ASp
la revue du GERAS

80 | 2021
Varia

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Electronic version
URL: https://journals.openedition.org/asp/7397
DOI: 10.4000/asp.7397
ISSN: 2108-6354

Publisher
Groupe d'étude et de recherche en anglais de spécialité

Printed version
Date of publication: 1 November 2021
Number of pages: 5-20
ISSN: 1246-8185

Electronic reference
David Banks, "Encoding processes in five physical sciences research articles: A systemic functional perspective", *ASp* [Online], 80 | 2021, Online since 01 November 2022, connection on 05 December 2022. URL: http://journals.openedition.org/asp/7397 ; DOI: https://doi.org/10.4000/asp.7397

Encoding processes in five physical sciences research articles: A systemic functional perspective

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1. Introduction

1 Processes are events or states and are typically encoded in language by finite verbal groups[1].

> (1) As scouring **proceeds** during high flows, plant roots **are** gradually **exposed**, mechanical anchoring **decreases** until it **balances** flow drag and then uprooting **occurs**. (Perona)[2]

2 In (1) there are five such finite verbs: "proceeds", "are (...) exposed", "decreases", "balances", and "occurs", all encoding processes. However, finite verbs are not the only means of encoding processes; this can also be done by using non-finite verb forms, and nominalized processes. Non-finite verb forms include participles and gerundives, which can function as adjuncts or as (pre- or post-) modifiers within nominal groups.

> (2) **Compared** with the ones **depicted** in figure 9, the **resulting** reservoir levels herein are better constrained due to the **increased** allowable water storage capacity. (Zhao)

3 In (2), "compared" is the verb of a circumstantial non-finite clause, "depicted" is the verb of a reduced relative clause post-modifying "ones", and "resulting" and "increased" function as pre-modifiers.

> (3) Material **comprising** mixtures of diverse particles, inclusions, defects or inhomogeneities **dispersed** inside a background medium arise in a wide range of applications, **including** composite materials, emulsions, gases, polymers, foods and paints. (Gower)

4 In (3) there are three non-finite verb forms: "comprising" and "including" are the verbs of participial clauses which post-modify the nouns "material" and "applications" respectively; the past participle "dispersed" is the verb of a reduced relative clause post-modifying the complex nominal group "diverse particles, inclusions, defects or inhomogeneities".

> (4) The **upscaled** equations agree with the **underlying** pore scale equations within less than 7% error. (Cooper)

5 In (4) the past participle "upscaled", and the present participle "underlying" function as pre-modifiers of the nominal groups "equations" and "pore scale equations" respectively. Non-finite verb forms also include infinitives like "to analyse" in (5).

> (5) In order **to analyse** the effects of the global Lewis number Le on individual flow topologies the chemical mechanism in this analysis is simplified by a single-step Arrhenius-type chemical reaction following several previous analyses. (Wacks)

6 Nominalized processes occur when a process is encoded in nominal form. In the vast majority of cases the language will have a cognate verb, though this is not absolutely essential; the language may simply lack the corresponding verb. The essential criterion is that the term does not encode an entity, but a process. It may be possible to distinguish between event nouns and nominalized processes, but an event noun can be seen as a process in nominal form and, for the purposes of this study, event nouns will be classed as nominalized processes.

> (6) To do this we have extended the **derivation** of Daly & Roose [8] by developing a pore scale **description** of exuding **diffusion**, which we have coupled to a two fluid model for water **movement**. (Cooper)

7 In (6) there are four examples of nominalized processes: "derivation", "description", "diffusion" and "movement". These four examples all function as heads of their respective nominal groups. It is also possible for nominalized processes to function in modifying position; this was rare in the scientific research article prior to the turn of the twentieth century, but it has been gathering speed throughout the century (Banks 2003, 2008) and is now quite common.

