Applied Linguistics 2022: XX/XX: 1–25
https://doi.org/10.1093/applin/amac044

Open Access Academic Lectures as Sources for Incidental Vocabulary Learning: Examining the Role of Input Mode, Frequency, Type of Vocabulary, and Elaboration

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Open access academic lectures are potential sources for incidental vocabulary learning. These lectures are available in various formats (transcripts, audios, videos, and video with captions), but no studies have compared the learning of vocabulary in these lectures through different input modes. This study adopted a pretest–posttest design to compare learning at the meaning recall level of 50 words in the same academic lecture through five input modes: reading, listening, reading while listening, viewing, and viewing with captions. One hundred sixty-five English for Academic Purposes learners in China were assigned to five experimental groups and a control group. The experimental groups received the treatment with the assigned input mode while the control group received no treatment. Results show that although learning occurred through all input modes, only viewing significantly contributed to the learning gains. Frequency of occurrence and type of vocabulary significantly predicted the learning gains, but the type of verbal elaboration and nonverbal elaboration did not. This study provides further insights into the value of academic lectures for incidental vocabulary learning and supports the multimedia learning theory and its principles.

1. INTRODUCTION

Second language (L2) learners need to know a large number of words to understand different discourse types, but it is challenging for teachers to explicitly teach all of these words due to limited classroom time (Webb and Nation 2017). Therefore, it is important to determine potential sources for L2 learners to learn vocabulary incidentally. Earlier research on incidental vocabulary learning has mainly focused on nonacademic sources (e.g. graded readers, television programs). Yet recently several well-known universities have made

their courses available online for nonprofit use. Lectures from these open access courses could be potential sources for L2 learners in English-medium universities as well as those in English for Academic Purposes (EAP) programs for several reasons. First, academic lectures contain frequently occurring topic-related words which are essential for learning a subject (Dang 2018). Second, the close link between topic-related vocabulary and academic content also means that academic lectures are likely to draw attention from learners (Coxhead 2018). Third, these lectures are publicly available, which makes it possible for teachers and learners to use them as learning materials. As repetition of topic-related words, learners' attention to input and material availability are important for incidental vocabulary learning to occur (Webb 2015; Godfroid *et al.* 2018), lectures from open access courses might be a potential source for incidental vocabulary learning.

Recognizing the importance of academic lectures, several studies have examined the learning of vocabulary through listening to (Vidal 2003, 2011) and viewing academic lectures (Dang *et al.* 2022). They found that learning did occur through these modes. However, they only used either the audios or videos of academic lectures as the input while lectures from open access courses are available in various formats (transcripts, audios, videos, and video with captions). Camiciottoli (2020, 2021) recommends that EAP teachers should encourage their students to take full advantage of all available materials (e.g. transcripts, captions), not just lecture recordings. Yet no studies have compared the learning of vocabulary in open access academic lectures through different input modes. Addressing this gap would help to determine which input mode best facilitates the learning of vocabulary from academic lectures, which in turn would allow teachers to make better use of this kind of input.

The present study was conducted with two aims. The first aim was to investigate the learning of vocabulary in an academic lecture through five input modes: reading, listening, reading while listening, viewing, and viewing with captions. The second aim was to examine the effect of frequency of occurrence, type of vocabulary, type of verbal elaboration, and nonverbal elaboration on vocabulary learning through these modes. By comparing aural input (listening), written input (reading), aural plus written input (reading while listening), audiovisual input (viewing), and audiovisual plus written input (viewing with captions), this study would provide further insights into the relative value of written input, aural input, and visual input for L2 vocabulary learning and how different factors affect vocabulary learning through these modes.

2. BACKGROUND

2.1. Incidental vocabulary learning through different input modes

The present study defines incidental learning as a byproduct of other activities (e.g. reading newspapers, watching movies) (Ellis 1999). That is, vocabulary learning occurs when the focus is on understanding the message in the

input rather than deliberately learning a set of words. Incidental vocabulary learning is an essential part of well-balanced vocabulary programs (Webb and Nation 2017). To successfully perform various tasks in English, L2 learners need to know a large number of words, but it would be impossible for teachers to explicitly teach all of these words in class time (Webb and Nation 2017). Meeting words repeatedly in meaningful contexts helps learners to expand and consolidate their vocabulary knowledge both in terms of breadth and depth.

Given its significant role in L2 vocabulary learning and teaching, incidental learning has received a great deal of attention from vocabulary researchers. Most previous studies have focused on written input. They have shown that L2 vocabulary could be learned through reading sets of short sentences (Webb 2007), graded readers (e.g. Brown *et al.* 2008; Webb and Chang 2015a, b), authentic nonacademic texts (Pellicer-Sánchez and Schmitt 2010), and academic texts (Vidal 2011).

Studies with audio input, however, are fairly limited in number. They have revealed that vocabulary learning can occur through listening to (Brown *et al.* 2008; van Zeeland and Schmitt 2013) and reading while listening to graded readers (Brown *et al.* 2008; Webb and Chang 2015a, b; Teng 2018), listening to songs (Pavia *et al.* 2020), and listening to teachers (Jin and Webb 2020). Only Vidal (2003, 2011) has investigated vocabulary learning through listening to academic lectures, but the lectures in her studies were modified from authentic sources. Whether vocabulary can be learned through listening to an unmodified lecture remains to be determined.

In recent years, with the popularity of audiovisual input, a growing number of studies have investigated vocabulary learning through viewing and viewing with captions. Research has revealed that vocabulary can be learned through viewing short video clips (e.g. Neuman and Koskinen 1992; Montero Perez *et al.* 2014; Puimège and Peters 2019), full-length television programs with captions (e.g. Peters 2019) and without captions (Peters and Webb 2018; Feng and Webb 2020; Rodgers and Webb, 2020). Only three studies have investigated vocabulary learning through viewing academic lectures. Smidth and Hegelheimer (2004) and Yang and Sun (2013) both found that viewing academic lectures led to vocabulary learning. However, the lack of a control group makes it less transparent whether the learning occurring in these studies was solely attributed to the treatment (viewing). To address this limitation, Dang *et al.* (2022) included a control group. They also found that viewing an academic lecture resulted in vocabulary learning.

Several studies have explicitly compared vocabulary learning across different input modes. Using graded readers as the input, Brown *et al.* (2008) found that reading while listening and reading led to greater learning gains than listening, but there were no significant differences in the learning gains of reading while listening and reading. However, later, both Webb and Chang (2012) and Teng (2018) found that reading while listening resulted in greater learning gains than reading. It can be inferred from these studies that as for graded readers, reading

while listening may better facilitate vocabulary learning than reading and listening whereas listening may facilitate vocabulary learning the least.

Several studies have compared vocabulary learning from different input modes with television programs as the source of input. Neuman and Koskinen (1992) found that viewing with captions led to greater learning gains than reading while listening. Meanwhile, Feng and Webb (2020) found that listening, reading, and viewing contributed equally to vocabulary learning gains. As for the comparison between viewing and viewing with captions, previous research consistently showed that viewing with captions resulted in greater learning gains than viewing at the meaning recognition level (Neuman and Koskinen 1992; Montero Perez et al. 2014, 2018; Peters 2019; Teng 2019). However, the findings related to the learning gains at the meaning recall level were fairly mixed. Some studies (Peters 2019; Teng 2019) revealed that viewing with captions led to significantly greater learning gains than viewing while the others (Neuman and Koskinen 1992; Montero Perez et al. 2014, 2018) did not find any significant difference in the learning gains under the two conditions. It can be inferred from previous studies that when television is the source of L2 input, viewing with captions may facilitate vocabulary learning better than viewing and reading while listening whereas viewing is likely to contribute to vocabulary learning as well as reading and listening.

