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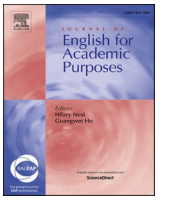

Exploring polysemy in the Academic Vocabulary List: A lexicographic approach

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1. Introduction

Lists of English general academic words, i.e., words occurring frequently in academic discourse across disciplines (e.g., Nation, 2013), such as the Academic Word List (AWL) (Coxhead, 2000) and the Academic Vocabulary List (AVL) (Gardner & Davies, 2014), are of great value to EAP course designers, materials developers and teachers since they facilitate the selection of words to be included in course materials or prioritised for direct teaching. However, the utility of wordlists is limited because, among other things, they lack supplementary information about words in them (e.g., Thompson & Alzeer, 2019). Recent research has attempted to make academic wordlists more user-friendly by providing, for example, grammatical (Green, 2019) and collocational (Lei & Liu, 2018) information about the words listed.

Another way of supplementing academic wordlists would be to indicate which words are polysemous. Information on polysemy in an academic wordlist would be useful to teachers and learners because language learners are unlikely to infer unknown meaning senses of polysemous words from context because they tend to assume that words are monosemous (e.g., Bensoussan & Laufer, 1984; Frantzen, 2003) whereas at least some English general academic words are polysemous (e.g., Granger & Paquot, 2009; Rhees, 2018). Examples include academic words with different meanings when used in general academic English and discipline-specific contexts,

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such as *solution*, denoting 'solution to a problem' in general academic English but also used as a discipline-specific term in chemistry (e.g., 'solution of ammonia in water') (Mudraya, 2006), and academic words whose meanings vary across discipline groups, such as *analyse*, which refers to 'methods of determining the composition of a substance' in science as opposed to the meaning of 'considering something carefully' in the social sciences (Hyland & Tse, 2007, p. 244). Although, as shown above, previous studies indicate that some academic words are polysemous, whole academic wordlists have not been examined for polysemy. Information on how many and which English academic words are polysemous can have implications for academic vocabulary teaching and thus enhance the pedagogical utility of academic wordlists for EAP teaching. With this aim, this study will examine polysemy in the AVL by identifying which AVL lemmas are polysemous and how many meaning senses they have.

This study also addresses a theoretical research gap. Zipf's (1945, 1949) claim that the more frequent a word is, the more meaning senses it tends to have has received support in relation to general vocabulary both in Zipf's aforementioned publications and others (e.g., Casas, Hernandez-Fernandez, Catala, Ferrer-i-Cancho, & Baixeries, 2019; Kuiper, Fromont, & Gerhard, 2017). However, research on the relationship between academic word frequency and meaning-sense number has not been conducted. Establishing the relationship between academic word frequency and meaning-sense number is of both theoretical and practical interest. Theoretically, it is of interest to determine whether academic words behave similarly to general words in terms of their polysemy-frequency relationship. Practically, the findings can be of benefit to EAP pedagogy by providing useful information about the profile of frequent academic words.

To summarise, this study aims to identify polysemous words in general English academic vocabulary operationalised as the AVL and examine the relationship between the frequency of academic words in an academic corpus and the number of their meaning senses. Our method relies on lexicographic and corpus data. In section 2 we discuss the notion of polysemy and dictionary treatment of polysemy, which is followed by an overview of previous research on the relationship between polysemy and word frequency, and on polysemous academic words. The study's research questions are presented in section 3. Section 4 describes the method employed in the study. Section 5 presents results. Section 6 discusses results and their implications for research and pedagogy.

2. Literature review

2.1. Defining polysemy

Polysemy is commonly defined as a type of meaning variation where a lexical item has two or more distinct meaning senses (e.g., Murphy, 2010). Unlike homonymy, where words sharing the same phonological or written form have unrelated meanings (e.g., $bank_1$, which means 'a financial institution' and $bank_2$, which means 'the land alongside a river'), in polysemy the different senses of a word are related to each other: for example, $bank_1$ also has the meaning sense 'a stock of something available for use when required, such as a blood bank' (*Oxford Dictionary of English*).

In the traditional conceptualisation of polysemy, the meaning senses of a polysemous word are considered discrete and well-defined linguistic units, which extend from its core meaning. However, research in corpus semantics and psycholinguistics in the last three decades has revealed that the boundaries between meaning senses of polysemous words are fuzzy rather than strict (Storjohann, 2016), leading to a shift to a more dynamic conceptualisation of polysemy based on the idea of words having 'meaning potentials' (Geeraerts, 2016; Hanks, 2013). To understand the meaning of a word in a particular context, it is necessary to investigate the phraseology of which it is part (Hanks, 2013).

Finally, it is not always easy to decide whether a word is polysemous or two or more homonyms (e.g., Cruse, 2004; Murphy, 2010), how many meaning senses a lexical item has (e.g., Pragglejaz Group, 2007) and which senses need to be taught to foreign language learners (e.g., Garnier & Schmitt, 2015). These practical problems have led researchers to operationalise polysemous words as those that have more than one definition in a learner dictionary (e.g., Dobrić, 2015; Pragglejaz Group 2007), which is the approach we follow in this study. The next section discusses polysemy treatment in dictionaries.

2.2. Polysemy in dictionaries

To infer word meaning, lexicographers examine word usage in large corpora. This process begins with studying many concordance lines with the key word in context (KWIC) and identifying usage patterns. Lexicographers also obtain summaries of a word's grammatical and collocational behaviour from corpus query tools (see, e.g., Kilgarriff, 2013). Word occurrences are then grouped according to meaning similarity and/or collocation and other usage patterns. Once distinct meaning senses are established, their definitions are developed and examples written or selected from the corpus (Alexander, 2015).

Dictionaries vary in the extent to which they differentiate among the senses of polysemous words. A distinction is commonly made between 'splitters', i.e., lexicographers tending to make very fine-grained word sense distinctions, and 'lumpers', i.e., those leaning towards grouping broadly similar senses together (Lew, 2013; Walter, 2010). A dictionary's approach to sense distinction also depends on its intended users. A learner dictionary aimed at beginners, for instance, will tend to adopt a 'lumping' approach, while a dictionary for linguists, such as the *Oxford English Dictionary*, is likely to fall on the 'splitter' side of the continuum.

