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Passive voice, first person pronouns, and mental process verbs in biological sciences research articles

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ABSTRACT

EN This paper sets out to study the use of passive forms, first person pronouns, and process types in the biological research article. Recent studies carried out on a small sample of articles in the physical sciences have suggested that in physical sciences research articles, there are two available models: one using many passive forms and avoiding first person pronoun subjects; and the other using few passives but first person pronoun subjects readily. The object of this study is to consider a similar sample from the biological sciences, and to compare them with the previously studied physical sciences articles. The six biological research articles that have been studied here, show restrained use of passives and a significant use of first person pronoun subjects. Overall, the relational process is the most common type, but the material process is the most frequent in some articles. Relational process is the most common type overall, but material process is the most frequent in some articles. Within mental process, cognitive process is the most common type, followed by processes of a mathematical nature. Most first person pronoun subjects occur with mental process verbs.

Key words: BIOLOGICAL SCIENCES, FIRST PERSON PRONOUN, PASSIVE, PROCESS TYPE, RESEARCH ARTICLE

ES Este artículo tiene por objetivo estudiar el uso de las formas pasivas, los pronombres de primera persona y los tipos de proceso en el artículo de investigación biológica. Estudios recientes realizados sobre una pequeña muestra de artículos en las ciencias físicas sugieren que, en el artículo de investigación de ciencias físicas, existen dos modelos disponibles: uno que utiliza muchas formas pasivas y evita sujetos con pronombres en primera persona; y otro que utiliza pocas pasivas pero emplea con facilidad los sujetos con pronombres en primera persona. El objetivo de este estudio es considerar una muestra similar de las ciencias biológicas y compararla con los artículos de ciencias físicas previamente estudiados. Los seis artículos de investigación biológica analizados muestran un uso moderado de la voz pasiva, y la mayoría utiliza pocos sujetos con pronombres en primera persona. El proceso relacional es el tipo más común, pero el proceso material es el más frecuente en algunos artículos individuales. Dentro de los procesos mentales, el proceso cognitivo es el tipo más común, seguido de los procesos de naturaleza matemática. La mayoría de los sujetos en primera persona aparecen con verbos de proceso mental.

Palabras clave: CIENCIAS BIOLÓGICAS, PRONOMBRE DE PRIMERA PERSONA, VOZ PASIVA, TIPO DE PROCESO, ARTICULO DE INVESTIGACIÓN

IT Questo lavoro si propone di analizzare come le forme passive, i pronomi di prima persona e i tipi di processo sono utilizzati negli articoli scientifici nell'ambito della biologia. Studi recenti, condotti su un piccolo campione di articoli nell'ambito delle scienze fisiche, suggeriscono che i testi di tali pubblicazioni tendono a seguire due modelli: uno che impiega frequentemente la forma passiva ed evita i soggetti con pronomi di prima persona, e un altro che, al contrario, privilegia l'uso dei pronomi di prima persona ma che ricorre a un numero relativamente ridotto di forme passive. Lo scopo del presente studio è esaminare un insieme comparabile di testi pubblicati nell'ambito delle scienze biologiche e confrontarne i modelli linguistici con quelli identificati in precedenza nelle scienze fisiche. L'analisi dei sei articoli appartenenti all'ambito della ricerca biologica rivela un uso moderato della voce passiva, mentre la maggior parte presenta un impiego limitato dei pronomi di prima persona come soggetto. I processi relazionali sono la tipologia più comune, sebbene in alcuni articoli individuali prevalgano i processi materiali. Tra i processi mentali, quelli cognitivi sono i più frequenti, seguiti da quelli di natura matematica. La maggior parte dei pronomi di prima persona compare in combinazione con verbi di cognizione.

Parole chiave: SCIENZE BIOLOGICHE, PRONOME DI PRIMA PERSONA, PASSIVO, TIPI DI PROCESSO, ARTICOLI SCIENTIFICI

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1. Introduction

The nature of the passive would appear to be simple, but, in fact, writers do not agree about what actually constitutes a passive verb. I consider that the passive is a verb form made up of the verb *to be* followed by a past participle. A number of writers, over a long period, have considered that the verb *to get* followed by a past participle, the so-called *get*-passive, constitutes an alternative to the passive with *to be* (Chappell, 1980; Hatcher, 1949; Hundt, Dallas, & Nakanish, 2024). However, almost fifty years ago I wrote that "the *get passive* is not a passive in any meaningful sense of the term, but an independent structure with its own semantic properties" (Banks, 1986, p. 74). I still believe this to be the case. Consequently, in this study consideration of the passive is restricted to the "*be*-passive." It is also restricted to the full finite verb. Some commentators include rankshifted non-finite clauses functioning as qualifiers (post-modifiers) in their count of passives. Pullum, (2014, p. 62), who refers to this as a "bare passive" gives the following example:

