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Suffixes in word-formation processes in scientific English

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Abstract

Scholars have stated the particularities of the language used in specialized discourse but little attention has been so far paid to the role derivational morphology may play in register variation. The present research makes a contribution to the study of word-formation in scientific registers by means of a corpus-based approach to the productivity of 14 suffixes in two scientific English registers, i.e., computer science and medicine. In order to empirically examine the productivity of the suffixes in each register, types, tokens and hapaxes ratio were used. Results obtained were then contrasted with the presence of the same suffixes in the written language wordlist of the *British National Corpus* (BNC). The study shows that suffixes are a productive word-formation resource in scientific registers and that their productivity differs in the registers under study. Findings ranked higher productivity of abstract noun-forming suffixes such as *-ity, -ion* and *-ness* in scientific registers than in the BNC. The suffix *–ize* reached values in the scientific corpora highly over the ranking drawn from the BNC. On the contrary, the BNC yielded an outstanding productivity rate of *–free* and *-like*, suffixes which proved to be fully unproductive in the scientific registers under study.

1 Introduction

Scientific English can be approached from different angles taking into account its specific vocabulary and the framework of the syntactic structures most commonly used. Specific disciplines often develop their own patterns of discourse which do not always coincide with those of general English; thus, an issue of current interest for researchers in applied linguistics is determining how the frequency of use of particular discourse-level patterns may be characteristic of certain disciplines.

To name new concepts and refer to issues of their field of studies, specialized registers extend their vocabulary mainly by borrowing words from another language but also by using their own linguistic resources in compounding and derivation processes**.** However, word-formation and the factors which govern the acceptance of new formations into the language are generally taken very much for granted by the average speaker (Adams, 1973). The ways in which new words are formed have long been discussed in classical literature from a theoretical perspective (see e.g., Adams, 1973, Bauer, 1983 or Marchand 1969, to name a

few). Halliday (1978: 195) identifies seven strategies commonly used in the formation of specialized terminology:

- Reinterpretation of existing words
- Creation of new words from a native word stock
- Borrowing of words from foreign languages
- Calquing
- Invention of totally new words
- Creation of locutions
- Creation of new words from a non-native word stock (cf. Moskowitch, 2010).

Halliday's second strategy, creating new words from a native word stock, may imply different word-formation processes making use of compounding, conversion, back formation or derivation. Derivation is yielded by means of affixation, i.e., adding a derivational affix to a word by means of prefixation, suffixation or infixation. Prefixes are attached to the front of a base, suffixes to the end of a base and infixes are inserted inside a root. The present research will focus on a productive process of word-formation making use of derivation, i.e., the use of suffixes, which allows the creation of new words enlarging or changing the structure of the headwords, and will analyse its productivity in specialized registers.

The notion of register refers to the fact that the language we speak or write changes according to the type of situation. In this context, the concept of register comes under the larger concept of language variation in applied linguistics (Ghadessy, 1993). Some concepts have to be clarified to predict the linguistic characteristics of a situational context, following Halliday (1982): discourse field (institutional framework in which language is used, which includes the topic dealt with), discourse tenor (relationships within participants), and discourse mode (communication channel). Differences regarding the discourse field, discourse tenor and discourse mode will produce different varieties of language that can differ from other forms of the language systematically and coherently. Studies in register variation have found evident differences among specialized registers both from a morphological and syntactic point of view, and have stated that the clustering of such properties can even be used in defining a certain type of discourse (cf. Biber, 1995). The present research will focus on the use of suffixes in scientific English registers represented by the discourse field of medicine and computer science. Specialized manuals will be the discourse tenor in which the productivity of the word formation process will be studied.

