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What is in a morpheme? Theoretical, experimental and computational approaches to the relation of meaning and form in morphology

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1. Introduction

Speakers use words to communicate. This may seem obvious, but obvious things can also be the most difficult to explain. Because what sets one word (or in sign languages, one sign) apart from another? Words have some kind of internal structure, but this structure can only be discovered by comparing words with one another. And while words and their subparts consist of phonemes, the latter are not associated with meanings themselves. Thus, understanding how exactly meaning and form relate in morphology is a non-trivial task.

In this introductory article, we would like to elucidate a specific view of morpheme-based morphology by reconsidering the relationship between form and meaning in morphology. On the view expressed here, there are three possible ways to approach the relation of meaning and form. These general scenarios are equally applicable to a formal view of language and to a processing-based view of what a language user does when seeing, hearing or reading a stimulus.

A. Form and meaning are thought simultaneously. Notations such as *-s* <PLURAL> stand for this type of form-meaning relation; morphemes in Minimalist Morphology

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(Wunderlich 1996, Stiebels 2011) relate meaning and form this way. In processing, this relation of meaning and form happens when one thinks of and sees an object simultaneously.

B. The association is from meaning to form. One first accesses the concept <PLURAL> and only afterwards a form that can express it; psycho- and neurolinguistic experiments with pictures as stimuli are of this type.

C. The association is from form to meaning. One sees -*s* and then tries to associate it with some meaning; visual form recognition tasks in experimental linguistics are of this type.

The most important difference between these scenarios consists in the fact that in scenarios B and C meaning may be assigned at the level of the word, i.e. one may claim that morphemes do not have meanings of their own or even that there are no morphemes at all (as in scenario B).

In what follows, we discuss theoretical, experimental and computational approaches to morphology and how they handle the meaning-form issue. It is shown that morphological theories tend to follow either scenario A or scenario B (or a combination of both), most of them being of type B, while experimental and computational approaches prefer scenario C.

1.1. Types of theories

On Stump's influential typology of morphological theories (Stump 2001; Stewart & Stump 2007:387), with respect to inflectional morphology, theories can be classified as:

1) lexical-incremental, e.g. Lieber (1992), Minimalist Morphology (Wunderlich 1996, Stiebels 2011).
2) inferential-incremental, e.g. Articulated Morphology (Steele 1995); Natural Morphology (Dressler et al. 1987) seems to be of this type, too.
3) lexical-realizational, e.g. Distributed Morphology (DM; Noyer 1997, Halle & Marantz 1993, Bobaljik 2017).
4) inferential-realizational, e.g. the general approach of Word-and-Paradigm morphology (Matthews 1972, 1974, 1991, Zwicky 1985, Blevins 2016), A-morphous Morphology (Anderson 1992), Network Morphology (Corbett & Fraser 1993, Brown & Hippisley 2012, among others), as well as Paradigm Function Morphology (PFM; Stump 1997, 2001). Construction Morphology (CxM; Booij 2010) should also fall under this general view, although its focus is not on inflectional morphology.

Lexical theories follow our scenario B and assume that morphosyntactic properties are associated with inflectional markings just as lexico-semantic properties are associated with lexemes. Incremental theories are of our type A and see the word's morphosyntactic properties as an effect of acquiring the exponents of those properties.

Lexical-incremental theories are thus of a mixed type and follow scenarios A and B, likewise for the other theories from the list above.

Realizational theories are of type B and presume that a word's inflectional markings are determined by that word's morphosyntactic properties. Inferential theories also follow scenario B, in the sense that they see word forms as deduced from more basic forms, such as roots and stems, but by means of rules associating given morphosyntactic properties with given morphological operations.

In theories of the inferential kind, morphology can be said to exist "by itself", in the words of Aronoff (1994, 2007), as its own branch of linguistics with its own constraints and rules. Words exist along the paradigmatic axis, in relation to other words. Morphology as such does not require morphemes. What is called morphemes in morpheme-based theories are markings without meaning in theories without morphemes; markings without meaning exist only as parts of larger units such as stems and words. Thus, PFM defines form and meaning based on the paradigm function (PF): $PF(\langle L,\sigma \rangle) = \langle R,\sigma \rangle$ (Stewart & Stump 2007, Bonami & Stump 2017) which states that the PF value of a cell $\langle L,\sigma \rangle$ in the paradigm of lexeme L is the pairing of this cell's realization R with the morphosyntactic property set σ.