> (7) The establishment of seedlings is controlled by a **selection** mechanism where uprooting often occurs with a single **flood** event. (Perona)

8 In (7), there are five nominalized processes: "establishment", "selection", "uprooting", "flood" and "event". Of these, "selection" and "flood" function as modifiers. It will be noted that the head of a nominal group which includes a nominalized process functioning as modifier, is not necessarily itself a nominalized process, as is the case here in "a selection mechanism".

9 The object of this paper is to look at the incidence of these three different ways of encoding processes (finite verbs, non-finite verb forms, and nominalized processes) in a small sample of research articles from the field of the physical sciences. I shall consider the possibility that certain process types correlate with ways of encoding processes. Previous studies of verb forms in scientific writing have concentrated on finite verbs and have usually been concerned with questions of form. The most obvious example of this is the use of the passive in scientific writing on which there is a vast literature (Turner1972; Tarone *et al.* 1981, 1998; Ding 2002; Rodman 1981; Seoane & Loureiro-Porto 2005; Seoane 2006; Leong Ping 2014; Banks 2017). Consideration of to-infinitives is much rarer, though a few studies of infinitives in academic writing do exist (e.g., Salager 198; Kozáčikova 2015). The nominalization of processes has also received

considerable attention, and in this case function as well as form has come into play, particularly within the framework of systemic functional linguistics. Halliday (1987, 1988, 1998, 2004) considers the nominalization of processes to be a type of grammatical metaphor, that is, the use of a non-congruent grammatical form. This means that the process can take on the grammatical functions of a noun (i.e. subject, complement, prepositional completive), and that, semantically, it attracts the features of solidity and permanence normally associated with an entity. However, to the best of my knowledge, the question of the relative weight of the different ways of encoding processes, and their relationship with different process types, is not one which has yet been addressed.

2. Sample and theoretical framework

10 For the purposes of this study I have looked at a random selection of five articles in the area of the physical sciences. They are all taken from *Proceedings of the Royal Society A* for the year 2018. Details are given in Appendix A. The five articles have a total of 18 co-authors, ranging from two to six per article. Eleven of the 18 authors have typically Anglophone names. The 18 co-authors give a total of ten institutional addresses, of which 9 are situated in the UK. It is true that one of the articles occasionally included some language which would have been non-standard in my native variety, but which was obviously considered acceptable in a highly respected scientific journal. Throughout this paper, each of these articles will be identified by its first-named author. In these days of computerized analysis, a sample of five articles seems exceedingly small. However, the form in which these articles are available is not immediately amenable to automatized analysis, and there is, as yet, no software for the analyses which I wish to carry out. This paper should therefore be considered more as a set of case studies than a simulacrum of a corpus study.

11 The general theoretical background and in particular the categorization of process types which I shall use is derived from systemic functional linguistics (Halliday 2014; Banks 2019). Within the range of possible interpretations of process types available (O'Donnell *et al.* 2008), I shall take a conceptual stance. I distinguish five basic process types, namely, material, mental, relational, verbal and existential. Material processes are physical events or actions, as in (8).

> (8) Recently, strict pollution control regulations **have increased** the need for low-emission premixed combustion, in which the reactants **are** homogeneously **mixed** prior to combustion. (Wacks)

12 Mental processes are events of a cerebral nature, as in (9).

> (9) In this section, we **consider** a selection of numerical examples to demonstrate the efficacy of (5.10) and other expressions. (Gower).

13 Relational processes link two entities, or an entity with one of its characteristics, as in (10).

> (10) The pilot area **is** a water distribution zone situated in the rural area of the west coast of North Wales. (Zhao)

14 Verbal processes are communicative events, as in (11).

> (11) More recent research **has observed** that these surface active chemicals alter fluid properties at the root-soil interface considerably. (Cooper)

15 Existential processes are statements of existence, as in (12).

(12) To our knowledge no complete dataset **exists** in the literature other than that concerning *Avenasativa*, as recently presented by [28].