Dictionaries typically represent polysemy as a numbered list of meaning senses within an entry for a polysemous word (however, see also, e.g., Nesi & Tan, 2011, for the use of signposts and menus to help users navigate longer entries easily). The senses of a polysemous word are listed in the order of frequency; however, this is mostly indicative only, because identifying frequencies of the different senses of a polysemous word would require an enormous amount of laborious sense coding since sense identification cannot be done automatically. Frequency counts of individual senses are affected by whether the dictionary adopts a 'splitter' or a 'lumper'

approach to sense identification (Walter, 2010). Dictionaries also differ in where they draw the line between the polysemy (where meaning sense definitions are listed in a single dictionary entry) and homonymy (where meaning sense definitions are presented in separate entries) of some words, as comparative analyses of commonly used English learners' dictionaries have shown (e.g., Moerdijk, 2003).

Relevant to this discussion is the emergence of online lexicographic resources and databases based on advances in computational lexicography, such as Wordnik[1] and WordNet (Fellbaum, 1998). Wordnik is a dictionary and a language resource which incorporates existing dictionaries and automatically sources examples illustrating a word's meaning senses from the internet, offering users large numbers of examples of target words in context without any editorial interventions. WordNet is a large database of words structured in networks based on their semantic relations, used for research in computational linguistics and natural language processing (see Method for more information).

Notwithstanding the challenges in word sense distinction described above, dictionaries are an excellent tool for examining polysemy from both a theoretical and an applied perspective. Corpus-based dictionaries in particular, such as most English learner dictionaries today (Yamada, 2013) (e.g., *MacMillan English Dictionary for Advanced Learners*, *Collins COBUILD Advanced Learners' Dictionary*), are considered good substitutes for the laborious process of intuitive sense tagging of corpora by linguists (Deignan, 2015). Moreover, consulting a corpus-based dictionary helps to limit the subjectivity of a researcher's sense tagging (Dorst & Reijnierse, 2015).

2.3. Word frequency and polysemy

A positive relationship between a word's frequency and its meaning senses was first formally posited by Zipf (1945, 1949). In addition to his own research, this relationship has been examined through various operationalisations of 'word frequency' and 'meaning senses' of English words and words in other languages (e.g., Casas, Hernández-Fernández, Català, Ferrer-i-Cancho, & Baixeries, 2019; Kuiper et al., 2017). Although the exact statistical findings differ among studies, they all support Zipf's claim. In applied linguistics, the validity of Zipf's exact formula about the relationship between word frequency and word meaning senses has not been examined per se but Reynolds, Wu, Kuo, and Yeh (2015) found a strong positive relationship between word frequency in the British National Corpus and the number of word definitions in WordNet ($r = 0.596$, $p<.0001$).

This issue has implications for vocabulary learning because being aware that high-frequency words tend to have more meaning senses than low-frequency words can inform language teaching. For example, according to Kuiper et al. (2017), a positive relationship between word frequency and the number of word's meaning senses means that language teaching materials for beginner learners should not only include high-frequency English words but also present them in contexts illustrating their different meaning senses.

The studies mentioned above have been conducted on general vocabulary. Examining the relationship between frequency and polysemy in English academic vocabulary can inform the learning and teaching of English academic vocabulary.

2.4. English academic vocabulary

Although *general academic vocabulary* is broadly defined as the vocabulary used in academic writing and speech across disciplines (e.g., Nation, 2013), which words one considers academic depends on which academic wordlist one uses. This section will explain why English academic vocabulary was operationalised as the AVL (Gardner & Davies, 2014) in the present study.

The AVL consists of 3014 word lemmas[2] (i.e., root word forms each with a specific part of speech [POS] and its inflected forms) which occur at least 50% more frequently in the Academic section of the Corpus of Contemporary American English (COCA) than would normally be expected. A lemma wordlist was preferred over a word-family wordlist,[3] such as the AWL (Coxhead, 2000), because the lack of POS tagging in word-family wordlists means that words with the same spelling are counted together although their frequency and meaning may differ depending on POS. Another reason why we preferred the AVL over the AWL is because in the former academic words are evenly distributed across disciplinary sections of the Academic section of COCA whereas the AWL has been found to be more representative of the social sciences than of the hard sciences (e.g., Durrant, 2014).

Finally, we operationalise English academic vocabulary as the AVL because it includes both high-frequency and low-frequency words. In this way, it differs from the AWL, which assumes that academic vocabulary is different from high-frequency vocabulary. This assumption has been criticised because it means that many high-frequency words used both in everyday life and academic settings can be labelled 'general' or 'academic' depending on which words are considered high-frequency (e.g., Cobb, 2010).

[1] Wordnik is freely available at https://www.wordnik.com/.

[2] The Excel file with the AVL provided as supplementary material in Gardner and Davies (2014) consists of 3105 lemmas but the entry for the word *disproportionately* appears twice (Durrant, 2016, p. 53). Therefore, the real number of lemmas in the AVL is 3014. In our study, we worked with 3013 AVL lemmas. We excluded the two *disproportionately* AVL entries from data analysis because these two entries provide different information about the frequency of *disproportionately* in COCA-Academic and, consequently, its rank in the AVL list.

[3] In a word-family wordlist each headword stands for itself and all its inflected and derived forms up to a certain level of Bauer and Nation's (1993) English affixes list, a list of affixes ordered in levels according to their frequency in written English.

2.5. Polysemy in English academic vocabulary

Research has not examined how many English academic words are polysemous. Nevertheless, various studies indicate that at least some English academic words are polysemous.

Studies indicate considerable word overlap between the AWL and wordlists other than the General Service List (West, 1953), such as wordlists derived from the British National Corpus (Cobb, 2010; Masrai & Milton, 2018) and the BNC/COCA word family lists (Masrai & Milton, 2018). For example, Cobb (2010, p.192) found that a "total of 280 AWL items falls within the first two 1000 levels of the BNC"; this overlap accounts for nearly half (49.12%) of the 570 AWL word family headwords. Although some of these AWL and BNC overlapping words may be homographs, this lexical overlap also indicates that some high-frequency English academic words are polysemous.

Corpus studies on various disciplines indicate that specific academic words have more than one meaning (e.g., Granger & Paquot, 2009; Martínez, Beck, & Panza, 2009; Mudraya, 2006; Partington, 1998). Within an academic wordlist, meaning variation has only been investigated with reference to the AWL; however, researchers tended to focus on homonymy rather than polysemy. For instance, Wang and Nation (2004) examined how many AWL word families contain homographs by classifying dictionary definitions of AWL items on a semantic relatedness scale, thus using intuition-based judgements to distinguish between polysemy and homography. They found that 60 out of the 570 AWL items contained homographs. Hyland and Tse (2007) investigated the cross-disciplinary variation in meaning and use of AWL headwords in a corpus of selected hard science, engineering and social science disciplines. Among others, they provide further evidence of cross-disciplinary semantic variation of AWL items due to the existence of homographs, based on the analysis of concordance lines of selected AWL headwords with potential homographs. Although they point to cross-disciplinary differences in the meaning senses of several individual words, such as 'analysis' (as mentioned in the Introduction), which indicate polysemy, polysemy in the AWL is not explored in their study.

