, a diminutive suffix *-ek* and an agentive suffix *-arz*), Reid and Marslen-Wilson (2000) find significant effects when all four suffixes were considered together as a group. For Czech, Smolík (2010) investigates inflectional affix priming for the nominal suffix *-a* (nominal) and the verbal suffix *-ete* (2nd person plural) at two different inter-stimulus intervals. Comparisons between the inflectional affix prime and phonological controls do not reach significance, whereas marginal effects are reported for verbal affix priming at a shorter ISI. Most recently, Goodwin Davies and Embick (2019) examined regular English plural suffixes, and report significant facilitation for inflectional affix priming (*crime<u>s</u>* → *tree<u>s</u>*) relative to phonological (*cleanse* → *tree<u>s</u>*) and singular (*crime* → *tree<u>s</u>*) controls.

There are two important questions that should be asked regarding inflectional affix priming: (i) *what exactly is being primed?*, and (ii) *what does primability imply*

[11] There are several reasons why we would expect facilitation for inflectional affixes to be small relative to stems and/or derivational affixes (such as high frequency, prosodic weakness and homophony, see discussion in Goodwin Davies and Embick 2019), and as a result, studies investigating inflectional affixes may be more susceptible to being underpowered.

*representationally?* The first question is a standard one. Taking into account the distinctions that we have focused on in §2, it is too coarse to say that *crimes* primes *trees* because both of these "involve a plural morpheme." Instead, it must be asked if the priming is driven by the morphological feature [+pl], the phonological exponent /z/, the semantic interpretation of plurality, or some combination of these; see Goodwin Davies and Embick (2019) for discussion and for suggestions about how these factors might be disentangled.

The second question concerns what can be inferred from the existence of a priming effect. Both pieceless and piece-based approaches employ features like [+past]. If features can be primed irrespective of whether they are represented "in their own morphemes" or not, then both approaches would predict facilitation like that discussed above. On the other hand, if priming were expected only of independently stored representations in memory, it is not clear that they would predict the same thing. A similar point can be raised with respect to how features are realized phonologically. In an amorphous approach, apparent affixes like plural /z/ are simply the by-product of a word-formation rule that rewrites phonological strings. In a piece-based theory, a Vocabulary Item like [+pl] ↔ /z/ is stored as an object in memory. To the extent that rules (and their byproducts) and pieces might differ with respect to facilitation, there is a further dimension along which the approaches might be compared.

The overall point that emerges is that when priming is employed to probe the representation and processing of morphology, the specific questions that arise connect with much more general ones about the nature of priming; questions like *Are features that are subparts of representations expected to show priming effect?* Or *Are rules capable of being primed like pieces in memory are?* As should be clear, these questions apply in other areas of language (phonology, syntax), suggesting a number of points of possible connection. Another question to

ask is what techniques other than priming might shed light on the pieces-or-not discussion, whether behavioral or neurological.

In summary, the questions here, though fine-grained, are central to morphological theory, since they implicate the basic representational status of morphemes and hence of words. The challenge is to develop experimental probes that are capable of testing the predictions derived from the pieceless/piece-based representational distinction. While some initial steps have been made in this direction, much work remains to be done in refining and testing the predictions of the views that differ with respect to (Q3).

## 5 Discussion

Our focus in this paper is on the questions **(Q1-3)** that we believe to be central to the study of morphology and the mental lexicon. These are repeated here in short form to facilitate our concluding remarks:

**(Q1) Is there independent morphological representation?**

**(Q2) What does it mean to store ("morphologically complex") words in memory?**

**(Q3) What does it mean to be morphologically complex, or, are morphemes pieces?**

At the beginning of the paper it was suggested that one of the main dividing lines between approaches, whether words are *decomposed* or not, is too coarse-grained to guide the development of competing theories. Having reviewed (Q1-3) in preceding sections, we now note

that there are several distinct and logically independent senses in which the term *decomposition* might be applied.

First, from (Q1), an approach positing specifically morphological features like [+past] etc. could be said to have morphological decomposition, in the sense that (at least some) words consist of more than one independently existing morphological representation.

