

Comprehension of biology texts in bilingual and monolingual university students: exploring the effect of presentation modality, previous knowledge and topic enjoyment

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Abstract

The present study investigated the effects of presentation modality (reading compared to reading while listening – RWL), biology enjoyment and biology knowledge on the comprehension of biology texts in a group of 94 university students with a wide range of language experiences. Language experience was measured both categorically (bilinguals compared to non-bilinguals) and continuously, using a detailed questionnaire on bilingualism. Participants were presented with two biology texts, one written, and one presented in two modalities simultaneously (oral and written) and completed a comprehension task after each text. They also rated their knowledge and enjoyment of biology and completed the language questionnaire. The results highlight an advantage for bilingual students when it comes to comprehending texts, and this advantage is especially notable in the Reading condition. Results also highlight a positive effect of students' subject enjoyment on performance, particularly in the case of bilingual students. Analyses including language experience as categorical or continuous showed the same results, except a lack of interaction between language experience and presentation modality in the analyses with language experience as continuous. This suggests that bilingual participants are those most likely to experience facilitation from the reading condition, but this facilitation might be experienced similarly by bilinguals past a certain language threshold. In conclusion, bilinguals had higher comprehension scores than non-bilinguals, and presentation modality affects bilingual and non-bilingual students differently, with bilingual university students being advantaged by a written presentation of the material and being more affected by their enjoyment of biology than their non-bilingual peers.

Keywords: Reading Comprehension, Bilingualism, University Students, Presentation Modality, Enjoyment Effects

Public significance statement: The results of the present study show an advantage for bilingual university students over non-bilingual students in comprehending written texts. The study also highlights that presentation modality (reading compared to reading while listening), as well as enjoyment of the subject of the text affect students' understanding of the presented text, especially in bilingual university students. This presents practical implications for teaching and learning strategies in Higher Education, suggesting that presenting material in a written format might be particularly helpful for bilingual students. The results also highlight the importance of considering students' enjoyment and suggest that activities that increase subject enjoyment might have the potential of increasing comprehension outcomes, especially in bilingual students.

Comprehension of Biology Texts in Bilingual and Monolingual University Students: Exploring the Effect of Presentation Modality, Previous Knowledge and Topic Enjoyment

Approximately 17.4% of students in England speak more than one language, with this number increasing with every academic year (Clark, 2022). Given this increase, it becomes increasingly important to explore whether language experience (i.e., the amount and quality of exposure to different languages in their daily lives) might affect university students' learning and success in Higher Education.

We aimed to explore whether students with different language experiences differ in their ability to comprehend texts when they are asked to only read the text (Reading condition: unimodal condition) vs. when they are presented with the text in two modalities (reading while listening: bimodal RWL condition). This research has many practical implications, as results might indicate which presentation modality best supports learning in students with different language experiences, allowing educators to create teaching material best suited to their specific students' population.

The effect of language experience and bilingualism on cognition has been widely studied (e.g., Bialystok, 2011; 2015; Marian & Shook, 2012). Language experience has been shown to have the potential to influence students' learning in different ways (e.g., Mahzoun, 2022; Ransdell, 2004). Burgoyne et al. (2006) found that monolingual participants outperform bilingual participants when asked to answer comprehension questions regarding written and oral texts. Other researchers suggest that a more varied language experience might positively affect comprehension in both children (Taboada Barber et al., 2021) and adults, including university students (Afsharrad & Sadeghi Benis, 2015; Bernhardt, 2005; Modirkhamene, 2006). The adoption of different definition and criteria for bilingualism, as well as differences in sample characteristics in other areas might explain the discrepancy in the results.

A number of mechanisms regarding the influence of language experience on language comprehension have been suggested. Bialystok (2011; 2015) identifies that, with a more varied language experience, executive functions (EF) i.e. the regulatory system of cognitive processes which allow for goal-orientated behaviour (Best & Miller, 2010) are strengthened over time. As EF have been shown to affect comprehension in both children (Nouwens et al., 2021) and adults (Follmer & Sperling, 2018; Ober et al., 2019), a more varied language experience might positively affect comprehension via its positive effect on

EF. This can also be traced back to the simple view of reading, which suggests that reading comprehension is the product of decoding (i.e. the ability to read words and non-words) and listening comprehension (Hoover & Gough, 1990). This theory would suggest that the effect of language experience on reading comprehension would depend on its effect on decoding and listening comprehension respectively. Most research to date suggests that bilinguals tend to perform less well than monolinguals in oral comprehension tasks (Droop & Verhoeven, 2003; Jean & Geva, 2009; Melby-Lervåg & Lervåg, 2011) and this would suggest that a more varied language experience might have a negative effect on reading comprehension due to its negative effect on oral language comprehension. However, Adesope et al. (2010) suggests that participants with varied language experiences, especially balanced bilinguals (i.e. those equally proficient in both their languages) may have stronger decoding skills than their monolingual counterparts, supporting a positive effect of bilingualism on reading comprehension. While the effect of decoding on reading comprehension decreases over time (Tilstra et al., 2009), and decoding tends to be less important than oral language in adults (Landi, 2010), research with second language learners shows that decoding continues to be an important correlate of reading comprehension in adulthood (Jeon & Yamashita, 2014). This suggests that the effect of bilingualism on reading comprehension might be mediated by language proficiency in the tested language (Jean & Geva, 2009) and results might differ between balanced bilinguals and second language learners.

Language experience is often described categorically by distinguishing between bilingual and monolingual participants (e.g. Ellis, 2008). However, this has a number of drawbacks. One source of difficulty arises from the chosen definition of bilingualism, with different researchers choosing different indicators to distinguish bilingual and non-bilingual participants. Some researchers use language proficiency in the second language and others use age of acquisition to distinguish between groups (Anderson et al., 2018; Li et al., 2006). The lack of consistency regarding definitions and inclusion criteria makes research difficult to compare (Prior & Macwhinney, 2009). Moreover, language experience is inherently multidimensional (Kremin & Byers-Heinlein, 2021), with a number of dimensions (e.g. age of acquisition, context of acquisition, usage of each language and proficiency) affecting participants' performance on any given language task (De Bruin, 2019; Marian & Hayakawa, 2020). Therefore, more recent studies suggest the use of a continuous scale to describe language experience (Luk & Bialystok, 2013; Kremin & Byers-Heinlein, 2021). In the present study, we analysed the effect of language experience on comprehension from

both a continuous and a categorical perspective using The Language and Social Background Questionnaire (LSBQ) designed by Anderson and colleagues (2018) to compare the results between the two types of classifications.

Presentation Modality and Language Experience

The mode in which information or material is presented to individuals (e.g. orally vs. written) affects participants' ability to comprehend the material presented (Diao & Sweller, 2007), but results are mixed with regard to which modality promotes better comprehension in different participants.