Regarding the registers under study, Salager-Meyer & Alcaraz Ariza have carried out research on different medical genres (see, e.g., Salager-Meyer & Alcaraz Ariza, 2001, Alcaraz Ariza & Salager-Meyer, 2002, among others). A considerable body of literature has debated medical discourse (Taavitsainen, 2004), its lexicon (Norri 1998, 2004) or have analyzed it in studies on code-switching (Pahta, 2004). As for computer science registers, a corpus-based lexical analysis has been attempted by James (1994). Plag, Dalton-Puffer & Baayen (1999) claimed that little attention has been paid to the role derivational morphology may play in register variation, and studied the productivity of suffixes in different types of discourse in the British National Corpus. Apart from these studies, there is so far not much research on the productivity of suffixes in specialized genres, and, besides, many word counts performed are based on diachronically and dictionary-based studies. However, approaches in which the dictionary is used to make affix counts are not altogether satisfactory and, as Booij (2007: 65) points out, a dictionary is not useful for these studies because it only registers the words

which have become established words after some time, making a corpus a better source of information than a dictionary.

The justification for the present research lies, thus, in the existing need of research on the productivity of suffixes as a word-formation process in specialized registers. By productivity we mean morphological productivity, defined by Bolinger (1948: 18), as "the statistically determinable readiness with which an element enters into new combinations". The term 'productive' is used to describe a pattern, meaning that "when occasion demands, the pattern may be used as a model for new items" (Adams 1973: 197). Productivity is, thus, the capacity of a word element to produce new words (Plag, Dalton-Puffer & Baayen, 1999). As a language evolves, different suffixes may rise in productivity and later fall in productivity, or may be predominantly used in certain discourse fields; the present study will assess the rate of use of suffixes across registers.

2 Some preliminary remarks on productivity

As opposed to free morphemes, affixes are bound morphemes, i.e. morphemes that cannot be used on their own but must be attached to another word. There has been scholarly attention over the past decades to identify constraints on word- formation that cause one affix to be less productive than another, e.g. Anshen & Aronoff (1989) Aronoff (1976) or Plag, Dalton-Puffer & Baayen (1999). The linguistic factors which affect the productivity of word-formation rules were addressed in studies by Fabb (1988), Marle (1986) or Rainer (2005). Stein (1977) offered contributions on affix ordering. The influence of suffixation on stress was studied by Bauer (1983). Hill (1974) and Levi (1973) addressed the problems of distinguishing suffixes and the specifications of their meanings. Quantitative measures of productivity were discussed by Aronoff (1976), Baayen (1991), Baayen & Lieber (1991), Baayen & Renouf (1996), Bauer (2001), Booij (2000), Nishimoto (2004), Plag (1996, 2003), Plag, Dalton-Puffer & Baayen (1999) or Marle (1986). From the different productivity measures proposed in these studies, the present study follows Baayen's (1991) productivity measures.

Often confused terms in productivity measurements such as type, token and hapax, merit a clarification before presenting the methodology used in the study:

- Type frequency is the number of different words, i.e., word types with a given suffix.
- Token frequency is the total frequency of use of all the words of that particular type. For example, if 500 different nouns in *–ity* were found in a corpus, the type frequency of this noun-forming suffix would be 500. The token frequency could be much higher than the type, as it counts the total number of times of its occurrence, which includes all repetitions of the same item.
- Hapax legomena or hapaxes are words that occur only once in a large text corpus. Their role is significant in the determination of productivity.

3 Purpose

English has a remarkably small inventory of affixes in comparison with languages such as Spanish. The aim of the present study was to assess and compare the productivity of 14 English suffixes in two different scientific registers, medicine and computer science in comparison with their productivity in the *British National Corpus* (BNC). The suffixes analyzed were those studied by Plag, Dalton-Puffer & Baayen (1999) in their contrastive study of the suffixes in the written and spoken wordlists of the BNC. Insofar as

nominalization is a common word-formation resource, the main criterion for choosing the suffixes for the study was the need to complement Biber's (1995) research on register variation through nominalization by the use of appropriate suffixes (e.g., *-ness -ity*, *-ance/-ence* or *–dom*) with other derivational patterns performing different morphosyntactic and morphosemantic functions. The suffixes analyzed can be grouped into different types according to the lexical items they generate:

- Suffixes forming abstract nouns: *-ity, -ness, -ion;*
- Suffixes forming participant nouns: - *er, -ist;*
- Suffixes forming measure partitive nouns: *-ful;*
- Suffixes forming derived verbs: *-ize;* and
- Suffixes forming derived adjectives: *-able, -free, -ful, -ish, -less, -like, -wise.*

4 Hypothesis

Our research will attempt to answer the following research questions:

1. Are there more productive suffixes in medicine registers than in computer science registers?

2. Is there a difference in the behaviour of these suffixes in the specialized registers of medicine and computer science compared to a wider, more general corpus, i.e., the *British National Corpus* (BNC)?

The analysis of the suffixes used will show their productivity in the registers under study. The hypothesis is that since derivational suffixes are very frequently used in word-formation processes in formal settings, their presence in the specialized discourse of medicine and computer science will be higher than in the BNC. This paper will thus observe to what extent scientific registers have their own word-formation processes reflecting specificity of the field, and whether differences in use can be observed from a more general corpus.

5 Methodology

5.1 The corpus

The study was based on the contrastive analysis of three different corpora compiled from the following sources:

- Miller, R.D. (ed.) (2000): *Anesthesia.* 5th ed. Philadelphia: Churchill Livingstone, Inc., chosen as representative of the language of medicine totalling 1.169.749 words. This specialized manual deals with anesthesiology, the branch of medicine that is concerned with the study and practice of anesthesia which requires competency in general medicine, a broad understanding of surgical procedures, and a comprehensive knowledge of clinical obstetrics, chest medicine, neurology, pediatrics, pharmacology, biochemistry, cardiology, and cardiac and respiratory physiology.

  The corpus obtained from Miller (2000) will, due to space constraints, sometimes be referred to as MC (medicine corpus) throughout the paper.

  Grama, A. et al. (2003): *Introduction to Parallel Computing*, 2nd ed. Boston: Addison Wesley, taken as a representative language sample of computer science, with 358.509 words. The manual presents new developments in parallel-computing and discusses

topics such as parallel architectures, designing and analyzing parallel algorithms, and programming techniques. Emerging areas such as computational biology and nanotechnology have implications for algorithms and systems development, while changes in architectures, programming models and applications have implications on how parallel platforms are made available to users in the form of grid-based services.

- In this study, a preliminary estimation of the productivity of the corpus suggested some changes on the size of the samples, as both scientific corpora chosen differed in length. As productivity may be dependent on the size of the corpus (Baayen, 1993), it was thought more convenient to compare equal-sized scientific samples. In the process of corpus compilation, Grama et al.'s (2003) was complemented with another source so as to equal the number of words of running text provided by the MC. A number of chapters from Tucker, A.B. (ed) (2004): *Computer Science Handbook* (2nd. ed). Brunswick Maine: Bawdain College, were randomly added to adjust the size requirements. Tucker (2004) offers a rich collection of theory and practice that fully characterizes the current state of the field of computer science. The number of words of running text of the new corpus was now estimated to be sufficient to obtain preliminary results of the behaviour of suffixes. The corpus obtained from Grama et al. (2003) and Tucker (2004) will be henceforth abbreviated as CSC (computer science corpus).

The analyses of these two corpora of scientific registers were compared with the productivity of the same suffixes in a more general sample, *The British National Corpus* (World Edition) (2000): Oxford: Oxford University Computing Services. The British National Corpus (BNC) contains 100 million word tokens from samples of written and spoken language drawn from a wide range of sources, designed to represent a wide cross-section of British English from the latter part of the 20th century. The written part of the BNC (90%) includes, for example, extracts from regional and national newspapers, specialist periodicals and journals for all ages and interests, academic books and popular fiction, published and unpublished letters and memoranda, school and university essays, among many other kinds of text. The wordlist that corresponds to written sources of this corpus was the basis for the contrastive study of the productivity of suffixes with the scientific corpus carried out in the present study.