(1) One of its ads shows a washed-out manager, **arms folded**, sitting in a corner.[1]

This involves considering such phrases as being derived from "full" forms (perhaps a hangover from generative grammar). I feel that one should take a text as it stands, and not add in elements which are not there; thus, I consider such phrases to be reduced relative clauses (Quirk, Greenbaum, Leech, & Svartvik, 1985), (in (1), the reconstructed full form might be *with his arms (which were) folded*), and not passives.

In the early 1960s, Barber initiated contemporary studies of scientific texts. His seminal study (Barber, 1962) considers a number of features of scientific writing including the passive. The rare earlier studies (e.g. Savory, 1953) did not get beyond remarks on technical vocabulary. Until recently, it has been generally believed that use of the passive was an important feature of scientific writing, and numerous studies in the late 20th century suggested a passive rate of about 30% of finite verbs for this genre. Barber's own figure is 33%[2], the tables in Huddleston (1971) suggest a figure of 32%, and in Banks (1994), I found a passive rate of 31%. Some writers (e.g. Seoane, 2010) consider passives as a percentage of those verbs which could have a passive form. This means interest is concentrated on the choice of the scientific writer. My interest, however, is in the impact of passives on the text as a whole, and hence I give passives as a percentage of all finite verbs.

Use of the passive in scientific writing has been variously interpreted, with some claiming that the passive voice is used to maintain what is seen as the "impersonal" nature of scientific text (Cooray, 1967; Ding, 2002; Hundt, Schneider, & Seoane, 2016); others argue that the passive is used for reasons related to thematic structure, whereby the writer places what he is interested in, the object of his study or the ongoing experiment, in thematic, hence in initial position in the clause, thus triggering, in many cases, the use of a passive verb (Arnold et al., 2013; Banks, 2008a, 2008b; Halliday, 1988; Leong Ping, 2014; Rodman, 1981). This use of the passive continued despite the fact that many style manuals and instructions for authors recommended avoiding the passive. Bennett (2009) studied a large number of style manuals and found that in general they argued in favour of using the active form.

More recently however, Seoane and her collaborators (Seoane, 2006; Seoane & Loureiro-Porto, 2005; Seoane & Williams, 2006) have suggested that the use of the passive is in decline in scientific writing. They found that there was a rapid and dramatic change in the late 20th century, which was even more marked in American than in British English. They suggest that this is not necessarily a move to a more colloquial style, but is influenced by "the democratization of society and the pressure to convey scientific knowledge as efficiently and clearly as possible" (Seoane, 2006, p. 206). They also point out differences between differing disciplines and subdisciplines (Hundt et al., 2016; Hundt, Röthlishberger, & Seoane, 2018; Seoane & Hundt, 2018).

If there is indeed a reduction in the use of the passive in scientific writing, then it would be natural to expect an increase in the use of first person pronoun subjects. Rather than expressing a process which has the human author as agent in a passive form, this would be expressed in the active with a first person pronoun subject. The use of first person pronouns in scientific texts has been studied over a fairly long period by Hyland and his collaborators. They point out that there are differences between different disciplines, but suggest that the increase in the use of first person pronouns is more marked in the biological sciences than elsewhere. Hyland and Jiang (2017) claim that, in their corpus, use of first person pronouns in biology rose by 213% between 1965 and 2015. These changes are mainly from 1985 onwards, and indicate a willingness on the part of scientific writers to be more overtly present in their texts (Hyland, 2001, 2002, 2010; Hyland & Jiang, 2016,

[1] Relevant parts of examples are printed in **bold**.

[2] Percentages throughout this paper are rounded to the nearest integer. Any discrepancies are due to rounding.

2017, 2018). An increase in the use of first person pronouns, but with differences between disciplines was also noted by Lafuente Millán (2010). Martínez (2005) noted different rates of first person pronoun use in the various rhetorical sections (introduction, method, results, discussion) of biology research articles.