In children and adolescents results tend to highlight that bimodal presentation, i.e. presenting material in two modalities simultaneously (e.g. written, and oral material concurrently) improves comprehension compared to unimodal, i.e. single modality presentations (e.g., oral or written texts) (Verlaan & Ortlieb, 2012; Rahman & Hajar, 2020). Verlaan and Ortlieb (2012) asked 15 and 16 year-old students to read extracts from a novel, alternating between reading only and reading while listening (RWL). Students obtained higher comprehension scores in the RWL condition. In a few studies (Verlaan and Ortlieb, 2012; Steele, 1996) the positive effect of a bimodal presentation was stronger for struggling readers, suggesting that less able readers experience higher levels of facilitation from bimodal presentations. Research with adults yields more inconsistent results. Some research found that comprehension improved when university students simultaneously read and listened to texts compared to when they listened only (Chang, 2009; Liu, Cao, & Wu, 2019; Moreno & Mayer, 2002). Contrarily, Diao and Sweller (2007) found significantly better comprehension in the unimodal condition (reading only) compared to the bimodal condition (RWL), whilst Rogowsky et al. (2016) found no significant differences in comprehension between RWL and single presentation modality (either reading or listening only) in college educated adults. These differences in results could be explained by differences in sample characteristics and methodology. Most of this research (Diao and Sweller, 2007; Chang, 2009; Rogowsky et al., 2016) was conducted on college educated participants, however, participants differed in their English proficiency and on other important features (e.g. community language and age of L2 acquisition). Both participants in Diao and Sweller's (2007) study and those in Chang's (2009) study were studying English as a Foreign Language in their home country and had studied English for only 6 years, while participants in the study by Rogowsky et al. (2016) were native English speakers in an English speaking country. The type of texts used might also affect the results: both

Chang (2009) and Rogowsky et al. (2016) used narrative texts while Diao and Sweller used newspaper articles. Research suggests that narrative texts are easier to comprehend than expository texts (Dickens & Meisinger, 2017), and different cognitive skills might predict comprehension of the two types of texts (Eason et al., 2012).

Results showing better comprehension from unimodal than bimodal conditions tend to support the cognitive load hypothesis (Mayer, 2014; Mayer et al., 1999) which hypothesizes that simultaneous inputs in two modalities increase cognitive load and, hence, can be detrimental to comprehension compared with single modality presentation. The redundancy effect further suggests that presenting the same information in different modalities is redundant and this is what increases cognitive load (e.g., see Kalyuga, Chandler & Sweller, 1998). This might particularly apply to adult readers, since, given the efficiency of their reading abilities, the phonological information provided by the oral presentation might be completely redundant. The same phonological information might not be redundant for younger or less efficient readers, potentially explaining difference in results between younger and older participants. These differences might be connected to the expertise reversal principle, which suggests that information that is non-redundant, and thus helpful, for novice readers might become redundant, and thus unhelpful for more skilled (expert) readers like university students (Kalyuga, 2007; Kalyuga, Chandler & Sweller, 1998).

Language experience could also affect the extent of the facilitation obtained in bimodal conditions. Bilinguals might experience similar effects to novice learners, due to their reduced levels of experience in English (Bialystok et al., 2010), and therefore show higher bimodal facilitation compared to monolinguals. Many studies, in fact, find a facilitation for bimodal conditions in bilingual participants (Conklin et al., 2020; Pellicer-Sánchez et al., 2020; Tragant & Vallbona, 2018), with RWL leading to higher levels of comprehension performance (Chang & Millet, 2015). Bilinguals also seem to find RWL more engaging than other input modes (Chang, 2009; Tragant et al., 2016). Thus, bimodal presentation might have important learning and comprehension benefits in the bilingual population. In monolinguals research shows no particular benefit of bimodality on comprehension in both adults and young learners (Pellicer-Sánchez, et al., 2020; Kalyuga & Sweller, 2014), supporting the redundancy effect.

Despite this positive effect, some studies suggest the opposite, i.e. better comprehension from unimodal presentations (Diao & Sweller, 2007). This could be explained by considering that the bimodal

condition can be unhelpful for participants who are unable to attend to both streams of information simultaneously. This could be the case for participants whose listening comprehension skills are not as good as their reading comprehension skills: these participants might benefit from a written presentation over a bimodal presentation. At the same time, students with high level of English, like balanced bilinguals, might experience similar levels of redundancy to monolingual readers, thus obtaining higher comprehension scores when presented with a written text only. Given that our measure of language experience can also capture a more balanced use of languages by our bilingual participants, it is possible that language experience might either have a positive effect on comprehension or no effect overall, but instead, interact with other variables.

In the light of these different results, we expected an interaction between language experience and presentation modality. We also explored whether this effect can be replicated when measuring language experience on a continuous scale. A significant interaction might suggest a more subtle effect of language experience on the facilitation effect produced by bimodal presentation, with participants with more varied language experience, i.e. participants with higher levels of use of their home-language (and thus higher bilingualism scores), potentially experiencing stronger facilitation effects. This is especially important now, seeing as the amount of diversity in individuals' language experience within schools, universities, and workplaces is steadily increasing (OECD Reviews of Migrant Education, 2009) and, in turn, so is the need to appropriately support these learners.

Subject Knowledge and Enjoyment on Comprehension

Individual differences in knowledge and enjoyment of the topic of the text can affect comprehension outcomes (Johnston et al., 2008). Research shows that having better subject knowledge positively predicts text comprehension (Best et al., 2008; Rydland et al., 2010; Tarchi, 2017). For example, Tarchi (2017) found that history knowledge predicted secondary school students' comprehension of a history text. Similarly, when looking at subject enjoyment, researchers tend to find that topic interest and enjoyment predict higher comprehension scores (Babbitt Bray and Barron (2004). Given the positive effect of subject knowledge and enjoyment on comprehension, we explored their effect on university students' comprehension of biology texts. The subject of Biology was chosen as we expected most of the participants to be Psychology students, familiar with scientific subjects, but with varied knowledge and enjoyment of the same.

We also considered that subject knowledge and enjoyment might interact with other variables to determine participants' comprehension. For example, people who are more knowledgeable on a certain subject or enjoy it more, might experience similar effects to expert rather than novice learners and therefore show different effects of presentation modality than those with lower knowledge or enjoyment. Students with more knowledge or enjoyment might comprehend texts better when presented in one modality, as a second modality would be completely redundant for them, while a bimodal presentation might increase comprehension performance in students who know or enjoy the subject less. The interaction between subject enjoyment and language experience is more difficult to predict, but considering the cognitive load hypothesis (Mayer, 2014) we could hypothesize that subject enjoyment and knowledge might have a bigger effect on bilingual than monolingual students, possibly counteracting some of the difficulty arising from their relatively lower language experience in English.

Research Questions

In the light of the previous literature, we explored the effect of measuring language experience in different ways by answering all our research using two analyses: one that included language experience as a continuous variable and one that included language experience as a dichotomous variable.

The main research questions we investigated are:

- 1) Does presentation modality (reading compared to RWL) affect comprehension in adult university students differently depending on their language experience?

We expected that students with more varied language experience might obtain lower scores in our comprehension task than students with more homogenous language experience (Jean & Geva, 2009). Specifically we expected that our measure of language experience might be correlated with variation in English proficiency, which is known to affect comprehension outcomes negatively (Jean and Geva, 2009). However, given that our measure of language experience could also capture a more balanced use of languages by our bilingual participants, which is known to have a positive effect on cognitive functions (Adesope et al., 2010), it is also possible that language experience might in fact have a positive effect on comprehension, or not have a direct effect, but just interact with other variables. We also hypothesized that presentation modality might affect students' comprehension, particularly, we expected presentation modality to have a different effect on students depending on

their language background, with learners with higher scores on bilingualism, i.e. those who use their first language more often and those who had had overall more exposure to their first language, to be more facilitated by a bimodal RWL presentation modality (Chang & Millet, 2015), and students with a less varied language experience to experience the opposite effect.