The empirical focus of different theories has also had natural influences on their development: PFM has explicitly been defined as a theory of inflectional morphology, while CxM is aimed more at derivational morphology (and compounding), broadly put. The distinction between inflection and derivation is captured by others under the so-called split morphology hypothesis, according to which derivation and inflection are distinct and belong to different components of grammar (see Beard 1995). Recently, however, the idea of a paradigmatic organization of morphology has been extended to derivational morphology; for an overview of research on derivational paradigms, see Bonami & Strnadová (2019).

Lexical theories, on the other hand, assume that words are built up of abstract morphemes which get interpreted. Such theories run the conceptual range from Distributed Morphology (DM; Halle & Marantz 1993), through the Exo-Skeletal Model (Borer 2005, 2013), to Lieber (2004). Whether the word itself is a grammatical object which can be defined varies, but all morpheme-based theories subscribe in one way or another to the idea that morphemes carry grammatical information and are combined syntagmatically as concatenated elements (Marantz 2013). DM in particular relies on syntactic structure, whereby the 'morpheme' is an abstract unit that refers to a syntactic terminal node and its content, not to the phonological expression of that terminal. Reducing morphological structure to syntactic structure also means that DM does not subscribe to the split morphology hypothesis. DM furthermore assumes that the phonological forms are exponents, called Vocabulary Items, that relate form and meaning but are inserted "late" (post-syntactically). Morphology is thus distributed between syntax and phonology.

Finally, some analyses operate on what can be seen as individual features, or parts of morphemes. In such "subanalysis", to borrow a term from Müller (2006), decomposition is even more radical than into morphemes (see also Kubrjakova 2000). Müller (2006) breaks affixes down into parts, such that the German 2nd person singular *-st* and

3rd person singular *-t* are decomposed into [-1] *-t*, [2] *-s-* and [3] *-ø*. And in Nanosyntax (Starke 2009) a syntactic tree is built up not of words as in traditional transformational grammar or of morphemes as in DM but of individual syntactic features.

All theories acknowledge that speakers use words when communicating (however defined, be it phonological word, morphological words or lexemes), and all acknowledge that there is some kind of internal structure to words. In order to establish what these word parts are, we need to compare whole words. In order to build up words, we need their parts. Where does this leave us?

1.2. Positional systems

In this introduction, we wish to unite the two views (cf. Herce, this issue). Just as a building can be seen as one object or as a collection of floors, and just as an organism can be seen as a whole or as a collection of cells, morphology can be observed at different levels. For some, the emphasis is on the parts; for others, the emphasis is on the whole.

We will propose to consider language as a positional system, where morphemes and their forms can be evaluated with respect to meaning in three ways:

1) In isolation (as building blocks of morphology, e.g. English *-s*, *-en*, *-ed*, *-er*).
2) Based on their position in the word form (i.e. templatically, e.g. inflection is outside derivation; prefixes, suffixes, infixes, interfixes are also established positionally).
3) Based on their combination with other morphemes (e.g. the contrast of *writ-er-s* with **small-er-s* in English points to two different *-er* suffixes, one that derives nouns (agents) and one that expresses comparative degree of adjectives).

As a result, we will see that morphemes associate form and meaning, as in scenario A, but that this association is not trivial and involves scenarios B and C at the different stages of derivation and in comprehension and production.

In order to compare and contrast different approaches to the question of the morpheme and its place in morphology, we solicited contributions to a workshop at the 50th annual meeting of the Societas Linguistica Europaea (SLE) held in Zurich in 2017. The current special issue brings together a number of papers presented at or inspired by the workshop. Our introductory contribution is structured as follows. We first outline the mapping problem between form and meaning in Section 2 and discuss it in the context of positional systems in Section 3. Sections 4 and 5 outline the role of morphemes in psycholinguistics and computational linguistics, respectively. Section 6 concludes with an overview of the papers in this special issue.

2. Relating meaning and form

2.1. Terminology

We should first clarify what exactly we mean by "morpheme", since different uses of the term are prevalent across the literature. To illustrate the challenging task of defining a morpheme, we cite the entries for 'morpheme' and 'exponent' from two major morphology textbooks.

