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Two suffix combinations in native and non-native English: Novel evidence for morphomic structures

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We demonstrate the existence of a novel type of morphomic structure: the suffix combination in word formation. We ran two psycholinguistic experiments with 45 native and 30 non-native English speakers, asking them to judge whether or not existing and non-existing two-suffix combinations presented without bases occur in English. Both groups identified existing and non-existing suffix combinations with very high accuracy; productive combinations were recognized more accurately than unproductive ones. Our research shows that suffix combinations are listed in the mental lexicon as morphomes. This finding accords with recent research in natural language processing that induces a language's patterns, rules, and semantics based entirely on form relations. We also discuss other possible applications of the morphome outside of theoretical linguistics.

Keywords: morphology, stem, morphome, word formation, suffix ordering, language processing, foreign language learning, psycholinguistics, computational linguistics, English

Так оставьте ненужные споры!

Я себе уже все доказал -

Лучше гор могут быть только горы,

На которых никто не бывал.

На которых еще не бывал.

Прощание с горами, Владимир Высоцкий[1]

1. Introduction

Since Aronoff's (1994) introduction of the concept of morphome to linguistic theory, there has been much debate on the exact definition and the diachronic development of mophomic patterns (recent overview in Luís & Bermúdez-Otero 2016; for the different definitions of 'morphome' see O'Neill 2014;[2] see also Aronoff 2012, 2016). Morphological forms and

[1] So stop the unnecessary debates.
I got it all figured out:
Only mountains can be better than mountains,
Those that nobody visited,
Those not yet visited.
Farewell to the mountains by Vladimir Vysotsky; the translation is based on the subtitles of https://www.youtube.com/watch?v=Da9UpNSFGIo

[2] O'Neill (2014: 31) identifies three basic definitions for the term 'morphome' and the adjective 'morphomic' in the literature:

patterns of various kinds have been identified as morphomic: single morphemes (inflectional material), stems and whole words, sets of paradigm cells as well as phenomena such as stem formation, stem indexing and inflectional classes. As one can guess from this list, in the literature so far morphomes have been related to inflectional morphology. Additionally, the usefulness of the concept of morphome outside of theoretical linguistics has been neglected, somehow. Thus, the goal of this contribution is to fill these gaps. We discuss morphomes in English word-formation as well as two applications of the morphome: for language processing (in both humans and machines) and for foreign language learning.

Our approach is grounded in mathematics. A mathematician believes that all problems are solved in the real world, i.e., that the solution to a problem consists of making the right analogy with a phenomenon in the real world. To illustrate: a one-floor house consists of rooms, the rooms consist of walls, the walls consist of bricks, the bricks are made of clay (-bearing soil, sand, and lime). Analogizing to grammar: the house is the parallel to a sentence that consists of words (rooms) which are built up of morphemes (bricks) that are made up of phonemes (clay ...). For the construction of a house, one can use not only bricks but also readymade walls, which will

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1. 'meaningless formatives' which show the same pattern of allomorphy; they can be stems, other inflectional material or even whole-word forms
2. a semantically and syntactically incoherent set of paradigm cells characterized by a particular type of allomorphy
3. phenomena that are not derived by semantico-syntactic features: stem formation, stem-indexing, inflectional classes.

facilitate the building of the house. Such readymade walls are the parallel of morphomes.

These analogies can also help us understand why the relation of meaning and form in morphology is an issue:

1. bricks (morphemes) can be linked to room types (words), e.g., bathroom bricks (cf. verbalizing morphemes) or other specific features, e.g., glass bricks (cf. number morphemes); this is how lexical approaches to morphology (e.g., Distributed Morphology (DM), Halle & Marantz 1993) treat morphemes.
2. bricks (morphemes) can be seen as unspecified units used for building up any type of room (word); this is how inferential approaches (e.g., Paradigm Function Morphology (PFM), Stump 2001) define morphological units.

Likewise for morphomes:

1. one can relate them to a word class (e.g., the L-shape morphome in Romance verb inflection, Maiden 2016 and earlier work) or to specific features (e.g., deponent verb stems and passive, Baerman et al. 2007, among many others)
2. one can also think of morphomes as unspecified pieces of morphological structure processed without any reference to meaning, including no word-class specification (our approach).

Based on the above analogies, we also differentiate between morphemes and morphomes. We see morphomes as readymade pieces of morphological structure consisting of two (or more) morpheme positions (cf. Manova et al. 2020) that can be identified and/or processed without any reference to meaning.

