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Professional and Popular Science: Mapping Linguistic Overlap and Divergence

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Abstract. The authors introduce a novel application of the Linguistic Inquiry and Word Count (LIWC) methodology to quantitatively differentiate the linguistic profiles of professional and popular science articles, establishing them as belonging to distinct functional styles. The results demonstrate that popular science articles are characterized by affective language, future-time orientation, and narrative devices to enhance accessibility and engagement for non-specialists. In contrast, professional articles exhibit terminological density, formal punctuation, and structural rigidity, reflecting their precision-oriented communication for experts. Statistically significant differences between professional and popular science articles show that the popular science functional style is being formed as an independent entity with its own linguistic system blending journalistic engagement with scientific discourse, rather than existing merely as a simplified derivative of professional science style.

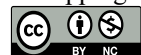
Keywords: scientific functional style, science discourse, popular science text, Linguistic Inquiry and Word Count (LIWC)

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Язык академической науки и научно-популярной литературы: сходства и различия

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Аннотация. Впервые методология ЛИВК (лингвистический анализ и подсчёт слов) применяется для количественного выявления различий между языковыми профилями академических и научно-популярных статей и их отнесения к разным функциональным стилям. Результаты показывают, что научно-популярные статьи отличаются эмоциональной окраской, ориентацией на будущее и использованием нарративных стратегий, что делает их более понятными и интересными для широкой аудитории. В то же время академические статьи демонстрируют высокую терминологическую плотность, формальную пунктуацию и структурную жёсткость, что соответствует установке на точность и адресность в коммуникации со специалистами. Статистически значимые расхождения между двумя типами статей подтверждают, что научно-популярный стиль сложился как самостоятельный лингвистический феномен, синтезирующий элементы научного и медийного дискурсов, а не является упрощённым вариантом академического научного стиля.

Ключевые слова: научный функциональный стиль, научный дискурс, научно-популярный текст, лингвистический анализ и подсчет слов (LIWC)

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Introduction

Globalization of science leads to the changes in the organization of science communication, defined by Burns et al. [1. P. 183]. as “the use of appropriate skills, media, activities and dialogue to produce one or more of the following personal responses to science (the AEIOU vowel analogy): Awareness, Enjoyment, Interest, Opinion-forming, and Understanding.” Thus, the main trends of professional communication development noted by Gunnarsson [2] — multi-linguality, multiculturalism, flexibility, and diversity — become the main features of science communication as well. The research community became aware that scientific progress was impossible without the global involvement of many researchers in the cycle of creating, exchanging, processing and evaluating large quantities of information. These global processes led to the development of new ways of disseminating knowledge, such as digital libraries, open access journals and social networking sites [3]. As science discourse became more international, less individualized, and more uniform and structured, it formed several subsystems

within it, fulfilling different functions besides research development: for example, informational, popularizing, educational, political, advertising, and social [4; 5]. On the periphery of science discourse, new subtypes were formed, e.g., popular, didactic, technical, and so forth, distinguished mainly by the audience they were aimed at and the functions they performed.

Online communication changes the processing of information. Publishing new articles and research data becomes easier and faster. Researchers can connect their new works with their previous ones, include references to preceding texts and data, and spread new data among wider audiences. New media allow showing and hiding essential and additional text components, to single out structural elements fulfilling different functions. Means for supporting the communication between members of the scientific community also acquire new features [7]. New tools appear that allow making comments, connecting new publications with similar ones, and uniting all publications on the same topic into clusters, ranging the publications according to number of citations, readings, and comments, all indicating the interest of the scientific community [8–11]. What is more, multimodal texts using various media prevail over purely verbal ones, as their non-verbal elements attract the attention of readers [11] and possibly increase the rating of the publication.

Therefore, the form of texts changes accordingly. New components fulfil specific functions, and the inner structure of the text becomes more oriented to dialogue and promotion by automatic tools. The discourse loses its homogeneous character, and its marginal subtypes separate and develop into new types with their various audiences, functions, genres and language peculiarities. Investigating emerging types of discourse can be carried out in several ways, e.g., via language means, genres, pragmatics and polymodality, depending on the aims of the research [12; 13]. According to Chernyavskaya [14], the key issue arising when studying popular science discourse is the role of the popularization type of narration in the system of functional styles, as popular science texts are quite flexible and combine features of different styles (academic, belles-lettres, and journalistic).

On the one hand, language is becoming more homogeneous and predictable, but on the other, new text elements appear to transform the text into cyber text with its complex nature. Text analysis is becoming impossible without a multidimensional approach, taking into account the characteristics of the members involved in the communication, and the aims and media used. What is more, large amounts of data require the application of computerized processing tools, that could help in revealing the text functions, define the genre of the text, and show stylistic errors to academic language learners. Applying such tools may identify the textual features relevant for distinguishing different genres and discourses.