16 I do not use the category of behavioural process mentioned in many presentations of systemic functional linguistics. The reasons for this are explained in Banks (2016).

17 For this register (research articles in the physical sciences), the category of mental process requires further elaboration. Traditionally, mental process has been subdivided into cognitive, perception and affective subtypes. To this some would add a desiderative type (Thompson 2004). Cognitive processes are "thinking" activities, as in (13).

(13) Here we **consider** an emulsion composed of hexadecane (oil) and glycerol in water, table 2, where the glycerol forms very small inclusions. (Gower).

18 Perception processes are, naturally, events of perception, as in (14).

(14) It **can be seen** from figure 7 that the behaviour of the distributions of the local flow topologies is very much dependent on the Lewis number. (Wacks).

19 Affective processes are processes of "liking" and "disliking". There are no examples of this in my five sample articles. Desiderative processes are processes of "desiring", as in (15).

(15) If we **wanted** to consider diffusion of solutes, which did not directly influence the properties of water, then setting [mathematical expression] and [mathematical expression] would provide a partially coupled set of equations describing the movement of air and water, from which the diffusion of solutes, which do not bind to the soil particle surfaces, could be calculated. (Cooper).

20 In addition, from the mid-nineteenth century onwards verbs of a mathematical nature were increasingly used, as research articles in the physical sciences gradually moved from being mainly experimental to mathematical modelling of physical phenomena (Banks 2008). This was compounded by the introduction of computers in the course of the 20th century. The question arises of how to categorize the processes encoded by these verbs. It seems to me that processes of calculation are basically cerebral in nature, so constitute a subtype of mental process. While in other registers it might be possible to treat these as being assimilated to mental cognitive processes, their frequency in this register means that it is appropriate to treat them as a separate subgroup. Example (16) illustrates this.

(16) Numerical methods **have been used** to investigate two fluid flow with mass transfer on the pore scale for applications in chemical engineering, such as determining the rate of CO_2 capture. (Cooper)

21 The use of computers does not essentially alter the nature of this type of process, so all processes of mathematical calculation and modelling fall into this category. In fact, it is highly likely that all calculation and modelling was carried out by computer in this sample. Example (17) illustrates this.

(17) We mathematically **model** the type II uprooting mechanism as a (deterministic) mechanical fatigue perturbed by a (random) process noise, where plant collapsing occurs after a given exposure time to riverbed scouring reducing the rooting depth. (Perona)

22 Hence for the purpose of this study, I shall use a system of five process types, with mental process being further divided into four subtypes. Though the categories are clear, this does not mean that the analysis itself is without difficulties. I cannot claim that there were no cases where I did not hesitate. This largely comes about because the modelization, which basically involves mental mathematical processes, is modelling

physical phenomena, which involve material processes. It is not always immediately evident whether what is in question is the model or the phenomenon. Indeed, I suspect that for the scientist himself this question may not be pertinent. To a certain extent, for the scientists involved the model and the phenomenon are "the same thing". The analysis therefore represents a linguist's reading of these texts, and although I would not claim that the figures given are absolute to the last digit, they do represent the relative weight of the features involved.

3. Encoding processes

3.1. Overview

23 The distribution of the three major types of encoding of processes is shown in Table 1.

Table 1. Distribution of three major types of encoding processes.

	Cooper		Gower		Perona		Wacks		Zhao	
	N	%	N	%	N	%	N	%	N	%
Finite	575	41[3]	527	50	342	32	571	37	490	25
Non-finite	334	24	299	28	212	20	380	25	702	35
Nominalization	479	35	238	22	520	48	582	38	798	40
Total	1,388	100	1,064	100	1,074	100	1,533	100	1,990	100

24 The total number of processes in each article ranges from 1064 to 1990. As can be seen, in these five articles finite verbs never count for more than 50% (Gower) of the processes, and can be as low as 25% (Zhao). In four of the articles, non-finite verb forms count for between 20% and 28%, with one case (Zhao) being rather higher. In three of the articles nominalizations account for between 35% and 40%, with one case (Gower) being rather lower, and one case (Zhao) rather higher. The relative importance of nominalizations can be seen from the fact that in three of the articles (Perona, Wacks, Zhao) it is the most frequent way of encoding processes. In the other two cases (Cooper, Gower) finite verbs constitute the most frequent method. In general, non-finite verb forms are the least frequent way of encoding processes, although in two cases (Gower, Zhao) it is the second most frequent.