The mathematical nature of our approach to suffix ordering will be addressed in the next section.

This chapter has the following structure. In §2, we discuss research on suffix ordering in English, introduce our own approach and the selection of the suffix combinations used in this study, including why we define them as morphomic. Section 3 describes two psycholinguistic experiments carried out with native and non-native speakers of English to confirm the morphomic nature of suffix combinations in English word formation. Section 4 contains the discussion and also addresses possible applications of morphomic structures. In §5 conclusions are drawn.

2. Suffix ordering in English: History of research, our approach and why suffix combinations are morphomes

There has been much research on the ordering of English derivational suffixes[3] and a number of specific proposals have been put forward (in chronological order): level ordering or stratal approach (Siegel 1974; Allen 1978; Selkirk 1982; Kiparsky 1982; Mohanan 1986; Giegerich 1999); selectional restrictions (Fabb 1988; Plag 1996, 1999); the monosuffix constraint (Aronoff & Fuhrhop 2002), and the parsability hypothesis (Hay 2001, 2002, 2003) or complexity-based ordering (CBO) (Plag 2002; Hay & Plag 2004; Plag & Baayen 2009). In this list of approaches, every approach was formulated in response to the incorrect predictions of the preceding approach. Likewise, our approach (Manova 2011) has been formulated as a reaction to CBO that has been illustrated primarily with data from English. In a series of articles, Manova (2010, 2011,, 2015) shows that CBO does not hold for Slavic, nor for Romance languages (Manova & Talamo 2015; for Italian, see also Talamo 2015) and suggests an alternative approach based on logic from mathematics: Gauss-Jordan elimination. This method serves to solve large linear systems (i.e., systems with a large number of variables) numerically with only the help of elementary operations (addition, subtraction, multiplication). The idea is to reduce the options for each variable to one, because if there is only one option for a variable, this option is the variable's value, i.e., the solution to the problem. Gauss-Jordan elimination is a masterpiece of logical reasoning because one comes to the solution without 'solving' the problem. What happens is elimination; the problem is eliminated

[3] On affix ordering in general, see Manova & Aronoff (2010).

in an easy and elegant way. Due to the limited space of this chapter, we cannot go into detail about Gauss-Jordan elimination, but we refer curious readers to Manova (2011) where the method is illustrated and its application to morphological data is discussed in detail.

Manova (2011) sees derivational suffix combinations as binary structures of the type SUFF1-SUFF2, where SUFF1 has three valency positions for further suffixation: $\text{SUFF2}_{\text{Noun}}$, $\text{SUFF2}_{\text{Adjective}}$ and $\text{SUFF2}_{\text{Verb}}$ (see Table 1). The idea of this distribution of outputs according to the syntactic-class specification of SUFF2 is to have one combination of a kind. And indeed, Manova observes that in most cases there is a single SUFF2 of each syntactic category, i.e., N, A, V, that follows a given SUFF1 (N: *-dom* and V: *-ize* in Table 1).

Table 1. Combinability of the suffix *-ist* (data from Aronoff & Fuhrhop 2002, based on OED, CD 1994)

SUFF1	**Syntactic category of SUFF1**	**SUFF2 according to syntactic category**
-ist	N	N: *-dom* (2) A: *-ic* (631), *-y* (5) V: *-ize* (3)

If more than one SUFF2 of the same syntactic category is available (A: *-ic* and *-y* in Table 1), there is one SUFF2 that attaches by default, that is, one of the competing SUFF2 suffixes (*-ic* and *-y*) derives almost all outputs (types/lemmas), *-ic* in our case, because *-ist-ic* derives 631 types in comparison to *-ist-y*, with only 5 types. In other instances of more than one SUFF2 suffix, the available SUFF2 options express completely different semantics (e.g., an abstract noun and an object) and thus do not really compete for the SUFF1. Manova (2011) interprets all these facts as evidence for the uniqueness of suffix combinations. If something is unique, it should be memorized as one of a kind, which for suffix combinations means listedness in the mental lexicon—that is, native speakers should know them by heart. This led to the idea to test native speakers' intuitions about suffix combinability with morphomic pieces of word structure, i.e., with sequences of two suffixes without any relation to lexical bases, be they roots, stems or words.