Rhees (2018) is another study of English academic vocabulary use across disciplines. In particular, this study conducted Corpus Pattern Analysis (CPA) on the concordance lines which included 30 AWL verb headwords in a corpus made out of research articles in History, Microbiology and Management. CPA is a corpus annotation approach whereby the collocates of verbs are annotated in terms of the broad semantic set they belong to (e.g., if the verb's subject is a person, the tag 'HUMAN' is used to annotate it). These annotations map onto different verb meaning senses and the aim of such annotations is to map meaning on text (Hanks, 2004) because different collocation patterns map onto different meaning senses.[4] By analysing only AWL headwords which are unambiguously verbs, this study examined, in effect, verb lemmas and, consequently, is an examination of polysemy as it is commonly defined. Another methodological strength of Rhees (2018) is that in addition to comparing patterns and meaning senses across the three disciplinary corpora, it examines pattern and meaning sense variation inside each subcorpus. Results indicated that with the exception of *accomplish*, all verbs appeared with more than one pattern, an indication that nearly all verbs are polysemous. Moreover, some of these patterns appeared significantly more in one discipline than in another and others were shared, an indication that some verb meanings are discipline-specific and others are not. Some of these patterns also appear in *The pattern dictionary of English verbs* (Hanks, 2001), an indication that they express meaning senses which are shared between General English and Academic English.

By combining quantitative and qualitative analysis with CPA, this study offers an in-depth view into the polysemy of academic vocabulary. However, this study is limited to a sample of AWL verbs and, therefore, like the other studies reviewed in this section, it does not give us an indication of polysemy in a whole academic wordlist.

3. The present study

The present study is motivated by the research gaps discussed in sections 2.3 and 2.5, namely, the lack of research on the relationship between English academic word frequency and polysemy and the lack of a large-scale identification of polysemous English academic words, respectively.

Regarding the first research gap, by examining whether English academic words tend to have more meanings the more frequent they are, this study addresses a theoretical issue that has implications for English academic vocabulary teaching and learning (see section 2.3). In relation to the second research gap, the present study identifies polysemous academic vocabulary in the AVL. This research aim is pedagogically worthwhile because it will provide EAP and ELT materials designers and practitioners information on which AVL words have more than one meaning sense, thus helping them to identify AVL words with meaning senses their students need to learn. In this way, this study contributes to recent research (e.g., Green, 2019; Lei & Liu, 2018) which supplements English academic wordlists with information teachers and language learners may find useful.

This study addresses these research questions:

1. What is the relationship between AVL lemma frequency in a corpus of academic English and AVL lemma number of meaning senses?
2. Which AVL lemmas are polysemous?

[4] The patterns and associated meanings of English verbs in general English appear in *The pattern dictionary of English verbs* (Hanks, 2001), available at https://www.pdev.org.uk/.

4. Method

4.1. Selection of lexicographic resources

Since dictionaries differ in their treatment of polysemy (see section 2.2), to avoid the shortcomings of identifying polysemous AVL lemmas based on a single dictionary, this study uses two different lexicographic resources, the *Collins COBUILD Advanced English Dictionary* (*COBUILD*) and WordNet (Fellbaum, 1998).

The *Collins COBUILD Advanced English dictionary* is a dictionary with a long history in corpus-based research; its current version is based on the Collins Corpus, which contains 4.5 million words. Aimed at advanced learners of English, such as those typically enrolling in pre-sessional EAP courses, it provides explicit explanations of sense distinctions in a language easily accessible to learners, using only the 3000 most frequent words for definitions and examples. Conversely, WordNet is a large online lexical database created within a research project at Princeton University. Focusing on words' lexical and semantic relationships, it is primarily aimed at researchers, and has been extensively used as a resource in studies of polysemy (e.g., Casas et al., 2019; Kuiper et al., 2017).

Although both are monolingual, they differ in terms of their intended users and purposes: *COBUILD* is an English learner dictionary, while WordNet is a lexicographic database aimed at researchers in computational linguistics and natural language processing. Based on this distinction, *COBUILD* is likely to follow a 'lumping' approach, focusing on sense distinctions of relevance to language learners, while WordNet is likely to be a 'splitter' when it comes to sense distinctions of polysemous words (see section 2.2). Consequently, *COBUILD* can be expected to underestimate polysemy, while WordNet is likely to overestimate it. Using these two lexicographic resources in the study is therefore likely to promote the validity of our AVL polysemous word identification thanks to triangulation (Cohen, Manion, & Morrison, 2018).

We use general English lexicographic resources rather than those limited to academic usage, such as the *Oxford Learner's Dictionary of Academic English*, because students on EAP courses will have encountered AVL lemmas in academic and non-academic discourse in their previous instruction. Research has shown that students tend to assume that words are monosemous and that the meaning they have first encountered applies to other usages of the word (Bensoussan & Laufer, 1984; Frantzen, 2003). We therefore believe it is useful for practitioners to take into account the full spectrum of meanings of AVL lemmas.

4.2. Polysemous AVL lemma identification

Polysemous lemmas in the AVL were operationalised as those with more than one definition in both *COBUILD* and WordNet.

The online *COBUILD* was searched via its Application Programming Interface (API) for the 3013 AVL lemmas (i.e., all AVL lemmas except the two *disproportionately* entries, see footnote 2) using a script written in the programming language Python (van Rossum, 1995). The results of this search were output in an Excel file which contained the lemma and POS columns of the AVL Excel file and an extra column entry for each definition found for every AVL lemma identified in the online dictionary.

202 of the 3013 AVL lemmas were not identified in the *COBUILD* API. A subsequent manual search of *COBUILD* for these lemmas did not result in the identification of any of them.

It should be pointed out that the AVL contains separate lemma entries for words which are spelled differently in American and in British English (e.g., British English *fulfil* and American English *fulfill*); due to the existence of these separate lemma entries in the AVL, we did not consider lemmas with different spellings as interchangeable and, consequently, API-undetected lemmas of this sort (namely, *fulfil*, *judgement*, *underly*) were not lumped together with their American English equivalents.