Literature Review

The variety of language associated with a certain social setting, time, and participants is the focus of attention of modern linguistic research. Different terms are used depending on the approach to the study. For example, Biber and Conrad

referred to the notion of a register as the combination of “an analysis of linguistic characteristics that are common in a text variety with analysis of the situation of use of the variety” [15. P. 2]. They noted that “some linguistic features are common in a register because they are functionally adapted to the communicative purposes and situational contexts of texts from that register”. The linguistic features distinguishing features of different registers are universal and found in different languages, e.g., Haider and Palmer [16] showed that advertising, novels, academic texts, and reports in German possess a set of linguistic features that were statistically different for genres belonging to different registers.

The term ‘functional style’, specific for the Czech and Russian schools of Functional Stylistics, denotes historically formed and socially organized speech variety that possesses the quality of systematicity, characterized by specific principles of selection and combination of language. This variety is correlated with a particular sphere of communication and form of cognition¹. Quite often distinguishing the terms ‘style’, ‘functional style’ and ‘register’ arouses confusion [17; 18]. The term ‘Functional Style’ is used in this paper to emphasise the dependence of linguistic features on the functions of the chosen language variety and its connection with spheres of communication. A detailed analysis of functional styles in English was given by Galperin [19] and developed in subsequent research connected with various languages (see [20–24]), which prove a universal character of functional styles features.

The scientific functional style appears as a result of science communication and is characterized by objectivity, logical evidence and consistency, high level of abstractness, preciseness, clarity, formality, and terminological uniformity [20; 21; 25], thus opposing the belles-lettres style characterized by individuality, heterogeneity, particular selection of words revealing new meanings in the context helping to create imagery, interactions of meanings, variability, and uniqueness [19; 22].

A field approach to the notion of functional style [26] allows regarding a functional style not as a closed entity, but as a phenomenon with a nucleus and periphery. Genres possessing all the specifics of a particular functional style belong to its nucleus, while those which display new peculiarities due to new extra-linguistic factors are attributed to the periphery. Popular science genres first appeared on the periphery of the scientific functional style. Initially, the popular science functional style was regarded as a substyle of the scientific functional style [20; 25; 27], then as a separate functional style with its own aim, purposes, participants, specific interaction between the author and the recipient of message, and content of the message [28].

The last 40 years witnessed an unprecedented growth in mass communications based on new technologies, and social and political changes. The following factors

¹ Kozhina, M.N. (2003). Functional style. In: M.N. Kozhina (Ed.), *Stylistic Encyclopedic Dictionary of the Russian language*. Moscow: Flinta, Nauka. (In Russ.).

enhancing the transformation of professional and popular science functional styles can be singled out [1; 7; 10; 13; 29]:

- ideological crises in mass consciousness due to globalization on all levels of social life;
- global character of topics interesting for the audience at a certain period of time;
- a considerable increase in the number of publications due to electronic versions;
- the necessity to address people of different ages, nationalities, educational and social background to achieve the goals of changing the mass picture of the world;
- a new characteristic of author/ reader interaction — a dialogue, in which the readers have become active participants in communication, their activity promoting the rating of the publication together with the topic and the quality of the text.

These extra-linguistic factors caused changes in the structure of professional and popular science texts. They are no longer linear, though according to Clyne [30], the linear form is specific to low-contextual Anglo culture dominating natural science communication [31]. All elements of discourse must be verbalized and unambiguous, and formal aspects play a dominant role. There is a tendency for texts in natural sciences to be more influenced by English discourse patterns, i.e., to be more linear and more symmetrical, while in more content-oriented cultures “people are freer to ‘digress’, and ‘digressions’ (excursions) are utilized to broaden the topic of the text, narrowed by the Anglo confines of ‘relevance’”. For instance, historical, ideological and polemic academic issues can be more readily incorporated into a text not specifically dealing with these” [30. P. 73].

Now science texts are represented as a system of nodes and links created in virtual cyberspace. According to Egorova: The hypertext information model, proposed back in the 80s and based on the hypothesis that the processing and generation of ideas by the human brain is associative, is increasingly recognized as a structure for the effective representation and transfer of knowledge. A hypertext system containing a network of nodes (fragments, modules, frames) and the associated links create a multidimensional information space adequate to the deep structure of the ideas processing by the human brain [32. P. 82].

A hypertext goes through the stage of a hypermedia text to become a cybertext. As Aarseth puts it, the concept of a cybertext focuses on the processing of the text, the medium and ‘the user’ of the text. “During the cybertextual process, the user will have effectuated a semiotic sequence, and this selective movement is a work of physical construction that the various concepts of “reading” do not account for” [33. P. 1]. The recipient is active, his/her interaction with the text may be successful or not, and s/he is always at risk like a gambler. The role of the medium is changing as well. New forms of electronic communication change the representation of different structural elements according to their functions. Electronic means of

publishing change the visibility of the whole structure; the recipient may include various nodes in his/her individual path of the text processing. Perception is limited by the size of the screen, on the one hand, but is unlimited in terms of penetrating into distant nodes following the links from the text elements. The text becomes creolized, i.e., verbal and non-verbal elements are united and influence the results of the text evaluation [7; 34; 35].