In Banks (2017), I suggested that there was some evidence for a reduction of the passive, at least in the physical sciences, with a corresponding rise in the use of first person pronoun subjects. I put forward the conjecture that this was due to the fact that mathematical modelling had been introduced in the physical sciences, but not in the biological sciences, from the late 19th century onwards (Banks, 2008a). This in itself leads to the use of verbs of a mathematical nature, that is, involved with mathematical calculation, which can be classed as expressing a type of mental process. Mental process verbs seem to be more conducive to the use of first person pronoun subjects, probably because of the more personal nature of the activity involved. In a recent study (Banks, 2021), attempting to test these hypotheses, I looked at six sample texts; these were all articles in the physical sciences taken from the 2018 *Proceedings of the Royal Society A*. I found that while the overall passive rate was close to the late 20th century norm of 30%, there was considerable variation between individual articles, with two having considerably more, and two considerably less than this figure. Half of the sample texts used first person pronouns to some extent, and where these were used it was almost always with mental or verbal processes, very rarely with material processes. There seemed to be two basic models in operation: a "traditional" model using the passive extensively, and avoiding first person pronouns, and a "progressive" model, with a reduced rate of passives and using first person pronouns readily. Some texts were hybrids of these two basic models.

The present study attempts to show how passives and first person pronouns are used in the biological research article, and to investigate to what extent the claims that use of the passive is declining, and that of first person pronoun subjects increasing are justified. While the results of this study are of interest in their own right, they will also be of interest to those involved in the teaching of academic writing in the biological sciences. Students need to learn not only what the correct forms are, but also when it is appropriate to use them. This is crucial, particularly for non-anglophone students, who will be required to publish in a language which is not their mother tongue (Cooke, 1993). Hinkel notes the difficulty that non-anglophone students have with, for example, the passive, and concludes that "the practically requisite usage of passive voice in constructing formal written discourse also needs to be taught intensively" (Hinkel, 2004, p. 24). In the following sections I will give details of the corpus, and then consider the incidence of passive forms and first person pronoun subjects, and their relationship to different process types.

2. Corpus and method

The present paper is an attempt to look at the situation in the biological sciences, which have received rather less attention from researchers than the discourse of the physical sciences (Banks, 2017). To do this, I have taken six sample texts (see Appendix) from the 2019 *Proceedings of the In the following sections I will give details of the corpus, and then consider the incidence of passive forms and first person pronoun subjects, and their relationship to different process types. Royal Society B*, thus paralleling the physical sciences articles used in Banks (2021). No particular selection criteria were used. These were simply the first that were freely available on the *Royal Society'*s website. The selection is therefore haphazard, if not strictly random in the technical sense. The total number of words in the main texts of these articles is 28838 (Aanen 3937; Benevento 5018; Byrne 4428; Kopperud 4479; Madin 6421; Senior 4555 – see full entries in the Appendix). The papers have between two and seven co-authors, with a total of 27 co-authors for the six papers. It is impossible to know whether the articles were drafted by native speakers of English, but it can be noted that while only 12 of the 27 co-authors have typically anglophone names, the co-authors give a total of 45 affiliations, since some of them give two, or even three institutional addresses, and of these, 40 are in anglophone countries (UK, USA Australia, New Zealand), and only 5 in non-anglophone countries (Netherlands, Sweden, Norway). In addition to the authors themselves, the recommendations of referees, editors and copy-editors may have influenced the final forms of these texts. Without an extensive sociological study, it is impossible to judge the degree of influence that these other actors may have had.

The sample is very small, and is closer to a set of six case studies than even a mini-corpus (Banks, 2005a). On the other hand, there is no reason to think that this selection is not representative, and it is not unreasonable to take the results found here as being of the right order, unless subsequently shown to be otherwise. The random nature of the selection reduces the possibility of bias, and increases its global representativity. The details of the sample texts are given in the Appendix. In the course of this paper, they will each be referred to by the first-named author.

The theoretical background of the paper is Systemic Functional Linguistics (Banks, 2005b, 2019; Halliday & Matthiessen, 2014), but I trust that any technical terms are sufficiently transparent to be understood by readers who are less familiar with this approach. The study will consider the incidence of passives and first person pronoun subjects, the distribution of process types, and the relationships between these features.

In what follows I shall look at the incidence of passive forms and first person pronoun subjects. I shall then look at the distribution of process types, of all verbs, of passive verbs, and of verbs with first person pronoun subjects.

3. Passives

Table 1 gives the incidence of passives for each article as a percentage of all finite verbs. Non-finite passive verb forms were not included in the count. Finite verbs have particular significance as the fulcrum of the clause, and attract a grammatical subject and, unless they are intransitive, a complement.