The definitions extracted from the *COBUILD* API for 100 randomly selected words were compared against those in the online Collins COBUILD dictionary (https://www.collinsdictionary.com/) to test the consistency of the API and online dictionary definitions. This comparison showed that the definitions extracted from the *COBUILD* API were consistent with those in the online *COBUILD* dictionary for all but the adjective *low*. For *low*, the API search yielded 15 whereas the online *COBUILD* consultation yielded 17 definitions; the definitions 'If you drive or ride a bicycle in a low gear, you use a gear, usually first or second, which gives you the most control over your car or bicycle when travelling slowly.' and 'If you describe someone such as a student or a worker as a low achiever, you mean that they are not very good at their work, and do not achieve or produce as much as others.' appeared in the online *COBUILD* dictionary but not in the API. This discrepancy is probably due to changes made in online *COBUILD* entries between the time when the *COBUILD* API was searched (2017) and the time when we checked the aforementioned 100 AVL lemmas in online *COBUILD* (2021). Such discrepancies are not unexpected since online dictionaries are continuously updated. As we considered the single discrepancy identified in the sample acceptable, we did not change the number of definitions for *low* and did not extend the test to further words.

The aforementioned comparison also alerted us to the fact that the *COBUILD* entry 'ethic' included definitions for both *ethic* and *ethics* whereas the AVL includes two separate lemmas, *ethic* and *ethics*. Consequently, the number of *COBUILD* definitions of *ethic* was manually changed from 3 to 1 and that of *ethics* from 4 to 3.

AVL words were manually looked up in the online version of WordNet.[5] The AVL lemmas found in WordNet and the number of WordNet definitions for each of these AVL lemmas were logged in an Excel file. 176 of the 3013 AVL lemmas were not found in WordNet.

Some of the entries in WordNet include definitions of proper names which are irrelevant to the head entries. For example, the entry

[5] The online version of WordNet is version 3.1. It is freely available at http://wordnetweb.princeton.edu/perl/webwn.

for the noun male includes the definition of Male, the capital of the Maldives. Such definitions were not included in the definition counts of AVL words.

The next step in the procedure involved the exclusion of homonyms to ensure that only polysemous AVL lemmas are included in the analysis. As mentioned in section 2.2, dictionaries differ in their approach to distinguishing between polysemy and homonymy. WordNet does not include separate entries for homonyms while analyses of *COBUILD* have shown inconsistent findings. For example, it treats $bank_1$, 'financial institution', and $bank_2$, 'the bank of a river', as homonyms (Oliviera, Miranda, & Siqueira, 2012) whereas $school_1$, 'place for the education of children', and $school_2$, 'school of fish', appear within a single entry, as different senses of a polysemous word (Moerdijk, 2003).

Given that the distinction between polysemous lemmas and homographs is treated differently in these lexicographic resources, to identify AVL lemmas which were truly polysemous according to *COBUILD* and WordNet we needed to identify and exclude from further analysis any AVL items which appear in *COBUILD* and WordNet but are homographs. The AVL items in *COBUILD* and WordNet were looked up in a dictionary which extensively distinguishes between homographs, the English-US dictionary at the Oxford Dictionaries Premium online resource.[6] 26 AVL items which appeared in both *COBUILD* and WordNet were homographs and 2 AVL items which appeared only in WordNet were homographs. This total of 28 AVL items were excluded from further analysis. They appear in the Supplementary materials.

5. Results

This section first presents an overview of the AVL lemmas in each lexicographic resource and those shared between them (5.1). It then reports on correlations between the number of definitions for the shared AVL lemmas in each lexicographic resource and COCA-Academic frequency (5.2); these correlations address research question 1. This section then gives an overview of the AVL lemmas with more than one definition in each lexicographic resource and in both resources (5.3) as a preamble to our answer to research question 2. Research question 2 is addressed via a discussion of the shared AVL lemmas which have more than one definition in both lexicographic resources (5.4).

5.1. AVL lemmas in COBUILD and WordNet

Table 1 provides a breakdown of the AVL lemmas in *COBUILD* and WordNet and those shared between them per POS. The per POS percentage of AVL lemmas found in each resource appears within parentheses.[7] For example, in the first row of Table 1, the 1054 nouns in *COBUILD* account for 93.61% of the 1126 nouns in the AVL following the exclusion of those which correspond to homographs (see section 4.2).

Table 1 shows that both *COBUILD* and WordNet provide excellent coverage of the AVL. The lemmas shared between *COBUILD* and WordNet are fewer than those found in either lexicographic resource due to a lack of complete lemma overlap. Nevertheless, a high percentage of AVL lemmas (89.55%) are shared between them.

5.2. Correlations between COCA-Academic frequency and number of definitions per AVL lemma

Correlation analyses were conducted between COCA-Academic frequency and the number of AVL lemma definitions in the 2673 AVL lemmas shared between *COBUILD* and WordNet. COCA-Academic frequency is the frequency each AVL lemma has in the 120 million words that the Academic section of COCA had when the AVL list was compiled.[8] AVL lemmas are ordered in the AVL list according to their COCA-Academic frequency.

More precisely, the logarithm with base 10 of the COCA-Academic frequency of each word was calculated and correlations were conducted with this variable, [log10(COCA-Academic frequency)].[9] Table 2 provides information on the variables involved in these correlation analyses. These variables are the log10(COCA-Academic frequency) of AVL lemmas shared between *COBUILD* and WordNet and the number of definitions for these lemmas in each lexicographic resource. Because correlations were conducted both between the whole variables and on a POS basis, the aforementioned variables also appear per POS. Because the number of times a lemma occurred in COCA-Academic is more easily interpretable than its log10 transformation, descriptive statistics for both measures are presented.

Kolmogorov-Smirnov tests indicate that none of the variables in Table 2 were normally distributed ($p < 0.001$ for each variable). Therefore, for all variables the median and interquartile range are more valid measures of centrality and dispersion, respectively, than

[6] This resource is subscription-based and available athttps://premium.oxforddictionaries.com. In this resource homographs are numbered (e.g., $bank_1$ and $bank_2$).

[7] All numbers are rounded up to the second decimal place.

[8] COCA-Academic frequency for each AVL lemma can be found in the Excel file which also contains the AVL at https://www.academicwords.info/ .

[9] Word counts from large corpora can be very disparate (e.g., the most frequent AVL lemma occurred 137,208 times in COCA-Academic at the time of AVL construction whereas the least frequent lemma occurred 111 times). Extreme word counts are likely to become outliers in statistical analyses. To decrease the possible effect of outliers on statistical results and increase symmetry around the mean score, researchers can replace raw word counts with their log10 (e.g., Allen & Conklin, 2013; Skoufaki, 2020).

Table 1
AVL lemma coverage by *COBUILD*, WordNet and shared coverage.

