Reading Materials for Learning to Read Scientific Papers:

A Suggestion from A Systemic Functional Perspective

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Abstract

This paper proposes abstracts of *Nature Reviews* as reading materials for Japanese university students who need to read scientific papers. It explores three sample abstracts of *Nature Reviews* from the perspective of Systemic Functional Linguistics. As a result of the exploration, this paper makes it clear that 'thing' as participant, nominalization and metaphorical realization of logical relation can cause difficulty in reading. These lexicogrammatical problems are often observed in scientific papers and Washitake (2021) has suggested solutions to them. However, some problems observed in abstracts of *Nature Reviews* are easier to resolve. In addition, abstracts of *Nature Reviews* are easier to approach than scientific research papers since the articles are generally written as accessible, introductory overviews. Thus, this paper concludes that abstracts of *Nature Reviews* are ideal materials for learning to read scientific papers because of their lexicogrammatical characteristics and approachability.

Key words: Systemic Functional Linguistics, the language of science, categories of 'things', nominalization, metaphorical realization of logical relations

1. Introduction

Students in Japanese universities have to read scientific research papers in their specialized courses, sometimes without adequate training. There are quite a few guides on how to read scientific papers and so many studies on the language of science (e.g., Böttcher, 2017; Halliday and Martin, 1993; Martin and Veel (eds), 1998; Halliday, 2004a; Banks, 2008). However, few studies have examined on the ways to approach the language of science. This present paper proposes abstracts of *Nature Reviews* as reading materials for learning to read scientific papers. It explores three abstracts of *Nature Reviews* from the perspective of Systemic Functional Linguistics, and illustrates lexicogrammatical characteristics of them. By this text

analysis, this paper makes it clear why these manuscripts are useful for university students in Japan to improve their English ability to read scientific papers.

I explored a significant number of abstracts of *Nature Reviews* and found that they can be proper reading materials to help students improve their English abilities to read scientific papers. There are practical reasons for that: 1) in both abstracts of *Nature Reviews* and scientific papers, general, abstract and metaphorical things serve as participants; 2) the organization of nominal groups in abstracts of *Nature Reviews* are complex, which contributes to the high value of lexical density, a major problem when reading scientific papers; 3) logical relations in abstracts of *Nature Reviews* are often metaphorically realized, which is characteristically seen in the language of science; 4) clause complexes in both text types are fairly simple; and finally, 5) for 'ordinary' English teachers, reading reports on *Nature Reviews* is quite difficult but understanding their abstracts seems possible with some specialists' help.

The purpose of this paper is to help students who are not familiar with reading scientific papers. The research question is this: are abstracts of *Nature Reviews* proper reading materials in advance of students' reading scientific papers? Thus, the results of lexicogrammatical analyses of them are compared with those of scientific papers.

2. Exploring Abstracts of *Nature Reviews*

Manuscripts in *Nature Reviews* are edited to make original research comprehensible and to show introductory overviews of scientific fields (nature.com). The manuscripts are still technical and are not intended for lay readers. However, their abstracts are, as far as I read, understandable with some help of specialists.

This section explores three abstracts from *Nature Reviews*: Example 1 is extracted from *Nature Revies Drug Discovery*, Example 2 from *Nature Reviews Cancer*, and Example 3 from *Nature Reviews Cardiology*. All of them are free access and available on the Web.

Example 1

mRNA vaccines represent a promising alternative to conventional vaccine approaches because of their high potency, capacity for rapid development and potential for low-cost manufacture and safe administration. However, their application has until recently been restricted by the instability and inefficient *in vivo* delivery of mRNA. Recent technological advances have now largely overcome these issues, and multiple mRNA vaccine platforms against infectious diseases and several types

of cancer have demonstrated encouraging results in both animal models and humans. This Review provides a detailed overview of mRNA vaccines and considers future directions and challenges in advancing this promising vaccine platform to widespread therapeutic use.