For Haspelmath & Sims (2010), both morpheme and exponence refer to morphological patterns:

- ***morpheme***: the smallest meaningful part of a linguistic expression that can be identified by segmentation; a frequently occurring subtype of morphological pattern. (p. 335)
- ***exponent***: when a morphological pattern (e.g. *-ed*) expresses an inflectional feature value (e.g. past tense), it is the *exponent* of that feature value. (p. 328)

The glossary in Aronoff & Fudeman's (2011) textbook defines both terms without reference to patterns:

- ***morpheme***: a word or a meaningful piece of a word that cannot be divided into smaller meaningful parts. Examples include *school*, *read*, or the *re-* and *-ing* of *rereading*. (p. 266)
- ***exponent***: the marker of a given morphosyntactic feature. For example, [s] is the exponent of plural in the word *kits*. (p. 263)

In this article, we distinguish the *morpheme*, an abstract unit identifiable by either decomposition and/or segmentation of words (in the sense that words can be decomposed and segmented into, and are composed of morphemes), from an *exponent*, which is a morpheme's phonological realization. In other words, a morpheme means a concept such as PLURAL as well as the set of phonological realizations associated with that concept, e.g. {*-s, -en,* -Ø, … } for PLURAL in English. In contrast, an exponent is the single phonological realization of a morpheme (e.g. each of *-s*, *-en* or *-Ø* on their own).

In what follows, we avoid theory-specific terms such as "Vocabulary Item" or general terms such as "lexical item" or "lexeme". When we wish to remain agnostic about a certain piece of morphology, we will use *form*, as in the different word forms of a paradigm.

2.2. The mapping problem

It is well known that the relationship between meaning and form in morphology is not a perfect one-to-one mapping.

To illustrate this point, the exponent *-ta* correlates with a number of meanings in Bulgarian (1), just as the exponent *-er* does in English (2).

(1) <u>Bulgarian *-ta*:</u>
meče 'little bear'
meče-ta 'little bear-PLURAL, i.e. little bears'
meče-ta-ta 'little bear-plural-DEFINITE, i.e. the little bears'

(2) English *-er*:
writ-er (AGENT)
(bottle) open-er (INSTRUMENT)
strong-er (COMPARATIVE)

It is just as difficult to go from meaning to a dedicated exponent. Both the Bulgarian and English plural forms show multiple exponents (3). There is no individual suffix which always spells out the morphosyntactic feature [plural] in these languages.

(3) Noun plural
Bulgarian
kniga 'book' – PL *knig-i*
more 'sea' – PL *more-ta*
etc.

English
book – PL *book-s*
ox – PL *ox-en*
etc.

It appears that we must abandon a naive view in which a certain meaning is always mapped onto a certain form. Nie (this issue) shows that the situation can be even more complex, whereby a certain form maps onto a complex meaning which arises from a combination of morphemes.

Some approaches to morphology have therefore eschewed the morpheme-based view, which investigates the mapping from abstract morphemes to exponents, in favor of a word-based approach, which investigates the mapping from word-level content to word forms. The word-based model PFM, for instance, studies the mapping between content-paradigm cells[1] and realized paradigm cells (Stump 2016). However, realized paradigm cells contain not just exponents but full word forms paired with sets of morphosyntactic properties (Table 1). In other words, Stump (2016) does not have two paradigms – content paradigm and form paradigm (cf. footnote 1) – but three paradigms: content paradigm, form paradigm and realized paradigm. All three types of paradigms are illustrated in Table 1.

It can be seen that in PFM content and form do not emerge simultaneously (our scenario A); Bonami and Stump (2017: 452) explicitly state that in PFM the content is logically prior to its realization[2] (our scenario B). In order to establish a meaning-form

[1] Stump (2002) speaks of syntactic paradigm and morphological paradigm; in Stump (2016), the author refers to these paradigms as content paradigm and form paradigm, respectively.

[2] Regarding the direction of the relation of content and realization in PFM, Bonami & Stump (2017: 452) write: "A core assumption of PFM is that inflectional morphology is both inferential and realizational in its definition. Thus, the content of the cell ⟨KALLA, {ind pst 2sg}⟩ is logically prior to its realization; it is this content that determines the form of its realization." The lexeme KALLA 'shout' is an Icelandic verb.

