Sentence Processing in Bilingual Children with and without Language Impairment

ABSTRACT

Reading comprehension is shaped by syntactic complexity, working memory, and linguistic proficiency, especially in bilingual students with language disorders. This study investigated the effects of bilingualism and syntactic complexity on reading comprehension performance among Indonesian-English bilingual students with and without Specific Language Impairment (SLI). Participants were 44 balanced bilingual elementary students (22 with SLI, 22 typically developing) who completed sentence-level reading tasks in Indonesian and English using a silent, self-paced reading paradigm. Comprehension accuracy, reading speed, recall speed, and fixation duration were analyzed via ANCOVA and MANOVA, controlling for sentence length, number of syllable, number of modifier, and the number of proposition. Results showed that SLI status significantly impaired all reading performance indicators, regardless of language. Language type had no effect on accuracy or reading speed, but did affect recall speed, especially in English, reflecting working memory load. Syntactic complexity—particularly the number of modifiers and propositions—negatively impacted comprehension accuracy and recall, disproportionately affecting SLI students. Fixation duration patterns revealed that SLI students allocated more visual attention in English. These findings indicate that comprehension challenges in bilinguals with SLI stem from limitations in working memory and content integration. Instructional strategies should target content chunking and memory scaffolds across both languages.

Keywords: Bilingualism; reading Comprehension; SLI; syntactic complexity

INTRODUCTION

Reading comprehension is a complex cognitive process that involves parallel mechanisms for decoding, integrating, and retrieving textual information. While these processes occur automatically in typically developing children (Layes et al., 2021), they present significant challenges for SLI students. Reading difficulties in individuals with SLI can arise at both lower and higher levels of processing, from decoding words to comprehending complex sentence structures. These challenges are further exacerbated in bilingual individuals, who must navigate two linguistic systems, increasing cognitive demands and the likelihood of cross-linguistic interference. When one language has a more complex orthography or syntax, reading deficiencies may become even more pronounced (Lallier et al., 2014). This study explores how bilingual SLI students process text in languages that share syntactic similarities. It also investigates whether these factors influence bilingual SLI students differently from their Non-SLI peers.

SLI is a developmental condition characterized by significant language deficits that cannot be attributed to hearing loss or other cognitive impairments (Bishop, 2006). Children with SLI typically experience difficulties in speech sound production, sentence processing, and reading comprehension. These difficulties stem from deficits in verbal working memory, which impairs their ability to store and process linguistic information simultaneously (Montgomery et al., 2016). As a result, sentence comprehension becomes increasingly challenging, especially when processing long or syntactically complex sentences. Unlike typically developing

children, who can efficiently balance storage and processing demands, children with SLI struggle to retain earlier sentence components, leading to reduced comprehension accuracy.

Bilingualism introduces additional complexity to reading comprehension as it requires individuals to manage two linguistic systems simultaneously, thereby further straining working memory resources and impair reading performance (Yang, 2017). Bilingual SLI students face distinct challenges in processing syntactically complex sentences (Zebib et al., 2019). Processing speed is often slower in children with reading impairment, hindering their ability to process text efficiently (Jacobson et al., 2011).

Despite extensive research on bilingualism, reading comprehension, and working memory, there remain significant gaps in understanding how Indonesian-English bilingual children with SLI process language. This is particularly relevant when participants have equal fluency in both languages and have acquired them simultaneously. Indonesian and English differ orthographically, with Indonesian being a transparent language and English an opaque one. While studies have explored the effects of working memory and executive functions on reading comprehension, few have controlled for identical syntactic complexity across two languages to precisely analyze reading speed, recall speed, and accuracy in bilingual sentence processing. This study employs self-paced silent reading with computerized eye tracking to capture real-time reading processes, providing novel insights into bilingual sentence processing, working memory deficits, and the effects of syntactic complexity on reading comprehension in children with SLI.

This research examines the impact of syntactic complexity and bilingualism on reading comprehension accuracy, reading speed, recall speed, and fixation in bilingual students with and without SLI. It is hypothesized that greater syntactic complexity negatively affects reading performance across all measures, while bilingualism influences recall speed without affecting accuracy. Additionally, SLI students are expected to perform worse than their typically developing peers in all conditions, highlighting potential cognitive processing differences in bilingual sentence comprehension.

THEORETICAL FRAMEWORK

Reading comprehension is a multi-level cognitive process that involves both lower-level mechanisms, such as word decoding and sentence structure recognition, and higher-level processes, such as semantic integration and inference-making (Kintsch & Rawson, 2005). Bilingual readers navigate these processes differently depending on the linguistic characteristics of each language they acquire, particularly in terms of orthographic transparency and syntactic complexity.

LANGUAGE ORTHOGRAPHY AND READING PERFORMANCE

One key factor influencing bilingual reading comprehension is phonological processing. According to the strong phonological theory, skilled readers access words directly without relying on detailed phonological representations (Frost, 2005). However, the extent to which phonological processing is required depends on the orthographic depth of the language. In transparent orthographies, lexical access is strongly tied to phonological representations, while in opaque orthographies, readers must engage in more complex grapheme-phoneme conversion. As a result, bilingual Indonesian-English readers may adopt different reading strategies depending on the orthographic structure of each language (Frost, 2005).