To the best of our knowledge, only Vidal (2011) has examined the effect of input modes on incidental learning of vocabulary in academic lectures. Comparing the learning gains through listening to academic lectures and reading academic texts, she found that both input modes resulted in learning gains, but listening led to smaller gains than reading. While Vidal's study provides useful insights into incidental learning of vocabulary in academic lectures, several areas need further investigation. First, the lectures and the readings used in her study had been modified. It would be useful to examine whether the same result would be found if an unmodified lecture was used. Second, with the popularity of open access courses, academic lectures have been available to language learners in various formats: transcripts, audios, videos, and video with captions. This means that these lectures could be presented to learners through different modes such as reading, listening, reading while listening, viewing, and viewing with captions. It would be useful to directly compare and determine the relative contribution of each mode to vocabulary learning. Such research would provide further insights into the relative value of written, aural, and audiovisual input to incidental vocabulary learning and shed light on the value of academic lectures as a source of input for L2 learners.

2.2. Multimedia learning theory

As this study compared vocabulary learning through different input modes, this section will review Mayer's (2014) multimedia learning theory. According to this theory, human beings can process information through two channels. As these channels have limited capacities, information processed through both

channels would make better use of these channels and in turn would result in better learning outcomes than information processed through only one channel. There are two approaches toward classifying these channels. The presentation-mode approach, which is based on the format of the stimulus, divides these channels into the verbal channel (e.g. written and spoken forms of words) and the nonverbal channel (e.g. images). The sensory-modality approach, however, categorizes these channels into auditory channel (i.e. the information is processed through the ears) and visual channel (i.e. the information is processed through the eyes). Given the variation in the approaches toward classifying the two channels, Mayer (2014) calls for further investigation to determine which approach is more appropriate.

Two important principles of the multimedia learning theory are the split-attention principle and the redundancy principle. The split-attention principle proposes that multimedia learning materials should not split students' attention among various sources otherwise this would create extraneous cognitive loads on their working memory and hinder learning (Ayres and Sweller 2014). Therefore, the redundancy principle suggests that redundant materials, which duplicate the same information in multiple forms will negatively affect learning because they make students to split their attention in order to coordinate redundant information from different sources (Kalyuga and Sweller 2014).

Research in the context of learning science in L1 has provided solid evidence supporting the multimedia learning theory and its principles (Mayer 2014). Second Language Acquisition (SLA) research also supports the multimedia learning theory by finding that multimedia input (graded readers, television programs) facilitated second language learning, but at the same time questions the split-attention principle and the redundancy principle when showing that duplicating the same information in multiple forms did not have negative effect on comprehension nor learning (e.g. Peters 2019; Pellicer-Sánchez *et al.* 2020). It is important to note that studies supporting the multimedia learning theory and its principles used academic texts as the input for L1 students to learn science. Meanwhile, studies that do not support these principles used nonacademic texts (e.g. graded readers, TV programs), which have lower degree of complexity, for L2 learners to learn another language. Therefore, it remains to be answered whether the split-attention principle and the redundancy principle hold true if academic input such as academic lectures is used as the input for L2 learning.

2.3. Factors affecting incidental learning of vocabulary in academic lectures

Four studies have examined factors affecting the learning of vocabulary in academic lectures. These studies focused on either listening (Vidal 2003, 2011) or viewing (Yang and Sun 2013; Dang *et al.* 2022) and they investigated the contributions of frequency of occurrence, type of vocabulary, and type of elaboration on incidental vocabulary learning.

2.3.1. *Frequency of occurrence.* Research indicated that frequency of occurrence significantly contributed to the learning gains through listening to (Vidal 2003, 2011) and viewing academic lectures (Yang and Sun 2013; Dang *et al.* 2022). No studies have investigated the effect of frequency on vocabulary learning through viewing academic lectures with captions and other input modes. Exploring the extent to which frequency influences vocabulary learning in different input modes is important. It would help to determine the amount of input needed to promote the learning of vocabulary in academic lectures in different conditions, which would effectively inform the selection and design of materials and activities for L2 vocabulary learning.

2.3.2. *Type of vocabulary.* Previous studies reported that the type of vocabulary significantly predicted vocabulary learning through listening to (Vidal 2003, 2011) and viewing academic lectures (Yang and Sun 2013). Technical vocabulary was more likely to be learned than academic vocabulary and low-frequency vocabulary, whereas low-frequency vocabulary was more likely to be learned than academic vocabulary. While these studies provide useful insights into the effect of the type of vocabulary on incidental learning of vocabulary in academic lectures, certain areas need further investigation. First, these studies used items from academic written word lists—Coxhead's (2000) Academic Word List and Xue and Nation's (1984) University Word List—to represent academic vocabulary in lectures. Vocabulary in academic spoken English is different from that in academic written English to some extent (Dang and Webb 2014; Dang 2020a). Wordlists developed from academic speech such as Dang *et al.*'s (2017) Academic Spoken Word List better reflect academic vocabulary in lectures. Second, previous studies considered specialized vocabulary (technical vocabulary and academic vocabulary) being different from low-frequency vocabulary. However, recent research (Gardner and Davies 2014; Dang *et al.* 2017; Dang 2020b) has suggested that academic vocabulary and technical vocabulary are no longer separate levels from high- and low-frequency words, but cut through these frequency layers. Finally, previous studies (e.g. Vidal 2003) only examined listening and viewing while academic lectures may be available in other formats. Taken together, it is important to investigate the effect of the type of vocabulary on vocabulary learning through different input modes. The classification of vocabulary types in such research should reflect the nature of vocabulary in academic spoken English. Its findings would provide us with valuable insights into the kind of vocabulary that is less likely to be learned incidentally so that teachers could plan accordingly.

2.3.3. *Elaboration.* Earlier studies found that elaboration made a significant contribution to vocabulary learning through listening to (Vidal 2003, 2011) and viewing academic lectures (Yang and Sun 2013). Words with explicit verbal elaboration (i.e. those explained through definitions, descriptions, and naming and questioning statements) were more likely to be learned than words with

implicit verbal elaboration (i.e. those explained through examples, paraphrase, or synonymy), which were more likely to be learned than words with no elaboration. Only Yang and Sun (2013) examined nonverbal elaboration (e.g. explanations through gestures, symbols, or images). Focusing on viewing, they found that words with nonverbal elaboration had higher learning gains than those without nonverbal elaboration. No studies have explored the effect of verbal elaboration and nonverbal elaboration on the learning of vocabulary in academic lectures through different input modes. Addressing this gap is important, because it would help language teachers to anticipate which kinds of elaboration are likely and unlikely to facilitate the learning of vocabulary in academic lectures and provide learners with relevant strategies to recognize these kinds of elaborations. It would also help content lecturers to select the kind of elaboration that best facilitates the comprehension of students whose L1 is not English.

2.4. Research questions

The review has shown that no previous studies have (i) compared the learning of vocabulary in academic lectures through different input modes and (ii) examined the influence of frequency of occurrence, type of vocabulary, and elaboration on the learning across these modes. To address these gaps, this study would investigate the following questions:

1. To what extent do L2 learners incidentally learn vocabulary in an academic lecture through reading, listening, reading while listening, viewing, and viewing with captions?
2. How do vocabulary learning gains compare across these input modes?
3. What is the relationship between the vocabulary learning gains and the following factors: frequency of occurrence, type of vocabulary, type of verbal and nonverbal elaboration?