(Pardi, N. et al., 2018)

Example 2

Detection of cancer at an early stage when it is still localized improves patient response to medical interventions for most cancer types. The success of screening tools such as cervical cytology to reduce mortality has spurred significant interest in new methods for early detection (for example, using non-invasive blood-based or biofluid-based biomarkers). Yet biomarkers shed from early lesions are limited by fundamental biological and mass transport barriers — such as short circulation times and blood dilution — that limit early detection. To address this issue, synthetic biomarkers are being developed. These represent an emerging class of diagnostics that deploy bioengineered sensors inside the body to query early-stage tumours and amplify disease signals to levels that could potentially exceed those of shed biomarkers. These strategies leverage design principles and advances from chemistry, synthetic biology and cell engineering. In this Review, we discuss the rationale for development of biofluid-based synthetic biomarkers. We examine how these strategies harness dysregulated features of tumours to amplify detection signals, use tumour-selective activation to increase specificity and leverage natural processing of bodily fluids (for example, blood, urine and proximal fluids) for easy detection. Finally, we highlight the challenges that exist for preclinical development and clinical translation of synthetic biomarker diagnostics.

(Kwong, G. A. et al., 2021)

Example 3

Cardiac rehabilitation is a complex intervention that seeks to improve the functional capacity, wellbeing and health-related quality of life of patients with heart disease. A substantive evidence base supports cardiac rehabilitation as a clinically effective and cost-effective intervention for patients with acute coronary syndrome or heart failure with reduced ejection fraction and after coronary revascularization. In this Review, we discuss the major contemporary challenges that face cardiac rehabilitation. Despite the strong recommendation in current clinical guidelines for the referral of these patient groups, global access to cardiac rehabilitation remains poor. The COVID-19 pandemic has contributed to a further reduction in access to cardiac rehabilitation. An increasing body of

evidence supports home-based and technology-based models of cardiac rehabilitation as alternatives or adjuncts to traditional centre-based programmes, especially in low-income and middle-income countries, in which cardiac rehabilitation services are scarce, and scalable and affordable models are much needed. Future approaches to the delivery of cardiac rehabilitation need to align with the growing multimorbidity of an ageing population and cater to the needs of the increasing numbers of patients with cardiac disease who present with two or more chronic diseases. Future research priorities include strengthening the evidence base for cardiac rehabilitation in other indications, including heart failure with preserved ejection fraction, atrial fibrillation and congenital heart disease and after valve surgery or heart transplantation, and evaluation of the implementation of sustainable and affordable models of delivery that can improve access to cardiac rehabilitation in all income settings.

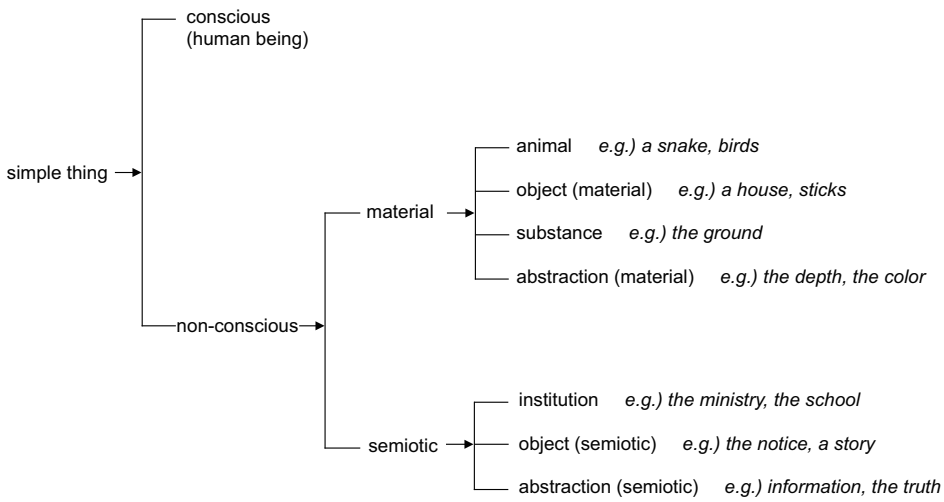
(Taylor, R. S. et al., 2021)