- 2) Do subject knowledge and subject enjoyment affect comprehension of biology texts in university students? We expected more knowledgeable students and those more interested in the proposed topic to comprehend the texts better.
- 3) Do subject knowledge and subject enjoyment moderate the effect of language experience and presentation modality on comprehension? Based on research on novice and expert learners (Kalyuga, Chandler & Sweller, 1998) we expected that students with lower levels of knowledge or enjoyment of biology might be more facilitated by RWL presentation modality, with students with higher levels of knowledge or enjoyment understanding texts better in the reading modality. We also expected knowledge and enjoyment might interact with language experience in affecting presentation modality effects, with students with a more varied language experience and lower levels of knowledge and enjoyment, as the most “novice” learners, being the most facilitated by a bimodal RWL presentation modality.

Method

Design and Data Source

Data, scripts, and supplementary materials are available at the following URL:

https://osf.io/zgmaq/?view_only=8d6c12ffbb714d1b8c0af9b8bae9d520

Participants

After receiving ethical approval, we recruited 158 university students through a mixture of opportunity sampling, using the SONA online participation platform used by university students throughout the UK, and volunteer sampling using social media. All participants were university students in the UK. Data were screened for quality, and participants with high amount of missing answers were excluded. We further excluded participants who reported learning difficulties, as learning difficulties might influence performance in the two conditions differently. The final sample size comprised of 94 participants (78 female, $M_{\text{age}} = 20.35$, $SD_{\text{age}} = 1.66$, $\text{Range}_{\text{age}} = 18\text{-}26$). The sample size is in line or much higher than that of previous literature on

both the modality effect (Valentini et al. 2018) and the modality effect with bilingual participants (Liao, Kruger, & Doherty, 2020; Pellicer-Sánchez et al., 2020). The sample size is also in line with the estimated sample size of 98 for a target power of 0.8, computed through https://koumurayama.shinyapps.io/summary_statistics_based_power/ (Murayama, Usami, & Sakaki, 2022); this effect size was computed using results from Valentini et al. (2018) as these data provided all the necessary information for a power analysis for mixed-effects models. The power analyses considered the results from the comparison of unimodal and bimodal conditions from that study, as well as including 2 cross-level interactions related to the focal level-1 predictor.

Our participants can be categorised as: bilinguals ($N = 48$, 47.5%), monolinguals ($N = 39$, 38.6%) and borderline (those with ambiguous language backgrounds as classified by LSBQ) ($N = 14$, 18.7%) using the LSBQ (Anderson et al., 2018). Monolinguals and participants with ambiguous scores were grouped together for the analyses, forming the non-bilingual group. Participants spoke 32 different languages (14 spoke Spanish, 5 Portuguese, 4 Arabic, 4 French, and all other languages had 3 or less speakers); 32 participants reported speaking 1 language, 57 reported speaking 2 (3 categorical monolinguals declared a second language), and 8 participants reported speaking 3 languages.

Procedure:

Participants completed the research online from their own devices and on their own time. The study was carried out in Qualtrics, an online survey software (Qualtrics, Provo, UT, USA. <https://www.qualtrics.com>).

After consenting to take part in the research, participants were asked to complete some demographic questions (age, gender, ethnicity, whether or not participants are university students, their university and IGCSE (or equivalent) grades, whether or not they have learning difficulties, and whether they have lived in countries where English is not the dominant language, and for how long). Participants were also asked to rate their knowledge and enjoyment of Biology on a scale from 0 to 5, before proceeding to complete the comprehension task. After the completion of the comprehension task, participants were asked to complete the language questionnaire (LSBQ) to assess their language experience. In the final page of the online survey participants were presented with a debrief which reiterated the purpose of the study, thanked them for their time, and reminded of the researchers' contact details.

Materials

Comprehension Task. The comprehension task was designed to assess comprehension of Biology texts in two conditions; when reading a text (Reading, unimodal reading presentation) and when reading while simultaneously listening (RWL, bimodal presentation). Each participant took part in each condition, reading two different texts (Text A and Text B). Both texts consisted of a university-level text extract on the subject of biology, extracted from Open Access academic textbooks (Betts et al., 2013; PHED 301 Students, 2018; please see Supplementary Material A). The 2 texts were similar in length and difficulty (Text A: $N_{\text{Words}} = 248$, Flesh Reading Ease = 40.6; Text B: $N_{\text{Words}} = 266$, Flesh Reading Ease = 34.8). Order of presentation modality (Reading vs. RWL), text (Text A vs. Text B) and text with presentation modality (Text A Reading and Text B RWL vs. Text B Reading and Text A RWL) were all randomised.

Texts were copied on Microsoft PowerPoint (font – Calibri (Body) and font size – 22), and converted into a video. The video links were embedded into the online survey. Video controls were hidden to ensure that participants could not pause, rewind, or go forward on the video.

For the Reading modality participants were presented with a video which included the written text without audio, for the RWL modality participants were presented with a video with a written text and the audio of a female British English speaker reading the same text aloud. We asked a pilot sample of 10 university students (3 males, 7 females, ages between 21-37, 9 bilinguals) to read Text A and B silently, in order to match video lengths to the reading speed of university students. The two videos for the Reading modality were made to the length of the mean pilot participants' reading speed (Text A = 94.71 seconds, Text B = 107.63 seconds), plus an additional 1.5 SDs (final video lengths: Text A = 2:53 minutes; Text B = 3:13 minutes), while RWL videos were made to the length of the mean pilot reading speed, plus an extra 500ms as (final video lengths: Text A = 1:44 minutes; Text B = 1:54 minutes). This ensured that, in the Reading modality participants had all the time to read the text at their own pace, while, in the RWL modality participants had to follow the reading speed of the narrator. Participants were asked to press the forward button once they had finished reading in the Reading modality, to try to avoid re-reading.

Each text was followed by 6 forced-choice comprehension questions, both literal and inferential (Supplementary Material A) accompanied by 4 possible answers. Questions were scored either correct (score of 1) or incorrect (score of 0). Score in each condition was computed as the number of correct

questions out of 6. Questions for each text were matched for difficulty using data from the pilot sample (Text A: Median of students correctly answering each question = 8.00; Text B: Median of students correctly answering each question = 8.00; $U = 16.00$, $z = -0.328$, $p = .810$).

Language experience questionnaire. The current study adapted The Language and Social Background Questionnaire (LSBQ; Anderson et al., 2018) to measure participants' language experience. The LSBQ was modified to allow for online self-administration via Qualtrics. The questionnaire consisted of three sections: Social Background, Language Background, and Community Language Use Behaviour. Social Background included demographic questions such as having lived abroad in countries where English is not the dominant language. Language Background involved questions about language proficiency and usage of English and additional language(s) (e.g., in speaking, listening, reading, writing). Community Language Use Behaviour asked questions regarding which language is predominantly used by participants in different social situations. Modifications were made in each section to serve the population being sampled, for example in the third section, 'High School' was changed to 'Secondary School', 'Roommates' was changed to 'People you live with' and a 'Not Applicable' column was added. To compute the final LSBQ score, when participants answered with 'Not Applicable', the mean from previous Anderson et al.'s (2018) results was applied to that specific question for that participant. Pilot study responses indicated that some participants might find it difficult to respond to certain fields that do not apply to their experience (e.g. questions about language used when participating in religious activities, or questions about language used with siblings) and needed a 'non applicable' option. Given the LSBQ necessitates complete answers in all questions to compute a bilingualism score, the average score for each question from Anderson et al. (2018) was used in the case of NA responses to specific questions. The responses from each individual were computed using the LSBQ Data Entry and Factor Score Calculator, which produced a singular score representing the language experience of each participant. These scores can be assigned to discrete categories or be kept on a continuous scale. Discrete categories distinguish between monolinguals (participants with a score that is less than -3.13), bilinguals (those with a score above 1.23) and ambiguous (scores between -3.13 and 1.23). Analyses were run with both continuous scores, and discrete categories in order to compare differences between the two types of classifications. Our participants' LSBQ scores ranged from -7.05 to 15.11.