5.2 Procedure

The register analysis undertaken has benefited from advances in computational linguistics. In the present research, after converting the PDF files containing Miller's (2000) and Grama et al.'s (2003) and Tucker (2004) corpora into plain text, *WordSmith Tools* (Scott, 1996) generated wordlists based on text analysis, and was instructed to find out the words containing the suffixes required. But in spite of the advantages of this software for extracting the suffixes from the corpus, the wordlists obtained were not totally reliable. The result of the process produced raw frequency data, that is, a long list of words with suffixes which had to be cleaned.

The main method used in this study for measuring productivity rates was the estimation of Baayen's (1992) productivity index. Baayen measures productivity rates (P) by calculating the ratio of hapax legomena to tokens for a given affix by using the following formula:

$$P = n_1/N$$

In Baayen's formula, n_1 is the number of hapax legomena with a given affix, and N is the number of tokens with the same affix.

6 Results and discussion

As mentioned above, preliminary results of the electronic processing of the corpus required a manual refinement of the wordlist obtained. This process discarded a large number of word counts which did not contain the expected suffixes, as many suffixes listed were, instead, part of the lexeme or even the proper lexeme: e.g. *cable, table* and the adjective *able* were included by *WordSmith* as items containing the suffix *–able*. The corpus was then manually analysed so as to eliminate entries which shared the string of letters of a suffix but were not the required morpheme. To clean the wordlist, one-syllable words as well as proper nouns were eliminated. Context as well as the *Oxford English Dictionary* were used to find out if the word under study contained the required suffix, a fact which was easier to tell with some suffixes than with others, with *-er* and *–ist* being the most problematic. As an example, from a total of 2258 types recorded in respect of *-er* in the CSC, only 179 were admitted as valid types. In contast, fewer inconsistencies were observed in other *WordSmith* suffix counts, such as, e.g., *-ion, -ity* or *–ness.* Table 1 exhibits the total types found for each suffix in the MC corpora, so as to show the reader the rate of suffixes rejected:

Medicine corpus (MC)		
Suffix	Total types	Valid types
-able	235	228
-er	2258	179
-free	2	0
-ful	36	36
-ion	1096	1058
-ish	49	28
-ist	109	47
-ity	312	309
-ize	78	76
-less	44	41
-like	5	2
-ness	114	113
-wise	10	8

Table 1. From raw frequency data to clean data. Valid types in the medicine corpus (MC).

Even the task of identifying words with capital letters as proper nouns was not straightforward, as wordlists compiled by means of this software used all initial capital letters. *WordSmith Tools* isolated the items containing suffixes in the context in which they were used, a task which helped to identify the words, e.g., *Bender, Berger* or *Benzer* as proper nouns, as headwords to which the *–er* suffix had been added or as neologisms. It was frequently problematic to decide if some words should be included or excluded as examples of suffixation.

The preparation of the corpus was followed by the estimation of tokens and hapaxes. A two stage analysis was then accomplished. In the first stage, the productivity of both corpora was

calculated by dividing the hapaxes by the number of tokens. Table 2 illustrates the rates obtained:

Suffix	Productivity (P) MC	Productivity (P) CSC
-able	0,01218658	0,009449466
-er	0,01649359	0,011346445
-free	0	1*
-ful	0,00681115	0,011235955
-ion	0,00341802	0,005245546
-ish	0,02325581	0,058823529
-ist	0,01481481	0
-ity	0,00762443	0,020016681
-ize	0,04004711	0,046728972
-less	0,03370787	1*
-like	1*	0
-ness	0,02889825	0,120000000
-wise	0,01063830	0,012658228

Table 2. Productivity of suffixes in medicine corpus (MC) and computer science corpus (CSC)

**An asterisk in the grid indicates that the presence of the corresponding suffix in the corpus reaches such low occurrences that productivity measuring was discarded.*

From the data obtained the following can be drawn when comparing both corpora:

- The high values of productivity in the case of *-free* or *-like* in both the MC and the CSC can be biased by the small number of tokens (*-free* accounts for 0 tokens in the MC and 2 in the CSC, and *–like* records 2 tokens in MC and 0 in the CSC). The productivity values obtained are misleading and thus cannot be accepted as true indicators of productivity in medicine and computer science registers.