3. METHODOLOGY

3.1. Participants

One hundred sixty-five postgraduate students at a university in China participated in the study. These participants were recruited on a voluntary basis following the authors' institutional ethical guidelines. These students majored in Technology and Engineering and were from six intact EAP classes. Each class was randomly assigned to either the control group or one of five experimental groups. The experimental groups encountered the target words in the same academic lecture in one of the following input modes: (i) reading, (ii) listening, (iii) reading while listening, (iv) viewing, and (v) viewing with captions. The reading group (n = 27) read the transcript of the lecture silently. The listening group (n = 27) listened to the audio version of the lecture. The reading while listening group (n = 28) listened to the audio version of the lecture and simultaneously

read the transcript. The viewing group (n = 28) watched the video of the lecture. The viewing with captions group (n = 28) watched the video of the lecture which contained captions. The control group (n = 27) did not receive any treatment but completed the same dependent measures as the experimental groups. The participants took Webb *et al.*'s (2017) Updated Vocabulary Levels Test (UVLT), which was delivered two weeks before the treatment as part of their program entry test (see online supplementary material for Appendix A for their scores). One-way between-groups ANOVA revealed no significant difference in the mean scores of the six groups on the UVLT: F (5,159) = 1.5, p = 0.19, η^2 = 0.05, which indicated that their vocabulary levels were similar.

3.2. Materials and target words

The materials were the video, audio, and transcript of an open access lecture in an introductory undergraduate course in Algorithms delivered by the Massachusetts Institute of Technology for nonprofit use (see online supplementary material for Appendix B). The steps of selecting the materials are described in detail in online supplementary material for Appendix C. The target words were 50 content words that occurred in the lecture and were unknown to at least 80 percent of the participants in a pilot study (see online supplementary material for Appendix D for detailed information of these words).

3.3. Variables

This study examined the relationship between vocabulary learning in each input mode and four factors: frequency of occurrence, type of vocabulary, type of verbal elaboration, and nonverbal elaboration. The frequency of occurrence was measured by counting the occurrences of the target words in the lecture. The type of vocabulary, type of verbal elaboration, and nonverbal elaboration were rated by the first and second authors. They independently watched the video, read the transcript of the lecture, and did the rating. Detailed descriptions of the rating of the vocabulary types and elaboration are presented in online supplementary material for Appendix E.

3.4. Dependent measures

A vocabulary test was designed to measure knowledge of the target words at the meaning recall level (see online supplementary material for Appendix F). This test was used as the pretest, immediate posttest, and delayed posttest, but the order of items in these tests was different to minimize the chances of a testing effect. To motivate the participants to do the test, the test also included two words known by at least 80 percent of the participants in a pilot study (*machine*, *analysis*). Data related to these items were not included in the analysis. To complete the test, the participants were presented with the spoken and written forms of the target words, and had to provide the translation of the words, the symbols for which the words stood, or explain

the meaning of the words in English or Chinese. To ensure the participants understood how to complete the test, examples were provided and instructions were given in Chinese. The internal consistency of the test was very good (Cronbach's $\alpha = 0.89$)

3.5. Comprehension test

To measure the participants' comprehension of the lecture, a 10-item True/False comprehension test was designed and delivered to the participants at the end of the treatment (see online supplementary material for Appendix G for the test and Appendix H for a detailed description of the steps taken when developing the test).

3.6. Procedure

The experiment was carried out for three consecutive weeks. All participants were informed that this study aimed to explore their comprehension of an academic lecture so that they would focus on the content rather than deliberately learn the unknown words in the lecture. In Week 1, all groups completed the pretest. In Week 2, the experimental groups received the treatment with the assigned input mode. Immediately after the treatment, all participants completed the comprehension test and the immediate posttest. The control group did not receive any treatment but still completed the immediate posttest. In Week 3, all groups took the delayed posttest.

3.7. Scoring and analysis

Data were scored dichotomously. Correct answers and incorrect answers were scored as 1 and 0, respectively. The tests were independently scored by the second author and another rater who was a native speaker of Chinese with an advanced level of English and a PhD in technology and engineering. There was almost perfect agreement between their ratings (Cohen kappa $\kappa = 0.99$, $p < 0.0005$). Disagreement was resolved through discussion.

Statistical analysis was conducted with the lme4 package in the R statistical platform. To address the first two research questions, we performed a single linear mixed-effects model to identify if there existed significant differences in the scores of the six groups representing different input modes (control, reading, listening, reading while listening, viewing, and viewing with captions) through the three testing times (pretest, immediate posttest, and delayed posttest). In this model, the score was the dependent variable. The fixed factors were mode, time, the interaction between mode and time, and vocabulary level. The random effect was the participant. Mode and time were categorical variables; therefore, treatment coding was used when coding them. The reference levels for mode and time were the control group and the pretest, respectively. The variance information factor scores of time, mode, and vocabulary level were around 1.0, suggesting no problems with multicollinearity.

To address the last research question, we performed a series of general linear mixed-effects models for each experimental group. These models allow us to analyze the correctness of the participants' responses to the target words as binomial variable (correct/incorrect). In each model, the dependent variable was the score (correct/incorrect). The fixed effects were frequency of occurrence, type of vocabulary, type of verbal and nonverbal elaboration, and the random effect was participant. Continuous variables (UVLT score, frequency of occurrences) were centered and standardized. We also followed the treatment coding when coding the categorical variables (type of vocabulary, type of elaboration, nonverbal elaboration). In terms of type of vocabulary, nonspecialized vocabulary, administrative vocabulary, academic vocabulary, and technical vocabulary in turn acted as the reference level. In terms of type of elaboration, no elaboration, implicit elaboration, and explicit elaboration took turns to be the reference level. In terms of nonverbal elaboration, without nonverbal elaboration was the reference level.

4. RESULTS

4.1. Incidental vocabulary learning gains

Table 1 shows that irrespective of the groups, there was an increase in the mean scores from the pretest to the immediate posttest and from the pretest to the delayed posttest. Results of the single linear mixed-effects model analysis showed that the whole model (both the fixed effects and random effects) explained 88 percent of the variance on the scores (conditional $R^2 = 0.88$) and the fixed effects (mode, time, mode by time interaction, and vocabulary level) explained 18 percent of the variance (marginal $R^2 = 0.18$).

Table 2 presents the results of the single linear mixed-effects model analysis. There was a significant main effect of time on the scores ($p < 0.05$). This suggests the participants' scores significantly went up from the pretest to the posttests. A significant main effect of input mode on the scores was seen in the case of viewing ($p < 0.05$), but not in the other cases. Group-by-time interaction significantly affects the scores on the immediate posttest of the reading, reading while

Table 1: Mean score (SD) on the pretest, immediate posttest, and delayed posttest (N = 165)

Group	*n*	Pretest	Immediate posttest	Delayed posttest
Control	27	8.41 (7.20)	10.89 (8.86)	11.78 (7.59)
Reading	27	9.04 (5.73)	13.81 (5.94)	13.30 (6.54)
Listening	27	10.41 (5.09)	14.81 (6.10)	15.30 (6.38)
Reading while listening	28	9.71 (5.38)	15.71 (7.24)	13.32 (8.03)
Viewing	28	13.54 (6.55)	17.61 (7.13)	18.75 (7.05)
Viewing with caption	28	8.96 (6.17)	14.29 (7.48)	14.29 (6.86)