Table 1.
Passives

Article	No.	%	No. of finite verbs
Aanen	41	16%	252
Benevento	66	25%	265
Byrne	55	22%	249
Kopperud	36	12%	295
Madin	80	21%	378
Senior	78	28%	274
Overall	356	20%	1713

In the physical sciences articles previously studied the overall passive rate was 29%, but with wide variation between individual articles from 1% to 53%. Two of the six had a high rate, two low, and two were close to the overall rate. In the biological articles studied here, the overall rate of passive use is 20% of finite verbs, notably less than the formerly supposed norm of about 30%. Senior is the closest to this figure with 28%, while Kopperud has the lowest rate with 12%. Hence, these six articles can be thought of as being relatively restrained in their use of the passive, and this would be consistent with the hypothesis that there has been a reduction in passive use. It is also well below the rate of 29% found in the six physical sciences articles studied previously, but where some articles, nevertheless, displayed greater diversity.

4. First person pronoun subjects

Table 2 gives the numbers of first person pronoun subjects of active verbs (there are no first person subjects of passives, and, although theoretically possible, such would be unlikely in any case) and the percentage of finite verbs which have such subjects. Since there are no single-authored articles in the sample, first person pronoun subjects are exclusively *we*.

Table 2.
First person pronoun subjects.

Article	No.	%
Aanen	22	9%
Benevento	12	5%
Byrne	9	4%
Kopperud	69	23%
Madin	23	6%
Senior	25	9%
Overall	160	9%

In the physical sciences articles studied, the overall rate of finite verbs with a first person pronoun subject was 11%, with a range of none at all to 33%. One article uses them extensively, two moderately, but the others use them hardly at all. In these biological articles, the overall rate of finite verbs with a first person pronoun subject is 9%. It should be noted that only overt pronouns were counted. Hence this does not include elided pronouns which occurred as the putative subjects of coordinate verbs. However these are fairly rare;

there are only nine such cases in the whole corpus, seven of them in Kopperud. However, the overall rate masks the fact that while five of the articles have rates of less than 10%, one, Kopperud, stands out, with the much higher rate of 23%. Since Kopperud also has the lowest rate of passive use, this may indicate some degree of correlation between restrained use of passives and a high rate of first person pronoun subjects. This hypothesis is not supported by the figures for the full set of articles. This can be seen in Table 3, where passive use and rates of first person pronouns are compared.

Table 3.
Passives and first person pronouns.

Article	Passives	First person pronouns
Aanen	16%	8%
Benevento	25%	5%
Byrne	22%	3%
Kopperud	12%	26%
Madin	21%	8%
Senior	28%	9%
Overall	20%	10%

Kopperud is paleontological in nature, and there may be sub-disciplinary influences at play (Biber & Gray, 2013), although this is a feature which it shares with Byrne, where the rate is only 3%.

The patterns found here are considerably different to those found in the review of the six physical sciences articles, where the use of passives varied considerably in different articles (from 11% to 53%), and where three of the articles virtually eschewed the use of first person pronouns altogether, and another used them extensively (33%). Hence, the results for this sample would seem to suggest that for the biological sciences, use of the passive is standard but not excessive, and use of first person pronoun subjects is restrained, but in exceptional individual cases, such as Kopperud, may be high. However, the idea that there is a simple correlation between use of passives and that of first person pronouns is not borne out. Moreover, these results do not corroborate earlier studies which claimed that use of the first person pronoun was particularly prominent in the biological field (Hyland & Jiang, 2017).

5. Process types

It is of interest to know whether a specific process type favours the use of either passives, or first person pronouns subjects. I use a set of five process types based on those provided for in Systemic Functional Linguistics (Banks, 2005b, 2019; Halliday & Matthiessen, 2014). The five process types are material, mental, relational, verbal and existential. Even within the Systemic Functional approach there is a fairly wide range of attitudes to the analysis of process types, from a more grammatical to a more conceptual point of view (O'Donnell, Zappavigna, & Whitelaw, 2008). My analyses are to the conceptual pole of this cline. Moreover, I do not use the category of behavioural process which is commonly used in Systemic Functional Linguistics. For example, some commentators (e.g. Matthiessen, 1995) suggest that verbs of communication that project (i.e. can be followed by direct or indirect speech, e.g. *say*) are cases of verbal process, while those that do not (e.g. *talk*) are cases of behavioural process. This does not seem to me to be coherent, and moreover, they do not correspond to the original definition of behavioural process as being between material and mental processes (Halliday, 1985). The reasons why I do not use the category of behavioural process are explained in detail in Banks (2016).