POS	AVL items without homographs and 'disproportionately'	*COBUILD*	WordNet	Shared
Noun	1126	1054 (93.61%)	1087 (96.54%)	1030 (91.47%)
Verb	542	528 (97.42%)	539 (99.45%)	528 (97.42%)
Adjective	1036	963 (92.95%)	915 (88.32%)	884 (85.33%)
Adverb	281	240 (85.41%)	268 (95.37%)	231 (82.21%)
Total	2985	2785 (93.3%)	2809 (94.1%)	2673 (89.55%)

Table 2
Descriptive statistics for the variables in the correlation analyses conducted to address Research Question 1.

	POS	Mean	Median	Min	Max	SD	Interquartile range	Skewness	Kurtosis
COCA-Academic frequency	Noun	7071.84	1757	111	1757	13310.29	6659.25	3.96	22.49
	Verb	5677.43	1524	120	93212	9926.02	5471.75	3.51	17.92
	Adjective	3409.29	890	111	99744	7433.23	2468.75	5.64	47.55
	Adverb	3465.34	1066	114	90906	7772.74	3071	7.37	73.48
	All	5273.47	1319	111	137208	10669.10	4392	4.60	31.11
Log10(COCA-Academic frequency)	Noun	3.31	3.24	2.05	5.14	0.70	1.09	0.23	−0.84
	Verb	3.27	3.18	2.08	4.97	0.65	1.02	0.32	−0.80
	Adjective	3.05	2.95	2.05	5.00	0.61	0.87	0.54	−0.38
	Adverb	3.09	3.03	2.06	4.96	0.60	0.97	0.45	−0.60
	All	3.20	3.12	2.05	5.14	0.67	1.03	0.39	−0.68
COBUILD definitions	Noun	1.81	1	1	10	1.25	1	2.15	5.54
	Verb	1.95	2	1	11	1.37	1	2.25	6.92
	Adjective	1.52	1	1	15	1.04	1	4.57	39.34
	Adverb	1.19	1	1	4	0.51	0	3.07	10.27
	All	1.69	1	1	15	1.18	1	2.87	13.34
WordNet definitions	Noun	3.1	3	1	16	2.17	2	1.59	3.35
	Verb	3.34	3	1	21	2.52	2	2.63	11.1
	Adjective	2.19	2	1	13	1.57	2	2.37	8.16
	Adverb	1.41	1	1	7	0.75	1	2.9	13.91
	All	2.7	2	1	21	2.08	2	2.31	8.86

the mean and SD (Field, 2013). A comparison of the median and interquartile range scores as well as the maximum number of definitions indicates that WordNet tends to include more definitions per AVL lemma in general.

In addition to not meeting the normality assumption, the variables in Table 2 also do not meet the linearity assumption of Pearson correlation, as the Loess lines on the scatterplots in Figures A, B and C in the Supplementary materials indicate. Consequently, Spearman correlations and Kendall correlations – which are appropriate for data which do not meet the assumptions of Pearson correlation (Field, 2013) – were conducted instead of Pearson correlations. We conducted Spearman correlations because they are the most commonly used correlations for non-parametric data (Field, 2013). We conducted Kendall correlations to triangulate the findings of the Spearman correlations. Table 3 reports on these correlations.

Table 3 shows that Spearman and Kendall correlations are both significant and positive. Thus, irrespective of how non-parametric correlation is calculated, findings indicate that the more frequent an AVL lemma is, the more definitions it is likely to have both in *COBUILD* and in WordNet[10]. Another important observation is that in both *COBUILD* and WordNet correlations for verbs have the highest strength, followed by correlations for nouns, then adjectives and finally adverbs.

5.3. AVL lemmas with more than one definition in COBUILD, in WordNet and in both

Table 4 provides a breakdown per POS of the AVL lemmas which have more than one definition in each of *COBUILD* and WordNet and those shared between them. The per POS percentage of AVL lemmas found in each resource appears within parentheses.

Table 4 shows that across POS, AVL lemmas with more than one definition form a larger proportion of the AVL lemmas found in WordNet than in *COBUILD*. The consistently higher proportion of polysemous lemmas according to WordNet than according to *COBUILD* agrees with other researchers' observation that WordNet tends to offer more definitions for words than other lexicographic resources (e.g., Navigli, Litkowski, & Hargraves, 2007).

In terms of which parts of speech tend to be polysemous, in all columns (*COBUILD*, WordNet and Shared) verbs have the highest proportion of polysemous lemmas, followed by nouns, then adjectives and finally adverbs.

[10] Kendall correlation coefficients are lower than Spearman correlation coefficients, as is often the case (Conover, 1999).

Table 3
Spearman's rho and Kendall's tau correlations conducted to address Research Question 1.

		Log10(COCA-Academic frequency)	
		Spearman's rho	Kendall's tau
COBUILD definitions for	shared AVL nouns	0.54	0.43
	shared AVL verbs	0.59	0.47
	shared AVL adjectives	0.37	0.3
	shared AVL adverbs	0.31	0.26
	all shared AVL lemmas	0.49	0.39
WordNet definitions for	shared AVL nouns	0.5	0.37
	shared AVL verbs	0.52	0.39
	shared AVL adjectives	0.35	0.27
	shared AVL adverbs	0.2	0.16
	all shared AVL lemmas	0.45	0.34

Note. All correlations are two-tailed and significant at the 0.001 level.

Table 4
AVL lemmas with more than one definition in *COBUILD*, WordNet and among those shared between *COBUILD* and WordNet.

		AVL items with more than one definition		
POS	AVL items without homographs and 'disproportionately'	*COBUILD*	WordNet	Shared
Noun	1126	460 (40.85%)	798 (70.87%)	415 (36.86%)
Verb	542	265 (48.89%)	436 (80.44%)	240 (44.28%)
Adjective	1036	300 (28.96%)	532 (51.35%)	244 (23.55%)
Adverb	281	34 (12.1%)	70 (24.91%)	20 (7.12%)
Total	2985	1059 (35.48%)	1836 (61.51%)	919 (30.79%)

5.4. Polysemous AVL lemmas

As explained in section 4.2, we consider an AVL lemma polysemous if it has more than one definition in both *COBUILD* and WordNet. Table 5 shows the 50 most frequent of these lemmas.