Popular science texts tend to be more comprehensive, i.e., they include elements bearing social, advertising, expressive, or emotional character reflecting the functions they fulfil. They verbalize the values set by the addresser [36]. Therefore, their non-linear information structure requires an integral approach for the analysis.

Several attempts were made to design a model of the popular science text integrating segments fulfilling different functions. According to Petrushka, the popular science content is “a multicomponent object in its purpose, with oriental and auditorial typological features which organically combine the functions of the scientific, educational, popular information source and, as far as possible, among all other kinds and types of content mediums best represents the processes of convergence” [37. P. 4].

The model based on four sectors (cognitive, linguistic, social and cultural) suggested in Khomutova & Petrov [38] reflects the production, development, perception and functioning of the text on different levels and allows focusing attention on a particular aspect, without losing the integrity of a text as a complex object. In the cognitive sector, the text is analysed as a fragment of knowledge of a certain subject area. And in the social sector, as a fragment of social space. The cultural sector reveals cultural nation-specific values expressed in a particular text. The linguistic sector helps identify linguistic categories and language means conveying knowledge, cultural values and social actions. Communicative activity is a core that unites all four sectors into a single whole, in which all aspects are interdependent and interrelated [39]. So, professional/popular science cybertexts comprise components with different functions related to different sectors, obliging the reader to follow a specific path in processing them.

In suggesting that science and popular science texts might show significant differences in several sectors, it was necessary to find a tool that could help process texts, analysing parameters connected with various fields. Linguistic Inquiry Word Count (LIWC) originally was used in psychometric research and proved to be a valuable instrument due to the following features. First of all, the procedure for dictionary words selection is transparent and demonstrated reliable results in estimating different variables of texts [40–43]. The default systemic LIWC2015 Dictionary consists of approximately 6.400 words, word stems, and emoticons that tap basic emotional and cognitive dimensions often studied in social, health, and personality psychology: numbers, punctuation, short phrases, “netspeak” language from Roget’s Thesaurus, standard English dictionaries and brain-storming sessions among judges. All items have undergone six stages of analysis and further selection:

Judge Rating Phase, Base Rate Analyses, Candidate Word List Generation, Psychometric Evaluation and Refinement Phase [41. P. 5–7] and have been distributed into different categories. The tool allows the analysis of punctuation, grammar, lexical, social, psychological, and emotive parameters (85 variables in total), which have demonstrated their reliability in various aspects of text analysis [44–46].

Summary variables were developed to investigate linguistic, social and psychological processes. They were: “Analytical thinking — a high number reflects formal, logical, and hierarchical thinking; lower numbers reflect more informal, personal, here and now and narrative thinking. Clout — a high number suggests that the author is speaking from the perspective of high expertise and is confident; low Clout numbers suggest a more tentative, humble, even anxious style. Authentic — higher numbers are associated with more honest, personal, and disclosing text; lower numbers suggest a more guarded, distanced form of discourse. Emotional tone — a high number is associated with a more positive, upbeat style; a low number reveals greater anxiety, sadness, or hostility. A number around 50 suggests either a lack of emotionality or different levels of ambivalence.” [46. P. 21–22]. The summary variables facilitate textual analysis of different sectors.

Methodology

The genre of articles was chosen for the research, as articles represent the most frequent type of professional science and popular science texts, demonstrating the core features of each style, covering recent scientific events addressed to wide circles of scientists and general public interested in the subject.

First, 30 open access popular science articles written by science journalists and published in *Scientific American* and *The Scientist* were selected. Those magazines were selected for their interdisciplinary character, the quality of the presented research, the address wide circles of scientists and the principles they pursued. For example, *Scientific American* publishes work by journalists, scientists, scholars, policy makers and people with lived experience of scientific or social issues”². The selected articles met the following criteria: 1) uniformity of the genre (feature article); 2) field of study connected with life sciences (medicine, health, biology, ecology); 3) topic interesting for broad audience.

Each popular science article was based on research, but we also chose open-access evidence-based professional science articles based on similar themes. This restriction on the choice of articles aimed at retaining the field of study and thematic alignment between the professional science and popular science articles. The factors in the selection of articles were as follows: 1) uniformity of the genre (popular or professional science article); 2) coverage of the topic discussed in both

² *Scientific American*. (2023, January 15). *About*. Springer Nature. URL: <https://www.scientificamerican.com/page/about-scientific-american/> (accessed: 15.01.2023).

articles, although in the popular science article in the most general way; 3) length of the article (professional articles should be longer than popular articles).