Material process are actions or events of a physical nature.

(2) In the bacterial species *Dinoroseobacter shibae*, at high density, bacteria **switch** from exponential to linear growth and quorum sensing **regulates** this switch. (Aanen)[3]

Mental processes are events of a cerebral nature.

[3]In text references have been omitted from examples.

(3) This **has been interpreted** as a result of the ecological release of mammals following the extinction of many species, including all non-avian dinosaurs, during the Cretaceous/Palaeogene (K/Pg) mass extinction event. (Benevento)

Relational processes link two entities, or an entity and one of its characteristics.

(4) The ectoneural portion **has** a distinct neuroepithalium containing neuronal cell bodies and an underlying neuropile that **contains** axons, analogous to the grey and white matter of the vertebrate spinal cord, respectively, as well as in the presence of radial glia as the supporting framework. (Byrne)

Verbal processes are processes of communication.

(5) We thus **hypothesized** that, through spatially constrained herbivory due to one or both of these indirect mechanisms, marine reserves could affect halo prevalence and/or size by altering herbivore and/or predator populations. (Madin)

Existential processes are statements of existence.

(6) While there **are** substantial advantages to text-mining genus/species age-observation data, we recognize several avenues for improvement in this study. (Kopperud)

Table 4 gives the distribution of process types for the six articles in the sample.

Table 4.
Process Types

Article	Material		Mental		Relational		Verbal		Existential	
	No.	%	No.	%	No.	%	No.	%	No.	%
Aanen	102	40%	45	18%	94	37%	11	4%	-	-
Benevento	82	31%	57	22%	98	37%	28	11%	-	-
Byrne	85	34%	16	6%	137	55%	11	4%	-	-
Kopperud	92	31%	51	17%	127	43%	17	6%	8	3%
Madin	156	41%	54	14%	141	37%	18	5%	9	2%
Senior	79	29%	70	26%	109	40%	12	4%	4	1%
Overall	596	35%	293	17%	706	41%	97	6%	21	1%

Overall, the commonest process type is relational, accounting for 41% of the finite verbs. Relational process is also the most frequently used type in four of the individual articles (Benevento, Byrne, Kopperud, Senior). However, in Aanen and in Madin the most frequent process type is material. Material process is the second commonest type in the other four articles, where relational process was the most frequent. Mental process is the third commonest process type overall, and in all of the individual articles. This contrasts fairly starkly with the six physical sciences articles I looked at, where, although relational process was the commonest process type overall and in four of the individual articles, mental process was the most frequent in two, second in two, and third in two. Material process was the third commonest type overall, and in four individual articles, being second most frequent in the other two. Hence, mental process seems to have a much less important place in the writing of biological articles than in the writing of articles in the physical sciences.

6. Mathematical processes

At the time when the first scientific research articles were published, in 1665, the physical sciences were largely experimental, and, therefore, used a relatively large number of material processes. The late 19th century saw a vast increase in the use of mathematical techniques, and this is reflected in the scientific writing of the time. In Banks (2008a), I noted "an explosion of mathematical themes in the physical sector from the late nineteenth century on" (p. 175), and concluded "The importance acquired over a short period from the nineteenth century on by the mathematical modelling of physical problems is reflected in the use of mathematical items as thematic choices" (p. 175). In the course of the 20th century, these techniques involved

the use of mathematical modelling, with the gradual use of computers for the purpose, particularly from about 1960 onwards. However, although this was the case for the physical sciences, mathematics did not seem to have made the same impact on the biological sciences, at least up to 1980 (Banks, 2008a). The question arises as to what type of process is encoded by verbs of a mathematical nature. Since events of a mathematical type, at least when they can be attributed to a human, are of a cerebral type, it seems reasonable to consider them a type of mental process. I would claim that this remains the case where an instrument, such as a computer is involved. In fact, it is likely that in modern scientific research all mathematical calculations are carried out using a computer, even where this is not specifically stated. In Systemic Functional Linguistics it is usual to distinguish three types of mental process: cognitive, perception and affective (Banks, 2005b, 2019; Halliday & Matthiessen, 2014). To this, some would add a separate class of desiderative processes (Thompson, 2004). In these six articles we commonly find cognitive processes:

(7) Little **is known** about how ASM is affected by dietary macronutrient content. (Senior)

There are also a small number of perception processes:

(8) More often, herbivores **have been observed** to be less abundant or not significantly different in GBR no-take reserves relative to fished reefs. (Madin)

There are no examples of the affective or desiderative types in these six articles. I am suggesting that for genres of this type, we should recognize a further mathematical type of mental process. It is true that in many genres these could reasonably be conflated with mental cognitive processes. In genres, such as political journalism, legal documents, or sports reports, one would not expect to find many, if any, verbs of a mathematical nature; therefore, isolating them as a distinct group would not be warranted, but their frequency in scientific genres means that it is useful to distinguish them as a separate group.