Table 1: Three types of paradigms (based on Table 7.1 in Stump 2016: 105)

The content paradigm of the lexeme SING	The form paradigm of the stem set S_{SING}	The realized paradigm of the lexeme SING
⟨SING, {present}⟩	⟨*sing*, {present}⟩	⟨*sing*, {present}⟩
⟨SING, {3sg present indicative}⟩	⟨*sing*, {3sg present indicative}⟩	⟨*sings*, {3sg present indicative}⟩
⟨SING, {past}⟩	⟨*sing*, {past}⟩	⟨*sang*, {past}⟩
⟨SING, {present participle}⟩	⟨*sing*, {present participle}⟩	⟨*singing*, {present participle}⟩
⟨SING, {past participle}⟩ …	⟨*sing*, {past participle}⟩ …	⟨*sung*, {past participle}⟩ …
	Each form cell is the form correspondent of the content cell to its left.	Each realized cell realizes the cells to its left.

mismatch, one must evaluate meaning and form simultaneously. Therefore, in contrast to scenarios A, B, C that relate meaning and form directly, PFM assumes that the content paradigm is linked to the realized paradigm through an additional intermediate step, the form paradigm (Stump 2016: 115, Figure 7.2). As shown in Table 1, the form paradigm contains stems[3] (roots in the earlier PFM literature) associated with sets of morphosyntactic properties. Regarding the question of morphemes, i.e. whether the form paradigm operates with morphemes, we believe it does, cf. the definitions of morpheme and exponent in section 2.1.

Consider also how PFM treats second-person imperative active forms in Sanskrit; (4) gives the 9th conjugation class (*-nī-*) verb KRĪ 'buy' (Bonami & Stump 2017, Table 5):

(4) 2sg *krī-ṇī-hi* 'you (sg) buy!'
    2du *krī-ṇī-tam* 'you two buy!'
    2pl *krī-ṇī-ta* 'you all buy!'

According to Bonami & Stump (2017:462f), "the default expression of membership in the ninth conjugation is a suffix *-nī* (sandhi form *-ṇī*), as in the imperative form *krī-ṇī-ta* 'you (pl.) buy!', and the default expression of second person singular subject agreement in active imperatives is *-hi*, as in *krī-ṇī-hi* 'you (sg.) buy!'." This gives the following rules of exponence, where X_V is a variable over verb stems:

(5) Rules of exponence in Sanskrit (cf. Bonami & Stump 2017, ex. (20))
   a. I, $X_V[_{\text{9th conjugation}}]$, {} → X*nī*
   b. II, X_V, {2sg imp active} → X*hi*

[3] It is a matter of much debate whether surface elements such as roots and stems (i.e. form paradigms) can be directly related to exponence without a morphemic layer. On stems and related issues, see Herce's article (this issue).

The DM formalism (i.e. analysis) of the same data would not look all that different:

(6) [2sg] ↔ *hi* / Imp __ v_9
nī / __ v_9

In DM, [2sg] (2 sg imp of 9th conjugation verb, V_9) is assembled in the syntax in two steps (6), while in PFM, the property set {2sg imp act} does not come from syntax (although recall the term 'syntactic paradigm' in earlier PFM writings, see footnote 1) but is a subset of the property set associated with a paradigm cell, the whole property set being "[9th conjugation],{2sg imp active}". It is not the property set "[9th conjugation], {2sg imp active}" that is produced step-by-step, but the form that realizes it (5). "[9th conjugation],{2sg imp active}" is defined as a whole as one part (i.e. σ) of the paradigm cell that the rules in (5) serve to realize. DM assumes that -*hi* and -*ni* are listed in the lexicon, while in PFM they are not, at least not as separate units:

3. Elements, rules and positions

What should we make of the mapping problem in morphology? In this section, we discuss cases outside of linguistics in which form and meaning (broadly construed) do appear in a well-defined correspondence. We highlight the importance of *positional systems* – syntagmatic systems in which the meaning of a basic set of individual *elements* (similar to morphemes in a language) is understood not only in isolation but also based on their position with respect to other elements – and ask whether language counts as such a system. The main thread running through all of these examples is that the rules of the system are established in advance and cannot be changed halfway through the calculation or derivation.

3.1. Mathematics

In mathematics we find basic elements such as different types of numbers: natural, rational, irrational, real, and so on.

- Natural numbers: all positive integers (whole numbers) and zero.
- Rational numbers: all numbers that can be expressed as a fraction of two integers.
- Irrational numbers: numbers that cannot be expressed as a fraction of two integers. Irrational numbers have decimal expansions that neither terminate nor become periodic.
- Real numbers: all rational and irrational numbers, i.e. any point anywhere on the number line.

These elements are combined in certain ways. Operations such as addition, subtraction, multiplication and so on manipulate the numbers. In other words, certain rules can be applied to these elements. The elements (numbers) and the rules (mathematical operations) are defined axiomatically in the system; they exist from the very beginning and cannot be redefined. For example, the definition of addition in mathematics cannot change from (7) to (8), nor can the order of operations be different in the two equations.