Five popular science articles out of 30 did not have professional science articles in their reference list which met the above-mentioned criterion of length. So, we had to select two shorter professional science articles for each to keep the length proportion between professional and popular science articles. This procedure provided 30 popular science and 35 professional science articles, matched in the same fields of study.

The number of articles and number of words collected in two corpuses — popular science and professional science articles — allowed undertaking statistical analysis of the data and at the same time considering their compositional and thematic features individually (see Table 1).

Table 1. Characteristics of Popular Science and Professional Science Corpuses

	Popular Science Corpus	Professional Science Corpus	Total
Number of articles	30	35	65
Number of words	86.003	222.559	308.562
Average number of words per one article	2.867	6.359	
Years of Publication	2018–2020	2011–2019	

Source: compiled by Keith Topping, Liudmila A. Egorova, Natalia V. Nikashina, & Ekaterina V. Nagornova.

Compositional peculiarities of articles are usually studied in relation to their connection to different discourses [47], functions of elements [5; 37; 48] and perception [49]. We aimed to consider common structural elements of articles of each corpus to define their functions. On the basis of a conceptual model of medium of popular science content suggested by Petrushka [37], the following functions were regarded as essential for popular science articles: 1) Popularization of research; 2) Creating a network on the topic; 3) Navigating the article; 4) Informing about publication details.

Professional science article components fulfilled a wider set of functions, most of which were related to proving the validity and reliability of the research data and forming a cluster of researchers [48; 50–55]: 1) Informing about the area, background, methodology, results of the research; 2) Giving additional information about the data of the research; 3) Creating the science net on the topic; 4) Informing about the participants of the research; 5) Navigating the article; 6) Informing about publication details; 7) Promoting the author/journal/institution/foundation.

The next stage was connected with the textual compositional analysis of selected articles. The task was to single out the components of multi-modal texts fulfilling different functions common for all analysed popular or professional science articles, to identify the components possessing stylistic distinctive features and suitable for a comparative analysis by means of LIWC2015, Version 1.6.0. The hypothesis was that the principal functions that distinguished the professional and

popular science discourses would be somewhat different, systemically influencing textual features, i.e., in informing about the area, background, methodology, results of the research and popularization of research respectively. Thereafter, statistical analysis might reveal stylistic features specific for each corpus, reflecting the differential formation of popular science and professional science functional styles.

Results

For popular science articles published in online editions, the common elements were: 1) Route to the article from Home Page of the magazine; 2) Headline (with the Hyperlink to the main body of the article); 3) Summary; 4) Author; 5) Date of publication; 6) Information about the author with visuals; 7) Copyright information; 8) Icons of Social Networks; 9) Main Body; 10) Visuals with captions; 11) Hyperlinks to different parts of the article; 12) References (or hyperlinks in the main body) to research data; 13) Keywords (optional); 14) List of references; 15) References to related popular science articles.

The structure of professional science articles was more complicated, determined by the publication requirements of the specific journal though somewhat similar across different journals. It comprised: 1) Route to the article from Home Page of the journal; 2) Headline (with the Hyperlink to the main body of the article); 3) Author(s); 4) Correspondence author; 5) Affiliations of the authors; 6) Information about the author(s) (with hyperlinks to their profiles); 7) Access information; 8) Copyright information; 9) DOI (Digital Object Identifier); 10) Abstract /In Brief /Highlights; 11) Publication history (Dates of submission, reviewing, publication); 12) Keywords; 13) Icons of article tools (save, share, print, figures, request permissions, citation tools etc.); 14) Icons of Social Networks; 15) Main Body (Introduction, Methods, Procedures Results, Discussion, Conclusion); 16) Visuals with captions; 17) Hyperlinks to different parts of the article; 18) References (or hyperlinks) to research data, figures, tables, previous research; 19) Advertisement; 20) Footnotes/Notes; 21) Supplementary material; 22) Acknowledgment; 23) Author Contributions; 24) Declaration of interest; 25) List of References; 26) Appendices.

If specific distinctive features appeared in the latter components as they were specific for each article and fulfilled style-determining functions, we retained only the components connected with the functions ‘popularization of research’ and ‘informing about the area, background, methodology, results of the research’ for the next stage of analysis. Two corpuses of abridged professional science articles and popular science articles were compiled. Each article contained the following components: 1) Headline (with the Hyperlink to the main body of the article); 2) Summary; 3) Author; 4) Main Body; 5) Visuals with captions.

Tables 2 and 3 (below) show the functions of the major components of the popular and professional science articles under analysis. Textual analysis showed that some components contained standard textual or visual elements required by the publisher, and built a frame for the article (Route to the article from Home Page of

the magazine, Headline (with the hyperlink to the main body of the article), Date of publication, Publication history (dates of submission, reviewing, publication); Affiliations of the authors, Copyright information, References (or hyperlinks in the main body) to research data, References, Digital Object Identifier, Access information, Acknowledgment, Author contributions, Declaration of interest, Icons). Others included information peculiar for each article (Author(s), Headline, Summary, Main Body (Introduction, Methods, Procedures Results, Discussion, Conclusion, Visuals with captions).