- The verb forming suffix *-ize* generates high values of productivity in both registers.

- The suffixes *-ity*, and *-ion* achieve high values of productivity in the MC and the CSC. These results are not surprising as these suffixes are often used in scientific texts to encode field or domain specific concepts (Plag, Dalton-Puffer & Baayen, 1999). The suffix *-ful* is also productive in both registers as an adjective-forming suffix.

- The suffixes *–ist* and *-less* are fully productive in the MC but unproductive in the CSC.

From the above mentioned data and in answer to our first research question, if there were suffixes more frequently used in medicine registers than in computer science registers, this study provides preliminary results that confirm the similarity of both registers regarding the productivity of the suffixes *–ize* forming derived verbs, and *-ity* and *–ion* forming abstract nouns. Suffixes forming adjectives from verbs, *-able* and *-ful* were also moderately productive in both registers. However, no occurrences were encountered of *-ful* forming partitive nouns in the analysis. The suffixes *-free* and *-like* do not account for word-formation processes in the scientific registers under study. As for the differences observed, some suffixes have to be

highlighted as their productivity stands out in the MC corpus and not in the CSC, i.e, *-ist*, a suffix which forms nouns from adjectives, and *-less*, a suffix which forms adjectives from nouns and also from verbs.

A second stage of the process implied the comparison between the productivity values obtained from the analysis of the scientific registers with the productivity rates of the suffixes in the British National Corpus. Table 3 exhibits the different productivity data of the suffixes across the corpora investigated.

Productivity index (P)			
Suffix	**MC**	**CSC**	**BNC**
_able	0,012186581	0,009449466	0,002211524
_er	0,016493586	0,011346445	0,019466634
_free	*	*	0,103613409
_ful	0,006811146	0,011235955	0,001025885
_ion	0,003418018	0,005245546	0,000382729
_ish	0,023255814	0,058823529	0,033828276
_ist	0,014814815	*	0,003582162
_ity	0,007624432	0,020016681	0,000917291
_ize	0,040047114	0,046728972	0,002109537
_less	0,033707865	*	0,009597742
_like	*	*	0,110412371
_ness	0,028898254	0,12	0,008816627
_wise	0,010638298	0,012658228	0,06121473

Table 3. Productivity index: medicine corpus (MC), computer science corpus (CSC) and British National Corpus (BNC).

Given the second research question motivating this study, if there were a difference in the productivity of suffixes in the specialized registers of medicine and computer science from the productivity in a more general corpus, the BNC, the following can be inferred:

- The BNC shows an outstanding productivity rate of the suffixes forming derived adjectives *-free, -like.* This productivity contrasts with the extremely low use of these suffixes in the scientific registers under study. From the other suffixes generating adjectives in the study, *-ish* offers similar values in the specialized registers to the ones of the BNC, although the CSC yields slightly higher counts; and *-able,* a suffix of Romance origin, derived from transitive verbs, recorded more counts in the MC and the CSC than in the BNC.

- The agentive deverbal *-er* forms participant nouns and accounts for very similar productivity in both the MC and the CSC registers and the data obtained from the BNC, although slightly lower in the latter. The overall results for the suffix *-er* seem to be plausible, since it has similar values in all the corpora attached to virtually any semantically appropriate verb.