2.1 Things as Participants

As an English teacher, I have found that quite a few students who are good at reading ‘story genres’ (Martin and Rose, 2008) are not familiar with the genre of reports and explanations which scientific papers exploit. Presumably, this is partly because in story genres, conscious participants participate in events, while in reports and explanations, general, abstract and even metaphorical things (i.e., nominalization) serve as participants. Thus, one of the barriers that students face in reading scientific papers seems to be types of ‘things’ as participants.

Halliday and Matthiessen (1999: 182–196) illustrate categories of simple thing as participants (‘simple’ in that they are not ‘metaphorical’). Figure 1 shows a taxonomy of simple thing. The primary distinction is whether the thing is conscious or non-conscious: typically, conscious things are adult humans, who can serve active participants and can participate in conscious processes; while non-conscious things are things other than humans and are further categorized. Non-conscious things are either material or semiotic. Material has four subcategories: animal (e.g., a snake, birds), object (material) (e.g., a house, sticks), substance (e.g., the ground) and abstraction (material) (e.g., the depth, the color). Semiotic has three subcategories: institution (e.g., the ministry, the school), object (semiotic) (e.g., the notice, a story) and abstraction (semiotic) (e.g., information, the truth).

Figure 1: The taxonomy of simple things



(adapted from Halliday and Matthiessen, 1999: 190)

For example, in Example 1, *mRNA vaccines* is a non-conscious - material - object thing; *This Review* is a non-conscious - semiotic - object thing.

Participants such as *their high potency*, *capacity for rapid development* and *potential for low-cost manufacture and safe administration* are quite different type of things: they are not 'simple' thing but 'metaphorical' things.

It seems helpful to give a short sketch of 'metaphorical' realization. The term, 'metaphorical' is often discussed with 'congruent'. In the model of Systemic Functional Linguistics, sequences (a series of events) are 'congruently' realized by clause complexes; figures (events) by clauses; and logical relations between figures by conjunctions. For elements making up figures, participants are congruently realized by nominal groups; processes by verbal groups; and circumstances by either adverbs or prepositional groups. However, these congruent realizations can be expanded when 'shift' and 'fusion' happen: figures and elements other than participants can be 'metaphorically' realized by nominal groups. These metaphorical realizations are called 'grammatical metaphor' and especially, metaphorically nominalized expressions are called 'nominalization' (for detailed discussion on grammatical metaphor, see e.g., Butt et al., 2012; Halliday, 2014; Halliday and Matthiessen, 1999; Simon-Vandenbergen et al. (eds), 2003; and Thompson, 2014). In section 2.2 and 2.3, I will discuss how grammatical metaphor work in examples.

According to the classification, I analyzed types of things in example texts. Table 1 shows a provisional analysis of types of 'things' in Example 1:

Table 1: Types of 'thing' as participant in Example 1

nominal group	*type of 'thing'*		
mRNA vaccines	non-conscious	material	object (material)
a promising alternative to conventional vaccine approaches	non-conscious	material	abstraction (material)
their high potency	metaphorical		
capacity for rapid development	metaphorical		
potential for low-cost manufacture and safe administration	metaphorical		
their application	metaphorical		
the instability and inefficient *in vivo* delivery of mRNA	metaphorical		
Recent technological advances	metaphorical		
these issues	non-conscious	semiotic	abstraction (semiotic)
multiple mRNA vaccine platforms against infectious diseases and several types of cancer	non-conscious	material	abstraction (material)
encouraging results in both animal models and humans	non-conscious	material	abstraction (material)
This Review	non-conscious	semiotic	object (semiotic)
a detailed overview of mRNA vaccines	non-conscious	semiotic	object (semiotic)
future directions and challenges in advancing this promising vaccine platform to widespread therapeutic use	non-conscious	material	abstraction (material)

Here I list some characteristics of types of things shown in Table 1:

Characteristics of types of 'things' in Example 1

(a) Nominal groups are either non-conscious or metaphorical.