(9) The MST **was calculated** based on the distance between occupied grid cells across function space. (Benevento)

(10) We then **model** α and β over the macronutrient space captured by the diets. (Senior)

Since mathematical processes have proved to be an important type in articles in the physical sciences, it is interesting to see to what extent it has made an impact on the biological sciences. Mathematical processes are included in the count of mental processes given above.

Table 5 gives the distribution of cognitive, perception and mathematical types of mental process.

Table 5.
Types of mental process.

Article	Cognitive		Perception		Mathematical	
	No.	%	No.	%	No.	%
Aanen	30	67%	1	2%	14	31%
Benevento	34	60%	6	11%	17	30%
Byrne	14	88%	2	13%	-	-
Kopperud	39	76%	5	10%	7	14%
Madin	42	78%	6	11%	6	11%
Senior	29	41%	5	7%	36	51%
Overall	188	64%	25	9%	80	27%

As can be seen, cognitive processes are by far the most common type of mental process overall, accounting for 64% of the mental processes, and this is the case in five of the individual articles, Senior being the single exception. This probably indicates that Senior's use of process types, compared to the other articles in the sample, concentrates more on the calculation of the results, and less on the argumentation, than they do. This contrasts with the situation for the six physical sciences articles studied, where mathematical processes were the most frequent overall, and in five of the individual articles. If the incidence of these types of mental process is calculated as percentages of all finite verbs, the results given in Table 6 emerge.

Table 6.
Mental process types as percentage of finite verbs

Article	Cognitive	Perception	Mathematical
Aanen	12%	*[4]	6%
Benevento	13%	2%	6%
Byrne	6%	1%	-
Kopperud	13%	2%	2%
Madin	11%	2%	2%
Senior	11%	2%	13%
Overall	11%	1%	5%

Cognitive processes account for between 11% and 13% in all articles except Byrne, where the rate is 6%. Perception processes never account for more than 2%. Mathematical processes account for 5% overall, and with the exception of Senior where the rate is 13%, they never account for more than 6%. In contrast, in the physical sciences articles studied, mathematical processes accounted for 18% overall, with a range of 8% to 25%. Cognitive processes accounted for 11% overall, with a range of 10% to 13%. So, while the incidence of cognitive processes is virtually the same in both the physical and biological articles, the incidence of mathematical processes is much less in the biological articles than in the physical. Perception processes are very rare in both the physical and the biological articles, 1% of the mental process in the former, 2% in the latter.

7. Passives and process types

If we now look at the process types of finite verbs in the passive form, the results given in Table 7 emerge.

Table 7.
Process types of passives

Article	Material		Mental		Relational		Verbal	
	No.	%	No.	%	No.	%	No.	%
Aanen	22	54%	14	34%	3	7%	2	5%
Benevento	16	24%	33	50%	8	12%	9	14%
Byrne	38	69%	7	13%	4	7%	6	11%
Kopperud	21	58%	7	19%	4	11%	4	11%
Madin	37	46%	35	44%	5	6%	3	4%
Senior	25	32%	38	49%	10	13%	5	6%
Overall	159	45%	134	38%	34	10%	29	8%

This means that, overall, 45% of the passive verbs encoded material processes, 38% mental processes, 10% relational and 8% verbal. Once again, there is a fairly strong contrast with the articles in the physical sciences where mental processes accounted for the majority of passive forms overall and in each of the individual articles. The overall rate was 62%, and the rate in individual articles ranged from 47% to 82%. Here, overall the majority of passives occur in the material process category, and in four of the individual articles (Aanen, Byrne, Kopperud, Madin). This goes hand in hand with the fact that material processes are more frequent in these biological articles than in the physical sciences sample. In two of these biological articles (Benevento and Senior), mental processes do account for the highest percentage of passive forms. On the other hand, in Kopperud and Byrne the percentage of mental process passives seems particularly low, 19% and 13% respectively. It is important to note that the relatively high percentage of passive relational processes, given that relational processes do not passivize readily. Here, they are more frequent than verbal process passives. Since relational processes do not frequently passivize, it is probably worth giving some examples to show the sort of process that has been included in this category.