Having counted suffix combinations in large dictionaries and corpora for different languages (Slavic and non-Slavic alike), Manova (2011) also observes that in cases in which more than one SUFF2 of the same syntactic category is available, one of the SUFF2 suffixes derives more than 10 types (the suffix *-ic* in Table 1). Such suffixes are referred to as default. The SUFF2 suffixes that compete with the default suffix always derive ten types or fewer each (e.g., the suffix *-y* in Table 1 derives 5 types). Thus, 10 types are seen as a threshold for productivity, i.e., suffixes that derive more than 10 types are productive, suffixes that derive 10 types or fewer are unproductive. Significantly, the number of types does not depend on the corpus size, and a dictionary of about 70–100 thousand words and a large corpus of millions of tokens give the same results (Manova & Talamo 2015), which is the case because at some point the suffix combinations start repeating. Since this study is part of a series of studies on the processing of morphological structure, for the sake of uniformity we follow Manova's (2011) understanding of productivity.[4] For alternative approaches to productivity in English word-formation, see, e.g., Baayen (1991, 1993, 2001), Baayen & Lieber (1991), Plag (1999), and Bauer (2001).

The suffix combinations used in the psycholinguistic experiments reported in this study are listed in Table 2 (existing combinations) and in Table 3 (non-existing combinations). In Table 2, the suffixes are given with their syntactic category specifications and the suffix combinations are illustrated with examples. The list of suffix combinations used in this study is mainly based on Manova (2011), i.e., these are the suffix combinations from Aronoff & Fuhrhop (2002) and Plag & Baayen (2009), plus some additional suffix combinations pointed out by native speakers as missing in the two studies. Aronoff & Fuhrhop describe the combinations of 44 English suffixes, based on the Oxford English Dictionary (1994). Plag & Baayen tackle the combinations of 31 English suffixes and their data come from the CELEX lexical database (Baayen, Piepenbrock & Gulikers 1995) and the subcorpus of

[4] Manova's approach is defined to make possible research on affix combinability in languages of the inflecting fusional type where derivational suffixes are followed by inflection and for which the resources available for English do not exist, including corpora with annotated derivational suffixes such as for, e.g., CELEX for English (Baayen et al. 1995).

written English of the British National Corpus. Both studies provide the number of the derivatives formed with a particular suffix combination. Suffix combinations in English appear first heavily restricted (of all possible combinations only a few exist) and second the majority of the existing combinations produce a very limited number of words (types), fewer than 10 types each. These facts also seem to favor listedness in the mental lexicon. Again, if morphology (morphological structure) plays a role in the organization of the mental lexicon, native speakers should know suffix combinations by heart, which means access without reference to meaning, i.e., morphomic processing.

Table 2. Existing suffix combinations used in the experiments reported in §3

Existing Combinations Used in Task							
Suffix combination		**SUFF1**	**SUFF1 syntactic category**	**SUFF2**	**SUFF2 syntactic category**	**Example word**	**Type frequency**
Productive	**-ative**	-ate	V	-ive	ADJ	neg-at-ive	>10
	-ership	-er	N	-ship	N	lead-er-ship	>10
	-icism	-ic	ADJ	-ism	N	sto-ic-ism	>10
	-ifiable	-ify	V	-able	ADJ	just-ifi-able	>10
	-ifier	-ify	V	-er	N	mod-ifi-er	>10
	-ional	-ion	N	-al	ADJ	profess-ion-al	>10
	-ishness	-ish	ADJ	-ness	N	fool-ish-ness	>10

	-ivate	-ive	ADJ	-ate	V	capt-iv-ate	>10
	-ivist	-ive	ADJ	-ist	N	relat-iv-ist	>10
	-ization	-ize	V	-ation	N	immun-iz-ation	>10
	-lessness	-less	ADJ	-ness	N	weight-less-ness	>10
	-liness	-ly	ADJ	-ness	N	friend-li-ness	>10
	-mentary	-ment	N	-ary	ADJ	comple-ment-ary	>10
	-ority	-or	N	-ity	N	seni-or-ity	>10
	-osity	-ous	ADJ	-ity	N	visc-os-ity	>10
Unproductive	**-ageous**	-age	N	-ous	ADJ	advant-age-eous	≤10
	-atee	-ate	V	-ee	N	repudi-at-ee	≤10
	-domless	-dom	N	-less	ADJ	king-dom-less	≤10
	-eeism	-ee	N	-ism	N	absent-ee-ism	≤10
	-eeship	-ee	N	-ship	N	trust-ee-ship	≤10
	-enment	-en	V	-ment	N	Enlight-en-ment	≤10
	-erish	-er	N	-ish	ADJ	quak-er-ish	≤10
	-ianness	-(i)an	ADJ	-ness	N	Christ-ian-ness	≤10
	-iless	-y	N	-less	ADJ	merc-i-less	≤10
	-ingless	-ing	N	-less	ADJ	mean-ing-less	≤10
	-isty	-ist	N	-y	N	tour-ist-y	≤10
	-lihood	-ly	ADJ	-hood	N	live-li-hood	≤10
	-mentous	-ment	N	-ous	ADJ	fila-ment-ous	≤10
	-orish	-or	N	-ly	ADJ	act-or-ish	≤10
	-thful	-th	N	-ful	ADJ	heal-th-ful	≤10