Table 2. Single linear mixed-effects model comparing the scores of the six groups of input modes over the three testing times

	b	SE	95% CI	df	*t*	*p*
(Intercept)	−3.44	4.89	[−13.02, 6.15]	160.21	−0.70	0.48
Time (Immediate vs. Pre)	2.48	0.71	[1.10, 3.86]	318.00	3.52	0.0005***
Time (Delayed vs. Pre)	3.37	0.71	[1.99, 4.75]	318.00	4.78	2.72e-06 ***
Mode (Reading vs. Control)	0.07	1.84	[−3.54, 3.67]	193.13	0.04	0.97
Mode (Listening vs. Control)	1.15	1.86	[−2.49, 4.78]	192.38	0.62	0.6
Mode (Reading while listening vs. Control)	0.92	1.82	[−2.64, 4.48]	193.43	0.51	0.61
Mode (Viewing vs. Control)	4.86	1.81	[1.31, 8.41]	193.58	2.68	0.008**
Mode (Viewing with captions vs. Control)	0.23	1.81	[−3.32, 3.79]	193.52	0.13	0.90
Vocabulary level	0.16	0.07	[0.04, 0.29]	158.00	2.51	0.013*
Mode (Reading vs. Control): Time (Immediate vs. Pre)	2.30	1.00	[0.34, 4.25]	318.00	2.30	0.02*
Mode (Listening vs. Control): Time (Immediate vs. Pre)	1.93	1.00	[−0.03, 3.88]	318.00	1.93	0.06
Mode (Reading while listening vs. Control):Time (Immediate vs. Pre)	3.52	0.99	[1.58, 5.46]	318.00	3.56	0.0004***
Mode (Viewing vs. Control): Time(Immediate vs. Pre)	1.59	0.99	[−0.35, 3.53]	318.00	1.61	0.11
Mode (Viewing with captions vs. Control): Time(Immediate vs. Pre)	2.84	0.99	[0.90, 4.78]	318.00	2.87	0.004**
Mode (Reading vs. Control):Time (Delay vs. Pre)	0.89	1.00	[−1.07, 2.84]	318.00	0.89	0.37
Mode (Listening vs. Control): Time (Delay vs. Pre)	1.52	1.00	[−0.44, 3.47]	318.00	1.52	0.13
Mode (Reading while listening vs. Control): Time (Delay vs. Pre)	0.24	0.99	[−1.70, 2.17]	318.00	0.24	0.81
Mode (Viewing vs. Control): Time (Delay vs. Pre)	1.84	0.99	[−0.09, 3.78]	318.00	1.87	0.06
Mode (Viewing with captions vs. Control): Time (Delay vs. Pre)	1.95	0.99	[0.01, 3.89]	318.00	1.97	0.04*

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (two-tailed).

listening, and viewing with captions ($p < 0.05$), but not in the case of listening and viewing. No significant effect of group-by-time interaction on the delayed posttest scores in most cases ($p > 0.05$), except for viewing.

To further compare the scores of different groups over different testing times, we ran a series of pairwise comparisons test using the emmeans package in R with Bonferroni adjustments for multiple comparisons. The comparison of the scores at different testing times of each group showed that in all cases, the immediate posttest scores and the delayed posttest scores were significantly higher than the pretest scores (all $p < 0.05$), but there were no significant differences between the immediate posttest scores and the delayed posttest scores (all $p > 0.05$). This indicated that learning happened in all conditions.

The pairwise comparison also showed the pretest scores of the six groups were not significantly different from one another (all $p > 0.05$). This suggests that the control group and the experimental groups had similar knowledge of the target words before the treatment. However, in the case of immediate posttests and delayed posttest, the viewing groups scored significantly higher than the control group ($p < 0.05$) whereas no significant differences were found between other experimental groups and the control group (all $p > 0.05$). This indicates that viewing an academic lecture made a unique contribution to learning while the other input modes did not. Similar findings were obtained when the model was releveled with the reading, listening, reading while listening, viewing, and viewing with captions, in turn, serving as the reference level.

4.2. Relationships between learning gains and the four variables

Results of the general linear mixed-effects models showed that the whole model explained 12 , 24, 19, 26, and 11 percent of the variance in the scores of the reading group (conditional $R^2 = 0.12$), listening (conditional $R^2 = 0.24$), reading while listening (conditional $R^2 = 0.19$), viewing (conditional $R^2 = 0.26$), and viewing with captions groups (conditional $R^2 = 0.11$), respectively. Meanwhile, the fixed factors explained 11, 18, 9, 18, and 5 percent of the variance in the case of reading (marginal $R^2 = 0.11$), listening (marginal $R^2 = 0.18$), reading while listening (marginal $R^2 = 0.09$), viewing (marginal $R^2 = 0.18$), and viewing with captions (marginal $R^2 = 0.05$).

Tables 3–7 present the effect of each factor on the learning gains of each experimental group. Regardless of the conditions, the type of verbal elaboration and nonverbal elaboration did not make significant contributions to learning, but the frequency of occurrence did. The kind of vocabulary significantly affected the learning gains of all groups, except for the viewing with captions group. Table 3 shows that in the case of reading, academic vocabulary had greater learning gains than nonspecialized vocabulary, but administrative vocabulary and technical vocabulary did not. When administrative vocabulary, academic vocabulary, and technical vocabulary were used as the reference level in turn, the learning gains of academic vocabulary were significantly higher than those of administrative vocabulary and nonspecialized vocabulary, but

Table 3: Results of the general linear mixed-effects model for the reading group

	b	SE	95% C*I*	*z*	*p*
(Intercept)	−2.70	1.33	[−5.31, −0.093]	−2.03	0.04*
Frequency	0.13	0.02	[0.09, 0.17]	5.94	2.82e−09***
Vocabulary type (administrative vs. nonspecialized)	-0.44	0.67	[−1.76,0.88]	−0.66	0.51
Vocabulary type (academic vs. nonspecialized)	0.89	0.45	[0.01, 1.77]	1.97	0.0484*
Vocabulary type (technical vs. nonspecialized)	0.68	0.49	[−0.28,1.64]	1.39	0.16
Verbal elaboration (implicit vs. no verbal elaboration)	0.12	0.28	[−0.43, 0.67]	0.44	0.66
Verbal elaboration (explicit vs. no verbal elaboration)	−0.86	0.52	[−1.87, 0.16]	−1.65	0.01
Nonverbal elaboration (yes vs. no)	−0.09	0.22	[−0.52, 0.34]	−0.41	0.68

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (two-tailed).

Table 4: Results of the general linear mixed-effects model for the listening group

	b	SE	95% C*I*	*z*	*p*
(Intercept)	−8.28	2.13	[−1.245637e+01, −4.11]	−3.89	9.93e−05***
Frequency	0.07	0.02	[1.946445e−02, 0.12]	2.75	0.00588**
Vocabulary type (administrative vs. nonspecialized)	0.81	0.89	[−9.233415e−01, 2.55]	0.92	0.36
Vocabulary type (academic vs. nonspecialized)	2.06	0.73	[6.245447e−01, 3.49]	2.81	0.00490**
Vocabulary type (technical vs. nonspecialized)	2.24	0.75	[7.603698e−01, 3.71]	2.97	0.00298**
Verbal elaboration (implicit vs. no verbal elaboration)	0.09	0.29	[−4.717720e−01, 0.66]	0.33	0.75
Verbal elaboration (explicit vs. no verbal elaboration)	−0.93	0.52	[−1.943432e+00, 0.08]	−1.80	0.07
Nonverbal elaboration (yes vs. no)	0.32	0.23	[−1.237844e−01, 0.76]	1.41	0.16

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (two-tailed).

were not significantly different from that of technical vocabulary. Meanwhile, no significant differences were found in the learning gains of nonspecialized vocabulary, administrative vocabulary, and technical vocabulary.

In the case of the listening group and viewing groups, Tables 4 and 5 show that academic vocabulary and technical vocabulary had significantly higher learning gains than nonspecialized vocabulary, but administrative vocabulary did not. When the models were releveled with administrative vocabulary, academic

Table 5: Results of the general linear mixed-effects model for the viewing group

	b	SE	95% CI	*z*	*p*
(Intercept)	−4.14	1.40	[−6.88, −1.39]	−2.96	0.003**
Frequency	0.09	0.03	[0.037, 0.14]	3.31	0.001***
Vocabulary type (administrative vs. nonspecialized)	−0.51	0.93	[−2.34, 1.32]	−0.54	0.59
Vocabulary type (academic vs. nonspecialized)	1.68	0.61	[0.48, 2.87]	2.75	0.006**
Vocabulary type (technical vs. nonspecialized)	2.09	0.63	[0.846, 3.329]	3.30	0.001***
Verbal elaboration (implicit vs. no verbal elaboration)	0.01	0.30	[−0.57, 0.60]	0.05	0.96
Verbal elaboration (explicit vs. no verbal elaboration)	-0.09	0.40	[−0.87, 0.70]	−0.21	0.83
Nonverbal elaboration (yes vs. no)	-0.11	0.23	[-0.56, 0.35]	-0.47	0.64

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (two-tailed).