(11) Insular dwarfism and gigantism, which are also geologically rapid. macroevolutionary phenomena, **can be accompanied** by little or no change in overall morphology. (Benevento)

[4] An asterisk in a Table indicates that although there were some examples they accounted for less than 0.5%.

(12) Asteroids are particularly amenable to the investigation of CNS regeneration because the RNCs **are located** on the ectodermal surface, rather than being internalized in development as they are in the other echinoderms. (Byrne)

(13) Diets either rich in protein or fat content **were associated** with a great deal of among-individual variation in the age at death. (Senior)

Some might consider these to be adjectival or pseudo-passives, but an active variant is easy to construct for (11) (*little change accompanied* ...), and even for (12) and (13) this is not impossible (*we locate* ..., *we associate* ...).

In the physical sciences articles analyzed, not only were mental processes the commonest type of passive, but within mental process passives the most commonly used type was mathematical, accounting for 60% of the mental process passives. The cognitive type accounted for 36%, and perception 5%. Table 8 shows that this is not the case for the biological articles studied.

Table 8.
Mental process and passives

Article	Cognitive		Perception		Mathematical	
	No.	%	No.	%	No.	%
Aanen	11	79%	-	-	3	21%
Benevento	18	55%	1	3%	14	42%
Byrne	6	86%	1	14%	-	-
Kopperud	7	100%	-	-	-	-
Madin	26	74%	3	9%	6	17%
Senior	14	37%	-	-	24	63%
Overall	82	61%	5	4%	47	35%

Here, cognitive processes are by far the commonest type of mental process passive, accounting for 61% of the sample, with mathematical processes accounting for 35%. Cognitive is the most frequent type in five of the individual articles, Senior being the exception.

8. First person pronoun subjects and process type

We will now turn our attention to the process types of verbs with first person pronoun subjects. The numbers of first person pronoun subjects and the percentages of verbs with such subjects are given in Table 9.

Table 9.
Process types and first person pronouns

Article	Material		Mental		Relational		Verbal	
	No.	%	No.	%	No.	%	No.	%
Aanen	2	10%	17	81%	-	-	2	10%
Benevento	-	-	8	62%	-	-	5	38%
Byrne	3	38%	5	63%	-		-	
Kopperud	28	36%	33	43%	6	8%	10	13%
Madin	16	53%	9	30%	-	-	5	17%
Senior	1	4%	22	92%	1	4%	-	-
Overall	50	29%	94	54%	7	4%	22	13%

Although some of the figures are relatively small, it is clear that for these articles the commonest process type with first person pronoun subjects is mental, and this is the case in all individual articles except Madin. The figure 54% is, however, considerably less than that found in the physical sciences articles, which was 76%. Moreover, here 29% of the verbs with first person pronoun subjects occur in material process, with half of the articles (Byrne, Kopperud and Madin, though in Byrne the raw numbers are very small) having a fairly high percentage ranging from 36% to 53%. This contrasts strongly with the situation found in the physical sciences articles where first person pronoun subjects hardly ever occurred with material process verbs, occurring in only one of the articles, and accounting for only 1% overall. The fact that the majority of

first person pronoun subjects occur with mental processes does not seem unreasonable. A person's acts (material processes) can, in principle, be replicated by someone else, but no-one else can have their thoughts or feelings (mental processes). Hence there is something more personal about mental processes which lends them to first person subject use. This tendency, however, seems to be much stronger in the physical than the biological sciences, perhaps because of the greater incidence of mathematical processes in that subgenre.

Since the figures in Table 9 are already fairly small, it is evident that those for individual mental process types will be even smaller. These are given in Table 10.

Table 10.
Mental process and first person pronoun subjects.

Article	Cognitive		Perception		Mathematical	
	No.	%	No.	%	No.	%
Aanen	8	47%	-	-	9	53%
Benevento	6	75%	1	13%	1	13%
Byrne	5	100%	-	-	-	-
Kopperud	26	79%	-	-	7	21%
Madin	9	100%	-	-	-	-
Senior	8	36%	3	14%	11	50%
Overall	62	66%	4	4%	28	30%

Despite the paucity of the raw numbers, perhaps it is worth noting that overall the cognitive processes account for two-thirds of the mental process sample with first person pronoun subjects. At the same time, in two individual articles (Aanen and Senior) mathematical processes with first person pronoun subjects are more common than cognitive processes.