Biology knowledge and Biology enjoyment. To measure Subject Enjoyment, participants were asked; ‘How much do you enjoy the subject of Biology?’, to measure Subject Knowledge, they were asked; ‘How much knowledge do you have on the subject of Biology?’. Both of these were measured on a self-rated scale of 0-5 (not at all – extensive knowledge / high enjoyment).

Data analysis

We performed three analyses in R version 4.1.1 (R Core Team, 2021). First, we explored the relationship between our continuous predictors using correlations.

Second, we used a repeated measures generalized binomial model to explore the effect of language experience, presentation modality, subject knowledge and subject enjoyment and their interaction, in order to answer research questions 1, 2 and 3. We considered each question separately for each participant, as the dependent measure. This simultaneously allowed us to consider different intercepts for each participant and for each question. Language experience measured continuously as LSBQ scores, presentation modality, subject knowledge and subject enjoyment were entered as predictors in the model.

Third, we ran the same analyses but included language experience as a bimodal variable, grouping all participants within two categories: bilinguals if their LSBQ score was higher than 1.23, non-bilingual if their LSBQ score was lower than 1.23. We grouped together monolinguals and participants with ambiguous scores as categorized by Anderson et al., (2018) to ensure groups with similar numbers.

Specific details on the model selection procedure can be found in Supplementary Material B, and is available in OSF at: https://osf.io/zgmaq/?view_only=8d6c12ffbb714d1b8c0af9b8bae9d520

Results

Table 1 presents the self-rated knowledge and enjoyment of biology which significantly correlated with each other, while, importantly, neither measure correlated with LSBQ scores. The mean LSBQ score was near the identified cut-off for fully bilingual participants, in fact, 45 participants were classified as fully bilingual, and 49 as non-bilingual.

Table 1. Mean, standard deviations and Pearson correlations between the main continuous predictors (alpha = .05).

	Mean	95% CI	1	2	3
1 – LSBQ score	1.15	-0.20 – 2.51	-	.18	.11
2 – Biology Knowledge	2.75	2.53 – 2.96		-	.64*
3 – Biology Enjoyment	2.65	2.37 – 2.93			-

Presentation time between the two conditions did not differ significantly (Reading time: $M = 106.3$ s, $SD = 45.4$; RWL time: $M = 112.9$ s, $SD = 6.5$; $t(93) = 1.4$, $p = .167$). When considering comprehension performance (Table 2), participants obtained similar scores in the two conditions. When considering language experience as binomial, bilinguals obtained slightly higher scores in the Reading modality, while non-bilingual participants obtained higher scores in the RWL modality, with scores for RWL in the two groups appearing very similar.

Table 2. Mean and 95% CI for total number of correct questions answered in each condition by all participants (out of 6), and by participants divided in groups depending on their language experience.

	All participants (N = 94)		Bilinguals (N = 45)		Non-bilinguals (N = 49)	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Reading	3.99	3.75– 4.23	4.29	3.91– 4.67	3.71	3.41 – 4.02
RWL	3.96	3.68 – 4.24	3.93	3.48 – 4.38	3.98	3.62 – 4.34

Table 3 reports two generalized repeated measures models: one with continuous LSBQ scores and the other with binomial division between bilingual and non-bilingual participants. As it is possible to see from the results from the two models both highlighted a main effect of Language Experience and Biology Enjoyment, but no main effect of Modality or Biology Knowledge. These main effects highlight that students with more diverse language experience and those who enjoyed biology more obtained better comprehension scores. Both models also highlighted a significant interaction between Language Experience (either dichotomous or continuous) and Biology Enjoyment. The interaction between Modality and Language Experience, however, was significant in the model with dichotomous language experience, but only approaching significance in the model with the continuous variable.

Table 3. Repeated measures generalized binomial models for comprehension.

Factor	Model 1 - LSBQ continuous model					Model 2 - Bimodal language experience model				
	Est.	SE	Est. odds ratio	z values		Est.	SE	Est. odds ratio	z values	
				z	p				z	p
Intercept	.83	.30	2.29	2.73	.006*	1.14	.33	3.12	3.43	.001*
Modality	-.02	.14	.98	-.13	.939	-.34	.21	.71	-1.60	.109
Language Experience	.19	.09	1.21	2.04	.041*	-.56	.23	.57	-2.41	.016*
Biology Knowledge	-.06	.12	.94	-.54	.590	-.04	.12	.96	-.37	.713
Biology Enjoyment	.30	.12	1.35	2.51	.012*	.56	.14	1.75	3.80	<.001*
Modality*Language Experience	-	-	-	-	-	.58	.29	1.79	2.04	.041*
Enjoyment*Language Experience	.21	.10	1.24	2.13	.033*	-.57	.19	.57	-3.07	.002*
Random effects	Var	SD	Marg R ² _{GLMM}	Cond R ² _{GLMM}		Var	SD	Marg R ² _{GLMM}	Cond R ² _{GLMM}	
Subject	.31	.55				.29	.54			
Question	.95	.97	.04	.30		.95	.97	.04	.31	

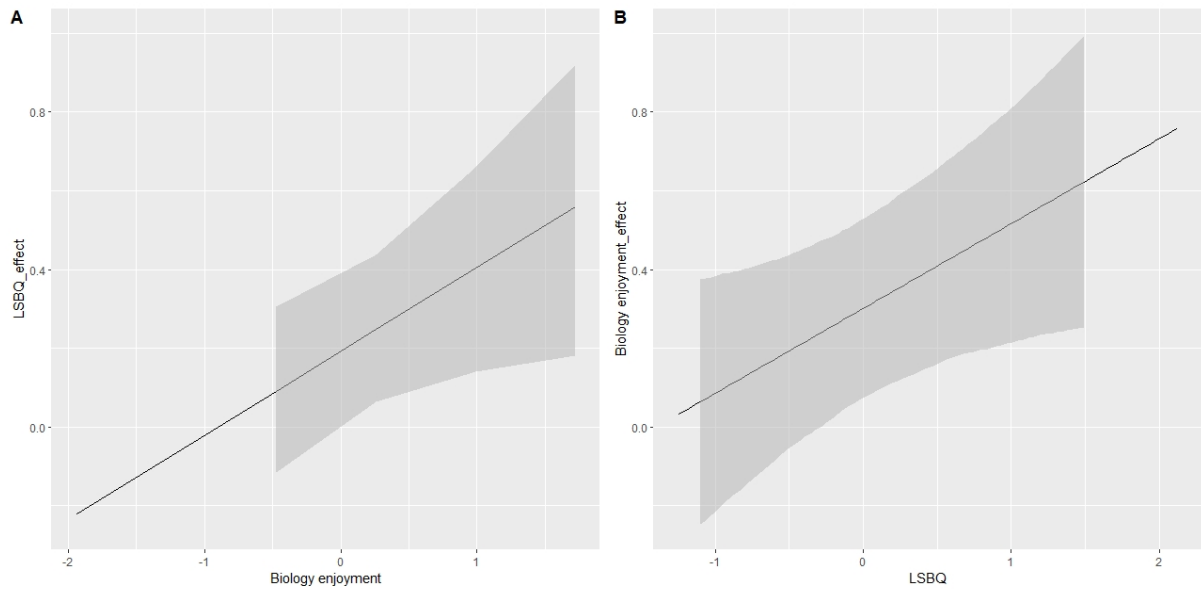


Figure 1. Exploration of interaction from Model 1. A – effect of LSBQ on the probability of answering a question correctly depending on level of Biology enjoyment; B - effect of Biology enjoyment on the probability of answering a question correctly depending on LSBQ scores (both Biology enjoyment and LSBQ scores centered around the mean).