Table 2. The Basic Functions of Components of Popular Science Articles

Component	Function			
	Popularisation of research	Creating a network on the topic	Navigating the article	Informing about publication details
Route to the article from Home Page of the magazine	–	–	+	+
Headline (with the Hyperlink to the main body of the article)	+	+	+	+
Summary	+	-	–	+
Author	+	+	–	+
Date of publication	–	–	–	+
Information about the author with visuals	–	+	–	+
Copyright information	–	–	–	+
Icons of Social Networks	–	+	–	–
Main Body	+	–	–	–
Visuals with captions	+	–	–	–
Hyperlinks to different parts of the article	–	–	+	–
References (or hyperlinks in the main body) to research data	–	+	–	–
Keywords (optional)	–	+	–	–
List of references	–	+	–	–
References to related popular science articles	–	+	–	–

+ = function present; – = function absent

Source: compiled by Keith Topping, Liudmila A. Egorova, Natalia V. Nikashina, & Ekaterina V. Nagornova.

Each abridged article in the corpora was analysed as independent. All available variables (92 in total) were calculated. The Shapiro-Wilk test was used to check each variable was normally distributed. Then the two corpora were compared using Levene’s test (to check that variances were equal for both samples). Where equal variances and normal distribution were confirmed, an independent t-test was applied. Where equal variances were not confirmed but the distribution

was normal, Welch's t-test was applied. Where the distribution was not normal, the non-parametric Mann-Whitney test was used.

Table 3. The Basic Functions of Components of Professional Science Articles

Component	Function						
	Informing about the area, background, methodology, results of the research	Giving additional information about the data of the research	Creating the science net on the topic	Informing about the participants of the research	Navi-gating the article	Informing about publication details	Promoting the Authors / Journal/ Institution / Foundation
1	2	3	4	5	6	7	8
Route to the article from Home Page of the journal	-	-	-	-	-	+	-
Headline (with the Hyperlink to the main body of the article)	+	-	-	-	+	-	-
Author(s)	+	-	-	+	-	-	+
Correspondence author	-	-	-	-	-	+	-
Affiliations of the authors	-	-	-	-	-	+	+
Information about the author(s) (with hyperlinks to their profiles)	-	-	-	-	-	-	+
Access information	-	-	-	-	-	+	-
Copyright information	-	-	-	-	-	+	-
DOI (Digital Object Identifier)	-	-	-	-	-	+	-
Abstract /In Brief /Highlights	+	-	-	-	-	-	-
Publication history (Dates of submission, reviewing, publication)	-	-	-	-	-	+	-
Keywords	+	-	+	-	-	-	-
Icons of article tools (save, share, print, figures, request permissions, citation tools etc.)	-	-	+	-	-	-	-
Icons of Social Networks	-	-	+	-	-	-	-
Main Body (Introduction, Methods, Procedures Results, Discussion, Conclusion)	+	-	-	-	-	-	-
Visuals with captions	+	-	-	-	-	-	-
Hyperlinks to different parts of the article	-	-	-	-	+	-	-
References (or hyperlinks in the main body) to research data, figures, tables, previous research	+	+	+	-	-	-	-
Advertisement	-	-	-	-	-	-	+

Ending of the Table 3

1	2	3	4	5	6	7	8
Footnotes/Notes	–	+	+	–	–	–	–
Supplementary material	–	+	+	–	–	–	–
Acknowledgment	–	–	–	+	–	–	–
Author Contributions	–	–	–	+	–	–	–
Declaration of interest	–	–	–	+	–	–	–
List of References	–	–	+	–	–	–	–
Appendices	–	+	–	–	–	–	–

+ = function present; – = function absent

Source: compiled by Keith Topping, Liudmila A. Egorova, Natalia V. Nikashina, & Ekaterina V. Nagornova.

The means and medians for each variable are presented in Table 4 (below), which lists statistically significant different variables in the two corpora. A further 27 variables were not significantly different between popular science and professional science. For each group, the total number of variables is also shown, which indicates how many differences in variables were not significant.