The full list of the resulting 919 polysemous AVL lemmas appears in Appendix 1 in the Supplementary materials, a file with the same structure as Table 5. In both, the second column indicates the 'AVL ID number' of each polysemous lemma, that is, the rank this lemma has in the AVL list. For example, in Table 5, *science* has AVL ID number 61, that is, it is lemma number 61 in the AVL list.[11]

The majority of polysemous AVL lemmas come from the first 1000 AVL lemmas. Fig. 1 shows the breakdown between polysemous AVL lemmas with IDs 1–1000 ('AVL frequency band 1'), IDs 1001–2000 ('AVL frequency band 2'), and IDs 2001–3015 ('AVL frequency band 3').[12]

Fig. 1 shows that most polysemous AVL lemmas are from the first AVL frequency band irrespective of POS. Taken as a whole, polysemous AVL lemmas are also concentrated in the first AVL frequency band, making up 607 (65.05%) of the 919 polysemous AVL lemmas.

These polysemous AVL lemmas also tend to have more meaning definitions than those from the second or third AVL frequency band. Table 6 presents descriptive statistics about the number of definitions of polysemous AVL lemmas across POS and AVL frequency bands as well as overall. The data in all variables are positively skewed. Consequently, Table 6 includes median scores, maximum scores and interquartile range scores, descriptive statistics which are more appropriate to non-normally distributed data than mean and standard deviation scores (Field, 2013).

Table 6 shows that polysemous nouns, verbs and adjectives tend to have more *COBUILD* and WordNet definitions when they come from the first AVL frequency band than from the other bands. Adverbs are the only exception to the general decrease in the number of definitions as we move down the frequency bands; they have a median number of 2 definitions irrespective of AVL frequency band.

Finally, a comparison between the median number of definitions in the polysemous AVL lemmas which appear in both *COBUILD* and WordNet suggests that WordNet tends to list a higher number of definitions than *COBUILD* across POS and AVL frequency bands. This finding agrees with our finding that across POS a higher percentage of AVL lemmas have more definitions in WordNet than in *COBUILD* (see Table 4).

[11] Table 5 does not include AVL IDs 7 (noun *research*), 13 (noun *use*), 15 (noun *data*), 20 (noun *policy*), 21 (noun *university*), 32 (adverb both), 50 (noun *need*), 51 (verb *base*), 53 (adjective *international*), 54 (noun *technology*), 55 (noun *individual*). Out of these lemmas, AVL ID 32 (adverb *both*) appears only in *COBUILD*, not in WordNet as well; the rest are shared between *COBUILD* and WordNet and do not have more than one definition in both.

[12] AVL homographs (see section 4.2) and the duplicate lemma *disproportionately* were excluded from this analysis. The AVL IDs in Table 5, Appendix 1 in the Supplementary materials and Fig. 1 are those in the original AVL list so that readers can easily map our findings onto lemmas in the AVL list.

Table 5
50 most frequent polysemous AVL lemmas shared by *COBUILD* and WordNet.

Rank	AVL ID number	Lemma	POS	*COBUILD* definitions	WordNet definitions
1	1	study	Noun	4	10
2	2	group	Noun	5	3
3	3	system	Noun	7	9
4	4	social	Adj.	3	6
5	5	provide	Verb	2	7
6	6	however	Adv.	3	4
7	8	level	Noun	5	8
8	9	result	Noun	4	4
9	10	include	Verb	2	4
10	11	important	Adj.	2	5
11	12	process	Noun	2	6
12	14	development	Noun	6	9
13	16	information	Noun	3	5
14	17	effect	Noun	4	6
15	18	change	Noun	6	10
16	19	table	Noun	2	6
17	22	model	Noun	7	9
18	23	experience	Noun	3	3
19	24	activity	Noun	3	6
20	25	human	Adj.	2	3
21	26	history	Noun	5	5
22	27	develop	Verb	11	21
23	28	suggest	Verb	4	4
24	29	economic	Adj.	2	5
25	30	low	Adj.	15	10
26	31	relationship	Noun	3	4
27	33	value	Noun	5	6
28	34	require	Verb	2	4
29	35	role	Noun	2	4
30	36	difference	Noun	3	5
31	37	analysis	Noun	3	6
32	38	practice	Noun	4	5
33	39	society	Noun	4	4
34	40	thus	Adv.	2	2
35	41	control	Noun	6	11
36	42	form	Noun	6	16
37	43	report	Verb	5	6
38	44	rate	Noun	4	4
39	45	significant	Adj.	2	4
40	46	figure	Noun	10	13
41	47	factor	Noun	3	7
42	48	interest	Noun	7	7
43	49	culture	Noun	4	7
44	52	population	Noun	2	5
45	56	type	Noun	3	6
46	57	describe	Verb	2	4
47	58	indicate	Verb	6	5
48	59	image	Noun	4	9
49	60	subject	Noun	7	8
50	61	science	Noun	3	2

6. Discussion and conclusion

This study breaks new ground by examining polysemy in the whole AVL instead of only in a small set of English academic words. In particular, this study examined a) the relationship between AVL lemmas' frequency in COCA-Academic and their number of definitions in each of two lexicographic resources and b) the identification of polysemous AVL lemmas.

The relationship between AVL lemmas' COCA-Academic frequency and their number of meaning definitions was examined through Spearman and Kendall correlations. A statistically significant non-linear positive relationship between lemma frequency and number of meaning definitions was found both for *COBUILD* and WordNet definitions. This relationship is non-linear and positive in that low-frequency words tend to have only one definition but once a frequency threshold is passed, the number of word definitions increases as word frequency increases. As Figure A in the Supplementary materials shows, in the correlation between log10(COCA-Academic frequency) and *COBUILD* definitions, the frequency threshold beyond which the correlation becomes positive is 3; a log10(COCA-Academic frequency) of 3 maps onto AVL lemmas with COCA-Academic word frequencies spanning 990 to 1008 counts in the 120 million words that the COCA-Academic corpus consisted of when the AVL was constructed. In the correlation between WordNet definitions and log10(COCA-Academic frequency), the frequency threshold beyond which the correlation becomes positive is log10