(7) (1 + 2) x 3 + 4
(8) (2 + 3) x 4 + 5

By analogy with language, numbers correspond to morphemes and operations correspond to morphosyntactic (e.g. Move and Agree in Minimalist syntax) or morphophonological processes (e.g. voicing assimilation).

3.2. Number systems

Now consider the decimal system, where the basic elements are the ten digits (0–9). To understand a numeral written in the decimal system, one must know the relative position of the atomic parts (0–9). This is because the value of the symbol depends on its position; the decimal system is thus positional with respect to the meaning of the element.

For example, the numeral 123 denotes a different number than 132, 213, 231, 312 and 321. The meaning of 123 is not 1+2+3 but 100+20+3: we need to know that the "1" is multiplied by 100, the "2" by 10 and the "3" by 1. No overt symbols represent this part of the value; instead, this manipulation depends solely on the position of the digit within the numeral. Some analogies with language might be our understanding of iconicity and semantic compositionality, but we will not expand on this point. Nevertheless, to illustrate our observations about the importance of the position of an element with linguistic data, we give an example of semantic compositionality. In (9), the same morphemes in different positions give rise to different readings:

(9)	yug-pag-cuar	yug-cuar-pag	
	person-big-little	person-little-big	
	'little giant'	'big midget'	Yup'ik (Mithun 1999: 43)

In a positional system the number of elements is not a hindrance to expressing meaning since the system is productive. Complex tasks and large amounts of information can be handled with a very limited number of basic elements, as long as these elements and the rules operating on them are known. For example, the decimal system is base-10. Looking instead toward a binary system, which is base-2, a number such as (10) has the equivalents in (11a–c), all used in programming languages. Here, again, the value of an element depends on its position.

(10) 110011111010010100

(11)	a. 212628	(decimal, base-10 using the numbers from 0–9)
	b. 0637224	(octal, base-8 using the numbers from 0–7)
	c. 0×33e94	(hexadecimal, base-16 using the numbers from 0–9 plus the letters A-F)

Complex computational tasks require large amounts of information and can be handled with a very limited number of basic elements, as long as one knows what these basic elements are and what the rules of the system are.

Machines can, of course, use more than one number system. In order to avoid confusion, programming languages mark different bases in specific ways, e.g. all octal numbers start with "0" (11b) and all hexadecimal ones with "0x" (11c). This would be similar to indexing all homophonous suffixes in the language, e.g. *-er*$_1$ in *writer* (agent noun), *-er*$_2$ in *open-er* (instrument noun), and *-er*$_3$ in *strong-er* (comparative).

3.3. Language as a positional system

We now propose that morphology (and language in general) should be considered a positional system in the sense sketched above. This point will be fleshed out using a few examples comparing the decimal system – which as seen above is positional – with basic affixation patterns.

A string of symbols such as "12" changes its meaning when another layer is added, (12a)-(13a). Similarly, the meaning of a morphological form changes when another (affixal) layer is added, (12b)-(13b).

(12) a. 12 → 123
b. Bulgarian *žen-a* 'woman' → *žen-a-ta* 'woman-DEF, i.e. the woman'

(13) a. 45 → 456 → 4566
b. *mor-e* 'sea' → *mor-e-ta* 'sea-PL, i.e. seas' → *mor-e-ta-ta* 'sea-PL-DEF, i.e. the seas'

The meaning of "12" also changes due to substitution in an existing layer.

(14) a. 12 → 13
b. *žen-a* 'woman' → *žen-i* 'woman-PLURAL'

Additional evidence from morphology and syntax can be adduced in support of the conclusion that language is a positional system. These include:

1. The differentiation between roots / affixes is positional.
2. Stratal affixes: Level 1 and Level 2 affixes are defined positionally.
3. Templatic morphology is entirely positionally defined (Stump 1997, 2001).
4. Layered morphology (and its relation to semantic scope, e.g. Rice 2000) is positionally defined.
5. Position classes in morphology (Inkelas 1993).
6. There are positional restrictions on the placement of an affix in a word (affix ordering constraints, see Manova & Aronoff 2010, Manova 2015).
7. Selection for specific affixes, whether as subcategorization frames (Lieber 1992), mobile affixes (Kim 2015) or sublexicons (Gouskova et al 2015).

8. Movement in syntax.
9. Word order in syntax.

Phonology also deals with positional systems, of course, although there no meaning is represented as such. See also Franzon et al (this issue) for a psycholinguistic example of how the meaning of Number is constant even when interacting with other factors such as animacy.