Table 4. Significant Variables for Popular and Professional Science Corpora

Category of Variable	Popular science corpus (mean/median)	Science corpus (mean/median)
Summary Language Variables (4)		
Analytical thinking	94,39/95,23	97,07/97,34
Clout	59,88/59,90	54,90/54,86
Authentic	28,04/26,33	17,75/13,31
Language Metrics (3)		
Words/sentence	26,86/27,03	23,48/24,03
Dictionary words	73,74/74,37	58,55/57,45
Linguistic Dimensions (15)		
Total function words	42.59/42.18	33.29/33.19
Total pronouns	6.51/6.49	3.33/3.08
Personal pronouns	2.07/1.98	1.09/0.93
2nd person	0.20/0.17	0.03/0.01
3rd pers singular	0.53/0.44	0.17/0.00
3rd pers plural	0.81/0.72	0.24/0.18
Impersonal pronouns	4.44/4.40	2.23/2.16
Articles	8.19/7.85	6.76/6.47
Prepositions	15.25/15.07	13.62/13.45
Auxiliary verbs	5.67/5.32	4.15/4.11
Common Adverbs	3.27/3.31	1.58/1.45
Conjunctions	5.47/5.52	4.47/4.36
Negations	0.67/0.70	0.47/0.44
Other Grammar (6)		
Common verbs	9.93/9.78	6.37/5.93
Common adjectives	4.94/4.85	3.97/3.76
Comparisons	2.97/3.07	2.17/1.97
Interrogatives	1.26/1.22	0.52/0.47
Numbers	2.11/2.01	7.73/6.79

Continuation of the Table 4		
Category of Variable	Popular science corpus (mean/median)	Science corpus (mean/median)
Quantifiers	2.28/2.37	1.59/1.47
Affective processes (6)		
Affective processes	2.99/2.84	2.12/1.90
Positive emotion	1.56/1.62	1.18/1.01
Negative emotion	1.38/1.05	0.92/0.86
Anger	0,21/0,17	0,09/0,06
Social processes (5)		
Social processes	5.47/5.53	3.06/2.68
Friends	0.23/0.20	0.12/0.03
Male references	0.40/0.31	0.13/0.03
Cognitive processes (7)		
Cognitive processes	11.02/10.69	8.16/8.61
Discrepancy	0.92/0.90	0.38/0.28
Tentative	2.47/2.26	1.45/1.32
Differentiation	2.74/2.81	1.77/1.64
Perceptual processes (4)		
Perceptual processes	2.10/2.01	1.31/1.06
Hear	0.65/0.58	0.09/0.03
Feel	0.32/0.23	0.25/0.14
Biological processes (5)		
Biological processes	4.10/3.96	2.54/2.40
Body	1.42/0.73	0.57/0.38
Drives (6)		
Drives	5.34/5.01	4.42/4.11
Affiliation	1.29/1.25	1.11/0.93
Achievement	1.43/1.41	1.01/0.85
Reward	0.75/0.72	0.56/0.48
Risk	0.58/0.51	0.40/0.37
Time orientations (3)		
Present focus	6.15/5.95	3.34/2.93
Future focus	0.90/0.75	0.53/0.46
Relativity (4)		
Relativity	13.08/12.67	11.26/10.60
Motion	1.73/1.63	1.25/1.03
Space	7.58/7.56	6.78/6.78
Time	3.87/3.67	3.20/2.62
Personal concerns (6)		
Work	3.86/3.75	2.63/2.39
Informal language (6)		
Informal language	0.16/0.14	0.75/0.65
Netspeak	0.05/0.00	0.62/0.56
Nonfluencies	0.06/0.06	0.14/0.10
Punctuation (12)		
Punctuation marks	15.74/15.53	23.58/22.83
Period	3.94/3.82	5.51/5.03
Colon	0.22/0.18	0.37/0.31
Semi-Colon	0.05/0.05	0.45/0.38

Ending of the Table 4

Category of Variable	Popular science corpus (mean/median)	Science corpus (mean/median)
Question mark	0.07/0.04	0.06/0.00
Dash	1.32/1.16	2.95/3.00
Quotation marks	1.59/1.44	0.34/0.16
Apostrophe	1.28/1.28	0.24/0.14
Parentheses	0.63/0.56	5.17/5.17
Other punctuation marks	0.52/0.23	2.57/2.07

Source: compiled by Keith Topping, Liudmila A. Egorova, Natalia V. Nikashina, & Ekaterina V. Nagornova.

All groups contained variables distinguishing Professional Science and Popular Science articles. Ranging the groups according to the percentage of these variables, we can single out ‘Biological processes’ and ‘Personal concerns’ as having less than 50% significant variables. Table 5 shows different groups indicating the percentage of significant variables for each.

Table 5. Statistically Significantly Different Variables between Popular and Professional Science

Name of group of variables	Total number of variables in the group	Number of variables showing statistically significant difference	Percentage of variables showing statistically significant difference, %
Relativity	4	4	100
Other Grammar	6	6	100
Linguistic Dimensions	15	13	87
Punctuation	12	10	83
Drives	6	5	83
Perceptual processes	4	3	75
Summary Language Variables	4	3	75
Language Metrics	3	2	67
Time orientations	3	2	67
Affective processes	6	4	67
Social processes	5	3	60
Cognitive processes	7	4	57
Informal language	6	3	50
Biological processes	5	2	40
Personal concerns	6	1	17
Total	92	65	68

Source: compiled by Keith Topping, Liudmila A. Egorova, Natalia V. Nikashina, & Ekaterina V. Nagornova.