Therefore, the nature of a language's orthography plays a crucial role in reading performance. Bilingual dyslexic children read more accurately and faster in languages with transparent orthographies (e.g., Spanish, Hindi, Indonesian) than in opaque ones (e.g., French, English) as they have consistent grapheme-phoneme mappings (Lallier et al., 2014). The severity of reading deviation varies across languages due to their orthographic depth.

For bilingual and reading-impaired populations, these findings highlight the impact of orthographic complexity on reading comprehension. Espi-Sanchis and Cockcroft (2022) found that bilingual readers with balanced proficiency had better working memory, enabling them to process longer words and recall information more efficiently. In addition, Nasrullah (2025) found that reading comprehension of bilingual students is significantly affected by working memory. Conversely, students with reading difficulties such as dyslexia struggled with phonological recoding and working memory, leading to slower reading speeds (Caravolas, 2005).

SENTENCE LENGTH AND READING PERFORMANCE

The length of a sentence can be defined based on the number of syllables or the word in a sentence. Syllable length significantly impacts reading speed and recall, particularly in deep orthographies. Müller, Richter, and Karageorgos (2020) found that in German, poor readers relied on phonological recoding, leading to slower reading of longer words with complex syllables, whereas skilled readers used direct word recognition strategies to minimize this effect. Finnish, a transparent orthography, exhibited a similar pattern, where syllable length affected reading speed primarily in poor readers.

Syllable length also affects working memory in recall processes. Kuperman and Van Dyke (2011) found that readers with higher working memory capacity were less affected by syllable length in recall tasks, while less-skilled readers exhibited longer fixations on polysyllabic words, slowing down recall speed due to their reliance on phonological decoding.

Sentence length, measured in terms of word length can influence reading accuracy, speed, and recall. In opaque orthographies, longer words require greater cognitive processing, leading to slower reading speeds (Müller et al., 2020). This effect is particularly strong in deep orthographies with unpredictable phoneme-grapheme mappings.

SYNTACTIC COMPLEXITY AND READING PERFORMANCE

Syntactic complexity plays an important role in reading comprehension. It refers to the structural intricacy of a sentence, determined by factors such as the number of clauses, sentence length, the use of subordinate clauses, and embedded syntactic elements (Grela et al., 2023). It includes elements such as the length of production units, amount of subordination, coordination, and degree of phrasal elaboration (Lu & Ai, 2015). It is measured by how varied and sophisticated the production units or grammatical structures are (Liu & Afzaal, 2021). The ability to parse sentence structures and integrate textual information efficiently varies across languages, particularly in bilingual individuals who must manage different syntactic rules. Research suggests that syntactic competence is a strong predictor of comprehension ability across both first and second languages (Siu & Ho, 2020). Because Indonesian and English differ in sentence structure, bilingual readers may rely on distinct strategies when constructing meaning from text. Comprehension also extends beyond individual word meanings, requiring readers to integrate propositions across sentences to establish semantic coherence (Kintsch & Rawson, 2005).

WORKING MEMORY AND READING PERFORMANCE

Working memory capacity is equally significant, as it determines a reader's ability to maintain and integrate textual information (Kintsch & Rawson, 2005). Readers with limited working memory struggle to retain relevant content, directly affecting comprehension accuracy. Processing information during reading efficiently depends on three primary factors: processing speed, available space for processing, and the energy required to sustain processing operations (see Grela et al., 2023). As the capacity in working memory is limited, efficient readers allocate cognitive resources effectively, whereas poor readers experience greater constraints in recalling and processing information (Kızılaslan & Tunagür, 2021).

These processing limitations are particularly evident in individuals with SLI, who exhibit working memory deficits, especially in verbal short-term memory. Such impairments affect their ability to retain and integrate linguistic information, leading to challenges in syntactic processing and sentence comprehension. Research has shown that SLI individuals struggle with wh-questions, passive constructions, and long-distance dependencies, primarily due to working memory overload, making it difficult for them to accurately parse syntactic structures (Penke & Wimmer, 2024). Their difficulties are not solely syntax-related but are also attributed to working memory constraints, limiting their ability to process complex linguistic input effectively (Islami et al., 2024).

Daneman and Carpenter (1980) established a strong correlation between working memory and reading comprehension, particularly in relation to reading span—the amount of information retained while reading. Dyslexic readers, in particular, tend to have a shorter reading span, making them difficult to construct coherent mental representations of text (Farmer et al., 2017; Kimel et al., 2020). They often focus on forming a basic textbase rather than engaging in higher-level comprehension processes such as inference-making and constructing situation models (Kintsch & Rawson, 2005).

READING SPEED AND RECALL SPEED

Another critical factor influencing reading comprehension is reading speed, which reflects efficiency in word recognition, lexical access, and syntactic parsing. Faster reading speeds allow readers to allocate more cognitive resources to inferencing and semantic integration, thereby improving comprehension accuracy (Rayner et al., 2016). Conversely, slower reading speeds are often linked to decoding difficulties, particularly among SLI individuals, who struggle with working memory limitations and inefficient linguistic processing thus weakens comprehension (Van Dyke et al., 2014).