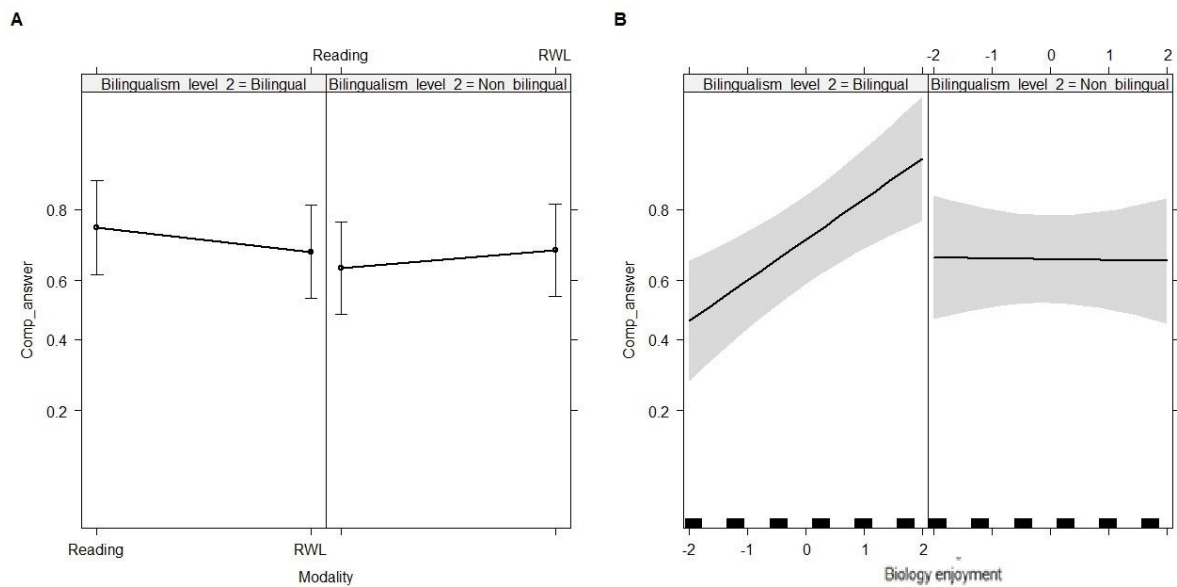


Figure 2. Exploration of interactions from Model 2. A- probability of answering the comprehension question correctly depending on Presentation modality and bimodal language experience; B – probability of answering the comprehension question correctly depending on bimodal language experience and Biology enjoyment scores (Biology enjoyment scores centered around the mean. Bars represent the score clusters.).

The significant interaction between LSBQ scores and Biology enjoyment in the first model suggests that the effect of Biology enjoyment increases at increasing LSBQ scores (Figure 1 B), while the effect of LSBQ scores increased less markedly at the increase of Biology enjoyment scores (Figure 1 A). Similarly, the significant interaction between language experience and Biology enjoyment in the second model suggests that Biology enjoyment was a significant positive predictor for bilingual students, but not non-bilinguals (Figure 2 B). This was explored through post-hoc analyses using similar models as the main analyses, without interactions. When including only bilingual participants the effect of Biology enjoyment was significant (OR = 1.59, $p = .004$); the same effect of Biology enjoyment was not significant in the model that only included non-bilingual students (OR = 1.09, $p = .610$). When dividing data depending on Biology enjoyment, the difference between bilingual and non-bilingual students was not significant in a model that included students with low enjoyment (scores 0 to 2: OR = .99, $p = .969$) nor in a model that included students with high enjoyment (scores 3 to 5: OR = .64, $p = .099$).

As reported in Table 3, there was no significant interaction between LSBQ and modality in the model with continuous LSBQ scores. However, this interaction was significant in the model that considered language experience categorically. As suggested by Figure 2, a post-hoc analyses confirmed that bilingual and non-bilingual students did not differ in their comprehension scores in the RWL condition (OR = 0.98, $p = .922$), but bilinguals outperformed non-bilinguals in the Reading condition (OR = 1.75, $p = .016$), which is the opposite of what we expected from previous research (Chang and Millet, 2015). Differences between conditions were not significant for either participant group (bilinguals: OR = 0.34, $p = .109$; non-bilinguals: OR = -.25, $p = .201$).

Discussion

The present study explored the effects of presentation modality (reading compared to reading while listening – RWL), biology enjoyment and biology knowledge on the comprehension of biology texts in a group of university students with a wide range of language experiences, where language experience was measured both categorically (bilinguals compared to non-bilinguals) and continuously.

Firstly, when assessing the effect of language experience on comprehension, both models highlight an overall significant effect of language experience: participants with higher scores in our language experience measure obtained higher comprehension scores and, when divided in groups, bilingual participants outperformed non-bilingual participants on comprehension. This finding is in contrast to what was originally hypothesised (Jean & Geva, 2009) but similar results have been found in previous research (Adesope et al., 2010; Afsharrad & Sadeghi Benis, 2015). In fact, while some research suggests that bilingual participants might have lower oral language skills than monolinguals (Droop & Verhoeven, 2003), and that this can negatively affect their comprehension abilities, other research suggests that bilinguals might have better executive function skills (Bialystok, 2011; 2015), which, in turn, can positively affect comprehension.

It is also possible that the superior performance of bilingual participants might be specific to our population of University students studying in an English-speaking country. Students in our sample likely had a high level of English, necessary to be admitted to study in the UK, thus, in their specific case, being bilingual could come with the benefit of improved executive functions (Bialystok et al., 2004), but without the drawback of lower oral language abilities (Droop & Verhoeven, 2003). This would be in line with the results of Adesope et al. (2010) that suggested that balanced bilinguals can have stronger reading skills than their monolingual counterparts. Given the expected high level of English in the present sample, it is possible that a higher score in our language experience measure would in fact identify more balanced bilinguals – i.e. participants that still use their L1 (first language) very often, and thus maintain it, while also exhibiting good levels of L2 (English) knowledge.