Positional systems give us a way of thinking about the question we started off with, namely why there are no morphemes that relate meaning and form uniquely. All theories mentioned above have a similar approach to this issue: the relationship between meaning and form is not one-to-one. And now we see why: If language is a positional system, its form-meaning mappings cannot always be one-to-one because the meaning of an element in a positional system depends on the position of the element.[4]

4. Morphemes in psycholinguistics

Given that we have reason to posit morphemes which mediate between form and meaning in specific ways, we would also like to know whether there is psycholinguistic support for this idea, how such elements are processed, and how their behavior can be modeled computationally. Here we briefly survey some relevant contributions from the psycholinguistic and neurolinguistic literature (for contrasting views see Marantz 2013; Plag & Balling 2016). Computational learning and modeling of morphology is addressed in the next section.

The most common experimental paradigm probing the mental lexicon is the lexical decision task (Meyer & Schvaneveldt 1971): a participant sees a string of characters (scenario C) and is asked to decide whether that string constitutes a word in their language. The basic setup thus involves decisions at the level of the orthographic word, that is, in terms of words versus non-words. Under the "affix stripping model" of Taft and colleagues (Taft & Forster 1975, 1976; Taft 1979), this is a task that involves implicit decomposition of the word into its constituent parts, i.e. morphemes. Taft's experiments manipulated the frequency of different words, stems and affixes, arguing that a prefixed word is accessed via its stem even when this stem is not a word in its own right. For example, *unhook* is related to *hook* in the same way as *persuade* is to *suade*. The findings indicate that the prefixes are stored in the mental lexicon, as are the stems, even though *suade* itself is not a word, (15).

(15) a. *unhook* → *un-*, *hook*
b. *persuade, dissuade* → *per-*, *dis-*, *suade*

[4] This view might be related to the discussion on whether natural language is context-free or not, an issue we will not broach here. See e.g. Pullum and Gazdar (1982).

Contemporary neurolinguistic work corroborating this model (Fruchter et al. 2013; Fruchter & Marantz 2015) demonstrates that speakers obligatorily decompose the (visual) stimulus into morphemes, look these up in the mental lexicon, and recombine them. All three steps can be individually observed and manipulated (showing sensitivity to frequency, family density and so on).

Related studies have investigated the extent to which parts of words are identified and obligatorily decomposed considering a range of factors and manipulations, including masked vs overt priming, different writing systems, and whether the written forms contain real affixes or merely orthographically identical parts (Rastle et al. 2004; Stockall & Marantz 2006; Crepaldi et al. 2010, 2013; Lewis et al. 2011; Marelli et al. 2013; Gwilliams & Marantz 2015, 2018; Deutsch & Kuperman 2018; Kastner et al. 2018; Neophytou et al 2018). Affixes can be identified and processed even without having a contentful stem to attach to (Crepaldi et al. 2016; Lázaro et al. 2016; Beyersmann et al. 2016). Manova & Brzoza (2018) and Manova (2019) provide evidence that native speakers of English, Italian, Polish and Slovene can differentiate between attested and unattested suffix combinations in isolation: native speakers do not need to see roots, stems or words in an experimental trial in order to correctly judge a suffix combination as attested or non-attested. This finding indicates that not only affixes but also subparts of words such as affix combinations are listed in the mental lexicon; a similar conclusion is implied by the results of de Lint (this issue).

Must we make reference to morphemes in order to explain these findings? Some models of processing argue that this is not the case. In particular, Naïve Discriminative Learning (NDL: Baayen et al. 2011; Plag & Balling 2016) links up form and meaning without a mediating morphological representation. This kind of approach follows earlier connectionist approaches (Seidenberg & McClelland, 1989; Plaut et al., 1996) and can be found in other works as well (Marelli et al. 2015; Amenta et al., 2017). Marantz (2013) discusses this family of models with particular reference to NDL, arguing in detail that they do incorporate a wealth of syntactic and morphological information and thus do not form a good argument for removing morphemes from lexical processing. Bondarenko et al. (2019) similarly claim that abandoning morphemes would render these models unable to explain some processing reflexes of allomorphy. We now move on to describing other computational approaches in some more depth.