Closely related to reading speed, recall speed is another important factor in reading comprehension. The ability to retain and retrieve propositional content efficiently determines how well a reader can integrate and process textual information. Faster recall speeds indicate a more efficient encoding and retrieval process, essential for comprehending complex syntactic structures (Rayner et al., 2016). Studies on bilingual readers have shown that recall strategies differ between typically developing individuals and those with SLI (Christopher et al., 2012). While bilinguals often exhibit cross-linguistic transfer in recall strategies, dual-language activation can sometimes slow processing compared to monolingual counterparts (Parshina et al., 2022). Furthermore, SLI conditions impair working memory and linguistic integration, affecting both reading and recall speeds (Van Dyke et al., 2014).

METHOD

PARTICIPANTS

The study involved 44 bilingual Indonesian-English elementary students (Grades 2–4), equally divided into two groups: 22 with SLI and 22 non-SLI peers. All participants were drawn from a private school in Surabaya that implements both the Cambridge International Curriculum and the Merdeka Curriculum. Purposive sampling ensured that participants met the following criteria: (a) formal diagnosis of SLI (for the SLI group), (b) balanced fluency in Indonesian and English based on school standardized assessments, and (c) completion of a vocabulary pretest confirming knowledge of all lexical items in the reading comprehension tasks. All participants completed the reading test administered by the researchers. Ethical approval for this study was granted by the Health Research Ethics Committee of the Faculty of Public Health, Universitas Airlangga (Approval No: 149/EA/KEPK/2024).

INSTRUMENTS

Two sets of reading comprehension instruments were developed, one in Indonesian and one in English, with each set consisting of 17 sentences. These sentences varied in syntactic complexity while maintaining equivalent structure across both languages to control for linguistic difficulty. Each sentence contained one to two target keywords, which were carefully selected to assess the participants' ability to extract meaning at the sentence level rather than at the word level, given that sentence reading fluency has been shown to be a stronger predictor of reading comprehension than word reading fluency (Kirschmann et al., 2021).

The keywords consisted of content words—nouns, verbs, adjectives, and adverbs—since these words carry the primary referential meaning in a sentence (Katamba, 2005). Additionally, to control for the influence of vocabulary knowledge on reading comprehension (Babayiğit, 2014), all keywords were selected from the participants' school textbooks.

Several linguistic factors were carefully controlled in the instrument to ensure consistency and comparability across languages. Morphological complexity was regulated by using only inflexional affixes in both languages, kept the affixes and minimum as possible to avoid processing interference from morphological aspect, as morphological awareness has been shown to significantly influence reading comprehension performance (Carlisle, 2000). Phonological complexity was also considered, with words containing diphthongs and consonant clusters minimized to reduce phonemic processing difficulties and ensure a more uniform reading experience for participants. Additionally, syntactic complexity was adjusted to align with the participants' developmental stage. Sentences were structured with a subject-predicate format, and no usage of complex sentences (Simard et al., 2014). Variations in sentence structure were primarily limited to the placement of adjectives and adverbials, with adverbs restricted to those indicating time and place, following previous research on sentence structure comprehension (Haenggi et al., 1995; Zwaan & Radvansky, 1998).

PROCEDURE

Participants were presented with sentences in two separate sessions, one in Indonesian and one in English, with the Indonesian test conducted first, followed by the English test one week later. Each sentence contained three to six propositions, ensuring consistency in syntactic complexity across both languages. For each test, participants were instructed to silently read a sentence

displayed on a screen. The reading test was administered using an eye tracking device. After reading the sentence, participants answered comprehension questions targeting specific propositions within the sentence.

The comprehension questions were delivered via pre-recorded audio, and participants responded using a joystick interface. The number of questions varied depending on the number of propositions in the sentence, ranging from three to six. For example, in the sentence *Ayah membaca koran* (*Father reads a newspaper*), the questions included *Siapa yang membaca?* (*Who was reading?*), targeting the subject; *Apa yang ayah lakukan?* (*What did Father do?*), targeting the verb; and *Apa yang ayah baca?* (*What did Father read?*), targeting the object.

Data collection focused on three key measures: reading accuracy, reading speed, and recall speed. Reading accuracy was assessed by categorizing responses as either correct or incorrect based on whether they precisely matched the information provided in the sentence. Reading speed was measured using the first forward-sweep of eye movement, ensuring that only the initial reading process was considered without including regressions. Recall speed was recorded as the time taken from the moment the pre-recorded question ended until the participant pressed the button on the joystick to submit their response. Silent reading tests with precise eye-tracking technology and controlled response timing was done to ensure a detailed and objective measurement of reading comprehension performance in natural setting.

DATA ANALYSIS

This study employed a combination of Multivariate Analysis of Variance (MANOVA), and Univariate Analysis of Covariance (ANCOVA) to comprehensively examine how group membership (SLI vs. Non-SLI) and language (Indonesian vs. English) influenced reading comprehension processes in bilingual students. The analysis focused on four dependent variables: accuracy, reading speed, response speed, and fixation duration.