25 The percentage distribution of process types for the three ways of encoding processes taken as a whole is given in Table 2.

Table 2. Distribution of process types across five research articles in physical sciences.

	Cooper	Gower	Perona	Wacks	Zhao
Verbs (N)					

	1388	1064	1074	1533	1990
Distribution (%)					
Material	37	20	59	59	45
Mental	37	45	21	10	36
Cognitive	*11*	*13*	*11*	*10*	*12*
Perception	*1*	*	*1*	*1*	*
Mathematical	*24*	*32*	*10*	*5*	*23*
Desiderative	**4*	*	-	-	-
Relational	22	28	16	21	15
Verbal	3	6	3	3	3
Existential	1	1	1	1	2
Total	100	100	100	100	100

26 While some of the process types vary considerably in frequency from article to article, some are relatively stable. Existential and verbal processes are rare in all cases; existential processes never account for more than 2%, and only in the case of Gower do verbal processes account for more than the 3% of the other articles. This is perhaps not surprising; more striking is the fact that mental cognitive processes account for between 11% and 13% in all cases, thus showing that the incidence of mental cognitive processes is stable throughout the sample. While this is not true of the other process types, it can be noted that there is a certain stability for the combination of material and mental mathematical processes. For four of the articles this lies in the range 63% to 69%. In Gower, its rate is rather lower at 52%. This stability might indicate that there is a correlation between material process and mathematical process. As the rate of material processes increases, that of mental mathematical processes decreases, and vice versa.

27 It might also be noted, in passing, that Cooper and Gower seem to favour mental mathematical processes at the expense of material processes, in comparison with Perona and Wacks. This comes about because Cooper and Gower are basically interested in the modelization and related calculations as such, whereas Perona and Wacks relate the modelization to the phenomena they are intended to represent. This means that, for example, in the former pair of papers we find examples like (18), where the mental mathematical processes have been highlighted, whereas (19), where the material processes have been highlighted, would be more typical of the latter two.

> (18) The equations **are coupled** through the viscosity, surface tension, saturation-dependant diffusion constant and the SWCC which **is calculated** numerically from equation (2.12). (Cooper)

(19) As a second boundary condition, we require that once a critical rooting depth, L_c, **has been reached**, the trajectory **is lost**, or, physically, the plant **is uprooted**. (Perona)

28 Let us now look at the distribution for each of the methods of encoding processes individually.

3.2. Finite verbs

29 The percentage distribution of the process types of finite verbs is given in Table 3.

Table 3. Distribution of process types in finite verb forms across five research articles in physical sciences.

	Cooper	**Gower**	**Perona**	**Wacks**	**Zhao**
	Finite verbs (N)				
	575	527	342	571	490
	Distribution (%)				
Material	15	9	32	32	29
Mental	35	39	28	20	34
Cognitive	*13*	*14*	*13*	*11*	*11*
Perception	*2*	*1*	*3*	*2*	*1*
Mathematical	*19*	*24*	*13*	*8*	*22*
Desiderative	*	*	-	-	-
Relational	45	42	35	44	31
Verbal	4	9	4	3	4
Existential	*	1	2	1	3
Total	100	100	100	100	100

30 The dominant type of process for finite verbs is relational. It is the most frequent type in four of the articles and in the other (Zhao) it is slightly less frequent than mental processes taken as a whole. Mental process is the second most frequent type in three of the articles, and in these three (Cooper, Gower, Zhao) mathematical processes are by far the commonest type of mental process. In the other two, mathematical and cognitive processes are of the same order. Perception processes are fairly rare, and desiderative processes virtually absent. Material processes are less frequent than relational and mental processes, except in Wacks where they are more frequent than mental processes. Verbal and existential processes are relatively rare. It might also be

noted that in two cases (Cooper, Gower) mathematical processes on their own are more frequent than material processes.