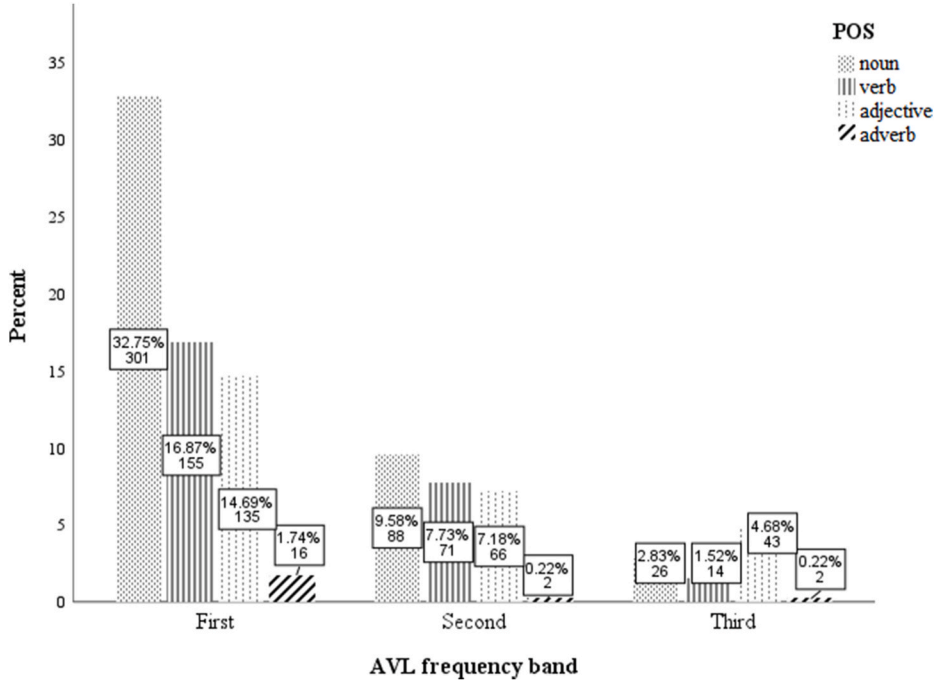

Fig. 1. Percentage of polysemous AVL lemmas across AVL frequency bands and POS.

Table 6
Descriptive statistics for the number of definitions of polysemous AVL lemmas shared by *COBUILD* and WordNet.

		COBUILD					WordNet				
AVL frequency band	POS	Median	Max	Interquartile range	Skewness	Kurtosis	Median	Max	Interquartile range	Skewness	Kurtosis
1	Noun	3	10	2	1.43	2.24	5	16	3	1.07	1.35
	Verb	3	11	2	1.62	3.67	4	21	3	2.32	7.55
	Adj.	3	15	1	3.62	20.32	4	13	3	1.53	2.76
	Adv.	2	4	1	1.50	1.58	2.5	4	1	0.73	−0.54
	All	3	15	2	2.15	8.39	4	21	3	1.76	5.31
2	Noun	2	4	0	4.26	19.38	3	8	1	1.07	1.11
	Verb	2	6	0	4.36	20.29	3	8	2	0.98	0.85
	Adj.	2	4	0	5.38	30.63	3	9	2	2.25	6.32
	Adv.	2	2	0	N/A	N/A	2	2	0	N/A	N/A
	All	2	6	0	5.51	35.79	3	9	2	1.37	2.27
3	Noun	2	7	0	2.83	8.03	3	6	1	1.93	5.37
	Verb	2	3	1	1.07	−1.03	3.5	9	3	0.98	0.57
	Adj.	2	5	0	2.83	8.00	2	6	1	1.71	2.54
	Adv.	2	2	0	N/A	N/A	2.5	3	0	N/A	N/A
	All	2	7	0	3.38	13.24	3	9	1	2.01	4.76
All AVL	Noun	2	10	1	1.77	3.37	4	16	3	1.31	2.10
	Verb	2	11	2	2.03	5.40	4	21	3	2.55	9.87
	Adj.	2	15	1	4.45	30.88	3	13	2	1.87	4.28
	Adv.	2	4	1	1.84	2.86	2	4	1	0.89	−0.24
	All	2	15	1	2.56	10.81	4	21	3	1.99	6.71

Note 1: Skewness and kurtosis data are not applicable for AVL frequency band 2 and 3 adverbs because in each of these AVL frequency bands only two such adverbs have more than one definition in both *COBUILD* and WordNet.
Note 2: The minimum number of senses for all POS in all AVL frequency bands is 2.

(COCA-Academic frequency) 2.7, which maps onto AVL lemmas with COCA-Academic word frequencies spanning 496 to 506 counts.

These findings agree with findings of earlier studies on the relationship between the frequency of general English words and their number of meaning definitions in lexicographic resources. Out of these studies, Casas et al. (2019) is the most comparable to ours because it statistically addressed this issue via correlation (not regression). Casas et al. (2019) found a significant and non-linear correlation between WordNet definitions and frequency in a large corpus, both when the latter was operationalised as frequency in the CHILDES database (MacWhinney, 2000) and as frequency in Wikipedia.

In our study, this statistically significant non-linear and positive relationship was also found across POS (i.e., noun, verb, adjective, adverb). Since Casas et al. (2019) did not conduct correlations per POS, this analysis and finding are novel. A related notable finding is that verb definitions (both in *COBUILD* and WordNet) had the strongest correlation with COCA-Academic frequency than the definitions of any other POS, followed by noun, adjective and adverb definitions.

In terms of the second research question, our study found that, after excluding the duplicate AVL item 'disproportionately' and AVL homographs from further analysis, 919 (34.38%) out of the 2673 AVL lemmas appearing in both *COBUILD* and WordNet have more than one definition in both resources. In addition to this high occurrence of polysemous lemmas in the AVL, 66.05% of the 919 polysemous lemmas come from the most frequent 1000 AVL lemmas, 24.7% from the second most frequent 1000 AVL lemmas, and 9.25% from the last 1013 AVL lemmas. This finding agrees with the findings from the correlation analyses that the more frequent an AVL lemma is, the more likely it is to be polysemous and that below a frequency threshold very few AVL lemmas are polysemous.

These 919 polysemous AVL lemmas seem to be of high utility to university students not only because they are likely to appear often in their reading materials but also because many of them are used in university students' writing. Durrant (2016) identified 427 AVL lemmas – all from the most frequent 1000 AVL lemmas – which appear more than 12 times per million tokens in 28 or more of the 31 disciplines in the British Academic Written English (BAWE) corpus. Because of their high cross-disciplinary occurrence in British university students' writing, these 427 AVL lemmas are likely to be useful for the writing needs of all British university students (Durrant, 2016). A cross-check between them and the 919 AVL lemmas identified as polysemous in the present study shows that 299 (70.02%) of these 427 AVL lemmas are polysemous.