Table 3. Non-existing suffix combinations used in the experiments reported in §3

Non-existing Combinations Used in Task				
	Permutation	**Existing Combination**	**Manipulation**	**Existing Combination**
From used existing combinations	-izic	-icize	-adive	-ative
	-ationize	-ization	-liress	-liness
	-ablify	-ifiable	-isiable	-ifiable
	-ariment	-mentary	-tsful	-thful
	-itior	-ority	-osify	-osity
	-lessdom	-domless	-aguous	-ageous
	-ousment	-mentous	-ieship	-eeship
	-ishor	-orish	-emment	-enment
From unused existing combinations	-istion	-ionist	-ausness	-ousness
	-ionalate	-ational	-iunism	-ionism
	-istal	-alist	-ionier	-ioneer
	-mentish	-ishment	-ifilation	-ification
	-istage	-agist	-oryst	-orist
	-izive	-ivize	-iarship	-(i)anship
	-nessic	-icness	-oful	-iful

All suffix combinations used in this study as well as their type frequency were additionally verified using the OneLook Dictionary database (available at: https://www.onelook.com/), which contains more than 19 million words (more than 1000 online dictionaries are indexed by the OneLook search engine). OneLook can be used as a reverse dictionary and allows for wildcard search. All searches for evaluation of productivity of suffix combinations were manually verified by a native English-speaking linguist.

3. Two psycholinguistic experiments

To probe the status of suffix combinations in the mental lexicon we ran two experiments: one with native and one with non-native speakers of English. The experiments consisted of an identification task similar to the lexical decision task (Meyer & Schvaneveldt 1971); however, the participants did not see whole words but two-suffix combinations such as *-mentary* (formed from *-ment* + *-ary*), *-ageous* (from *-age* + *-ous*), etc. Appendix 1 contains the list of stimuli in the order in which they were presented to the participants. The subjects had to decide as soon as possible whether the form they saw was the termination of an English word or not.

3.1. Participants

Participants in the study comprised 45 native and 30 advanced non-native speakers of English, who self-identified as having a CEFR level of C1 (n=16) or C2 (n=14). Of the native English speakers, 11 were male and 34 were female. Thirty-three were citizens of the US, 10 of the UK, and one participant each of Australia and Malta. Three listed a second native language of either Spanish or French; the rest only listed English as a native language. Twenty-seven listed only English as a spoken language, while 18 listed one or more additional non-native spoken languages with at least intermediate (B1 or higher) proficiency. Of the non-native English speakers, 12 were male and 18 were female. Their native languages and nationalities varied, with a majority (n=25) listing either a Romance (French, Spanish, Romanian) or Germanic (Dutch or German) native language, while the remaining five participants listed a Slavic (Serbian, Russian, Slovenian), Uralic (Hungarian) or Mongolic (Mongolian) native language. Most non-native English-speaking participants (n=25) listed another spoken non-native language with at least intermediate proficiency in addition to English and their native language.

3.2. Stimuli

Sixty suffix combinations were presented to participants, 30 of which exist in English and 30 of which do not (see Tables 2 and 3, and Appendix 1). Of the existing combinations, 15 were productive (as defined in §2) and 15 unproductive. Of the non-existing combinations (shown in Table 3), 15 were created from a permutation of an existing combination (reversing the order of the two suffixes such that the combination was not possible in English), and

15 were created through a spelling manipulation of an existing combination (changing one letter from an existing combination such that the new form does not exist in English). No non-existing combinations included any phonological and/or orthographical impossibilities in English.

3.3. Testing method

The task was presented via an online questionnaire developed using Google Forms that was completed on a voluntary basis. The questionnaire contained three sections: the first was a series of general demographic questions, including age, gender, nationality, native language(s), English fluency level, other languages spoken, level of education, and experience in a linguistic or other language-related field. The second was a practice test to familiarize participants with the nature of the main task and ensure that they understood it properly. The training included 10 example suffix combinations, five of which were productive existing combinations and five of which were non-existing combinations. These suffix combinations were not from the test stimuli. The third section was the main task, in which the 60 suffix combinations described above were presented in a randomized order, and participants were then asked to identify which of the combinations exist and which do not exist as word terminations in English. Participants were given a 10-minute time limit to complete the main task.

