The Construction of Medical Knowledge: A Semantic Taxonomy of Processes

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Doi: 10.19044/llc.v9no3a1 URL:http://dx.doi.org/10.19044/llc.v9no3a1

Submitted: 04 July 2022
Accepted: 01 November 2022
Published: 30 September 2022

Abstract

The semiotic reality of medical discourse is linguistically organised into *figures* arranged in the grammar of the clause. Each clause is comprised of entities and processes in various relationships to each other. The writers of medical texts represent and bestow meaning on their experience of the world by choosing from among a selection of different types of *figures*: of happening, sensing, doing, being, having, and saying. Processes play a central role in *figures* since they provide their own models for construing the experiential content and organising the information flow of medical texts. The rich architecture of Systemic Functional Linguistics can provide the theoretical background and analytical tools for a thorough investigation of the linguistic selections made by medical writers to convey clinical knowledge. Considering this key role, the present paper aims at investigating the most frequent verbs used as processes in a corpus of medical research articles. The study reveals that the most recurrent verbs used as processes in this type of textual configuration share semantic features. This makes it possible to propose a taxonomic approach to processes with a view to studying their grammatical configuration and the discourse functions they serve.

Keywords: medical discourse, experiential content, semantic taxonomy, processes

Introduction

This paper is part of a broader project aimed at investigating the construction and dissemination of knowledge within the sphere of healthcare provision. The focus here is on how medical researchers organise and represent their clinical experiences when writing them up for publication in specialised medical journals.

As Halliday and Matthiessen claimed, "All knowledge is constituted in semiotic systems, with language as the most central; and all such representations of knowledge are constructed from language in the first place. (Hence when we consider the knowledge enshrined in a particular discipline, we understand this

by examining the language of the discipline – the particular ways of meaning that it has evolved […])" (1999, p.3). Therefore, the semiotics of medical texts relies heavily on the linguistic structures physicians employ to construe their collective and individual experiences as evidence used to respond to clinical questions. Typically, the information flow of these texts is arranged in *figures* sorted out in the resources of the lexicogrammar. They are fragments of experience which create a network of preferential semantic relationships operating at different ranking levels: the clause, the group/phrase, and the clause complex. The focus here is on the clause which, in Systemic Functional Linguistics, encodes the experiential metafunction. In keeping with the study of Halliday and Matthiessen (1999, p.213), "The central element of a figure is the process; 'things' are construed as entities participating in processes, having different roles, of which one is 'that participant in which the process is actualized'". This key role is also underlined by Thompson (2004, p.87), when he explains that "Processes are the cores of the clause from the experiential perspective: the clause is primarily 'about' the event or state that the participants are involved in".[1]

When we look at the grammar of the clauses occurring in articles published in medical journals, we cannot but notice the high incidence of relational clauses, something which seems to confirm Halliday's (1998, p.193) claim that the relational is the process-type favoured by science. Relational processes appear to be a favourite lexico-grammatical resource employed by medical writers to organise and convey evidence-based knowledge. Furthermore, in line with the "cognitive shift" which has underlined the conceptual networks underlying the representation of specialised knowledge (Faber, 2009; 2012; Gil-Berrozpe *et al.*, 2018), the selection of these processes seems to "activate domain-specific semantic frames that are in consonance with the users' specialized knowledge" (Faber, 2015, p.15). In keeping with Evans, a *frame* is "a schematisation of experience (a knowledge structure), which is represented at the conceptual level and held in long-term memory and which relates elements and entities associated with a particular culturally embedded scene, situation or event from human experience" (2007, p.85). Semantic frames allow medical researchers to attribute significance to their clinical experiences and convert them into meaningful, transmissible knowledge.

Therefore, the aim of this paper is twofold. The investigation of a corpus of authentic texts presented here seeks to provide a picture of how the most frequently used relational processes are configured at clause-level. Furthermore, given the fact that the verbs used as processes share some semantic features, a taxonomic approach will be proposed to explore how these relational constructs can provide cognitive structuring devices for the organisation of medical knowledge.

[1]In a clause, the process is typically realised by the verbal group. In this study, the focus is on the process from the experiential perspective. This means that the interpersonal elements of verbal groups associated with tense (past, present, or future), modality (can, could, etc.), and polarity (positive/negative) are ignored.