Table 6: Results of the general linear mixed-effects model for the reading while listening group

	b	SE	95% CI	*z*	*p*
(Intercept)	−7.00	1.72	[−10.38, −3.62]	−4.06	4.83e−05 ***
Frequency	0.09	0.02	[0.05, 0.13]	4.47	7.81e−06 ***
Vocabulary type (administrative vs. nonspecialized)	0.46	0.49	[−0.50, 1.42]	0.94	0.35
Vocabulary type (academic vs. nonspecialized)	1.03	0.40	[0.24, 1.81]	2.56	0.01*
Vocabulary type (technical vs. nonspecialized)	0.88	0.44	[0.02, 1.73]	2.01	0.05*
Verbal elaboration (implicit vs. no verbal elaboration)	0.19	0.24	[−0.27, 0.66]	0.82	0.41
Verbal elaboration (explicit vs. no verbal elaboration)	−0.71	0.44	[−1.57, 0.15]	−1.62	0.10
Nonverbal elaboration (yes vs. no)	−0.23	0.20	[−0.62,0.17]	−1.14	0.26

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (two-tailed).

vocabulary, and technical vocabulary served as the reference level, the learning gains of academic vocabulary and technical vocabulary were significantly higher than those of nonspecialized vocabulary and administrative vocabulary. In the meantime, there were no significant differences in the learning gains of academic vocabulary and technical vocabulary. Nor were there any differences in the learning gains of nonspecialized vocabulary and administrative

Table 7: Results of the general linear mixed-effects model for the viewing with captions group

	b	SE	95% CI	*z*	*p*
(Intercept)	−3.98	1.12	[−6.17, −1.78]	−3.55	0.0004***
Frequency	0.07	0.02	[0.03, 0.11]	3.71	0.0002***
Vocabulary type (administrative vs. nonspecialized)	0.08	0.54	[−0.98, 1.14]	0.15	0.88
Vocabulary type (academic vs. nonspecialized)	0.58	0.42	[−0.23, 1.40]	1.40	0.16
Vocabulary type (technical vs. nonspecialized)	0.23	0.47	[−0.69, 1.14]	0.49	0.63
Verbal elaboration (implicit vs. no verbal elaboration)	−0.04	0.27	[−0.57, 0.49]	−0.15	0.88
Verbal elaboration (explicit vs. no verbal elaboration)	−0.26	0.42	[−1.08, 0.55]	−0.64	0.52
Nonverbal elaboration (yes vs. no)	0.26	0.20	[−0.13, 0.66]	1.30	0.19

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (two-tailed).

vocabulary. In the case of reading while listening, Table 6 shows that academic vocabulary and technical vocabulary had significantly higher learning gains than nonspecialized vocabulary. However, there were no significant differences in the learning of academic vocabulary and technical vocabulary, and in the learning gains of administrative vocabulary and other three kinds of vocabulary. Taken together, in most cases, academic vocabulary and technical vocabulary had higher learning gains than nonspecialized vocabulary and administrative vocabulary. Meanwhile, no significant differences in the learning gains were found between academic vocabulary and technical vocabulary and between administrative vocabulary and nonspecialized vocabulary.

5. DISCUSSION

5.1. Vocabulary learning through different input modes

In answer to the first two research questions, although all groups learned the target words, only the viewing group had significantly higher learning gains in the immediate posttest than the control group, while the reading, listening, reading while listening, and viewing with captions groups did not. Similarly, one week after the treatment, all experimental groups retained the vocabulary learned, but only the viewing group had significantly larger learning gains than the control group. These findings indicate that viewing led to vocabulary learning gains at the meaning recall level, but reading, listening, reading while listening, and viewing with captions did not. The significant gains of the viewing group found in this study are consistent with previous studies (Smidt and

Hegelheimer 2004; Yang and Sun 2013; Dang *et al.* 2022) which also found the positive effect of viewing academic lectures on vocabulary learning. However, expanding on these studies, this study reveals that other input modes (reading, listening, reading while listening, and viewing with caption) did not lead to significantly vocabulary learning gains. This finding is surprising because earlier studies comparing different input modes showed that viewing was just as good at facilitating vocabulary learning as reading, listening, and reading while listening (Neuman and Koskinen, 1992; Feng and Webb 2020) or was not as good as viewing with captions (Neuman and Koskinen 1992; Peters 2019; Teng 2019).

As the first study indicating that viewing might be superior to other input modes in vocabulary learning at the meaning recall level, this study provides further insights into the relative value of different input modes on incidental vocabulary learning when academic lectures are used as L2 input. It suggests that aural input alone is not likely to make a significant contribution to the learning of vocabulary in academic lectures. This study found that listening alone did not lead to significantly greater learning gains than the control group. This contrasts Vidal's (2003, 2011) finding that vocabulary learning occurred through listening to academic lectures. The conflicting results might be because the current study used an unmodified lecture of 50 minutes. In contrast, Vidal's (2003, 2011) lectures were only 14–15 minutes long and modified from authentic sources in which the lecturer read aloud prepared scripts and pretend that 'she was interacting with the listeners', and the reading texts were also modified from written authentic sources (Vidal 2003: 62).

There are several reasons why audio input alone might not lead to the learning of vocabulary in academic lectures. First, in academic lectures, L2 learners need to unpack a large amount of dense and abstract information quickly (Flowerdew 1994; Biber 2006). Their capacity of attention might be reduced because of the information load and lecture length (Wilson and Korn 2007). As a result, they might not attend to all unknown words in the lecture. Additionally, due to real-time processing, the participants may not have the opportunities to backtrack the information and attend to unfamiliar words in the input (Flowerdew and Miller 2005; Ellis *et al.* 2008; Vidal 2011). Second, similar to other kinds of L2 listening, academic listening requires L2 learners to deal with problems posed by the sound systems (e.g., the mismatch between the spoken and written form of the words, connected speech, irregular pauses, false starts, hesitations, stress, and intonation patterns) (Flowerdew 1994; Goh 2000; Field 2011). These problems are even more serious for L2 learners who have been learning English in "an idealized, perhaps written, form and have thus not been exposed to the characteristics of rapid colloquial speech" (Flowerdew 1994: 10) and may have a greater impact in EFL contexts where learners have a smaller amount of aural input than those in EFL context (Webb and Nation 2017). The problems caused by the nature of academic listening, in particular, and L2 listening, in general, may hinder learners' comprehension of a lecture, which then decreases their attention to the unfamiliar words in the input and their ability to infer unknown words from context. This finding supports VanPatten's (2007) Input

Processing Theory that learners would not have sufficient attention resources to notice the unfamiliar linguistic forms if they are kept busy with processing the message in the input.

This study also indicates that written input alone is unlikely to significantly contribute to the learning of vocabulary in academic lectures. The reading group did not have greater learning gains than the control group. This finding is different from Vidal's (2011) finding that learning happened under the reading condition. However, the reading text in the present study was the transcript of the academic lecture while Vidal's reading texts were modified from authentic sources. Moreover, the reading text in this study was much longer (5,871 words) than Vidal's texts (1,516–1,723 words). The insignificant effect of written input alone on vocabulary learning in academic lectures can be explained by the nature of L2 reading. Compared to aural input alone, the cognitive load of processing written input may be lighter because L2 learners may have opportunities to pause and return to the parts of a lecture which they do not understand and adapt the perceptual process to match their needs (Flowerdew 1994). However, the complexity and length of the academic text and the fact that the participants had to complete the reading under the time pressure mean that the cognitive load was still heavy, which may explain the insignificant learning gains of the reading group.