Before conducting MANOVA, Box's M Test was performed to check the assumption of homogeneity of covariance matrices across groups. Results indicated a significant violation of this assumption, Box's M = 1632.595, p < .001. Given this violation, Pillai's Trace was selected as the primary multivariate test statistic, as it is considered the most robust to heterogeneity when sample sizes are large (Todorov et al., 2020).

Univariate ANCOVA was conducted separately for each dependent variable, incorporating syllable length, sentence length, modifier count, and constituent count as covariates. Before conducting ANCOVA, Levene's Test of Equality of Error Variances was performed to assess homogeneity of variance across groups. All dependent variables violated this assumption (p < .001 for each). However, parametric tests remain valid even when normality and homogeneity assumptions are violated, particularly when sample sizes are large (Azwar, 2015). Given that this study involved a large dataset (N = 1,496 observations) and balanced group sizes, ANCOVA was deemed appropriate despite assumption violations. To enhance the robustness of ANCOVA estimates, bootstrapping with 200 resamples was employed, allowing statistical inference without relying on normality assumptions (Hesterberg, 2011).

RESULTS

The analysis included data from 44 bilingual Indonesian-English elementary students, divided equally into two groups: 22 SLI students and 22 typically developing (Non-SLI) students. Each participant completed reading comprehension tasks in both Indonesian and English, resulting

in a total of 1,496 reading comprehension trials (748 per group). Table 1 provides the descriptive statistics for the key dependent variables (Accuracy, Reading Speed, Response Speed, and Fixation Duration) for each group and language.

TABLE 1. Descriptive Statistics for Dependent Variables

Variable	Group	Language	M	SD
Accuracy	SLI	Indonesian	0.6619	0.2950
	SLI	English	0.6403	0.3088
	Non-SLI	Indonesian	0.8392	0.2231
	Non-SLI	English	0.8120	0.2417
Reading Speed	SLI	Indonesian	12.43	14.23
	SLI	English	12.65	16.01
	Non-SLI	Indonesian	7.95	5.49
	Non-SLI	English	8.65	6.38
Response Speed (ms)	SLI	Indonesian	6159.99	5818.02
	SLI	English	8505.57	9372.15
	Non-SLI	Indonesian	4269.00	2764.42
	Non-SLI	English	5449.59	3298.89
Fixation Duration (ms)	SLI	Indonesian	468.84	190.37
	SLI	English	518.03	256.46
	Non-SLI	Indonesian	404.29	124.33
	Non-SLI	English	380.62	121.38

The descriptive statistics demonstrate a consistent reading comprehension disadvantage for the SLI group in both languages, with a pronounced accuracy difference between SLI group and their Non-SLI peers across both languages. The average accuracy in Indonesian was M = 0.6619 (SD = 0.29497) for SLI students and M = 0.8392 (SD = 0.22311) for non-SLI students. While non-SLI students obtained M = 0.8120 (SD = 0.24169), SLI students' average accuracy in English was marginally lower at M = 0.6403 (SD = 0.30879). Across both languages, the overall accuracy of SLI students was M = 0.6511 (SD = 0.30195), while that of non-SLI students was M = 0.8256 (SD = 0.23283).

According to the reading speed data, SLI students needed a lot more time to read sentences than their peers who were not SLI. While non-SLI students averaged M = 7.95 seconds (SD = 5.49) per sentence in Indonesian, SLI students averaged M = 12.43 seconds (SD = 14.23). SLI students performed better than non-SLI students in English, averaging M = 12.65 seconds (SD = 16.01) versus M = 8.65 seconds (SD = 6.38). The average reading time for SLI students was M = 12.54 seconds (SD = 15.14) in both languages, whereas the average for non-SLI students was M = 8.30 seconds (SD = 5.96).

SLI students took significantly longer to remember and respond to comprehension tasks. The average reaction time for SLI students in Indonesian was M = 6159.99 ms (SD = 5818.02), while the average time for non-SLI students was M = 4269.00 ms (SD = 2764.42). The difference increased in English, where SLI students took M = 8505.57 ms (SD = 9372.15) and non-SLI students took M = 5449.59 ms (SD = 3298.89). In all languages, SLI students took an average of M = 7332.78 ms (SD = 7882.84), whereas non-SLI students took an average of M = 4859.29 ms (SD = 3098.20).

Fixation data, which gauges how long a pupil looks at a sentence, also reveals processing difficulties for SLI kids. The average fixation time for SLI students in Indonesian was M = 468.84 ms (SD = 190.37), while the average fixation time for non-SLI students was M = 404.29 ms (SD = 124.33). The average fixation time for SLI students in English was 518.03 ms (SD = 256.46), whereas the average for non-SLI students was 380.62 ms (SD = 121.38). SLI students fixated for M = 493.44 ms (SD = 227.03), which was substantially longer than the Non-SLI group's M = 392.46 ms (SD = 123.35), when comparing all languages.

TABLE 2. Multivariate Effects

Effect	Pillai's Trace	F	df (hyp)	df (error)	p	ηp²
Group	.184	83.454	4	1485	<.001	.184
Language	.019	7.070	4	1485	<.001	.019
Group x Language	.014	5.209	4	1485	<.001	.014

A Box's M test was used to assess the assumption of homogeneity of covariance matrices across groups prior to doing the Multivariate Analysis of Covariance (MANCOVA). With a p-value of less than.001 and a Box's M value of 1632.595, the test revealed a severe breach of the homogeneity assumption. Because of its resilience to breaches of this presumption, the Pillai's Trace statistic was chosen as the main multivariate test.