Theoretical Framework and Methodology

As many scholars (Gilbert & Mulkay 1984; Latour & Woolgar, 1979; Hyland, 1998) claimed, the research article represents a rhetorical "artefact" that seeks to construct knowledge and persuade readers to accept the validity of the claims made by the writers. The rich architecture of Systemic Functional Linguistics can provide the theoretical background for a thorough investigation of the linguistic selections made by medical writers to convey clinical knowledge. According to Halliday (2003), language is functional in that it is a meaning-making resource used to achieve some desired results. Simultaneously, it fulfils three major meta-functions: ideational, interpersonal, and textual. These three levels of meaning are mapped onto the lexico-grammatical structure of a clause. It is through the ideational function that a writer embodies his/her experience of the phenomena of the world in language. The system of choices in and by which writers realize ideational meanings is Transitivity, that is "the ideational grammar of the clause where the semantics of *figures* is construed" (Halliday & Matthiessen, 1999, p.134). The ideational function includes two sub-functions: the experiential function, which encodes our "experience of the world", and the logical function, which weaves all these experiences. Therefore, text writers represent and bestow meaning on their experience of the world by choosing from among a selection of different types of *figures*: of happening, sensing, doing, being, having, and saying. An experiential configuration of meaning relates a process to one or more participants and frames this relationship circumstantially.

As stated above, the focus of this paper is on clauses grounded in relational processes selected frequently by medical writers to construct their knowledge based on proof which, according to the Evidence-Based paradigm introduced by Sackett (1996),[2] is organized around the PICO model (Table 1): Patient/Problem, Intervention, Comparator, and Outcome (see Mocini, 2020).[3]

Table 1. The PICO elements

P	**I**	**C**	**O**
Population/Patient Problem	Intervention or Exposure	Comparator	Outcome
Who are the Patients? What is the Problem?	What is the main intervention being considered? What is the population exposed to?	What are the gold standards, or the alternative benchmarks being considered, if any?	What is the end result of interest?

All the examples discussed in the present paper are taken from a corpus

[2]As the name suggests, evidence-based medicine (EBM) is an approach which aims at finding evidence to make clinical decisions. David Sackett is considered the father of EBM. He referred to essentially qualitative evidence-based approaches to medical investigation and treatment defined as "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett *et al*., 1996, p.71).

[3]For reasons of clarity, here and elsewhere, the PICO elements are capitalised.

still in the making drawn from prestigious medical journals available on the PubMed database[4] and dealing with different randomly chosen topics[5] (Table 2).

Table 2. Examples of topics dealt with in some of the journal articles included in the corpus

TOPICS	**JOURNALS**
Syndrome presenting in adolescence	Case Reports in Genetics
Obesity	Journal of the American Association of Nurse Practitioners
Primary glioblastoma	Molecular Neurobiology
Psoriasis	Clinical and Experimental Dermatology
Basal cell carcinoma	British Journal of Dermatology
Nonalcoholic fatty liver disease	Clinical and Translational Gastroenterology
Lyme disease	BMJ Open
Dietary factors and prostate cancer risk	Clinical Nursing Research
DLBCL	Blood Advances
Free online weight loss programme	BMC Public Health
Invasive placebo interventions	British Journal of Surgery.
Metabolic syndrome and risk of cancer	BMJ Open
Vitamin D treatment and stones formation in the urinary tract	Nutrients
Inflammation and fibrosis in chronic liver diseases	World Journal of Gastroenterology
Vitamin d deficiency and risk from COVID-19	Journal of Clinical Endocrinology & Metabolism
Adjuvant chemotherapy in patients with stage iii colorectal cancer	Journal of Pathology: Clinical Research

To study the semantics of the most frequent relational processes, reference is made to the ISO Standard 704 (2000),[6] by adopting a tripartite classification into generic, partitive, and associative relations.

The *WordSmith Tool* 6.0 software (Scott 2012) was used to find the verbs used as relational processes that recurred most frequently in the corpus. In particular, the most frequent lemmatized verbs acting as processes dealt with in this study were retrieved by means of the software's *Wordlist* function The

[4]The PubMed database contains more than 34 million citations and abstracts of biomedical literature. Links to the full text are often present when available from other sources, such as the publisher's website or PubMed Central (https://pubmed.ncbi.nlm.nih.gov/about/).