5. Morphemes in computational linguistics

Much work in computational linguistics has been directed towards encoding the outcome of classic morphological analysis in a suitable computational formalism. This allows efficient data analysis and generation (e.g. Hulden 2009) which serve great practical purposes for various downstream tasks in Natural Language Processing (Machine Translation, Information Retrieval, etc). Since hand-crafting a computational morphology involves a significant amount of manual labour, a common solution has been to use Machine Learning methods to extract rules from (hand-annotated) form-analysis pairs (e.g. <"books", book-PL>, see Kann & Schütze 2016 and Chrupala 2008, Ch. 6), with the advantage that the rules can also make guesses at the analysis of previously unseen words. Such rules typically recognize morphemes, but as neural network approaches have entered the field, far more "emergent" representations are gaining popularity (see e.g. Heinzerling & Strube 2018). These representations recall Naïve Discriminative Learning (NDL) in that clear and specific morphemes are not realized.

The next step from generalization over form-analysis pairs is to generalize from forms only. To computationally induce morphological rules from (unannotated) raw text is known as Unsupervised Learning of Morphology (ULM). ULM takes large amounts of raw text data as its input and attempts to induce the morphology of the input language. The reason why this might be possible at all is due to the great difference in substring frequencies reflected in recurrent morphological formations. For example, the frequency of the final substring *-ing* in English will be much greater than that of a random substring of the same length, and words that end in *-ing* will also appear with the terminal segment *-ed* much more often than chance. There have been many dozens of concrete proposals on exactly how to exploit frequency asymmetries (see the overview in Hammarström & Borin 2011).

Most work in ULM is motivated by the potential to save human labour in annotating or rule-writing towards a computational morphological analyzer. Another form of motivation, however, predating any practical computational work, is the idea of formalizing the process of linguistic description, into so-called linguistic discovery procedures (Harris 1955). Since most subsequent work in the area has been practically oriented, the theory has not made significant progress beyond its initial insights.

Nearly all work in ULM has targeted concatenative morphology, but there are a few approaches that address non-concatenative templatic morphology, morphophonological changes and suprasegmental morphology (see Hammarström & Borin 2011). Similarly, nearly all work in ULM focuses exclusively on the form side of morphology, postponing the mapping to meaning to future work. The few approaches that do address semantics are aided by the fact that representations can also be extracted in an unsupervised manner through standard techniques of context-occurrence analysis (e.g. Deerwester et al. 1990, Mikolov et al. 2013).

There have been practical achievements in ULM, wherein the results of ULM resemble manual linguistic analysis and are useful for downstream NLP tasks. But it is also fair to say that the ULM problem has not been "solved"; there is no system that can be applied off the shelf to any language and yield near-human-like results without additional manual tuning or engineering work. There is no single system which can be heralded as the "best" (see Hammarström & Borin 2011) and used faithfully as a representative for comparison with non-computational approaches.

6. The papers in the special issue

The four contributions in this special issue approach the question of morphemes and positions, i.e. of the relation of meaning and form in a morpheme, from different angles and diverse empirical domains. Two of the papers are experimental and two are theoretical.

The first paper, 'Effects of animacy on the processing of morphological Number: a cognitive inheritance?' by **Chiara Zanini, Rosa Rugani, Dunia Giomo,**

Francesca Peressotti & Francesca Franzon, is experimental and sees morphemes (specifically those encoding Number) as relating meaning and form in a classical way (scenario A in the introduction). However, some Number morphemes appear to contain more meaning than other Number morphemes, for example, when they are part of animate nouns in a language that does not encode animacy morphologically. In their experiment, the authors tested the processing of morphological Number in relation to animacy. The experiment consisted of a phrase-completion task: Noun phrases of a demonstrative and a noun appeared on the screen one at a time and the demonstrative or the noun lacked an inflectional morpheme. The authors found out that it was easier to inflect nouns for Number when the inflectional morpheme was interpretable with respect to a semantic feature related to animacy. Since in the real world animacy appears important for counting, the paper also concludes that morphology is designed to easily express information that is salient from a cognitive point of view.

From the perspective of positions in morphology, one can describe the findings of this paper in terms of the ability of the Number morpheme to combine with different types of bases, namely those that denote animate and inanimate nouns. Such an approach relates animacy to the semantics of the morphological base and allows the meaning associated with the Number morpheme to remain constant.