This study also reveals that in the case of academic lectures, not all kinds of multimodal input make a significant contribution to vocabulary learning. Audiovisual input (viewing) led to significant learning gains, but aural plus written input (reading while listening) and audiovisual input plus written input (viewing with captions) did not. The positive contribution of audiovisual input is consistent with the findings of previous research that vocabulary learning could be learned through viewing TV programs (e.g. Peters and Webb 2018). However, the fact that aural plus written input (reading while listening) and audiovisual plus written input (viewing with captions) did not lead to significant learning gains in the current study is surprising. Previous research has found that reading while listening better facilitated vocabulary learning than reading only and listening only (e.g. Brown *et al.* 2008), and viewing with captions led to greater vocabulary learning than viewing (Neuman and Koskinen 1992; Peters 2019). The conflicting findings may be because previous studies used nonacademic input (graded readers and television programs) while the present study used academic input (academic lectures). Apart from this reason, the insignificant learning gains of the viewing with captions group might also be because this study measured vocabulary learning at the meaning recall level. According to Montero Perez *et al.* (2014), captioning does not provide precise information about word meaning; therefore, learners have to construct meaning based on inferring process. However, inferring word meaning is a difficult, slow, and often unsuccessful process, while in viewing with captions, learners have to process the information from captions in real time while still keeping up with the on-screen image and sound. Therefore, they may have little time to infer the meaning from context and make good use of captions. This burden

is even greater in the case of academic lectures whose information is highly abstract and complex.

The relative value of audiovisual input, aural plus written input, and audiovisual plus written input found in the current study provide further insights into the multimedia learning theory. To begin with, it indicates that perhaps the presentation-mode approach is a better approach toward classifying the two channels for processing information from multimedia input than the sensory-modality approach. According to the presentation-mode approach, written forms and aural forms are processed in the same channel (verbal) whereas visual input is processed in another (nonverbal). Meanwhile, the sensory-modality approach considers aural input being processed in one channel (auditory) while written input and visual input being processed in another (visual). According to the multimedia learning theory, processing information from multimedia input through two channels is better than through one channel. This study found that aural input plus visual input (viewing) led to learning, but aural input plus written input (reading while listening) did not. This suggests that aural input and written input is likely to be processed in the same channel while visual input appears to be processed in another, which supports the presentation-mode approach.

This study also supports the split-attention and redundancy principles. According to these principles, processing multimedia learning materials through one channel will create extraneous cognitive load for learners' working memory and negatively affect learning, but processing these materials through both channels will lighten the cognitive load and facilitate learning. This study showed that combing visual input and aural input (viewing), which belongs to two different channels, resulted in learning. However, combining written input and aural input (reading while listening), which were both processed in the verbal channel, did not. In the case of audiovisual input plus written input (viewing with captions), although the aural input and visual input were processed in two separate channels, the fact that aural input and written input were processed in the same channel may still create extraneous cognitive load on the learners' working memory, which explained why learning did not happen through this mode.

By supporting the split-attention and redundancy principles, this study contrasts earlier SLA research which does not support these principles (e.g. Peters 2019; Pellicer-Sánchez *et al.* 2020). Yet it is important to note that this study used an unmodified academic input whereas earlier studies used nonacademic input (graded readers, TV programs). Compared to nonacademic texts, academic input appears to have a higher level of complexity, and therefore may be more challenging for the participants to integrate information from multiple sources of input. As mentioned, when listening to academic lectures, the participants were under the pressure of processing large amounts of abstract and complex information spontaneously and at the same time have to decode the meaning of the input in another language. This would result in extraneous cognitive burdens on their working memory. When visual input was used to support aural

input, the information was processed in both channels, which helps to lighten the burdens on participants' working memory. As the result, the participants could make full use of their capacity for processing information and would be able to attend and learn the vocabulary in the lecture. However, when written input was used to support aural input and audiovisual input, the fact that written input and aural input were processed in the same channel would add more burdens to the participants' working memory. The participants may have to split their attention between written input and aural input but at the same time have to keep up with the speed of the lecture. Consequently, they may not have sufficient cognitive resources to notice and learn vocabulary in the lecture.

In this study, on average, the viewing group learned more than four words and the control group learned just over two words at the meaning recall level. The relatively small gains of the viewing group do not mean that we should disregard the value of viewing academic lectures for vocabulary learning. First, the gains of the viewing group, though small, were still significantly larger than those of the control group, which indicates that viewing contributes to vocabulary learning. Second, the gains demonstrated in the present study through viewing may be smaller than occurred. This study only examined the gains at the meaning recall level and the gains of the target words, but other aspects of the target words and non-target words could be acquired from repeated exposure to meaning-focused input (Webb 2020). Moreover, viewing academic lectures may allow learners to notice how known words are used in specialized contexts and facilitate their acquisition of their specialized meaning. Third, this study only examined the viewing of one lecture and the participants only viewed it once, but the gains may be larger if learners view a series of lectures regularly. Research has found that exposure to multiple texts led to greater learning gains than from a single text (Webb and Chang 2015a, 2015b; Rodgers and Webb 2020) and that exposure to the same texts multiple times resulted in greater gains than exposure to the text once (Pavia *et al.* 2020). Last but not least, it may be challenging to explicitly teach specialized words in EAP courses like the one examined in the present study because EAP teachers lack discipline-specific knowledge and the classroom time is limited. Viewing academic lectures in the students' target disciplines offer them a good chance to incidentally learn these words.

5.2. Effects of different variables on vocabulary learning

This analysis revealed that frequency significantly contributed to the learning of vocabulary in academic lectures in all input modes. That is, the more frequently the target words occurred in the lecture, the more likely they were to be learned. This is in line with research on incidental vocabulary learning (Uchihara *et al.* 2019), and findings of previous studies indicating that frequency of occurrence significantly contributed to learning gains through listening to (Vidal 2003, 2011) and viewing academic lectures (Yang and Sun 2013; Dang *et al.* 2022).

This study found that the type of vocabulary significantly predicted the learning of vocabulary in academic lectures of all groups, except for viewing with captions. This finding is consistent with earlier research which found that the type of vocabulary affected the learning of vocabulary in academic lectures through listening, reading, and viewing conditions (Vidal 2003, 2011; Yang and Sun 2013). However, expanding on previous research, this study showed that this pattern also holds true in the case of reading while listening. This study found that in most cases, academic vocabulary and technical vocabulary were more likely to be learned than nonspecialized vocabulary and administrative vocabulary; meanwhile, there were no significant differences in the likelihood of being learned between academic vocabulary and technical vocabulary and between nonspecialized vocabulary and administrative vocabulary. This finding is likely due to the nature of these kinds of vocabulary. Technical vocabulary is closely related to the participants' specific subject area (Nation 2013) and academic vocabulary tends to be used to support or explain technical terms (Coxhead 2020). As they are closely related to the specialized content of the lecture, technical vocabulary and academic vocabulary are likely to be attended and learned by the participants than administrative vocabulary, which is related to the management of lectures and courses (Dang 2018), and nonspecialized vocabulary, which is not related to the specific context of the lecture at all.

This study found that the type of verbal elaboration and nonverbal elaboration did not affect the learning gains in any condition. This contrasts with the findings of Vidal (2003, 2011) and Yang and Sun (2013) that these factors significantly contributed to vocabulary learning through reading, listening to, and viewing academic lectures. The conflicting results may be the lecture in this study was much longer (50 minutes) than those in Vidal's studies (14–15 minutes) and in Yang and Sun's study (20–36 minutes). As the participants had to process large amounts of abstract and complex information for a long time, they may not make good use of the elaboration clues to learn the words.