Two additional senses connect with (Q2). Recall that we identified two kinds of effects: those relating to the composition of complex objects like past tense verbs (called (R1) above), and those relating to the phonological realization of the composed objects (R2). For (R1), an approach that composes [SING] and [+past] to produce the past tense of this verb could be called *decompositional* in comparison to one that says that [sang +past] is stored in memory "as a single object", i.e. with no operation responsible for the composition of its component elements. For (R2), an approach that says that *sang* is derived from a representation that is shared with *sing* could be called *decompositional* with in comparison to an approach in which *sang* is stored as an allomorph of *sing*. In the former, *sang* is composed (morpho)phonologically, while in the latter it is not.

Finally, and connecting with (Q3), an approach that says that morphological features are represented in independent pieces (i.e. morphemes), similar to what is done with stems, could be called *decompositional* with respect to "amorphous" alternatives, since words are composed out of independently existing pieces.

In summary form, our primary argument is that work on morphological decomposition must take these distinct senses into account in framing opposing theoretical positions, and identify which of (Q1-3) is being examined. An example from the literature helps to illustrate why it is important

to be clear about this level of detail. Baayen et al. (2011) investigate the properties of a Naïve Discriminative Learning (NDL) model of morphology, with an emphasis on reading. They frame their investigation with reference to linguistic theories that "…take the word as the basic unit of morphological analysis", pitting this view against one that takes morphology to be "a formal calculus with morphemes as basic symbols." These comments look very much like a stance on (Q3), as does their general claim that "the questions of whether and how a complex word is decomposed during reading into its constituent morphemes are not the optimal ones to pursue." But the sentence immediately following this one goes in another direction; it asks "how a complex word activates the proper meanings, without necessarily assuming intermediate representations negotiating between the orthographic input and semantics." The intermediate representations that they are talking about eliminating are independent morphological representations, whose existence or not (in our (Q1)) is logically independent of the question in (Q3) of how such features are represented.

Baayen et al. describe their model as one that forms associations between forms and meanings. The former are represented as letter strings. The latter are represented in a "semantics" that allows certain orthographic sequences to be associated with meanings. The idea is that these form/meaning connections will be learned directly, i.e. without intermediate (morphological) representations. A closer look at the details of the representations used in the learning model highlight the tension between (Q1) and (Q3) identified above. For example, *hand* is represented as Lexical Meaning = {HAND}, Number = {}, while *hands* is stored in the lexicon as Lexical Meaning = {HAND}, Number = {PLURAL}; the model would then succeed if it learned the connection between orthographic *s* and PLURAL. But what kind of representation is {PLURAL}?

This question is at the center of Marantz (2013), which argues that these features are crucially morphological in nature, not semantic. This is because they are given to the learner as discrete and abstract features, independent of the semantic representation of plurality. Put simply, the system is not given the form *hands* and a situation in which there is more than one hand; it is given that form and an association with {PLURAL} directly. Seen in this way, it is not the case that the Baayen et al. model does away with morphological features by directly learning form/meaning correspondences. Rather, it is given the morphological features like {PAST}, and it learns an association between these features and their phonological realization(s). Far from dispensing with independent morphological representations, the model crucially assumes them. So, while the model might be amorphous in the way that is implicated by (Q3), it posits morphological features along the lines of (Q1). This point seems to us to be very much on target. At the same time, Marantz describes the Baayen et al. approach as requiring *morphemes*, a way of talking about things that connects closely with (Q3) in a great deal of work, not (Q1).

For our purposes, whether one's sympathies lie with the Baayen et al. (2011) type of project, or with Marantz's take on what it assumes is not at issue; what matters is that the question at issue must be properly identified. This exchange is clearly about decomposition in a general sense, but in order to determine what precisely is at issue, a framework for discussion at the grain of (Q1-3) is required.

## 6 Conclusions

Questions about decomposition will continue to dominate the investigation of morphology and the mental lexicon. An important trend has brought a range of research programs in experimental and quantitative/computational areas into contact with very specific claims in morphological

theory. The particular one that occupies much of the discussion above is the idea that the "classic" morpheme must be abandoned, in a way that connects with the Separation Hypothesis. If the main lines developed above are on the right track, incorporating Separation into debates about decomposition calls for a reassessment; the specific one that we have argued for here centers on the idea that investigation of topics implicating decomposition has proceeded to the point that it is necessary to move beyond a simple "decomposition or not" dichotomy. We hope to have taken a step toward doing this, by developing a framework for discussion based on questions (Q1-3).

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