A second important result in regards to language experience was that the model that considered language experience as categorical highlighted a significant interaction between presentation modality and language experience, while in the model with continuous LSBQ scores this interaction was not significant. The significant interaction in one of the models suggests that bilingual students performed better than non-bilinguals in the Reading condition, but not in the RWL condition. The fact that this interaction is only significant in the model that categorises bilinguals and non-bilingual in groups might suggest that this is a general effect found at any level of bilingualism, but does not increase with the increase in diversity of language experience. Again, this is contrary to our

initial hypothesis that bilinguals would be more facilitated by RWL than non-bilinguals (Chang & Millet, 2015). This result however is similar to what Diao and Sweller (2007) found in a previous study with bilingual students.

It is particularly interesting that we found an effect similar to that of Diao and Sweller (2007), as the two bilingual samples were quite different. Our sample of university students studying at British Universities was composed of either monolingual students or highly proficient bilingual students, used to studying in English. Our bilingual students also would have had to meet the standard set by their British Universities in order to be admitted into their chosen course. In contrast Diao and Sweller (2007) tested students studying English as a Foreign Language in China and suggested that their relatively low reading ability would have impaired their performance in the bimodal task by preventing good audio-visual correspondence. In our sample, on the other hand, given the relatively high proficiency compared to the general bilingual population, it is possible that having a more varied language experience might have been an advantage for these students. For example, a more varied language experience might have strengthened students' executive functions (Bialystok, 2011; 2015), which in turn would have had a positive effect on their comprehension abilities (Follmer & Sperling, 2018; Ober et al., 2019).

Bilingual students outperformed non-bilinguals in general but the fact that this positive effect of bilingualism was especially evident in the reading-only and not in the RWL condition might be due to the freedom granted by the Reading condition, where students could read the text at their own pace, compared to the RWL condition where students had to follow the oral narration. The oral narration in the RWL condition was made to match the mean reading speed of a sample of university students but might not have matched the reading speed of all students, thus, potentially masking any positive effect of bilingualism. For example, if the students' reading speed was slower than the oral narration, this may have impaired their ability to read the text while simultaneously listening, and thus their ability to make full use of the bimodal presentation. This may have subsequently affected their comprehension of the text, and potentially masked the positive effects bilingualism might have had on their comprehension outcomes, specifically in the RWL condition.

It is also possible that, given the high language ability required of bilingual students by British Universities, these students were more expert comprehenders than their monolingual counterparts (due to the possible positive effect of bilingualism on executive functions), and thus they were more likely to show the more standard redundancy effect (i.e. better performance in the reading than RWL condition) than their monolingual peers. To explore the underlying mechanism of executive function being the facilitator for bilingual advantages, future studies could include a measure of executive function. This second interpretation, however, is tempered by the lack of significant difference between conditions, even in the bilingual group. Another possibility, however, is that there might be differences in the motivation and attention paid to the task by monolingual and bilingual students. This idea could be further explored by conducting the study in person rather than online and by including a measure of engagement with the task.

Overall, our results suggest that the best way to promote comprehension in university students, especially bilingual university students, might be to provide them with written material they can read at their own pace, rather than oral narration. The results also suggest that bilingual students might be advantaged over non-bilingual students, especially when provided with written material. These results could be applied to recorded lectures, suggesting that providing scripts or just written material would be particularly beneficial for bilingual students, though further research on videos and videos with captions is needed to confirm this effect.

In regard to the effect of biology knowledge, biology enjoyment, and their interaction with language experience, the analysis with language experience as continuous and that with language experience as categorical highlight similar effects. Students with higher self-reported enjoyment, but not those with higher self-reported knowledge had higher comprehension scores. The interaction between enjoyment and language experience also suggested that the positive effect of biology enjoyment was greater for students with more diverse language experiences. In fact, in the analysis with a categorical distinction between bilingual and non-bilingual students, the positive effect of biology enjoyment was significant only in the bilingual group. These results are in line with previous research on the effect of subject enjoyment on comprehension (Babbitt Bray and Barron, 2004) but not the research on subject knowledge (Rydland et al., 2010), suggesting that, when considering both

knowledge and enjoyment, enjoyment might have the greatest effect on comprehension. This effect might be explained by hypothesising that students who enjoy biology the most might be more likely to pay closer attention to a biology text and thus comprehend it better. Their enjoyment of the subject might also influence their more general reading habits, making them more familiar with biology or scientific texts.

The lack of an effect of subject knowledge could be due to the relative importance of subject knowledge and subject enjoyment, with enjoyment having the biggest effect. Given the relatively high correlation of these two variables, it is also possible that part of the variability explained by subject enjoyment could be shared variability explained by both enjoyment and knowledge. It could also be possible that the relatively high academic achievement of our sample (university students) could explain the lack of knowledge effect, as this sample might be composed of students that are all relatively knowledgeable in the subject of science, despite their self-reported scores. Future research might disentangle these effects by including young adults with a more varied educational experience.

It is also possible that the subjective nature of the self-rating measures used might have influenced the results, and including quantitative objective measures of knowledge might clarify these effects. In fact, previous research on self-assessment of knowledge suggest that these correlate moderately with more quantitative knowledge assessments, but correlate more highly with motivation and satisfaction measures (Sitzmann et al., 2010).

The interaction between subject enjoyment and language experience is more difficult to account for, as in our knowledge this is the first study to compare the effect of subject enjoyment between bilingual and non-bilingual students. It is possible that subject enjoyment might have a bigger effect on bilingual students by accentuating the effects suggested above thus making bilingual students more likely to be affected by attention to the text or relative familiarity with the subject due to their relatively lower English language skills.

As explored in the introduction, previous research tended to explore the effect of language experience categorically, comparing bilingual and non-bilingual participants (Ianco-Worrall, 1972), while more recent research highlights the importance of using continuous measures (Luk & Bialystok, 2013). In the present study we found similar results when comparing bilingual and non-bilingual

students and when using a continuous variable to measure language experience, except in the case of the interaction between presentation modality and language experience, where the interaction was significant in the model with a categorical variable, but not significant in the model with a continuous variable. This suggests that bilingual participants are those most likely to experience facilitation from the Reading condition compared to the RWL condition, but this facilitation might be experienced similarly by all bilinguals past a certain language threshold. Measuring language experience continuously allows for a more nuanced analysis of individual differences in the bilingual population (Luk & Bialystok, 2013), however, a categorical distinction between bilingual and non-bilingual students might still be of use when exploring specific effects. To take this possibility into account future research on bilingualism might consider including both a categorical distinction between bilingual and monolingual participants, but also a continuous measure of language experience (Kremin & Byers-Heinlein, 2021), at least for the bilingual group, where language experience can be extremely varied.

Limitations and Conclusions

Some limitations are present in the current study: Firstly, this study was conducted online, thus we relied on participants to focus and pay attention and perform the task appropriately without supervision. While this allowed us to collect a larger quantity of data in a short amount of time, a more controlled, in person environment would have granted more control over participants' attention and performance. A second limitation is linked to the specific features of the RWL condition. Specifically, presentation time in the RWL condition was fixed at the mean reading time of the pilot group while students could read at their own pace in the Reading condition, thus, presentation time might have differed between conditions for each individual participant and might have had an effect on performance. However, overall, we did not find a difference between time spent reading or RWL (see Results section). Our chosen presentation time matches that adopted by previous studies (Valentini et al., 2018), however future studies could allow for variation in presentation time in the RWL modality between participants to match their reading time, to explore effects of individual differences in reading time on presentation modality effects more thoroughly.