On the whole, articles in the Popular Science Corpus are characterized by longer sentences, lower analytical thinking parameters, higher parameters of authenticity and clout, higher numbers of pronouns, articles, auxiliary verbs, conjunctions and negations. Time orientation words also distinguish two corpuses. Parameters connected with focus on the present/future are twice as high in popular

science articles. Their authors use more words out of the systemic dictionary (see the description in [41. P 5—7]), which belong to different categories and are validated to reflect various psychological/social/cognitive/biological processes and states, as well as words connected with the future. Professional science articles contain more informal words, Internet abbreviations and fillers though they are very rare. As for punctuation marks, the number of these is higher in professional science articles, and colons, semi-colons, parentheses, and dashes are more typical for professional science articles, while quotation marks and apostrophes are more typical for popular science texts.

Discussion

Summary

The obtained results show that professional science and popular science articles, being the core genres of professional science and popular science functional styles, differ in many and indeed most variables reflecting Language metrics, Linguistic dimensions, Perceptual processes, and Punctuation. The articles' structures reflect their multi-level communicative character — elements of all sectors (cognitive, linguistic, social and cultural, according to Khomutova & Petrov [38]) are present and sustain the development of science communication involving audiences of different background. Interdiscursivity and multimodality enhance the properties of the text connected with putting the research into the general context of science communication and facilitating the perception of information. Distinctive features of professional science articles structure (such as Correspondence author; Affiliations of the authors; Information about the author(s) (with hyperlinks to their profiles); Access information; Copyright information; DOI (Digital Object Identifier); Highlights; Publication history (Dates of submission, reviewing, publication); Icons of article tools (save, share, print, figures, request permissions, citation tools etc.); Advertisement; Footnotes/Notes; Supplementary material; Acknowledgment; Author Contributions; Declaration of interest) confirm the validity of results.

Limitations and Strengths

This study chose to focus on science articles rather than other kinds of written science communication. It also chose a limited number of articles, and found difficulty in sourcing the requisite amount in one category. By no means all variables showed significant differences between the two corpuses, but this might have been expected. The LIWC methodology gives a means of analysing texts which might be useful for multiple purposes.

Relationship to Previous Literature

The articles are also built into the net of similar research creating a net of publications, which supports the trends in the development of digital science

communication (see [3; 9; 10]. Analysis of abridged versions of articles showed that such structural elements, as ‘Headline (with the Hyperlink to the main body of the article)’; ‘Summary’; ‘Author’; ‘Main Body’; ‘Visuals with captions’ distinguished professional and popular science articles, irrespective of the theme of research.

A popular science article is supposed to be persuasive and emotional, oriented on social processes, and focused on the present. Its addressee is a non-specialist, so the text should be easy to understand, interesting for the reader, emotional and coherent. The language used reflects this communicative intention. The LIWC analysis allowed defining the specific percentage of dictionary (non-terminological) words, time orientation and functional words, and different punctuation marks for popular science articles. Variables associated with social and psychological processes revealed the inner characteristics of popular science texts as more affective, evaluative (positive or negative), and tentative in comparison with science texts.

As for Linguistic dimensions, the corpora differed in the proportion of pronouns, articles, prepositions, auxiliary verbs, conjunctions and negations they contained. Functional words played a significant role among interactive meta-discourse markers that organized, signposted and facilitated processing the text in general. Recent studies proved their significance for science articles (e.g., [56]). Psychological studies (e.g., [40]) proved their correlation with the interest in objects and things (indefinite articles), education, concern with precision (prepositions), and inhibition (negations). Popular science articles demonstrated a more developed system of connectors and substitutive words rather typical for journalistic and newspaper texts in contrast with professional science texts, with their uniformity, repetitions of nouns, rigid inner structure, and precise information presentation.

Popular science is addressed to non-specialists, so the texts are less terminologically charged, they contain more paraphrases, explicatory constructions, and comparisons. Quantifiers are preferred to numerals, and comparisons and evaluations to neutral factual presentation of data. That accounts for longer sentences, and a larger number of LIWC systemic dictionary words (words of high frequency describing processes) in popular science articles in contrast to professional science articles full of terms which are usually of lower frequency and do not constitute part of the LIWC dictionary.

Time orientation words also distinguished the two corpora. Parameters connected with a focus on the future were almost twice as high in popular science articles. Popular science articles tended to render scientific information as the content of a story developing along a timeline, so they contained more references to the past, present, and future in general. However, the main objective of a popular science discourse was to attract the audience to urgent scientific news and events, which were usually associated with the changes in the future of mankind. Therefore, the number of verbs in future tenses and adverbial modifiers referring to the future was higher in popular science articles.