Accuracy, Reading Speed, Response Speed, and Fixation Duration were the four dependent variables that were subjected to the combined effects of Group (SLI vs. Non-SLI), Language (Indonesian vs. English), and their interaction in the MANCOVA study. To account for differences in syntactic complexity, factors such as syllable length, sentence length, number of modifier, and number of propositions were also included.

With Pillai's Trace = 0.184, $F(4, 1485) = 83.454$, p <.001, and partial $\eta^2 = 0.184$, the analysis demonstrated a significant main impact of Group. This finding confirms that SLI students consistently performed worse than typically developing students in accuracy, reading speed, response speed, and fixation duration. Group (SLI vs. Non-SLI) explained roughly 18.4% of the variance in the combined dependent variables.

With Pillai's Trace = 0.019, $F(4,1485) = 7.070$, p <.001, and partial $\eta^2 = 0.019$, the main effect of language was likewise significant. This suggests that there are minor variations in reading proficiency between the two languages, with language type (English vs. Indonesian) accounting for a tiny but statistically significant 1.9% of the variance across the combined dependent variables.

Furthermore, there was a significant interaction effect between Language and Group, as seen by partial $\eta^2 = 0.014$, $F(4, 1485) = 5.209$, p <.001, and Pillai's Trace = 0.014. Despite being statistically significant, this interaction only accounted for 1.4% of the variance, suggesting that language type had a negligible effect on the performance difference between SLI and non-SLI pupils.

Additionally, the analysis assessed how syntactic complexity variables affected reading performance. There was a significant effect of sentence length (Pillai's Trace = 0.006, $F(4, 1485) = 2.420$, p =.047, partial $\eta^2 = 0.006$), suggesting that participants had more difficulty understanding longer sentences. The combined dependent variables also showed minor but significant effects from modifier count (Pillai's Trace = 0.011, $F(4, 1485) = 4.036$, p =.003, partial $\eta^2 = 0.011$) and number of proposition (Pillai's Trace = 0.007, $F(4, 1485) = 2.796$, p

=.025, partial η^2 = 0.007), confirming that poorer reading performance was generally a result of increased syntactic complexity. However, the combined dependent variables were not substantially affected by syllable length (Pillai's Trace = 0.003, F(4, 1485) = 1.258, p =.285, partial η^2 = 0.003), suggesting that the number of syllables in a sentence was not a crucial component of students' performance.

RESULTS OF BETWEEN-SUBJECTS EFFECTS

Levene's Test of Equality of Error Variances was used to determine whether the error variances of the dependent variables were equal across groups before performing the Univariate Analysis of Covariance (ANCOVA) for each dependent variable. The findings showed that for every dependent variable, the homogeneity of variance assumption was broken: F(3,1492) = 30.33, p <.001 for accuracy; F(3,1492) = 37.51, p <.001 for reading speed; F(3,1492) = 41.53, p <.001 for response speed; and F(3,1492) = 43.37, p <.001 for fixation duration. The ANCOVA's F-test is thought to be resilient to violations of homogeneity when the sample size is large enough (Azwar, 2015), therefore even if the violation of homogeneity could raise worries, this risk is reduced in this study because of its large sample size (N = 1496).

TABLE 3. Results of Between-Subjects Effects Analysis for Accuracy, Reading Speed, Response Speed, and Fixation Duration

Dependent Variable	Effect	F	df	p	ηp^2
Accuracy	Group	158.27	1	<.001	.096
	Language	1.163	1	.281	.001
	Group x Language	0.041	1	.840	.000
Reading Speed	Group	51.24	1	<.001	.033
	Language	0.000	1	.985	.000
	Group x Language	0.158	1	.691	.000
Response Speed	Group	65.38	1	<.001	.042
	Language	24.77	1	<.001	.016
	Group x Language	3.63	1	.057	.002
Fixation Duration	Group	115.22	1	<.001	.072
	Language	1.77	1	.183	.001
	Group x Language	14.998	1	<.001	.010

The ANCOVA results revealed several significant effects of group status, language type, and syntactic complexity variables on reading comprehension performance across four key dependent measures: accuracy, reading speed, response speed, and fixation duration. For accuracy, the model significantly explained 10.8% of the variance, F(7, N) = 25.635, p < .001. The intercept and unmeasured variables accounted for an additional 27.8% of the variance (F = 572.193, p < .001), indicating a strong baseline effect. Among the covariates, sentence length (F = 5.132, p = .024), modifier count (F = 6.996, p = .008), and constituent count (F = 9.268, p = .002) were significant predictors. Group status (SLI vs. TD) had a substantial effect, explaining 9.6% of the variance (F = 158.266, p < .001). For reading speed, the overall model was significant (F = 9.539, p < .001), explaining 4.3% of the variance. Unmeasured factors contributed 1.4% (F = 21.033, p < .001), while group status remained a significant factor (F = 51.241, p < .001), accounting for 3.3% of the variation. In terms of response speed, the model explained 6.8% of the variance (F = 15.513, p < .001), with the intercept accounting for 5.2%

(F = 81.757, p < .001). Modifier count (F = 4.533, p = .033), group status (F = 65.382, p < .001), and language type (F = 24.766, p < .001) were all significant predictors. For fixation duration, the model explained 8.3% of the variance (F = 19.139, p < .001), with a substantial effect from unmeasured factors (F = 483.472, p < .001). Group status again showed a strong influence (F = 115.224, p < .001), and a significant interaction between group and language was observed (F = 14.998, p < .001).