(b) In both material and semiotic, abstraction tends to form large and complex nominal groups.

(c) Metaphorical things are used.

As space is limited, instead of showing full analysis of Example 2 and 3, I list some comments on the result.

Characteristics of types of 'things' in Example 2

(a) As observed in Example 1, in both material and semiotic, abstraction tends to form large and complex nominal groups.

(b) As observed in Example 1, metaphorical things are used.

(c) Conscious thing, *we* is used three times as either Sayer or Sensor.

(d) A clause is rankshifted to serve as a 'macro-thing', which is not typical in the language of science.

Characteristics of types of 'things' in Example 3

(a) As observed in Example 1 and 2, in both material and semiotic, abstraction tends to form large and complex nominal groups.

(b) As observed in Example 1 and 2, metaphorical things are used.

(c) As observed in Example 2, conscious thing, *we* is used as Sayer.

In the example texts, abstraction and metaphorical things tend to be realized by large and complex nominal groups. In the next section, I will analyze the organization of nominal groups in the example texts.

2.2 The Organization of Nominal Groups

Abstracts of *Nature Reviews* are complex in that the value of lexical density is quite high. Lexical density is the proportion of content words to the text (Halliday, 2002). It can be measured as the number of lexical words per clause. According to Halliday (2004b: 33), an ordinary value of lexical density in casual speech is 1–2 and that in technical writing is 6–10. The values of lexical density in extracted texts that I have counted are: 10.8 in Example 1; 12.6 in Example 2; and 17.0 in Example 3. The high value of lexical density is due to the complexity of nominal groups. In this section, I will analyze the organization of nominal groups in example texts.

A nominal group in English can be interpreted as Figure 2.

Figure 2: An interpretation of a nominal group

text	these	two	splendid	old	electric	trains	with pantographs
function	Deictic	Numerative	Epithet		Classifier	Thing	Qualifier
			Attitude	Quality			
class	determiner	numeral	adjective	adjective	adjective	noun	prepositional phrase

(adapted from Halliday, 2014: 388)

According to this interpretation, for example, *a promising alternative to conventional vaccine approaches*

from Example 1 can be interpreted as follows: *a* serves as Deictic; and *promising* serving as Epithet and *to conventional vaccine approaches* serving as Qualifier modify *alternative*, Thing (see Figure 3).

Figure 3: An interpretation of a nominal group in Example 1

text	a	promising	alternative	to conventional vaccine approaches
function	Deictic	Epithet	Thing	Qualifier
class	determiner	adjective	noun	prepositional phrase

To take another example, *an emerging class of diagnostics that deploy bioengineered sensors inside the body to query early-stage tumours and amplify disease signals to levels that could potentially exceed those of shed biomarkers*, one of the most complex nominal groups in Example 2 can be interpreted as Figure 4.

Figure 4: An interpretation of a nominal group in Example 2

text	an	emerging	class	of	diagnostics	that deploy bioengineered sensors inside the body to query early-stage tumours and amplify disease signals to levels that could potentially exceed those of shed biomarkers
function	extended Numerative (Variety)				Thing	Qualifier
	Deictic	Epithet	Thing			Embedded Clause Complex
class	det.	adjective	noun	prep.	noun	defining relative clause

In this example, *an emerging class of* functions as extended Numerative, where the head noun is a word of measure or type (Halliday, 2014: 394). Here, the noun, *diagnostics* serving as Thing is delimited in terms of variety. In addition, an embedded clause complex, *that deploy bioengineered sensors inside the body to query early-stage tumours and amplify disease signals to levels that could potentially exceed those of shed biomarkers* serves as Qualifier.