3.4. Data analysis

We used independent t-tests to consider possible significance of overall scores for individual groups and between native and non-native speakers, as well as for each stimulus type (i.e., existing vs. non-existing, productive vs. unproductive, and manipulation vs. permutation). As is typical practice in psycholinguistics, participants that were above or below 2.5 standard deviations from the mean score for all participants were excluded from the analysis. This exclusion is based on the assumption that if a participant makes mistakes above 2.5 SD, s/he was not focused on the task. One native English-speaking participant was eliminated from the data for this reason. The data of three other native English-speaking participants were not considered in the analysis due to exceeding the allotted time limit, leaving 41 native English speakers whose data were analyzed. Likewise for stimuli, if the accuracy score of an individual stimulus was more than 2.5 SD below the mean for all stimuli, this indicates that there could be something wrong with that stimulus. The unproductive existing combination *-ianness* (as in *Christ-ian-ness*) was the only stimulus eliminated from the data for this reason. *-ianness* had an accuracy score of more than 2.5 SD below the mean for all stimuli in both native and non-native speaker groups.

Additional possible affective variables for which data was gathered via the demographic questions (e.g., age, gender, education level, socioeconomic status, and linguistics experience) were also tested for possible significance using independent t-tests. The results of these tests are reported below.

3.5. Results

Both native and non-native speaker groups showed a strong ability to recognize existing suffix combinations and differentiate them from non-existing combinations, with an overall mean score of 46.29 (79%) for the native speaker group and 44.73 (76%) for the non-native speaker group. Although native speakers showed slightly higher overall scores, no significant difference was found between the native and non-native speaker groups (p-value = 0.19). Similar to previous iterations of this study using other test languages, productive combinations were the most accurately recognized of the four types (Figure 1), with both groups showing a mean score of 92% for identifying this type of stimulus. The other three types had more evenly distributed accuracy levels, with the only significant differences being found between productive and unproductive combinations in both groups (p-value < 0.001).

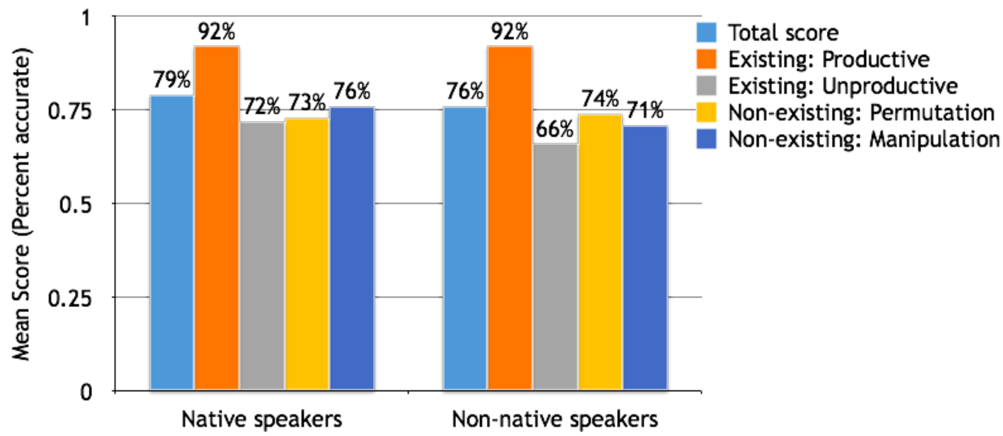

Figure 1. Mean scores for native and non-native speakers

One question concerning how participants come to an answer refers to the time required to complete the test. While we were not able to measure reaction times to individual stimuli, we did obtain information about the duration of the main task: participants indicated the time immediately before beginning the main task and this was compared with the time of submission of the questionnaire. As was noted in §3.4, three native-speaker participants were eliminated from the analysis because their total time exceeded the 10-minute time limit for the task. While no significance was found between time and overall accuracy for native speakers, non-native speakers tended to perform slightly better when taking longer to complete the test (p-value = 0.04). The results are summarized in Figure 2.