TABLE 4. Predicted Means from ANCOVA Equation for Accuracy, Reading Speed, Response Speed, and Fixation Duration (Adjusted Means and 95% Confidence Intervals)

Variable	Group	Language	Adjusted Mean	95% CI
Accuracy	SLI	Indonesian	0.662	(0.63, 0.69)
	SLI	English	0.641	(0.61, 0.67)
	Non-SLI	Indonesian	0.839	(0.81, 0.87)
	Non-SLI	English	0.812	(0.78, 0.84)
Reading Speed (seconds)	SLI	Indonesian	12.67	(11.30, 14.04)
	SLI	English	12.41	(11.05, 13.78)
	Non-SLI	Indonesian	8.19	(6.82, 9.56)
	Non-SLI	English	8.41	(7.04, 9.77)
Response Speed (ms)	SLI	Indonesian	5829.27	(5123.33, 6535.21)
	SLI	English	8836.29	(8130.35, 9542.24)
	Non-SLI	Indonesian	3938.28	(3232.33, 4644.22)
	Non-SLI	English	5780.31	(5074.36, 6486.25)
Fixation Duration (ms)	SLI	Indonesian	465.25	(443.54, 486.96)
	SLI	English	521.62	(499.92, 543.33)
	Non-SLI	Indonesian	400.70	(378.99, 422.41)
	Non-SLI	English	384.21	(362.50, 405.92)

Table 4 presents the adjusted means for all dependent variables across groups and languages after controlling for syntactic complexity covariates. When computing projected performance, the covariates were set at their mean values (syllable length = 10.18, sentence length = 5.71, modifier count = 0.94, and constituent count = 4.18).

Following ANCOVA's first coefficient estimate, residuals were subjected to Kolmogorov-Smirnov test with Lilliefors adjustment to find that residuals were not normally distributed (p <.001 for all dependent variables). Bootstrapping with 200 resamples was used to solve this violation and generate bias-corrected confidence ranges for every parameter estimate.

Using syllable length, sentence length, moderator count, and constituent count statistically controlled at their average values (syllable length = 10.18, sentence length = 5.71, moderator count = 0.94, constituent count = 4.18), the projected grand means for each dependent variable were computed using the ANCOVA equation. After adjusting for phrase difficulty, participants showed an average accuracy rate of almost 74% according to the modified predicted accuracy of 0.738 (SE = 0.007). With an average time that students needed to silently read each sentence at 10.419 seconds per sentence (SE = 0.297), predicted reading speed was 10,419 seconds. The expected average of response speed was 6096.04 milliseconds

(SE = 152.95). Meanwhile, the expected average fixation duration came out to be 442.95 milliseconds (SE = 4.70). These grand means offer a baseline knowledge of the adjusted reading performance across both languages and groups when sentence complexity is held constant.
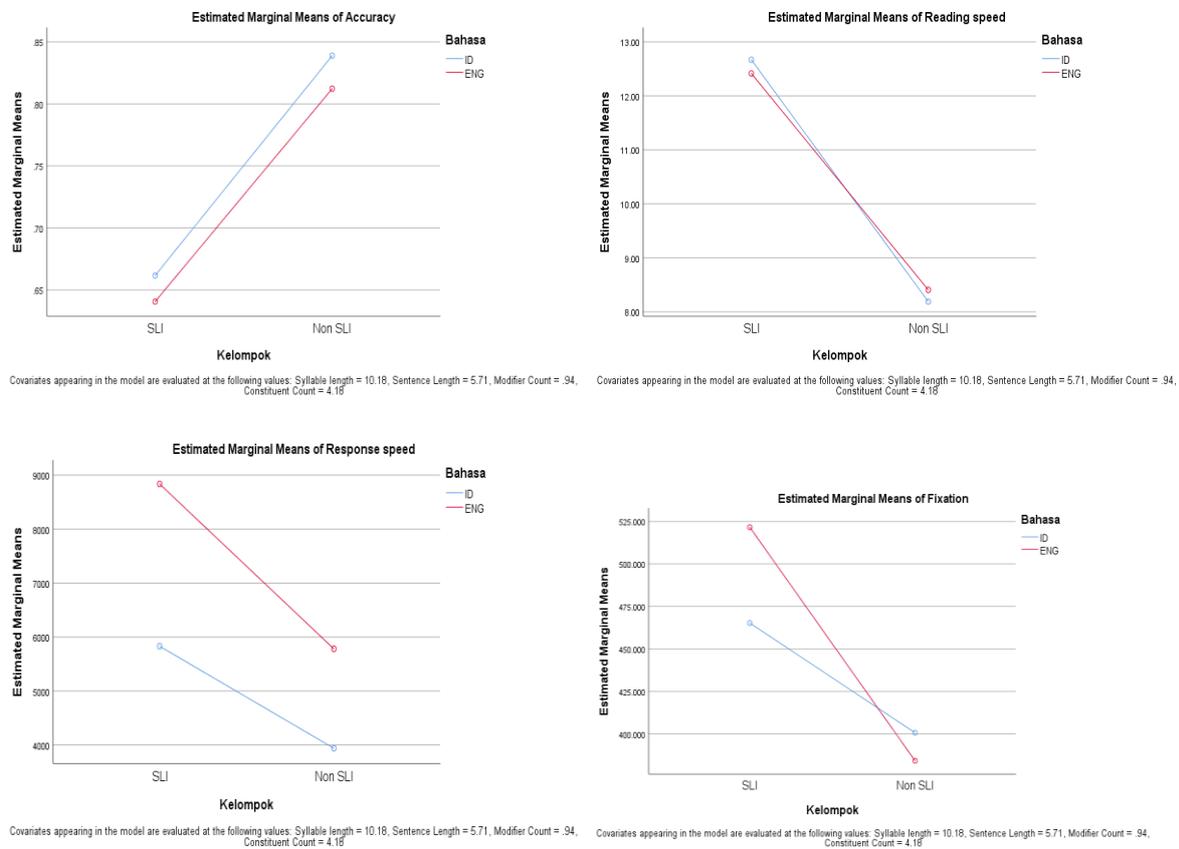