31 Overall, it would seem that the relative weights of the different process types would suggest that relational process is the dominant type, followed by mental process, with mathematical processes having a particularly significant place within this category. Despite the fact that the physical sciences deal with physical phenomena, material process comes only third in this pecking order.

32 In (20) we see an extract which shows a concentration of finite verbs encoding relational processes.

> (20) The equations derived by Daly and Roose [8] **are** appropriate for modelling bulk soil. However, they **might not be** directly applicable to the region of soil close to the roots over which the plants **have** influence, known as the rhizosphere [12]. The rhizosphere **can have** different structural, chemical, biological and hydraulic properties to the bulk soil [13-15]. This **can be** partially due to the presence of root exudates. (Cooper)

33 A typical example of a series of finite verbs encoding mental mathematical processes is given in (21).

> (21) If we **fix** the location and properties of the *j*th cylinder, Λ_j and **average** over all the properties of the other cylinders, we **obtain** a *conditional average* of *F* given by [mathematical expression] where we **do not integrate** over Λ_j. (Gower)

3.3. Non-finite verb forms

34 Compared with the distribution for finite verbs, relational processes are relatively rare in non-finite verb forms, accounting for between 5% and 18% in individual articles (see table 4).

Table 4. Distribution of process types in non-finite verb forms across five research articles in physical sciences.

	Cooper	**Gower**	**Perona**	**Wacks**	**Zhao**
	Non-finite verbs (N)				
	334	229	212	380	702
	Distribution (%)				
Material	24	20	37	61	
Mental	65	60	37	23	44
Cognitive	*18*	*15*	*20*	*16*	*18*
Perception	*	-	*	*1*	*
Mathematical	*47*	*45*	*16*	*6*	*26*
Desiderative	*	-	-	-	-

Relational	9	14	18	5	12
Verbal	1	4	7	3	4
Existential	1	1	1	*	3
Total	100	100	100	100	100

35 Compared with the distribution for finite verbs, relational processes are relatively rare in non-finite verb forms, accounting for between 5% and 18% in individual articles. The dominant processes are mental and material, which together account for between 74% and 89% of the processes in individual articles. However, the frequency of these two process types varies considerably from article to article. In Cooper and Gower, mental processes clearly dominate, accounting for 65% and 60% of the processes in these two articles, with mathematical processes alone accounting for 47% and 45%. This situation is virtually reversed in Wacks, where material processes account for 61% and mental processes 23%. Zhao is similar to Cooper and Gower, in that mental processes are more frequent than material processes, but the difference is much less, with mental and material processes accounting for 37% and 44% respectively. In Perona, the frequency rate for these two process types is the same.

36 Hence, there is no clear overall dominance of one process type for non-finite verbs forms. The dominant type for individual articles is either mental or material, with these two being more frequent than other process types in all five articles.

37 An example showing non-finite verb forms encoding mental mathematical processes is given in (22), and one showing material processes in (23).

> (22) Our aim is **to start** with a set of equations on the pore scale and **to use** these **to derive** a set of macroscale equations. (Cooper)
> (23) This leads to the simultaneous occurrence of strong **focusing** of heat and weak **defocusing** of reactants in the regions which are concave to the **unburned** gases in the *Le*> 1.0 flames and thus the **burning** rate and thermal expansion effects (e.g. high magnitudes of the negative value of P*) are strong in these locations. (Wacks)

3.4. Nominalizations

38 As can be seen in table 5, it is clearly material process which is the dominant type. Material process has the greatest frequency in all five articles and in four of them the frequency is in the range 62% to 85%. In Gower the frequency is lower (43%), with mental processes having virtually the same rate (41%). Hence one can say that nominalization of processes is predominantly the nominalization of material processes.