- The suffixes *-ist,* forming nouns from verbs, and *–less,* added to nouns to form adjectives, record a higher productivity in the MC than in the BNC.

- What is outstanding is the behaviour of *-ity* and *-ion*, abstract noun-forming suffixes mainly attached to words of classical origin. These suffixes record much higher productivity values in the MC and the CSC than in the BNC. This high frequency of use is also shown in the CSC by *-ness*, a suffix added to adjectives to form abstract nouns.

- The suffix *–ize*, forming verbs from nouns and adjectives frequently of neoclassical origin, is fully productive in the MC and the CSC: values are higher than in the BNC.

Figure 1 displays the differences observed in the behaviour of the suffixes in the different corpora more visually:

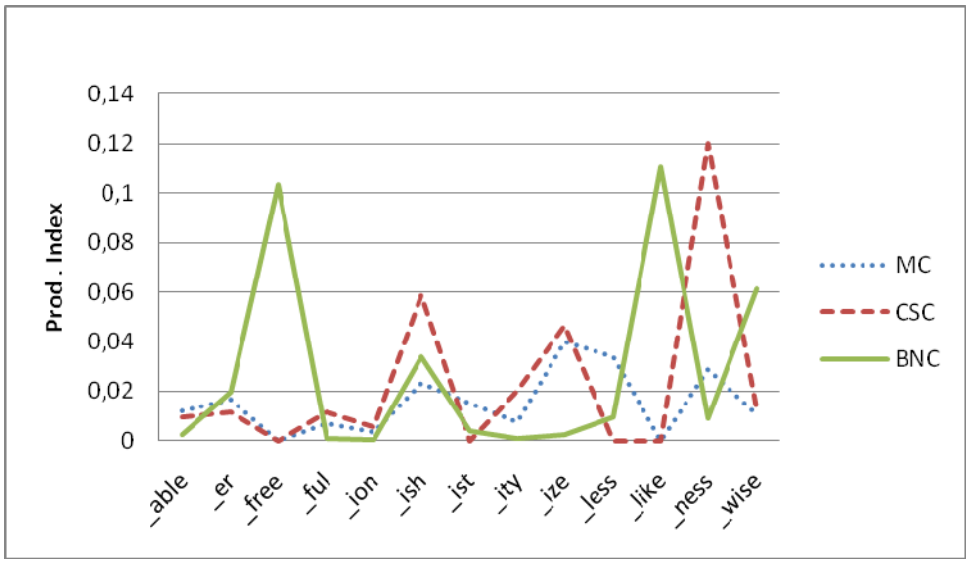

Figure 1. Productivity index: medicine corpus (MC), computer science corpus (CSC) and British National Corpus (BNC).

6 Conclusion

The quantitative description of the productivity of suffixes can be interesting in the study of specialized discourse to reveal their morphological differences, and as some scholars have pointed out, the productivity ranking obtained with a corpus-based productivity measure will be useful in many forms of linguistic research, not necessarily limited to the study of word-formation.

On the theoretical level, the foregoing study makes a contribution to the study of word-formation in scientific registers and describes differences among different fields of study, a fact which turns out to be even more outstanding when findings are compared with the BNC. The hypothesis on the higher prevalence of suffixes in scientific registers has been partly confirmed. Our results confirm that there is a difference in the behaviour of some suffixes across scientific registers, and confirm that morphological productivity is subject to register variation. A higher productivity of certain suffixes in scientific registers than in the BNC has been revealed. However, scientific registers have also recorded a total absence of some suffixes which were fully productive in the BNC.

Although some preliminary conclusions have been drawn, these are not definite. Further studies are required to confirm these findings across larger corpora. The intention here was to

consider patterns in the behaviour of the suffixes rather than to determine definite measures for individual affixes. Future studies on morphological derivation by the author will also strive to assess the characteristics of individual suffixes with higher productivity in scientific registers from the point of view of their morphological and syntactic level and will also consider the semantic value of the derived form.

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