Figure 1. Estimated measures of Accuracy, Reading Speed, Response Speed, and Fixation of SLI and NON-SLI participants.

When examining the predicted means for each group, the analysis showed that bilingual SLI students consistently performed worse across all dependent variables when compared to NON SLI group. After controlling for sentence complexity, the predicted average accuracy for the SLI group was 0.651 (SE = 0.010), whereas the predicted accuracy for the Non-SLI group was significantly higher at 0.826 (SE = 0.010). A similar pattern emerged for reading speed, where the SLI group required an average of 12.542 seconds per sentence (SE = 0.419), compared to 8.297 seconds per sentence (SE = 0.419) for the Non-SLI group. Predicted response speed, which measures the time required to recall and answer comprehension questions, was also slower for the SLI group at 7332.78 milliseconds (SE = 216.31) compared to 4859.29 milliseconds (SE = 216.31) for the Non-SLI group. Finally, the predicted fixation duration for SLI students was 493.44 milliseconds (SE = 6.65), which was notably longer than the 392.46 milliseconds (SE = 6.65) observed for Non-SLI students. These findings emphasize that SLI status consistently impaired reading comprehension processes across all performance indicators.

When analyzed by language, the predicted means showed relatively minor differences between Indonesian and English overall. After controlling for sentence complexity, the predicted accuracy in Indonesian was 0.750 (SE = 0.013), which was slightly higher than the

predicted accuracy in English at 0.726 (SE = 0.013). Predicted reading speed was nearly identical in both languages, with students requiring 10.428 seconds per sentence (SE = 0.558) in Indonesian and 10.410 seconds per sentence (SE = 0.558) in English. However, for response speed, students responded more quickly in Indonesian (M = 4883.77 milliseconds, SE = 287.63) compared to English (M = 7308.30 milliseconds, SE = 287.63), indicating that the recall process was slightly slower when answering comprehension questions in English. In terms of fixation duration, students also showed slightly shorter fixations in Indonesian (M = 432.97 milliseconds, SE = 8.85) compared to English (M = 452.92 milliseconds, SE = 8.85). These results indicate that language differences had a smaller impact on performance than SLI status, but there was a tendency for slightly better performance in Indonesian, especially in terms of recall speed and fixation duration.

A more detailed analysis examining predicted performance for each group within each language confirmed that SLI students consistently performed worse in both languages compared to NON SLI group. For accuracy, SLI students scored 0.662 (SE = 0.016) in Indonesian and 0.641 (SE = 0.016) in English, while Non-SLI students achieved 0.839 (SE = 0.016) in Indonesian and 0.812 (SE = 0.016) in English. A similar trend emerged for reading speed, with SLI students requiring 12.669 seconds per sentence (SE = 0.698) in Indonesian and 12.415 seconds per sentence (SE = 0.698) in English, compared to Non-SLI students who required 8.188 seconds (SE = 0.698) in Indonesian and 8.406 seconds (SE = 0.698) in English.

For response speed, SLI students needed 5829.27 milliseconds (SE = 359.89) to recall answers in Indonesian, but required 8836.29 milliseconds (SE = 359.89) in English, indicating that recall was slower in English for this group. Non-SLI students required 3938.28 milliseconds (SE = 359.89) in Indonesian and 5780.31 milliseconds (SE = 359.89) in English, following a similar language pattern, but with faster response times overall.

In terms of fixation duration, SLI students fixated for an average of 465.25 milliseconds (SE = 11.07) in Indonesian and 521.62 milliseconds (SE = 11.07) in English, reflecting longer fixations when processing English sentences. In contrast, Non-SLI students fixated for 400.70 milliseconds (SE = 11.07) in Indonesian and 384.21 milliseconds (SE = 11.07) in English, demonstrating more efficient visual processing across both languages.