Since this embedded clause complex is intricate, it might be helpful to interpret it (see Figure 5). In this clause complex, the dominant clause (notation: α), *that deploy bioengineered sensors inside the body* is qualified by reference to result (notation: ×β), *to query early-stage tumours and amplify disease signals to levels that could potentially exceed those of shed biomarkers*. In the dependent clause, the initiating clause (notation: 1), *to query early-stage tumours* is followed by the continuing clause (notation: +2), *amplify disease signals to levels that could potentially exceed those of shed biomarkers*. Types of relationship between clauses will be illustrated and discussed in section 2.4.

Figure 5: A clause complex analysis of the Qualifier

that deploy bioengineered sensors inside the body	to query early-stage tumours	and amplify disease signals to levels that could potentially exceed those of shed biomarkers
α	×β	
	1	+2

High value of lexical density and complex nominal groups are characteristics of scientific papers (Washitake, 2021). In his discussion of choosing reading materials toward academic reading, Washitake (forthcoming) also discusses that complexity of nominal groups in scientific papers is not typically derived from the complexity of Qualifier. However, since he discusses general tendency, it seems a hasty to conclude that the analyses shown in Figure 4 and 5 contradict his suggestion.

Metaphorical things, such as *their high potency*, *capacity for rapid development* and *potential for low-cost manufacture and safe administration* (from Example 1) may require further analysis. There are a number of merits of nominalizations: it can 'freeze that event in time and make it an object that participates in a different sort of Process' (Butt, et al. 2012: 99); and 'turning an event into a noun offers opportunities to point out, count, describe, classify and specify further and further' (Butt, et al. 2012: 99). On the other hand, however, nominalizations often keep non-specialists away from the discourse because they tend to make discourse abstract and 'denser'.

A way to approach this problem is 'unpacking' texts (Halliday 2004b). For example, the nominalizations can be unpacked to more 'congruent' form, i.e., to clauses: *their high potency* can be unpacked as *they are highly potential (vaccine approaches)*; *capacity for rapid development* can be unpacked as *(mRNA vaccines) can be developed rapidly*; and *potential for low-cost manufacture and safe administration* can be unpacked as *(mRNA vaccines) can be manufactured at low cost and administered safely*.

Nominalizations realized by more complex nominal groups such as *Detection of cancer at an early stage when it is still localized* and *patient response to medical interventions for most cancer types* (both are from Example 2) are sometimes cannot be unpacked properly without special knowledge in the field in question. For example, *Detection of cancer* can be unpacked either as *(doctors) detect cancer* or *cancer detects (something)*; and in *patient response to medical interventions for most cancer types*, *response* and *intervention* are too abstract for laypersons to be unpacked.

Another problem with nominalization is that there are such nominalizations as *cardiac rehabilitation* and *heart failure* (from Example 3). According to Halliday and Matthiessen (1999: 261), this type of nominalization *was* a grammatical metaphor but 'the metaphorical quality has since been lost, or at least

significantly weakened': its metaphor is 'dead' and cannot be unpacked. Thus, *cardiac rehabilitation* and *heart failure* are congruent forms and are treated as just technical expressions.

To solve problems regarding nominalization and 'dead' metaphor, English teachers may have to ask for specialists' support. Still, the support seems limited compared with what English teachers need when reading scientific papers.

Typically, metaphorical expressions are exploited as a series of 'syndrome': they cooperate with each other to *re*construe experience. In the next section, I will illustrate how metaphorical realization of logical relations are related to nominalization.

2.3 Metaphorical Realization of Logical Relations

As mentioned earlier, nominalization is not the only grammatical metaphor. Relator that relates two clauses can also be metaphorically realized. Relator is congruently realized by conjunction such as *because* and *if*. However, it can be metaphorically realized by other grammatical classes. As Halliday and Matthiessen (1999: 244–267) and Halliday (2004b: 40–43) illustrate, there is a general principle of metaphoric shift: relator can be realized by preposition, verb, adjective and even noun. Figure 6 shows the direction of metaphorical shift.