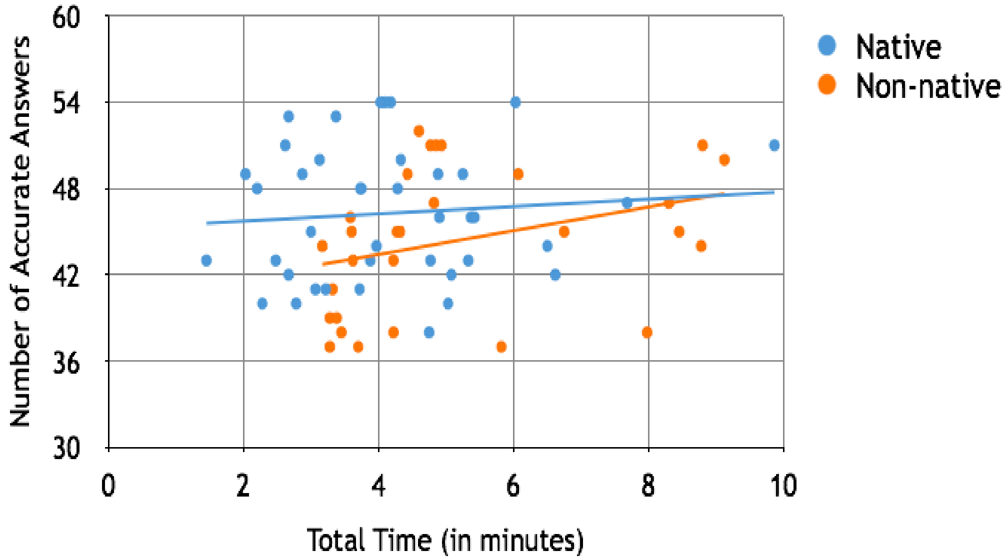

Figure 2. Individual scores and time required to reply to all stimuli

As can be seen from Figure 2, the majority of the participants needed about four minutes to complete the task (identification of 60 existing and non-existing suffix combinations), which means an average of 4s per suffix combination. We interpret this fact as evidence that the participants responded intuitively and did not relate the stimuli to whole words.

Finally, non-native speakers with a Romance or Germanic first language tended to perform better than those from other language groups. All other variables considered showed no significant differences in either group.

4. Discussion

Situated in the psycho- and neurolinguistic literature, our research relates to pioneer work such as the 'affix stripping model' of Taft and colleagues (Taft & Forster 1975, 1976; Taft 1979) who provided evidence that not only stems but also affixes (prefixes in their case) are stored in the mental lexicon; recent neurolinguistic studies also support this finding: Fruchter, Stockall & Marantz (2013), Fruchter & Marantz (2015) demonstrate that speakers obligatorily decompose the (visual) stimulus into morphemes, look these up in the mental lexicon, and recombine them. However, of all recent research on the topic, the closest to our experiments seems to be Lázaro, Illera & Sainz (2016) who investigate the effect of suffix priming on the lexical decision of suffixed (ero-JORNALERO) and pseudosuffixed (ero-CORDERO) Spanish words, as well as the effect of orthographic priming on nonsuffixed words (eba-PRUEBA). Their results show that in the case of suffixed and pseudosuffixed words, related primes significantly accelerate response latencies in comparison to unrelated primes (ista-JORNALERO; ura-CORDERO). Importantly, there was no facilitation effect of the orthographically related prime for simple words in comparison to the unrelated prime (eba-PRUEBA; afo-PRUEBA). Thus, the study concludes that the priming effect of suffixes is not orthographic but morphological, i.e., the effect holds only for derived and pseudo-derived words (such as *corn:er* in English; *corner* is a pseudo-derivative because *corn* is not its root). In our experiments we went further: we presented the participants with only suffix combinations (purely morphologically-derived items) and encouraged them to identify the stimuli as existing and non-existing pieces of word structure without relating them to whole words. The participants recognized existing and non-existing suffix combinations with very high accuracy, which we interpret as evidence that not only affixes but also affix combinations are stored in the mental lexicon.

As a rule, English language pedagogy, both for native and non-native speakers, does not include information about the combinability of the English derivational suffixes. In other words, the participants in our experiments have never learned English suffix combinations in a systematic way. Also, theories of morphology do not allow suffix combinations to have a life of their own, that is, according to grammatical theory all derivations in a language start with either a root, stem or word to which then affixes are attached. Yet, in an experiment trial, native and advanced non-native speakers of English do not need to see lexical bases to decide which suffix combinations exist and which do not. The only plausible explanation of why the participants in our experiments successfully accomplished a task they are not supposed to be able to solve is that they have extracted the necessary knowledge about the combinability of English suffixes subconsciously.