[5]The corpus is still in progress and, at the time of writing, covers a span ranging from 2016 up to now.

[6]The ISO Standard 704 "establishes the basic principles and methods for preparing and compiling terminologies both inside and outside the framework of standardization, and describes the links between objects, concepts, and their terminological representations. It also establishes general principles governing the formation of designations and the formulation of definitions" (https://en.wikipedia.org/wiki/ISO_704).

details of the corpus are provided in Table 3 below:

Table 3. Details of the corpus

Tokens	2,284,246
Types	50,092
Types/Token Ratio	2.29
Number of files	582

Results

Relational clauses set up a relationship of "being" between two inherent participants. Unlike material processes, the verbs that are used in this kind of clause do not encode action meanings but meanings of "being". When medical writers select a relational verb, they intend to define and classify entities, by assigning them a quality or an identity. Two different types of relational processes are therefore possible: attributive and identifying. While the former sets up an *x-has-y* relationship, the latter constructs an $x = y$ relationship.

(1) Pallister-Hall syndrome (PHS) is an extremely rare syndrome (Mahtabfar *et al*., 2019).

(2) Almost 75% of patients had a BMI corresponding to overweight or obese, and 74.5% had a waist grade of increased or substantially increased risk (Mahtabfar *et al*., 2017).

(3) Glioblastoma multiforme (GBM) is the most aggressive and common primary central nervous system tumour (Prasad *et al*., 2020).

In (1), the Pallister-Hall syndrome is qualified as *rare*, while in (2), groups of patients are attributed a different quality each (one a certain BMI, the other a certain risk grade). Instead, in (3), an entity (GMB) is identified in terms of another (*the most aggressive…system tumour*). Only identifying clauses are reversible (both $x = y$ and $y = x$). Therefore, while *The most aggressive and common primary central nervous system tumour is GBM* is an acceptable agnate variant, a sentence like *Rare is full recovery from untreated chronic fatigue syndrome* would sound unnatural. As Thompson points out, "in certain context, the Attribute may come first, but this typically sounds slightly unusual or unmannered" (2004, p.97).

Since relational clauses rotate around "processes of being and having" (Halliday & Matthiessen, 2004; 2004), it is no surprise that *be* and *have* are widely used. However, other verbs are employed by medical writers to construe clinical knowledge, interpret evidence or illustrate the outcomes that were hoped for and achieved or not. In short, the PICO elements are frequently expressed relationally through a set of verbs acting as processes. These verbs can occur either in the attributive or identifying mode. In the former case, we have an

attributive clause where the two participants are Carrier and Attribute,[7] while in the latter case, we have an identifying clause with Token and Value as participants. Occurrences of the most frequent lemmatised verbs acting as Process in these two types of clauses are displayed in Table 4 below:

Table 4. Occurrences of the most frequent lemmatized verbs acting as relational processes

include**	5444	result in***	767
show*	3924	match***	620
associate***	3672	contain**	438
follow***	3396	concern***	412
suggest*	1817	correspond***	408
cause***	1419	reflect***	393
need**	1118	consist**	303
lead to***	1017	represent*	266
remain*	993	depend***	191
indicate*	918	comprise**	137

Discussion

Since relational verbs share the fact that they link concepts, a 'delicate' analysis of these verbs can be better pursued if they are categorised according to the type of semantic relationship they establish. The taxonomic criterium adopted is indebted to the categories used by ISO Standard 704 (2000), which envisages a tripartite classification: specific-generic, partitive, and associative.

First Group: Generic-Specific Relationships

The semantic relationship construed by the verbs included in this group (see verbs with one asterisk in Table 2 above) is mainly hyponymic, expressed in the form of "a kind of", "an instance of", "a symbol of". A hyponymic relationship can be also conceived in terms of class/type membership:

(4) Psoriasis remains one of the commonest conditions seen in dermatological practice, and its treatment is one of the greatest cost burdens for the UK National Health Service (Smith *et al*., 2020).