A third limitation is that we only measured biology knowledge and biology enjoyment with two separate questions. To explore effect of knowledge and enjoyment more fully, future research might use more nuanced methods to measure knowledge and enjoyment, including more subtle questions, or a direct assessment of subject knowledge that would not rely on self-report. The inclusion of a measure of reading-habits might also help clarify the source of enjoyment effects. Future research could also include a question to control whether participants are studying Biology at University level: these participants might be able to answer the comprehension questions without reference to the text, and their inclusion might affect the data. The present data was collected through Qualtrics and distributed mainly to Psychology students, but the presence of Biology students in the sample cannot be excluded.

A fourth limitation of the present study is that we did not pilot comprehension questions separately from the texts. It is therefore possible that questions might have been too easy for the participants, and more difficult questions might highlight a difference between conditions or between monolingual and bilingual participants more clearly. While the performance of the pilot participants and that of our experimental sample was not at ceiling at text-level, it is still possible that some ceiling effects at question-level might have affected our ability to differentiate performance between conditions and groups. Finally, it must be noted that caution may be warranted in the interpretation of the interaction between language experience and modality, as this interaction was only significant when bilingual and non-bilingual participants were divided in two groups. Given that we did not measure decoding abilities or EF in these two groups, it is possible that the groups differed on more than one feature, and that other important individual differences, like reading skills or executive function abilities, might have affected the result. In fact, this applies to the main effect of language experience as well, as language experience might function as a proxy of other skills that were not measured in the present study. Future research might include measures of reading abilities and executive functions in order to better differentiate the role of language experience from that of other measures of individual differences, especially reading and cognitive skills.

In conclusion, the present study shows a general advantage of bilingual university students over non-bilingual students in comprehending texts. It also highlights how presentation modality and

enjoyment affect bilingual and non-bilingual students differently, with bilingual university students being advantaged by a written presentation of the material and being more affected by subject enjoyment. This can have important implication for education practices: for instance, our results show that bilingual students might outperform non-bilingual students in text comprehension. The results also suggest that, when catering to university students with a varied language experience, presenting material in the written modality might be the best way to ensure highest levels of comprehension. It also highlights the importance of considering students' interest in the subject, which might suggest that activities that foster students' engagement and improve their enjoyment might be particularly beneficial in increasing comprehension of the material, and thus, educational attainment and success.

References

- Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A Systematic Review and Meta-Analysis of the Cognitive Correlates of Bilingualism. *Review of Educational Research*, 80(2), 207–245.
- Afsharrad, M., & Sadeghi Benis, A. R. (2015). Differences between monolinguals and bilinguals/males and females in English reading comprehension and reading strategy use. *International Journal of Bilingual Education and Bilingualism*, 20(1), 34–51.
- Anderson, J. A. E., Mak, L., Keyvani Chahi, A., & Bialystok, E. (2018). The Language and Social Background Questionnaire: Assessing degree of Bilingualism in a Diverse Population. *Behavior Research Methods*, 50(1), 250–263.
- Babbitt Bray, G., & Barron, S. (2004). Assessing Reading Comprehension: The Effects of Text-Based Interest, Gender, and Ability. *Educational Assessment*, 9(3–4), 107–128.
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *arXiv preprint arXiv:1406.5823*.
- Bernhardt, E. (2005). Progress and Procrastination in Second Language Reading. *Annual Review of Applied Linguistics*, 25, 133–150.
- Best, R. M., Floyd, R. G., & McNamara, D. S. (2008). Differential Competencies Contributing to Children's Comprehension of Narrative and Expository Texts. *Reading Psychology*, 29(2), 137–164.
- Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child development*, 81(6), 1641-1660.
- Betts, J.G., Young, K. A., Wise, J. A., Johnson, E., Poe, B., Kruse, D. H., Korol, O., Johnson, J. E., Womble, M., & DeSaix, P. (2013). *Anatomy and Physiology* (1st ed.). OpenStax: Houston, Texas. <https://openstax.org/books/anatomy-and-physiology/pages/1-introduction>
- Bialystok, E. (2011). Reshaping the mind: The benefits of bilingualism. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale*, 65(4), 229–235.
- Bialystok, E. (2015). Bilingualism and the Development of Executive Function: The Role of Attention. *Child Development Perspectives*, 9(2), 117–121.

- Bialystok, E., Luk, G., Peets, K. F., & Yang, S. (2010). Receptive vocabulary differences in monolingual and bilingual children. *Bilingualism: Language and cognition*, 13(4), 525-531.
- Burgoyne, K., Kelly Née Hutchinson, J. M., Whiteley, H. E., & Spooner, A. (2009). The comprehension skills of children learning English as an additional language. *British Journal of Educational Psychology*, 79(4), 735–747.
- Chang, A. C. S. (2009). Gains to L2 listeners from reading while listening vs. listening only in comprehending short stories. *System*, 37(4), 652-663.
- Chang, C.-S., & S. Millett, S. (2015). Improving reading rates and comprehension through audio-assisted extensive reading for beginner learners. *System*, 52, 91-102.
- Clark, D. (2022, August 3rd). Percentage of pupils whose first language is not English in England 2021, by region. *Statista*. Retrieved 19 February 2022, from <https://www.statista.com/statistics/331675/england-region-english-additional-language/>
- Conklin, K., Alotaibi, S., Pellicer-Sánchez, A., & Vilkaitė-Lozdienė, L. (2020). What eye-tracking tells us about reading-only and reading-while-listening in a first and second language. *Second Language Research*, 36(3), 257-276.
- De Bruin, A. (2019). Not All Bilinguals Are the Same: A Call for More Detailed Assessments and Descriptions of Bilingual Experiences. *Behavioral Sciences*, 9(3), 33.
- Diao, Y., & Sweller, J. (2007). Redundancy in foreign language reading comprehension instruction: Concurrent written and spoken presentations. *Learning and instruction*, 17(1), 78-88.
- Dickens, R. H., & Meisinger, E. B. (2017). Examining the effects of reading modality and passage genre on reading comprehension in middle school students. *Reading Psychology*, 38(3), 321-347.
- Droop, M., & Verhoeven, L. (2003). Language proficiency and reading ability in first- and second-language learners. *Reading Research Quarterly*, 38, 78–103.
- Eason, S. H., Goldberg, L. F., Young, K. M., Geist, M. C., & Cutting, L. E. (2012). Reader–text interactions: How differential text and question types influence cognitive skills needed for reading comprehension. *Journal of educational psychology*, 104(3), 515.
- Ellis, E. M. (2008). Defining and investigating monolingualism. *Sociolinguistic Studies*, 2(3), 311–330.
- Follmer, D. J., & Sperling, R. A. (2018). A latent variable analysis of the contribution of executive function to adult readers’ comprehension of science text: the roles of vocabulary ability and level of comprehension. *Reading and Writing*, 32(2), 377–403.
- Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing*, 2(2), 127-160.
- https://osf.io/zgmaq/?view_only=8d6c12ffbb714d1b8c0af9b8bae9d520
- Ianco-Worrall, A. D. (1972). Bilingualism and cognitive development. *Child Development*, 43(4), 1390–1400.
- Jean, M., & Geva, E. (2009). The development of vocabulary in English as a second language children and its role in predicting word recognition ability. *Applied Psycholinguistics*, 30, 153–185.
- Jeon, E. H., & Yamashita, J. (2014). L2 reading comprehension and its correlates: A meta-analysis. *Language Learning*, 64(1), 160-212.
- Johnston, A. M., Barnes, M. A., & Desrochers, A. (2008). Reading Comprehension: Developmental Processes, Individual Differences, and Interventions. *Canadian Psychology*, 49(2), 125-132.
- Kalyuga, S. (2007). Expertise reversal effect and its implications for learner-tailored instruction. *Educational psychology review*, 19(4), 509-539.