In the processing of suffix combinations, productivity seems to play a major role and productive combinations are more readily recognized than unproductive ones. The effect of productivity is well known in the psycholinguistic literature and we will not pay special attention to this issue but to how we established the productivity of a suffix. Almost all approaches to productivity of derivational suffixes control for token frequency because the more a subject sees or hears a token, the easier its recognition. However, a reliable estimation of token frequency requires linguistic resources that contain a large amount of (appropriately annotated) data (tokens), which is problematic for some languages. In this study, we defined productivity in an alternative way, based on type frequency (as discussed in §2). We assumed that suffix combinations that derive more than 10 types are productive, while those that derive 10 or fewer types are unproductive (see the distribution of the suffixes in Table 2) and we found that the difference in processing of productive and unproductive combinations is statistically significant (p-value < 0.001). We see this result as a confirmation of our productivity criterion and believe to have suggested a useful and easy way to estimate productivity of a suffix in word formation.

This study is part of a series of experiments on the processing of suffix combinability in languages belonging to different language families such as Slavic, Germanic and Romance, and it confirms what has been established so far for the processing of suffix combinations by native speakers of Slavic (Polish and Slovene) and Romance (Italian) languages, who also recognized existing and non-existing combinations surprisingly accurately (Manova, ms); in addition, productivity (as defined in this study) plays a role in suffix combination processing. Thus, although the results of the present study indicate that non-native speakers with a Romance or Germanic first language tend to perform better in the recognition of English suffix combinations than those with a Slavic first language, all participants seem to know by heart a significant portion of the suffix combinations of their native languages. Taken together, the results of the experiments reported here and the results for Polish, Slovene and Italian obtained in previous experiments suggest that native and native-like language competence presupposes knowledge of suffix combinability with a morphomic access to suffix combinations in the mental lexicon.

Theoretical morphology research on rule conflation (Stump 2019) provides indirect support to what we observed for the organization of the mental lexicons of native and non-native speakers of English with respect to suffix combinability. Table 4 is a comparison of rule conflation and suffix combination:

Table 4. Rule conflation versus suffix combination (Data adapted from Stump 2019)

Base	**Rule conflation**	**Suffix combination**
whimsy, *nonsense*	*whimsic, *nonsensic *whims-ical, nonsens-ical*	*cycle → cycl-ic* *cycl-ic-al*
probable, simple	*probabilist, *simplist	*national → national-ist*

	probabil-istic, simpl-istic	*national-ist-ic*
beauty, mort	*beautic, *mortic *beaut-ician, mort-ician*	*academy → academ-ic* *academ-ic-ian*

As can be seen from Table 4, in the case of suffix combination, the two suffixes attach in two steps, while in the case of rule conflation, we deal with a single suffix that we see as attaching directly. Since we are interested in suffix combinations, our Table 2, the list of all existing combinations used in the psycholinguistic experiments, does not include rule conflation patterns. Nevertheless, we see rule conflation as important evidence for memorization of two-suffix combinations and for their use as ready-made structures, which are defining properties of the morphome.

Further, morphomic patterns appear highly relevant to computational linguistics (computational extraction of grammatical rules from (unannotated) raw text, e.g., within Unsupervised Learning of Morphology (ULM)) and Natural Language Processing (NLP) — including machine translation—based on neural networks, i.e., inspired by the organization of the human brain (see, e.g., Wu et al. 2016). ULM and NLP seem to employ strategies similar to the morphomic one we identified in native and advanced non-native speakers of English in relation to suffix combinability. ULM and neural network approaches take large amounts of raw text data as input and attempt to induce the patterns and rules of the input language or to translate one language into another. The procedure is entirely form-based (thus morphomic) and relies on sequence-to-sequence comparisons (sequences can be of any length) and weighting of substring frequencies in recurrent formations. An example of ULM logic: the frequency of the final substring -*ing* in English will be much greater than that of a random substring of the same length, and most of the words that have -*ing* will also get -*ed* much more often than chance (for an overview of computational approaches to morphology, see Hammarström & Borin 2011). The same logic applies to the identification of stems; as well as to suffix combinations: the frequency of, for example, -*ifier* (-*ify* + -*er*) will be much greater than that of a random substring of the same form, and words with -*ifier* will also combine with -*s* (to form plural) more often than chance. Facilitation and accuracy of rule extraction can be achieved by the addition of portions of annotated data to the raw data. For example, for morphological purposes, pairs such as <"bags", bag-PL> have been used (Kann & Schütze 2016 and Chrupala 2008, Ch. 6). Rules based on such annotations serve to make guesses when analyzing previously unseen data. For suffix combinations, one may use annotations such as <"-ifier", -ifier-NOUN from -ify-VERB> and <"-ifiers", -ifier-PL>; such annotations can be used, for example, to prepare corpora for word-formation research. As for semantics, it has been assumed 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), i.e., forms that are semantically related tend to co-occur.