Table 5. Distribution of process types in nominalizations across five research articles in physical sciences.

	Cooper	**Gower**	**Perona**	**Wacks**	**Zhao**
	Nominalizations (N)				
	479	238	520	582	798

	Distribution (%)				
Material	75	43	85	84	62
Mental	21	41	11	9	30
Cognitive	*4*	*8*	*5*	*6*	*9*
Perception	-	-	-	-	-
Mathematical	*17*	*33*	*6*	*3*	*21*
Desiderative	-	-	-	-	-
Relational	2	13	3	5	7
Verbal	2	3	1	3	1
Existential	1	*	*	*	*
Total	100	100	100	100	100

39 An example of nominalized material processes in given in (24).

> (24) Measuring plant **uprooting** by **flow** both at field and laboratory scales requires **monitoring** of the riverbed **evolution** while **erosion** proceeds, and the **recovery** of the uprooted plants. (Perona)

40 This information can be looked at from another point of view, that is, how a given process type is distributed over the different means of encoding processes.

3.5. Material process

41 As table 6 indicates, it is clear that where a material process is used, there is a high likelihood of it being encoded as a nominalization.

Table 6. Distribution of material process across five research articles in physical sciences.

	Cooper	Gower	Perona	Wacks	Zhao
	Material process (N)				
	525	211	632	901	895
	Distribution (%)				
Finite	17	23	17	20	16
Non-finite	15	28	13	26	29
Nominalization	68	50	70	54	55

Total		100	100	100	100

42 The five articles seem to fall into two groups. In three of the articles (Gower, Wacks, Zhao) the likelihood of a material process occurring in nominalized form is high (50% to 55%). In the other two (Cooper, Perona) it is very high (68% to 70%). Hence there is a very strong correlation between material process and nominalization.

3.6. Mental cognitive process

43 The situation of mental cognitive processes is less clear (see table 7). There is no clear preference of encoding form for all articles.

Table 7. Encoding forms of mental cognitive process.

	Cooper	**Gower**	**Perona**	**Wacks**	**Zhao**
	Mental cognitive process (N)				
	154	136	113	153	247
	Distribution (%)				
Finite	51	54	40	39	22
Non-finite	37	32	38	39	50
Nominalization	12	14	22	22	28
Total	100	100	100	100	100

44 In two cases (Cooper, Gower) there is more than 50% chance of a mental cognitive process being coded as a finite verb. In one case (Zhao) there is a 50% chance of such a process being encoded as a non-finite verb form, and in two cases (Perona, Wacks) there is a more or less equal chance of such a process being encoded either as a finite verb or a non-finite form. Nominalization is the least favoured form in four of the articles, but in Zhao this feature belongs to finite verbs. Overall, it can be said that there is a fairly low chance of a mental cognitive process being nominalized.

3.7. Mental mathematical process

45 Again, the results in table 8 show that there is no clear pattern for mental mathematical process.

46 Table 8. Encoding forms of mental mathematical process.

	Cooper	**Gower**	**Perona**	**Wacks**	**Zhao**
	Mental mathematical process (N)				

	350	340	107	84	457
	Distribution (%)				
Finite	32	37	40	54	23
Non-finite	45	40	32	27	40
Nominalization	23	23	28	19	37
Total	100	100	100	100	100

47 Three of the articles (Cooper, Gower, Zhao) have a relatively high preference (40%-45%) for encoding mental mathematical processes as non-finite verb forms. In the other two (Perona, Wacks) finite verbs are preferred (40%, 54%). Nominalization is the least favoured form, except, again, in Zhao, where the category of finite verbs is the least favoured form.