The second paper, 'On morphemes and morphomes: exploring the distinction' by **Borja Herce**, is a theoretical paper that argues that there is no principled difference between morphemes and morphomes. Since Aronoff (1994), morphomes (purely morphological forms that cannot be defined in terms of meaning) have been seen as the strongest evidence for the existence of morphology proper. Herce makes the following claims about morphemes and morphomes: 1) they can have the same sources; 2) they can exhibit the same diachronic resilience; and 3) they can both be stems or affixes. For assessment of morphomicity, the author relied on quantitative measures "applied to **forms which recur within a single lexeme's paradigm**" (author's emphasis); these measures capture the positioning of a morphological form (be it a morpheme or a morphome) in a paradigm and the morphosyntactic information associated with the paradigm cells occupied by that form. Herce finds that no property, besides the defining one, systematically differentiates morphomes from morphemes and concludes that the distinction between the two types of morphological form is not one of kind but of degree.

It has to be mentioned here that morphemes and morphomes, at least their prototypical instances, differ positionally, in the sense that a prototypical morphome is a stem[5] and as such is the equivalent of two morpheme positions, one for a root and another for an affix.

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[5] We define prototypical morphomes as stems. There are three basic definitions for the term 'morphome' and the adjective 'morphomic' in the literature (O'Neill 2014: 31, see also Luís & Bermúdez Otero 2016):

1. 'meaningless formatives' which show the same pattern of allomorphy; they can be stems, other inflectional material or even whole-word forms

In the third paper, 'From meaning to form and back in American Sign Language verbal classifier morphemes,' **Vanja de Lint** reports on an experiment designed to test a hypothesis about a class of markers in American Sign Language, commonly known as *classifiers*. These signed formatives, which can be used to depict an object, individual or instrument iconically, have been argued to differ with respect to the arguments entailed by their use: one type encodes the external argument, one type encodes the internal argument, and one type encodes both external and internal arguments. Previous theoretical work has analyzed these elements as morphemes spelling out specific parts of the syntactic tree, with one explicit proposal being that three different types of classifiers spell out different instantiations of two functional morphemes. The different types are claimed to have different internal structure which also correlates directly with their form. The paper uses a novel experimental paradigm in order to investigate what entailments native signers assume about the use of the three types of classifiers, corroborating some of the existing claims while discovering a new contrast between causative verbs and manner verbs.

This case comes perhaps closest to a direct relationship between form and meaning, and it is unsurprising that this kind of correlation can be found in iconic constructions used by sign languages (see Sandler & Lillo-Martin 2006 for general discussion and additional references). In own our terminology above, the analysis makes reference to both rules and positions.

The final paper, a theoretical contribution by **Yining Nie** entitled 'Morphological causatives are Voice over Voice,' discusses what are commonly referred to as "causative" constructions in languages such as Halkomelem, Japanese and Tagalog. Much research has tackled the question of how complex causative events are and what kind of elements are involved: do causatives embed a verb or another kind of phrase, and what syntactic projection is causative morphology associated with? Nie argues that rather than having one morpheme be spelled out as causative morphology, what looks like an exponent of one morphemic affix is in essence a configuration: two morphemes (the syntactic head Voice) attached recursively.

This strongly positional analysis assumes very general rules of semantic composition, which certain languages can utilize by making specific positional arrangements. An analysis such as this one makes a strong case for form and meaning emerging simultaneously, here from shared syntactic structure.

Taken together, these papers emphasize the positional nature of various morphological phenomena, allowing us to further probe the question of how morphemes relate form and meaning in word structure.

2. a semantically and syntactically incoherent set of paradigm cells characterized by a particular type of allomorphy
3. henomena that are not derived by semantico-syntactic features: stem formation, stem-indexing, inflectional classes

In sum, in most cases 'morphome' and 'morphomic' refer to stems, including stem formation, stem-indexing, a set of paradigm cells and inflectional class.

Summing up, we started with the observation that there are three possible scenarios how to approach the relation of meaning and form in morphology:

A. Form and meaning are thought simultaneously.
B. The association is from meaning to form.
C. The association is from form to meaning.

We then showed that morphemes and their forms can be evaluated with respect to meaning in three ways:

1) In isolation (as building blocks of morphology).
2) Based on their position in the word form (i.e. templatically).
3) Based on their combination with other morphemes (morpheme combinations).

Word structure of various kinds seems relevant to morphology (in order of increasing size): (phonemes and) submorphemes > morphemes (i.e. roots and affixes) > stems, (prototypical) morphomes and affix combinations > words. However, structurally all of these depend on the morpheme in some way, in the sense that they are defined as either building parts of the morpheme or as containing a number of morphemes, i.e. having one or more morpheme positions that are related. Thus, the morpheme appears to have a central role with respect to word structure and to accommodate not only grammatical information (meanings relevant to grammar) but also positional information.

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