The present study has several limitations. First, it only measured knowledge of single words at the meaning recall level. Second, the data in this study were limited to the vocabulary occurring in the examined lecture. Therefore, the findings related to the influence of word-related factors should not be generalized but be treated as a starting point for further investigation. Third, in this study, we did not ask the participants in the control group to complete the comprehension test for several reasons. Our study investigated incidental vocabulary learning, not comprehension. A number of previous studies on incidental vocabulary learning did not include comprehension tests (e.g. Pellicer-Sánchez and Schmitt 2010; Feng and Webb 2020; Pavia *et al.* 2020; Webb and Chang 2020). Therefore, while the comprehension test in our study might not have been perfect for a comprehension study, it did involve careful piloting and went far beyond the norm of incidental vocabulary studies. Moreover, the vocabulary tests took a considerable amount of time. The participants in the control group did not receive the treatment. Following our institutional ethical guidelines, it

is not appropriate to ask these participants to devote more time on the comprehension test, which was not related at all to their learning materials and activities. However, not checking the control group's answers on the comprehension test is a limitation of the present study.

Several areas need further investigation. First, future research examining other aspects of vocabulary knowledge and the learning of multiword combinations is needed. Second, apart from the factors examined in this study, research on the effects of other factors (e.g. cognates) would also be useful to examine. Third, this study only investigated one academic lecture. Studies investigating how input mode affects vocabulary learning in multiple lectures would be valuable. Moreover, this study only examined the effect of the lecture itself on vocabulary learning. In real life, students are often required to complete a set of required reading before a lecture. It would be useful to explore the effect of pre-lecture reading on the learning of vocabulary in academic lectures. Fourth, the viewing, listening, and control groups had higher scores on the delayed posttest than on the immediate posttest. This indicates that exposure to the target words in the pretest and immediate posttest may affect the result of the delayed posttests. Testing effect is a common issue in incidental vocabulary studies. Future research could probably avoid this problem by counterbalancing the target items. That is, they could assess knowledge of half of the target items in the immediate posttest and the other half in the delayed posttest. Last but not least, focusing on open access academic lectures, this study is among the few attempts to identify potential sources for incidental learning of specialized vocabulary. Future research should investigate other resources for L2 learners to incidentally learn vocabulary.

6. PEDAGOGICAL IMPLICATIONS

Viewing led to vocabulary learning gains at the meaning recall level, but reading, listening, reading while listening, and viewing with captions did not. This finding suggests that if open access lectures are used as meaning-focused input for EAP learners, viewing is the best among the five examined input modes. Moreover, the lack of significant contribution of reading while listening and viewing with captions indicates that teachers should be mindful when using transcripts and captions to support L2 learners with academic listening. Presenting the transcripts or captions while learners listen to or view academic lectures is likely to create extraneous cognitive load on their working memory and hinder their vocabulary learning. Topical knowledge and pre-learning have a positive effect on incidental vocabulary learning (Pellicer-Sánchez *et al.* 2021; Pulido 2007). Therefore, before viewing an academic lecture, teachers could organize pre-viewing activities for learners to read the lecture transcript or texts related to the content of the lecture. They could also pre-teach the keywords in the lecture. This study found that academic vocabulary and technical vocabulary are more likely to be learned than nonspecialized vocabulary and administrative vocabulary when an academic lecture was used as the input. It also

showed that frequency of occurrence significantly affected incidental vocabulary learning. These findings suggest that academic lectures are useful resources for L2 learners to learn specialized vocabulary, and teachers should encourage students to view academic lectures regularly to develop and consolidate their knowledge of this kind of vocabulary.

7. CONCLUSION

This study is the first to examine the learning of single words in open access academic lectures through different input modes. It showed that viewing an academic lecture significantly contributed to the learning gains, but reading, listening, reading while listening, and viewing with captions did not. The study also revealed that frequency of occurrences and the type of vocabulary significantly affected vocabulary learning, but the type of verbal elaboration and nonverbal elaboration did not. Overall, this study provides further insights into the value of open access academic lectures for vocabulary learning and empirical evidence supporting the multimedia learning theory and its principles.

SUPPLEMENTARY DATA

Supplementary material is available at *Applied Linguistics* online.

ENDNOTES

1 The Concise Oxford Dictionary of Mathematics and the Dictionary of Algorithms and Data Structures. These dictionaries were selected based on the consultation with a lecturer working in the field of engineering and technology.

ACKNOWLEDGMENTS

We would like to thank the editor and the anonymous reviewers for their constructive and useful feedback. Our sincere thanks to all the learners and expert raters who participated in this study, to Haiyan Gao, Wenhua Liang, and Ying Shen for their support with the data collection, and to John Read, Dogus Oksuz, Matt Homer, and Sedar Olmez for their advice on statistics.

REFERENCES

Ayres, P. and **J. Sweller**. 2014. 'The split-attention principle in multimedia learning' in **R. E. Mayer** (ed.): *Cambridge Handbook of Multimodal Theory*. Cambridge University Press, pp. 206–226.

Biber, D. 2006. *University Language: A Corpus-based Study of Spoken and Written Registers*. John Benjamins.

Brown, R., **R. Waring**, and **S. Donkaewbua**. 2008. 'Incidental vocabulary acquisition from reading, reading-while-listening, and listening to stories,' *Reading in a Foreign Language* 20/2: 136–63.

Coxhead, A. 2000. 'A new academic word list,' *TESOL Quarterly* 34/2: 213–38.

Coxhead, A. 2018. *Vocabulary and English for Specific Purposes Research: Quantitative and Qualitative Perspectives*. Routledge.

Coxhead, A. 2020. 'Academic vocabulary' in **S. Webb** (ed.): *The Routledge Handbook of Vocabulary Studies*. Routledge, pp. 97–110.

Camiciottoli, B. C. 2020. 'The OpenCourseWare lecture: A new twist on an old genre?,' *Journal of English for Academic Purposes* 46: doi:10.1016/j.jeap.2020.100870.

Camiciottoli, B. C. 2021. 'Teaching lecture comprehension skills through OpenCourseWare video-recorded lectures: A research-informed classroom application,' *Journal of English for Academic Purposes* 54: doi:10.1016/j.jeap.2021.101055.

Dang, T. N. Y. 2020a. 'Corpus-based word lists in second language vocabulary research, learning, and teaching' in **S. Webb** (ed.): *The Routledge Handbook of Vocabulary Studies*. Routledge, pp. 288–304.

Dang, T. N. Y. 2020b. 'High-frequency words in academic spoken English: Corpora and learners,' *ELT Journal* 74/2: 146–55.

Dang, T. N. Y. 2018. 'The nature of vocabulary in academic speech of hard and soft sciences,' *English for Specific Purposes* 51: 69–83.

Dang, T. N. Y., **A. Coxhead**, and **S. Webb**. 2017. 'The academic spoken word list,' *Language Learning* 67/4: 959–97.

Dang, T. N. Y., **C. Lu**, and **S. Webb**. 2022. 'Incidental learning of single words and collocations through viewing an academic lecture,' *Studies in Second Language Acquisition* 44: 708–36. doi:10.1017/S0272263121000474.

Dang, T. N. Y. and **S. Webb**. 2014. 'The lexical profile of academic spoken English,' *English for Specific Purposes* 33: 66–76.

Ellis, N., **R. Simpson-Vlach**, and **C. Maynard**. 2008. 'Formulaic language in native and second language speakers: Psycholinguistics, corpus linguistics, and TESOL,' *TESOL Quarterly* 42/3: 375–96.