Figure 6: The direction of metaphorical shit (italic: *example*)

relator (conjunction)	circumstance (preposition)	process (verb)	quality (adjective)	thing (noun)
			unstable →	*instability*
		transform *can* →		*transformation possibility*
	with →			*accompaniment*
so →				*cause/ proof*
		is increasing used to →	*increasing previous*	
	for a long time →		*lengthy*	
then →			*subsequent*	
	(be) instead of →	*replace*		
then →		*follow*		
when →	*in times of*			

(adapted from Halliday, 2004b)

In example texts, the following metaphorical realizations of logical relations are observed:

(1)

mRNA vaccines represent a promising alternative to conventional vaccine approaches because of their high potency, capacity for rapid development and potential for low-cost manufacture and safe administration.

(from Example 1)

(2)

Detection of cancer at an early stage when it is still localized improves patient response to medical interventions for most cancer types.

(from Example 2)

(3)

The success of screening tools such as cervical cytology to reduce mortality has spurred significant interest in new methods for early detection (for example, using non-invasive blood-based or biofluid-based biomarkers).

(from Example 2)

In (1), a logical relation is realized by the prepositional phrase consisting of the prepositional group, *because of* and three nominalizations. The relator in this logical relation can be, more congruently, realized by a conjunction *because* and the three nominalizations can be unpacked as analyzed in section 2.2. Thus, this text can be unpacked as follows:

(1) unpacked example

mRNA vaccines represent a promising alternative to conventional vaccine approaches because they are highly potential (vaccine approaches), they can be developed rapidly and they can be manufactured at low cost and administered safely.

In (2) and (3), logical relations are realized by a verb and a verbal group, *improves* and *has spurred* respectively instead of more congruent form, conjunctions. In these clauses, nominalized expressions *The success of screening tools such as cervical cytology to reduce mortality* and *significant interest in new methods for early detection* serve participants that participate in the processes. (3) can be unpacked as follows. Since (2) and (3), as already discussed, include too abstract nominalizations, it is extremely

difficult to unpack it without specialists' support.

(3) unpacked example

Since screening tools such as cervical cytology to reduce mortality are succeed, (doctors?) are significantly interested in new methods that detect (cancer) early.

The following example does not show metaphorical logical relation between clauses but it is worth analyzing as another example of metaphorical shift.

(4)

The COVID-19 pandemic has contributed to a further reduction in access to cardiac rehabilitation.

(from Example 3)

The word *pandemic* seemes 'dead' metaphor and *The COVID-19 pandemic* is treated as a congruent form. However, in this text, circumstance element, which is more congruently realized by a prepositional phrase is more metaphorically realized by a verbal group, *has contributed to*. In addition, *a further reduction in access to cardiac rehabilitation* is a nominalization. This clause can be unpacked as follows:

(4) unpacked example

Due to the COVID-19 pandemic, less and less patients have undergone cardiac rehabilitation.

Unpacked texts do not always carry the same meanings as metaphorical ones. As observed in this and previous sections, sometimes unpacking is not successful and some texts are too abstract to be unpacked without specialists' support. Still, unpacking seems a proper way to remove difficulty from the language of science. In addition, as Washitake (2021) has illustrated, there are more difficulties in unpacking texts in scientific papers. Thus, at least in terms of learning how to unpack nominalizations, it seems reasonable to conclude that abstracts of *Nature Reviews* are suitable reading materials for students.