Here the health Problem[8] is construed using the verb *remain* which creates a semantic relationship between psoriasis and the class to which it belongs (*commonest* dermatologic *conditions*). The same goes for its treatment that belongs to the class including treatments, which represents *the greatest cost burdens for the UK National Health Service*. The two clauses in (4) are both attributive since the participants acting as Carriers do not exhaust the class. For example, there are other common conditions in dermatological practice and Psoriasis is just one instance of them.

Conversely, in (5) below, the verb *represent* establishes a hyponymic

[7]Functional labels are traditionally capitalised.
[8]Henceforth, referring to any of the PICO elements, capital letters will be used.

identifying relationship since BCC is assigned an identity:

(5) Basal cell carcinoma (BCC) represents the most common nonmelanoma skin cancer worldwide, affecting mainly adult, fair-skinned individuals (Morton *et al*., 2018).

Here, one entity *x* acting as Token is identified by *y* acting as Value, where *y* refers to the general category or class to which *x* belongs. In fact, following Langacker (1989, p.2), the instantiation model can also be applied to identifying clauses since they convey the implicature that, for a given entity, the instantiation does exhaust the whole class. The sentence in (5), for example, implies that at world level, besides BBC, no other equally common skin cancers affecting mainly adult and fair-skinned individuals exist. As shown, Token and Value enter into a relationship of identification, with the latter establishing the identity of the former.

Both (4) and (5) above illustrate the use of relational clauses in the construction of medical knowledge, by qualifying and identifying the health problem investigated. As Halliday and Matthiessen pointed out (214), class-membership and identity are abstract relationships. In fact, the two entities involved are not related materially but semiotically as members of a class. The identifying mode of this category of verbs tends to dominate when medical writers report their results and assess the effects, both positive and negative, of an intervention or treatment. In similar cases, the selection of processes that create a generic-specific relationship is justified on the grounds that "the meanings that are being construed are inherently symbolic ones" (Halliday & Matthiessen, 2004, p.234).

Examples (6) and (7) below illustrate how medical researchers construe the Outcome of their research, exploiting the Token-Value structure (indicated in square brackets):

(6) Importantly, [Token/Identified] our study findings suggest [Value/Identifier] that short sleep duration could be a risk factor for lean NAFLD because we also know that short sleep duration is associated with an increased risk of NAFLD in nonobese subjects (Um *et al*., 2021).

(7) [Token/Identified] Sensitivity analyses indicated [Value/Identifier] that allowing a time window of ±30 days for the antibiotic prescription around the date of coding of a laboratory test would have increased the number of cases by 13.9% (Cairns *et al*., 2019).

Second Group: Partitive Relationships

The semantic relationship partitive verbs construe occurs in the form of "x is part of y", "x has parts a, b, and c". Partitive relations refer to part/whole or whole/part relationships. All these verbs (see verbs with two asterisks in Table 2 above) are agnate with the possessive verb *have*, but possession is meant "in a broader, more generalized sense – possession of body parts and other part-whole

relations, containment, involvement, and the like […]. Possession thus has to be interpreted quite broadly, in the sense of 'extension': one entity being extended by another" (Halliday & Matthiessen, 2004, p.244-245). These 'extensive' verbs can be used to describe the population sample, or the Patients involved in a study (8), or when referring to the composition of the arms of a trial (9):

(8) The sample included 165 prostate cancer patients in the case group and 177 healthy participants in the control group (Al Qadire *et al*., 2019).

(9) The R-CHOP[9] arm contained more patients with unfavorable factors, stage IV disease (25.8% vs 20.7%), and IPI HI/H risk (23% vs 12.5%) (Ohmachi *et al*., 2021).

Both (8) and (9) are possessive attributed clauses. The "possessor", that is, *The sample* in (8) and *The R-CHOP arm* in (9), acts as Carrier and represents the "whole" in the partitive relationship the two possessive processes construe. What is "possessed" acts as Attribute and is represented by the different parts into which each Carrier is subdivided. The same semantic relationship can also be established when reference is made to the Intervention (10) or the Comparator (11):

(10) The 12-week HWP intervention consisted of ten nutrition coaching sessions and 20 exercise sessions (Innes *et al*., 2019).