Ellis, R. 1999. *SLA Research and Language Teaching*. Oxford University Press.

Feng, Y. and **S. Webb**. 2020. 'Learning vocabulary through reading, listening, and viewing: Which mode of input is most effective?,' *Studies in Second Language Acquisition* 42/3: 499–523.

Field, J. 2011. 'Into the mind of the academic listener,' *Journal of English for Academic Purposes* 10: 102–12.

Flowerdew, J. 1994. *Academic Listening: Research Perspectives*. Cambridge University Press.

Flowerdew, J. and **Miller, L.** 2005. *Second Language Listening*. Cambridge University Press.

Gardner, D. and **M. Davies**. 2014. 'A new academic vocabulary list,' *Applied Linguistics* 35/3: 305–27.

Godfroid, A., et al. 2018. 'Incidental vocabulary learning in a natural reading context: An eye-tracking study,' *Bilingualism: Language and Cognition* 21/3: 563–84.

Goh, C. C. M. 2000. 'A cognitive perspective on language learners' listening comprehension problems,' *System* 28/1: 55–75.

Jin, Z. and **S. Webb**. 2020. 'Incidental vocabulary learning through listening to teacher talk,' *Modern Language Journal* 104/3: 550–66.

Kalyuga, S. and **Sweller, J.** 2014. 'The redundancy principle in multimedia learning,' in **R. E. Mayer** (ed.): *Cambridge Handbook of Multimodal Theory*. Cambridge University Press, pp. 247–262.

Mayer, R. E. 2014. *Cambridge Handbook of Multimodal Theory*. Cambridge University Press.

Montero Perez, M., **E. Peters**, **G. Clarebout**, and **P. Desmet**. 2014. 'Effects of captioning on video comprehension and incidental vocabulary learning,' *Language Learning and Technology* 18: 118–41.

Montero Perez, M., **E. Peters**, and **P. Desmet**. 2018. 'Vocabulary learning through viewing video: The effect of two enhancement techniques,' *Computer Assisted Language Learning* 31: 1–26.

Nation, I. S. P. 2013. *Learning Vocabulary in Another Language* (2nd edn.). Cambridge University Press.

Neuman, S. B. and **P. Koskinen**. 1992. 'Captioned television as comprehensible input: Effects of incidental word learning from context for language minority students,' *Reading Research Quarterly* 27: 94–106.

Pavia, N., **S. Webb**, and **F. Faez**. 2020. 'Incidental vocabulary learning through listening to songs,' *Studies in Second Language Acquisition* 41/4: 745–68.

Pellicer-Sánchez, A., **K. Conklin**, and **L. Vilkaite-Lozdien**. 2021. '(Re)Examining the benefits of pre-reading instruction for vocabulary learning,' *TESOL Quarterly* doi:10.1002/tesq.3058.

Pellicer-Sánchez, A. and **N. Schmitt**. 2010. 'Incidental vocabulary acquisition from an authentic novel: Do Things Fall Apart?,' *Reading in a Foreign Language* 22/1: 1–26.

Pellicer-Sánchez, A., et al. 2020. 'Young learners' processing of multimodal input and its impact on reading comprehension: An eye-tracking study,' *Studies in Second Language Acquisition* 42: 577–98.

Peters, E. 2019. 'The effect of imagery and on-screen text on foreign language vocabulary learning from audiovisual input,' *TESOL Quarterly* 53/4: 1008–32.

Peters, E. and **S. Webb**. 2018. 'Incidental vocabulary acquisition through viewing L2 television and factors that affect learning,' *Studies in Second Language Acquisition* 40/3: 551–77.

Puimège, E. and **E. Peters**. 2019. 'Learning L2 vocabulary from audiovisual input: An exploratory study into incidental learning of single words and formulaic sequences,' *Language Learning Journal* 47: 424–38.

Pulido, D. 2007. 'The relationship between text comprehension and second language incidental vocabulary acquisition: A matter of topic familiarity?,' *Language Learning* 57/1: 155–99.

Rodgers, M. P. H. and **S. Webb**. 2020. 'Incidental vocabulary learning from viewing television,' *ITL-International Journal of Applied Linguistics* 171/2: 191–220.

Smidt, E. and **V. Hegelheimer**. 2004. 'Effects of online academic lectures on ESL listening comprehension, incidental vocabulary acquisition, and strategy use,' *Computer Assisted Language Learning* 17/5: 517–56.

Teng, F. 2018. 'Incidental vocabulary acquisition from reading-only and reading-while-listening: A multi-dimensional approach,' *Innovation in Language Learning and Teaching* 12/3: 274–88.

Teng, F. 2019. 'Incidental vocabulary learning for primary school students: The effects of L2 caption types and word exposure frequency,' *The Australian Educational Researcher* 46: 113–36.

Uchihara, T., **S. Webb**, and **A. Yanagisawa**. 2019. 'The effects of repetition on incidental vocabulary learning: A meta-analysis of correlational studies,' *Language Learning* 69/3: 559–99.

van Zeeland, H. and **N. Schmitt**. 2013. 'Incidental vocabulary acquisition through L2 listening: A dimensions approach,' *System* 41: 609–24.

VanPatten, B. 2007. 'Input processing in adult second language acquisition' in **J. Williams** and **B. VanPatten** (eds.): *Theories in Second Language Acquisition*. Erlbaum, pp. 115–135.

Vidal, K. 2003. 'Academic listening: A source of vocabulary acquisition?,' *Applied Linguistics* 24/1: 56–89.

Vidal, K. 2011. 'A comparison of the effects of reading and listening on incidental vocabulary acquisition,' *Language Learning* 61/1: 219–58.

Webb, S. 2007. 'The effects of repetition on vocabulary knowledge,' *Applied Linguistics* 28/1: 46–65.

Webb, S. 2015. 'Extensive viewing: Language learning through watching television' in **D. Nunan** and **J. C. Richards** (eds.): *Language Learning Beyond the Classroom*. Routledge, pp. 159–168.

Webb, S. 2020. 'Incidental vocabulary learning' in **S. Webb** (ed.): *The Routledge Handbook of Vocabulary Studies*. Routledge, pp. 225–239.

Webb, S. and **A. C. Chang**. 2020. 'How does mode of input affect the incidental learning of collocations?,' *Studies in Second Language Acquisition* doi:10.1017/S0272263120000297.

Webb, S. and **A. C. Chang**. 2015a. 'How does prior word knowledge affect vocabulary learning progress in an extensive reading program?,' *Studies in Second Language Acquisition* 37/4: 651–75.

Webb, S. and **A. C. Chang**. 2015b. 'Second language vocabulary learning through extensive reading with audio support: How do frequency and distribution of occurrence affect learning?,' *Language Teaching Research* 19/6: 667–86.

Webb, S. and **A. C. Chang**. 2012. 'Vocabulary learning through assisted and unassisted repeated reading,' *The Canadian Modern Language Review* 68/3: 267–90.

Webb, S., **Y. Sasao**, and **O. Balance** 2017. 'The Updated Vocabulary Levels Test: Developing and validating two new forms of the VLT,' *International Journal of Applied Linguistics* 168/1: 34–70.

Webb, S., and **Nation, I. S. P.** 2017. *How Vocabulary Is Learned*. Oxford University Press.

Wilson, K. and **J. H. Korn**. 2007. 'Attention during lectures: Beyond ten minutes,' *Teaching of Psychology* 34/2: 85–9.

Xue, G. and **I. S. P. Nation**. 1984. 'A university word list,' *Language Learning and Communication* 3/2: 215–29.

Yang, H. -C. and **Y. -C. Sun**. 2013. 'It is more than knowledge seeking: Examining the effects of OpenCourseWare lectures on vocabulary acquisition in English as a foreign language (EFL) context,' *Computer Assisted Language Learning* 26/1: 1–20.

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