3.8. Relational processes

48 As shown in table 9, it is clear that relational processes are highly likely to be encoded as finite verbs. The lowest is Zhao with a rate of 52%, and the others are all in the range 68% to 87%.

Table 9. Encoding forms of relational process.

	Cooper	**Gower**	**Perona**	**Wacks**	**Zhao**
	Relational process (N)				
	260	294	177	323	289
	Distribution (%)				
Finite	87	75	68	77%	52%
Non-finite	10	15	22	15%	29%
Nominalization	3	10	10%	8%	19%

3.9. Verbal processes

49 Table 10 shows that verbal processes are less common than those discussed above. However, where they do occur, Cooper and Gower have a very clear preference for encoding verbal processes as finite verbs forms (63%, 70%). This is also the preferred form for Wacks, but at a much more modest rate of 38%. In Perona and Zhao it is non-finite forms which are preferred, at 48%.

Table 10. Encoding forms of verbal process.

	Cooper	Gower	Perona	Wacks	Zhao
	Verbal process (N)				
	38	66	29	48	60
	Distribution (%)				
Finite	63	70	41	38	35
Non-finite	13	19	48	27	48
Nominalization	24	11	10	35	17

50 The incidence of existential process seems too low for a percentage distribution to give results of any significance. Hence, there seem to be two very clear trends indicated by the distribution of process types: material processes have a strong tendency to be encoded as nominalizations, and relational process have a strong tendency to be encoded as finite verbs.

4. Halliday's diachronic insight

51 Halliday (1988, 2004) has suggested that in scientific writing there is a gradual diachronic movement from statements about physical events to one where the events are nominalized and one is said to be the cause of the other. He represents this diagrammatically as follows:

a happens; so *x* happen
because *a* happens, *x* happens
that *a* happens causes *x* to happen
happening *a* causes happening *x*
happening *a* is the cause of happening *x*

52 He describes this as an external viewpoint, and he gives the following as an internal viewpoint:

a happens; so we know *x* happens
because *a* happens, we know *x* happens
that *a* happens proves *x* to happen
happening *a* proves happening *x*
happening *a* is the proof of happening *x*

53 Both of these imply a movement from one where material processes are encoded as finite verbs to one where material processes are nominalized and linked by relational processes, the relationship in Halliday's examples being that of causality, which itself is nominalized. The nominalization of processes is a specific example of the phenomenon that Halliday has called grammatical metaphor (Halliday 2014; Ravelli 1988; Taverniers 2003). Grammatical metaphor, as mentioned above, is a linguistic resource whereby a non-congruent form is used. Thus, the congruent form for encoding processes is a verb; a nominalized process is a non-congruent form and so constitutes a grammatical metaphor.

54 Trawling through scientific articles, it is not easy to find examples at the level of the clause, of the final stage of Halliday's pattern. This would imply an example like (invented example) *Scouring is the cause of uprooting*. Nevertheless, our analysis shows that there is a strong tendency for material processes to be nominalized, and for relational processes to be encoded as finite verbs. That would seem to imply that there is an overall structure of the form:

> nominalized material process – finite relational process – nominalized material process

55 Hence, I would suggest that the analysis shows an overall structure which is the reflection in authentic text of Halliday's insight.

5. Final thoughts

56 Processes can be encoded as finite verbs, non-finite verb forms or nominalized processes, and we have seen that for this sample of five recent physical sciences research articles, nominalized process is the most frequent form in three out of five of the articles. When process types are considered overall, material process is the most frequent type in four out of five cases, and it seems there may be a correlation between material process and mental mathematical process.

57 Among finite verbs, relational processes are the most common in four out of five cases, followed by mental process, as second most frequent in three out of five cases. Within mental process, mathematical processes seem particularly important. For non-finite verb forms, mental process is the most common type in three out of five cases, and in one further case mental and material processes are equally frequent. Where nominalized processes occur, material processes are always the most frequent type. For nominalized processes, material process is the commonest type in all five sample cases.