2.4 Clause Complexes

Clause complexes are related to grammatical intricacy, another complexity in a text. According to Halliday (2014: 438–451), clauses are linked by two principles: taxis and logico-semantic type. When the status of two clauses are equal, the relation is called parataxis (notation: 1 2 3); and when one clause

depends on the other, the relation is called hypotaxis (notation: α β γ). Logico-semantic type is grouped into two: expansion with three subcategories and projection with two subcategories. By expansion one clause expands the other by elaborating it (notation: =), extending it (notation: +) or enhancing it (notation: ×); on the other hand, by projection, one clause projects the other as a locution (notation: “) or an idea (notation: ‘).

As far as I observed, abstracts of *Nature Reviews* do not tend to exploit clause complex: Example 1 uses two clause complexes and Example 2 and 3 use only one clause complex respectively. In addition, the clause complexes are simple: two clauses are linked in each clause complex. Clause complexes in examples are analyzed as follows:

Figure 7: Analyses of clause complexes in Examples

Recent technological advances have now largely overcome these issues,	and multiple mRNA vaccine platforms against infectious diseases and several types of cancer have demonstrated encouraging results in both animal models and humans.
1	+2

(from Example 1)

This Review provides a detailed overview of mRNA vaccines	and considers future directions and challenges in advancing this promising vaccine platform to widespread therapeutic use.
1	+2

(from Example 1)

To address this issue,	synthetic biomarkers are being developed.
×β	α

(from Example 2)

Future approaches to the delivery of cardiac rehabilitation need to align with the growing multimorbidity of an ageing population	and cater to the needs of the increasing numbers of patients with cardiac disease who present with two or more chronic diseases.
1	+2

(from Example 3)

As these analyses illustrate, clause complexes in example texts are not complex. Thus, it does not seem that clause complexes cause difficulty in reading abstracts of *Nature Reviews*. This characteristic applies to reading scientific papers (Washitake, 2021).

2.5 Approachability

Since reading scientific papers is related not only to construing specialized knowledge but also interpreting the grammar of scientific discourse, teaching how to read scientific papers requires commitment of English teachers. However, English teachers are specialists of language teaching but not experts of science: reading scientific papers is a huge burden to them.

As illustrated in this paper, abstracts of *Nature Reviews* share significant lexicogrammatical characteristics with scientific papers. However, it seems that they are different in the following ways:

(a) As far as I observed, meanings of words in example texts are identified by consulting with general English-Japanese dictionaries: presumably abstracts of *Nature Reviews* do not utilize 'peculiar usage', using general words as technical terms (Washitake, 2021). Understanding 'peculiar usage' requires specialized knowledge in the field in question.

(b) Since articles in *Nature Reviews* are written as accessible, introductory overviews (nature.com), at least their abstracts are not too difficult for those with little knowledge in the scientific field in question.

Thus, it seems possible for English teachers to understand abstracts of *Nature Reviews* with some or no support from specialists.

3. Conclusion

This paper has explored three abstracts of *Nature Reviews* from the perspective of Systemic Functional Linguistics. It focused on 'thing' as participants, nominalization, metaphorical realization of logical relations, clause complexes and approachability. As a result of exploration, it found that 'thing' as participants, nominalization and metaphorical realization of logical relations can cause difficulty in reading. These lexicogrammatical problems are observed in scientific papers (Washitake, 2021). In addition, to 'ordinary' English teachers, abstracts of *Nature Reviews* are easier to approach since the articles are generally written as accessible, introductory overviews. This means that with some or no specialists' support, English teachers can read abstracts of *Nature Reviews* and instruct students how to read scientific papers in terms of their lexicogrammatical characteristics.

In conclusion, abstracts of *Nature Reviews* are helpful materials toward students' reading scientific

papers in two ways: the lexicogrammatical tendencies are similar; and abstracts of *Nature Reviews* are more approachable to those with little specialized knowledge.

Abstracts of *Nature Reviews* treat a wide range of contents regarding latest science and medicine. However, this is one factor to be considered but not the crucial point in deciding reading materials. When choosing reading materials for a specific purpose, focusing on lexicogrammatical characteristics is important as well as on its content.

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