Professional science articles contain more punctuation marks, especially colons and semi-colons. However, popular science articles are characterized by a larger number of quotation marks and apostrophes. The usage of graphical means to structure the text reveals their significance in making scientific text coherent, with a more explicit hierarchy of principal and minor non-essential components. Popular science articles also use other means of cohesion, and the results are close to expressive writing [41].

Interpretation

If we compare the results of popular science and professional science articles using LIWC analysis based on different types of texts (novels, expressive writing, natural speech, newspaper articles, blogs, tweeter) [41], we see that science communication texts represent a peculiar type of writing with specific parameters. Popular science articles (Pop) are closer to the New York Times corpus than professional science articles (Pro) in variables reflecting the pragmatic aspect of communication, for example, total number of functional words (NY Times 42.39 — Pop 42.59 — Pro 33.29), common verbs (NY Times 10.23 — Pop 9.93 — Pro 6.37), affective processes (NY Times 3.82 — Pop 2.99 — Pro 2.12), social processes (NY Times 7.62 — Pop 5.47 — Pro 3.07), and time orientation future focus (NY Times 0.80 — Pop 0.90 — Pro 0.53). These features reflect the specifics of journalistic texts addressed at ordinary non-specialist people. These facts are presented from the point of view of their importance for the everyday life of the readers, and benefits they may derive from them. A certain information redundancy is created to facilitate the perception of the journalistic text and maintain the interest of the reader. However, the data obtained show significance differences between them and popular science articles in terms of emotional tone ((NY Times 43.61 — Pop 32.47), and past focus (NY Times 4.09 — Pop 2.84). The LIWC analysis shows popular science texts as a separate entity, with specific language features reflecting the stage of developing a popular science functional style on the periphery of science and journalistic styles.

So, LIWC analysis can be applied not only to individual corpuses to measure textual specifics conditioned by individual or situational peculiarities, but also to distinguish corpuses of texts belonging to different functional styles. LIWC dimensions cover important aspects of textual features significant for the differentiation of these styles. The differences between science and popular science articles are relevant in terms of information structure, degree of formality and evaluation, means of cohesion, and time orientation. The LIWC analysis reveals the language features that reflect pragmatic components of the text meaning, such as the relations between members of communication, their characteristics, their attitude to the subject of communication, and their involvement in the process of communication.

The fact that most LIWC variables show statistically significant differences between science and popular science articles demonstrates their complex character,

and proves the formation of a popular science functional style as an independent entity with its own system of language means, selection and combination. The model of science/popular science cybertext helped to distinguish the components of electronic hypertexts fulfilling different functions and compare the compositions of science and popular science articles as core genres of contemporary science and popular science discourses.

Practical Implications & Future Research

Using LIWC can help attribute a text as a scientific or popular science text, which could be important in big data analysis. Another useful application for educational purposes would be to evaluate students' essays as belonging or not to a professional science style, and to show the students the features that are to be changed. At the present stage the following procedure might be suggested to assess the stylistic features of a science article: 1) Abridge the text, so that it includes Headline, Summary, Author, Main Body, Visuals with captions; 2) Using LIWC variables, check the number of words in a sentence, number of pronouns, articles, auxiliary verbs, conjunctions, negations and punctuation marks. Attribute the text to professional or popular science style on the basis of the results obtained.

This procedure could also be used to assess ease of comprehension, which is supposed to be greater in popular science articles. However, further research based on a bigger corpus of professional and popular science texts would be necessary to determine the parameters influencing the perception of different elements. Also, revealing genre specifics of articles in contrast with reviews/monographs/news items/headlines/abstracts, as well as comparing the results for different languages, might be beneficial both for educational purposes and discourse studies.

Conclusions

The development of mass communication led to the differentiation of a system of functional styles. Substyles are transformed into separate entities with their own peculiarities on all language levels, so the texts acquire specific features in terms of cognitive, linguistic, social and cultural aspects, or 'sectors'. This research examined language features which were statistically significant to distinguish professional and popular science articles as core genres of professional and popular science functional styles, thereby adding weight to this tendency.

The numerical method of analysis facilitated identification of the features statistically significant for distinguishing popular and professional science styles and defining their role in text formation. Word counting methods were reliable in identifying distinctive stylistic features, as they singled out different groups of words (functional words, time orientation words, informal words, words connected with psychological/biological/affective/cognitive processes), punctuation marks, number of words in a sentence (which reflected a sentence structure), the level of formality and means of cohesion typical for the chosen material. It has been shown

that language features that appeared due to the functions of textual elements, information structure, and audience characteristics formed a stable system of language means specific for popular science texts in the field of life sciences.

The findings may contribute to educational practices related to teaching English for Academic Purposes, as they showed the importance of identifying structural elements, usage of functional elements and punctuation marks to build up a coherent science text, which could properly fulfil its functions. Using computing tools may be beneficial for the preliminary assessment of academic texts in terms of their consistency with stylistic requirements.

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