- Kalyuga, S. & Sweller, J. (2014). The redundancy principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed.) (pp. 247-262). New York, NY: Cambridge University Press.
- Kalyuga, S., Chandler, P., & Sweller, J. (1998). Levels of expertise and instructional design. *Human Factors*, 40, 1–17.
- Kremin, L. V., & Byers-Heinlein, K. (2021). Why not both? Rethinking categorical and continuous approaches to bilingualism. *International Journal of Bilingualism*, 25(6), 1560–1575.
- Landi, N. (2010). An examination of the relationship between reading comprehension, higher-level and lower-level reading sub-skills in adults. *Reading and Writing*, 23(6), 701-717.
- Li, P., Sepanski, S., & Zhao, X. (2006). Language history questionnaire: A Web-based interface for bilingual research. *Behavior Research Methods*, 38(2), 202–210.
- Liao, S., Kruger, J. L., & Doherty, S. (2020). The impact of monolingual and bilingual subtitles on visual attention, cognitive load, and comprehension. *The Journal of Specialised Translation*, 33, 70-98.
- Liu, H., Cao, S., & Wu, S. (2019). An experimental comparison on reading comprehension effect of visual, audio and dual channels. *Proceedings of the Association for Information Science and Technology*, 56(1), 716-718.
- Luk, G., & Bialystok, E. (2013). Bilingualism is not a categorical variable: Interaction between language proficiency and usage. *Journal of Cognitive Psychology*, 25(5), 605–621.
- Mahzoun, P. (2022). The Effect of Bilingualism and Multilingualism on Academic Behavior. In Jiang, X. (Ed.) *Multilingualism-Interdisciplinary Topics*. IntechOpen.
- Marian, V., & Hayakawa, S. (2020). Measuring bilingualism: The quest for a “bilingualism The quest for a “bilingualism quotient”. *Applied Psycholinguistics*, 42(2), 527–548.
- Marian, V., & Shook, A. (2012, September). The cognitive benefits of being bilingual. In *Cerebrum: the Dana forum on brain science* (Vol. 2012). Dana Foundation.
- Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.) *The Cambridge Handbook of Multimedia Learning* (pp. 43-71). Cambridge: Cambridge university press.
- Mayer, R. E., Moreno, R., Boire, M., & Vagge, S. (1999). Maximizing constructivist learning from multimedia communications by minimizing cognitive load. *Journal of Educational Psychology*, 91(4), 638-643.
- Melby-Lervåg, M., & Lervåg, A. (2011). Cross-linguistic transfer of oral language, decoding, phonological awareness and reading comprehension. *Journal of Research in Reading*, 34, 114–135.
- Modirkhamene, S. (2006). The reading achievement of third language versus second language learners of English in relation to the interdependence hypothesis. *International Journal of Multilingualism*, 3(4), 280-295.
- Moreno, R., & Mayer, R. E. (2002). Verbal redundancy in multimedia learning: when reading helps listening. *Journal of Educational Psychology*, 94, 156e163.
- Murayama, K., Usami, S., & Sakaki, M. (2022). Summary-statistics-based power analysis: A new and practical method to determine sample size for mixed-effects modelling. *Psychological Methods*.
- Nouwens, S., Groen, M. A., Kleemans, T., & Verhoeven, L. (2021). How executive functions contribute to reading comprehension. *British Journal of Educational Psychology*, 91(1), 169-192.
- Ober, T. M., Brooks, P. J., Plass, J. L., & Homer, B. D. (2019). Distinguishing Direct and Indirect Effects of Executive Functions on Reading Comprehension in Adolescents. *Reading Psychology*, 40(6), 551–581.

- OECD Reviews of Migrant Education. (2009). Closing the gap for immigrant students: Policies, practice and performance.
- Pellicer-Sánchez, A., Tragant, E., Conklin, K., Rodgers, M., Serrano, R., & Llanes, Á. (2020). Young learners' processing of multimodal input and its impact on reading comprehension: an eye-tracking study. *Studies in Second Language Acquisition*, 42(3), 577-598.
- PHED 301 Students (2018). *Advanced Anatomy 2nd. Ed.*
- Prior, A., & MacWhinney, B. (2009). A bilingual advantage in task switching. *Bilingualism: Language and Cognition*, 13(2), 253–262.
- R Core Team (2019). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL: <http://www.R-project.org/>
- Rahman, A., & Hajar, I. (2020). The effect of audiobook on reading comprehension of the eleventh grade students of SMA Negeri 2 Buru. *ELT Worldwide: Journal of English Language Teaching*, 7(2), 104-115.
- Ransdell, S. (2004). The care and feeding of monolingual and bilingual university students in South Florida: implications for assessment and training. *Psychology Learning & Teaching*, 3(2), 126-130.
- Rogowsky, B. A., Calhoun, B. M., & Tallal, P. (2016). Does modality matter? The effects of reading, listening, and dual modality on comprehension. *SAGE Open*, 6(3), 2158244016669550.
- Rydland, V., Aukrust, V. G., & Fulland, H. (2010). How word decoding, vocabulary and prior topic knowledge predict reading comprehension. A study of language-minority students in Norwegian fifth grade classrooms. *Reading and Writing*, 25(2), 465–482.
- Sitzmann, T., Ely, K., Brown, K. G., & Bauer, K. N. (2010). Self-assessment of knowledge: A cognitive learning or affective measure?. *Academy of Management Learning & Education*, 9(2), 169-191.
- Steele, E. (1996). The Effectiveness of Bimodal Text Presentation for Poor Readers. Paper presented at the Annual Convention of the National Association of School Psychologists (28th, Atlanta, GA, March 12-16, 1996).
- Taboada Barber, A., Cartwright, K. B., Hancock, G. R., & Klauda, S. L. (2021). Beyond the Simple View of Reading: The Role of Executive Functions in Emergent Bilinguals' and English Monolinguals' Reading Comprehension. *Reading Research Quarterly*, 56, S45-S64.
- Tarchi, C. (2017). Comprehending and recalling from text: The role of motivational and cognitive factors. *Issues in Educational Research*, 27(3), 600-619.
- Tilstra, J., McMaster, K., Van den Broek, P., Kendeou, P., & Rapp, D. (2009). Simple but complex: Components of the simple view of reading across grade levels. *Journal of Research in Reading*, 32(4), 383-401.
- Tragant, E. & Vallbona, A. (2018). Reading while listening to learn: young EFL learners' perceptions. *ELT Journal*, 72, 395–404.
- Tragant, E., Muñoz, C., & Spada, N. (2016). Maximizing young learners' input: An intervention program. *The Canadian Modern Language Review*, 72, 234–257.
- Valentini, A., Ricketts, J., Pye, R. E., & Houston-Price, C. (2018). Listening while reading promotes word learning from stories. *Journal of Experimental Child Psychology*, 167, 10-31.
- Verlaan, W., & Ortlieb, E. (2012). Reading while listening: Improving struggling adolescent readers' comprehension through the use of digital-audio recordings. *What's hot in literacy*, 30.