Finally, in this study we did not measure reaction times to individual stimuli (only the duration of the completion of the task) and cannot provide fine-grade analyses of the response latencies. We are aware that our results will be regarded as only preliminary by some scholars and that more precise testing should be done. Psycholinguistic experiments with reaction time measuring are planned for future research, but we also hope that the findings of this paper will encourage other scholars to carry out similar or replication experiments. Additionally, to establish the exact relation between morphomic access of suffix combinations in the mental lexicon and language competence, non-native speakers with CEFR A and B (beginning and intermediate) levels of language skills should also be tested, and, of course, not only with English data.

5. Conclusion

Based on theoretical observations about the uniqueness of suffix combinations, we ran two online psycholinguistic experiments as part of a series of experiments on the processing of morphological structure in languages from different families (Slavic, Germanic and Romance). To probe the status of suffix combinations in the mental lexicon, in the first experiment only native speakers of English were tested, while the second experiment was with advanced (C1 and C2 level) non-native speakers of English. Although knowledge of suffix combinability is not systematically acquired at school, and linguistic theories recognize only derivations that start from either a root (DM and lexical and incremental approaches to morphology) or from roots/stems/words (PFM and inferential approaches to morphology), in the experimental trials, native and advanced non-native speakers did not need to see lexical bases to differentiate between existing and non-existing suffix combinations. In the processing of suffix combinations, productivity plays a role and productive combinations were more readily recognized than unproductive ones. Since the task to identify suffix combinations as either existing or non-existing pieces of word structure was without any semantic cues and the average time for processing a suffix combination (approx. 4s) was too short to allow associations with whole words, we see two-suffix combinations as morphological structures listed in the mental lexicon in terms of purely morphomic patterns. Two-suffix combinations also attach as single suffixes, i.e., as readymade pieces of morphological structure, in rule conflation patterns, which provides further evidence for listedness in the mental lexicon and resembles the repurposing of morphomes in inflectional morphology. Computational approaches to grammar such as ULM and NLP models based on neural networks seem to employ a morphomic procedure similar to the one reported in this study for humans to induce (grammatical) patterns and rules and for machine translation.

The results of this research show that not only words, stems, roots and affixes but also affix combinations are of importance to the mental lexicon and natural language processing. Moreover, morphomic knowledge of suffix combinability seems to correlate with high language competence in humans and can thus be used for educational purposes, e.g., to facilitate foreign language learning, as well as for testing language proficiency.

Acknowledgments

We dedicate this chapter to the *morphomeman*, Mark Aronoff, and hope that it is original enough for the occasion.

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Appendix 1: List of suffix combinations (existing and non-existing) used as stimuli

Stimulus	Existing	Non-existing	Stimulus	Existing	Non-existing
-ority	prod(uctive)		**-oryst**		manip(ulation)
-ership	prod		**-tsful**		manip
-izic		perm(utation)	**-ative**	prod	
-lessness	prod		**-ionier**		manip
-adive		manip	**-ariment**		perm
-ishness	prod		**-ivist**	prod	
-erish	unprod		**-iless**	unprod	
-ifilation		manip	**-iarship**		manip
-lessdom		perm	**-mentary**	prod	
-itior		perm	**-ianness**	unprod	
-liness	prod		**-mentous**	unprod	
-iunism		manip	**-lihood**	unprod	
-ifiable	prod		**-istal**		perm
-ingless	unprod		**-domless**	unprod	
-thful	unprod		**-ishor**		perm
-eeship	unprod		**-mentish**		perm
-aguous		manip	**-ionalate**		perm
-izive		perm	**-ausness**		manip
-istion		perm	**-osity**	prod	
-nessic		perm	**-istage**		perm

-ationize		perm	**-eeism**	unprod	
-ivate	prod		**-ablify**		perm
-osify		manip	**-isty**	unprod	
-ional	prod		**-ieship**		manip
-orish	unprod		**-emment**		manip
-ageous	unprod		**-ization**	prod	
-enment	unprod		**-atee**	unprod	
-liress		manip	**-ousment**		perm
-ifier	prod		**-icism**	prod	
-isiable		manip	**-oful**		manip