However, it needs to be acknowledged that not all meanings of the 919 polysemous AVL lemmas are equally likely to occur in academic contexts. In addition, some polysemous AVL lemmas may have specific meanings in specific fields. While a qualitative analysis of the meaning definitions of polysemous AVL lemmas is out of the scope of this paper, we discuss the meaning definitions of the most frequent polysemous AVL lemmas, the nouns *study* and *group* as examples, illustrated with excerpts from COCA. Of the ten definitions of *study* in WordNet and four in *COBUILD* (see Appendix 2), some (e.g., definition 3 in WordNet, 'a written document describing the findings of some individual or group', and definition 2 in *COBUILD*, 'a study of a subject is a piece of research on it') are more likely to occur in academic texts than others (e.g., meaning 5 in WordNet, 'a room used for reading and writing and studying' and meaning 4 in *COBUILD*, 'a study is a room in a house which is used for reading, writing, and studying'). Some meanings are likely to appear in specific disciplines, such as meaning 10 in WordNet ('a composition intended to develop one aspect of the performer's technique; "a study in spiccato bowing"). By contrast, other meanings are likely to appear in both academic and non-academic texts; for instance, meaning 2 in WordNet ('applying the mind to learning and understanding a subject (especially by reading)') and meaning 1 in *COBUILD* ('study is the activity of studying') can occur in both academic and everyday contexts as the following excerpts from different sections of the COCA corpus show: 'some of them choosing Schussler Fiorenza as their object of study' (Academic), 'His rigorous study of the two thinkers, his attempt to understand them' (Fiction), 'these are fascinating creatures, worthy of study' (TV/Movies), and 'it does not require a lot of study to understand what the best situation for a child is' (Blog).

The definitions of noun *group*, the second most frequent polysemous AVL, offer further examples of the difficulty to distinguish between academic and non-academic meanings of some polysemous AVL lemmas: meaning 1 in both WordNet ('any number of entities (members considered as a unit)') and *COBUILD* ('a group of people or things is a number of people or things that are together in one place at one time') are likely to occur in both academic and non-academic discourse. As explained in section 2.2, this difficulty reflects the nature of polysemy and the fact that meanings of polysemous words are not strictly delineated in real-life discourse; rather their meaning is shaped in interaction with the context in which the word occurs. This has important implications for future research and pedagogy, which we discuss in the next sections.

6.1. Implications for future research

This study identified polysemous lemmas in the whole AVL thanks to its lexicographic approach to polysemy. However, this lexicographic approach has also meant that examining which AVL lemma meaning senses are shared across disciplines and which occur only or mainly in one discipline or a group of disciplines was out of the scope of this study. Identifying the meaning senses of AVL lemmas across disciplines is of high pedagogical value because it would direct EAP teachers and students to meaning senses that are worth learning across disciplines or within disciplinary groups. Such research would require coding many instances of polysemous AVL lemmas in large academic corpora representative of all disciplines.

Which academic-word meaning senses students will need to learn also depends on which meaning senses they already know. This fact calls for the development of academic-word tests which assess not only one's ability to recognise the most frequent meaning sense – as, for example the academic-words sublist in Schmitt, Schmitt and Clapham's (2001) versions of the Vocabulary Levels Test – but also other meaning senses of academic words. Moreover, tests examining students' ability to produce the right academic word in specific sentential contexts are needed. As we saw in section 6, 70.02% of the 427 AVL lemmas which appear more than 12 times per million tokens in 28 or more of the 31 disciplines in the BAWE corpus are polysemous according to our analysis. Finally, tests examining students' ability to recall (not just recognise) academic-word meaning senses will be useful indicators of students' reading comprehension ability because the ability to recall word meaning (meaning recall) is a more reliable predictor of reading comprehension than the ability to recognise word meaning (meaning recognition) (e.g., McLean, Stewart, & Batty, 2020).

6.2. Pedagogical implications

The fact that most polysemous AVL lemmas (66.05%) are among the most frequent 1000 AVL lemmas (see Fig. 1) and that, as

mentioned above, 70.02% of the AVL lemmas shared across disciplines in BAWE are polysemous indicate that university students are likely to encounter many of the polysemous AVL lemmas and use them in academic writing tasks. Unfortunately, research indicates that the incidental learning of the meaning senses of words is very slow (e.g., Pigada & Schmitt, 2006). This slow learning rate can be due to aspects of students' input, such as the insufficient and ambiguous contextual clues common in natural text (e.g., Frantzen, 2003). It may also be due to learners' behaviour. For example, learners have been found to resist inferring meaning senses from context because of a 'monosemy bias'. Research suggests that learners tend to assume that the meaning sense they already know for a word applies to all contexts (e.g., Bensoussan & Laufer, 1984; Frantzen, 2003). This can cause particular problems if the meaning sense they already know is the one typically used in everyday life rather than in academic discourse. Combined with L2 university students' difficulty with selecting appropriate definitions from the dictionary entries of polysemous words (Nesi & Haill, 2002), this monosemy bias indicates the need to alert students to the polysemous nature of high-frequency academic words.

To raise students' awareness of the polysemous nature of many academic words, EAP teachers and materials developers can design tasks consisting of sets of sentences or passages containing selected polysemous academic words used with different meaning senses; students can then be asked to infer a word's meaning from context and/or select the relevant definition for each word from a dictionary. Because, as mentioned, L2 students may face difficulty with dictionary consultation, teachers may need to raise learners' awareness of various aspects of dictionaries which facilitate lookup (e.g., sense signposts, grammatical/collocational information in a dictionary entry). The list of polysemous AVL items provided in this study (see Appendix 1 in the Supplementary materials) can serve as a resource for word selection for such tasks, while suitable authentic sentences and passages containing target AVL items can be sourced from freely accessible academic and general corpora (e.g., COCA, including its academic section, and the British National Corpus are available athttps://www.english-corpora.org).

Dictionary selection is another important issue to consider. As our study has found, dictionaries differ in how they treat polysemy and how many meaning senses of academic words they identify. While our study used general English dictionaries aimed at learners (*COBUILD*) and expert users (WordNet), EAP practitioners may consider using a dictionary of academic vocabulary usage, such as the *Oxford Learner's Dictionary of Academic English*, which uses sentences from the Oxford Corpus of Academic English to illustrate the meaning definitions of words, including those that students may previously have encountered in non-academic contexts.

Tasks applying the principles of data-driven learning (see, e.g., Friginal, 2018) can be designed to promote students' discovery of meaning variation of polysemous AVL items across registers and disciplines. Such tasks would require students to analyse concordance lines containing target polysemous AVL lemmas and classify their occurrences according to similarities in meaning, which can be followed by small group comparison and discussion activities. Existing academic and discipline-specific corpora, such as the disciplinary subsections of COCA-Academic, can be used for such data-driven tasks. Alternatively, students can be encouraged to compile their own small corpora from articles in their discipline (see, e.g., Charles, 2012), which they can explore to gain an understanding of the meaning senses of target polysemous AVL words commonly used in their field.

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Appendix A. Supplementary data

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