58 Looking at the question from the point of view of process type, rather than encoding form, we find that material processes have a strong chance of being encoded as nominalizations. This is the preferred form in all five articles. For mental cognitive processes, finite verbs are the preferred form in two out of five cases, and non-finite verb forms in one out of five. In the other two cases finite verbs and non-finite forms are equally preferred. In the case of mental mathematical processes, non-finite verb forms are the preferred form in three out of five cases, and finite verbs in the other two. For relational processes, finite verbs are preferred in all five sample cases. For verbal processes, finite verbs are preferred in three out of five cases and non-finite forms in the other two. Hence the two clearest cases are the preference for nominalization of material processes and the encoding of relational processes as finite verbs.

59 The nominalization of material processes combined with relational process finite verbs might be seen as a reflection of Halliday's insight into the diachronic progress of grammatical metaphor.

60 While the sample used here is admittedly tiny, there is no immediate reason to suppose that these results would not be globally borne out by study of a larger sample, and I would suggest that they can be taken as being provisionally correct until shown to be otherwise. These features are of interest in their own right, as evidence of the ways in which the research article in the physical sciences is at present written, but they will

also be of interest to non-anglophone researchers who have to publish their findings in English, and students aiming to occupy this type of position at some point in the future. These researchers and students need to know, for example, that in the research article, as at present written, the majority of material processes will typically be encoded in nominalised form, and they will be typically linked by relational process finite verbs.

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APPENDIXES

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NOTES

1. Relevant parts of examples are highlighted in **bold.**
2. All examples are taken from the sample, details of which are given in Appendix A. Individual items are identified by the first-named author. They are all dated 2018 and this date not repeated in the body of this article.
3. Throughout, percentages are rounded to the nearest integer. Minor discrepancies are due to rounding.

ABSTRACTS

This paper considers the encoding of processes in five physical sciences research articles. Processes may be encoded as finite verbs, non-finite verb forms or as nominalizations. Relational process is the most common process type for finite verbs, followed by mental process as the second most common type, with mathematical processes forming an important subgroup within this type. Mental process is the most common type for non-finite verb forms, and material process the most common type for nominalizations. Viewing this from the point of view of the processes themselves, material processes have a strong chance of being encoded as nominalizations, and relational processes of being encoded as finite verbs. For mental cognitive processes, there is a reasonably strong chance of them being encoded as finite verbs, with non-finite forms being a second preference. For mental mathematical processes, non-finite forms would provide the first preference with finite verbs being a second choice. These findings are important for non-anglophone researchers and students hoping to publish their results in English.

Cette contribution est une étude de l'encodage des procès dans cinq articles de recherche dans le domaine des sciences physiques. Un procès peut être encodé par un verbe conjugué, par une forme verbale non conjuguée, ou par le biais d'une nominalisation. En ce qui concerne les verbes conjugués, le type de procès le plus fréquent est le procès relationnel, suivi du procès mental, une catégorie dans laquelle les procès mathématiques constituent un sous-groupe important. En ce qui concerne les formes non-conjuguées, le type le plus fréquent est le procès mental, et pour les nominalisations, le procès matériel. Du point de vue des procès eux-mêmes, les procès matériels ont une forte chance d'être encodés comme des verbes conjugués. Les procès mentaux cognitifs ont une chance relativement forte d'être encodés comme des verbes conjugués, avec les formes non conjuguées comme préférence secondaire. Dans le cas des procès mentaux mathématiques, les formes non conjuguées seraient une première préférence, avec des verbes conjugués en deuxième position. Ces résultats sont importants pour des chercheurs et doctorants non-anglophones, qui souhaitent publier leurs articles en anglais.

INDEX

Keywords: Finite, nominalization, non-finite, physical sciences, process type, research article
Mots-clés: Article de recherche, forme non-conjuguée, nominalisation, sciences physiques, procès, verbe conjugué

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