9. Final thoughts

In these six articles, we have seen that the rate of passive use is relatively modest, at 20% of finite verbs. It would require a diachronic study to ascertain whether passive use in the biological sciences has reached a peak, and is leveling off as seems to be the case in the physical sciences, or whether passive use is still rising at this point.

There is a relatively low rate of first person pronoun subjects. They appear with only 9% of the finite verbs, but in individual cases the rate may be much higher, which is the case of one of the six articles in the sample studied here.

The most frequent process type in this sample is relational process, though material processes, the second most common overall, may be the most frequent in individual cases. This contrasts with the small sample of physical sciences articles studied (Banks, 2017), where mental processes were more common than material processes.

Within mental process, cognitive processes are the most common type followed by mathematical processes. This contrasts with the physical sciences articles where mathematical processes were the most frequent.

When passive forms are considered, material processes account for more passives than mental processes. This contrasts with the physical sciences articles where mental process passives were more common than material. Within mental process, cognitive mental passives are more frequent than mathematical passives.

The majority of finite verbs with first person pronoun subjects are examples of mental process. This is true also of the physical sciences articles, but where in the physical sciences articles mental processes account for 76% of the verbs with first person pronoun subjects, in the biological articles the rate is only 54%.

These facts are probably interrelated. The relatively low incidence of first person pronoun subjects is probably due to the low rate of mental processes, since first person pronoun subjects tend to occur with this process type. The low rate of mental processes is itself partly due to the relatively low incidence of mathematical processes. The biological field still includes an interest in visible organisms and their description, which do not require the degree of mathematical modelling necessary in many areas of the physical sciences such as particle physics. It is perhaps these facts which account for the lack of direct correlation between the incidence of first person pronoun subject and passives.

While the sample of six articles studied here is far too small to give anything like firm conclusions, the points raised might be considered to provide food for thought, and taken as indicators of possible future fruitful research. Such research might include carrying out similar analyses of a larger sample, and on different subgenres, and carrying out a diachronic study to show the direction and speed of the changes taking place. Moreover, while these results are interesting in themselves, and can act as indicators for future research, they will also be of interest to those involved in the teaching of English for academic purposes. Students need to know, for example that, (to the extent that these results can be taken as representative) use of first person pronoun subjects now seems to be permissible in the scientific research article; nevertheless, this has to be tempered by the knowledge that first person pronoun subjects are more likely to occur with mental process verbs. This is particularly true of the physical sciences, but also the case, if even to a lesser extent, in the biological sciences. Taking such factors into account will enhance the chances of non-English-speaking researchers successfully playing a part in an increasingly competitive international scene.

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Appendix
Analyzed papers from the Proceedings of the Royal Society B for the year 2019

Aanen, Duur K. & Debets, Alfons J.M. (2019). Mutation-rate plasticity and the germline of unicellular organisms. Proceedings of the Royal Society B, 286 (1902).

Benevento, Gemma Louise, Benson, Roger B.J. & Friedman, Matt (2019). Patterns of mammalian jaw ecomorphological disparity during the Mesozoic/Cenozoic transition. Proceedings of the Royal Society B, 286 (1902).

Byrne, Maria, Mazzone, Franca, Elphick, Maurice R., Thorndyke, Michael C. & Cisternas, Paula (2019). Expression of the neuropeptide SALMFamide-1 during regeneration of the seastar radial nerve cord following arm autotomy. Proceedings of the Royal Society B, 286 (1901).

Madin, Elizabeth M.P., Harborne, Alastair R., Harmer, Aaron M.T., Luiz, Osmar J. Atwood, Trisha B,. Sullivan, Brian J. & Madin, Joshua S. (2019). Marine reserves shape seascapes on scales visible from space. Proceedings of the Royal Society B, 286 (1901).

Kopperud, Bjørn Tore, Lidgard, Scott & Liow, Lee Hsiang (2019). Text-mined fossil biodiversity dynamics using machine learning. Proceedings of the Royal Society B, 286 (1901).

Senior, Alistair M., Solon-Biet, Samantha M., Cogger, Victoria C., Le Couteur, David G., Nakagawa, Shinichi, Raubenheimer, David & Simson, Stephen J. (2019). Dietary macronutrient content, age-specific mortality and lifespan. Proceedings of the Royal Society B, 286 (1902).

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