(11) In accordance with the review of Wartolowska and colleagues, placebo interventions included surgical placebo, sham surgery, or any intervention intended to mimic the active intervention (Cousins *et al*., 2020).

The verbs belonging to this group can also construe a relationship of identity, especially when glossing technical names.

(12) Metabolic syndrome (MS) consists of the clustering of various cardiometabolic risk factors such as obesity (Puente *et al*., 2019).

Here, the "whole" (MS) functions as Token/Identified, while the various clustering cardiometabolic risk factors assign a Value to the Token and act as Identifier.

Third Group: Associative Relationships

Associative relationships refer to any kind of non-hierarchical relationship, of cause, time, reason, etc. This group (see verbs with three asterisks in Table 2 above) includes verbs that are agnate with the verb *be* + a

[9]Rituximab plus cyclophosphamide-doxorubicin-vincristine-prednisone (R-CHOP) is the standard of care for untreated diffuse large B-cell lymphoma (DLBCL).

circumstantial element, of time, cause, place, etc. Rather than being realized congruently by a prepositional phrase, circumstantial meaning is encoded in the Process. As shown in the examples, these processes can be employed to draw conclusions by examining the effects of a therapy following an Intervention or to refer to the Outcome of a study measured either through laboratory tests or medical examination:

(13) Supplementation with vitamin D caused a statistically significant increase in the concentration of 25(OH)D in serum (Milart *et al*., 2020).

(14) Thereafter, the development of both lipotoxicity and steatohepatitis is followed by HSC activation which results in ongoing fibrogenesis (Tanwar *et al*., 2020).

(15) Vitamin D deficiency is associated with higher risk of COVID-19 hospitalization (Jude *et al*., 2021).

(16) In 1343 SCOT trial patients, the effect of treatment type significantly depended on phenotypic subtype ($p_{interaction}$= 0.011) (Rosevir *et al*., 2020).

In (12), the verb *cause* can be paraphrased as "be + causal: reason", while in (13) 'follow" as "be + extent in time", in (14) "associate" as "be + accompaniment/causal: reason", "depend on" as "be + causal: condition". As Halliday and Matthiessen pointed out, for this type of clause, "the line between the 'attributive' and 'identifying' modes is less clear" (2004, p.243). Some help to disambiguate them can come from their reversibility. Clauses are categorized as identifying when "they have passive forms and are thus reversible" (Thompson, 2004, p.123). Accordingly, (12), (13), and (14) above can be classified as identifying. Conversely, (15) is not reversible and, as such, can be interpreted as an attributive circumstantial clause. Table 2 below provides an illustrative analysis of the circumstantial clauses revolving around "associative" verbs acting as Process.

Conclusion

We have analysed some of the lexico-grammatical choices made within the domain of the clause by medical writers who wish to share their clinical experiences with the healthcare-provision community. Focusing on the process as the main constituent of the clause, the quantitative analysis based on a corpus of journal articles carried out has shown that some verbs are frequently employed as processes that establish semantic relationships between their inherent participants. According to the nature of the semantic relation that a verb establishes, a taxonomy has been proposed whereby each category appears to match the tenets of medical knowledge conceptualized within the PICO framework. The selection of processes seems to activate a set of domain-specific semantic frames in line with the writers' specialised knowledge, a modelling mechanism conceived as a "mental template that individuals impose on an

information environment to give it form and meaning" (Walsh, 1995, p.281). Seeing the repetitive modality that characterises specialized medical discourse, the structural configurations summoned by frequently employed relational verbs act as cognitive structuring devices through which the experiential content informing medical knowledge is construed, communicated, and more easily shared by the members of the medical discourse community. As Faber puts it, "the best way to study specialized knowledge units is by studying their behavior in texts. Since the general function of specialized language texts is the transmission of knowledge, such texts tend to conform to templates in order to facilitate understanding. […]. Each knowledge area thus has its own event template" (2009, p.120).

This article does not contain any studies with human participants performed by any of the authors.

This article does not contain any studies with animals performed by any of the authors.

Conflicts of interest.

The author of this paper certifies that he has NO affiliations with or involvement in any organization or entity with any financial or non-financial interest (such as honoraria; educational grants; membership, employment; affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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