DISCUSSION

The influence of syntactic complexity on reading comprehension performance among bilingual Indonesian-English elementary students with and without SLI was explored in this work. Affecting reading accuracy, speed, memory, and fixation time across both languages, results from MANOVA and ANCOVA analyses revealed that SLI status was the biggest predictor of lowered reading comprehension ability. Measuring constituent count, modifier count, and sentence length, syntactic complexity—especially for SLI students—also had a major impact on performance, therefore verifying that higher content density raises cognitive load. Language had no effect; this suggests that broad cognitive-linguistic processing deficiencies rather than language-specific causes caused reading comprehension problems.

The Linguistic Interdependence Hypothesis suggests that reading skills acquired in one language can support literacy development in another, highlighting the interconnected nature of bilingual literacy development (Brunfaut et al., 2021). The results of this study suggest that the tendency is similar in both groups. This indicates that the reading comprehension processes

of students both with and without SLI operate similarly across languages regardless of the transparency of the language, if the participants are fluent in both languages.

Despite the manipulation of sentence-level syntactic complexity—such as sentence length, syllable length, number of modifiers, and number of propositions—no significant effects were found on reading speed or recall speed in either group. However, SLI students consistently read more slowly than their typically developing peers. This suggests that the slower reading speed observed in the SLI group is not attributable to syntactic factors, but rather to underlying cognitive processing limitations—specifically, deficits in working memory (Johann et al., 2020).

Although previous research has shown that opaque orthographies such as English and French increase cognitive processing demands—particularly with longer words—leading to slower reading speeds (Müller et al., 2020), our findings do not align with this pattern. In the current study, no significant difference in sentence-level reading speed was observed between Indonesian and English in either the SLI or the Non-SLI group. This lack of difference may be attributed to the participants' balanced fluency and vocabulary knowledge in both languages, which likely mitigated orthographic complexity effects typically observed in less proficient bilinguals. Interestingly, while reading speed remained stable across languages, SLI students exhibited significantly longer fixation durations when reading English compared to Indonesian, a pattern not observed in NON SLI group. This suggests that the additional cognitive load imposed by English's opaque orthography did not affect overall timing but did manifest in localized processing difficulties—reflected in more prolonged fixations—specifically among SLI students. These findings highlight that, for bilingual children with SLI, orthographic complexity may disrupt lower-level visual-linguistic integration without necessarily slowing overall reading speed, pointing to subtle inefficiencies that are not captured by timing measures alone.

Comprehension involves the construction of propositional meaning and the integration of these propositions into a coherent mental representation (Kintsch & Kintsch, 2005). SLI group appear to find the integration phase, where efficient use of working memory is needed (Grela et al., 2023), more taxing in English. This is reflected in their accuracy score, which was lower in English, albeit not significantly so. This discrepancy between effort (as seen in fixation) and outcome (as reflected in accuracy), despite similar sentence-level reading times, indicates inefficiencies in sentence integration and resource allocation during reading typical to poor comprehenders (Kuperman & Van Dyke, 2011). It appears that SLI students may compensate for processing difficulty by maintaining overall reading pace while over-focusing on certain segments, ultimately leading to reduced comprehension accuracy. In contrast to the SLI group, Non-SLI students showed no significant differences between Indonesian and English in fixation duration, reading speed, or accuracy. This consistency suggests balanced processing strategies across both orthographies. Their equal fluency in both languages likely supports efficient and flexible reading, regardless of orthographic transparency (Weaver & Kieffer, 2022). This emphasizes that working memory limitations are central to reading difficulties in both monolingual and bilingual SLI students.

The consistently lower accuracy in the SLI group, especially as sentence length, number of modifiers, and number of constituents increase, suggests that their comprehension difficulties stem not from fluency or vocabulary deficits as both groups are fluent in both languages. When readers are fluent in both languages and familiar with the vocabularies used in the text, phonological processing is not the limiting factor (Mekheimer, 2024). Instead,

syntactic load—the number of constituents (propositions) and modifiers taxed the participants' working memory and integration capacity (Smail et al., 2024). Though this pattern is shown in both group, the SLI group is affected more severely. It appears that SLI students can process only a subset of propositions during a single read-through (Perfetti & and Stafura, 2014), and modifiers—being peripheral elements—are the most likely to be omitted (Kim & Wagner, 2015). This can happen as SLI students have a lower ceiling for how much information they can hold and integrate, particularly under time constraints (Taboada Barber et al., 2022) while Non-SLI students can manage more propositions and maintain accuracy better under increased load (Stanford & Delage, 2020). This explains why accuracy decreases as the number of modifiers increases. These effects appear across both languages, thus confirmed limitation in working memory strongly associated with reduced accuracy on syntactically dense texts in bilinguals with reading difficulties (Brunfaut et al., 2021; Kieffer et al., 2021).

The present study found that language type and the number of modifiers significantly influenced recall speed, defined as the time taken by students to answer comprehension questions, regardless of accuracy. These findings are consistent across groups and languages, indicating a robust effect of syntactic and linguistic complexity on processing demands during comprehension. Specifically, SLI students demonstrated slower recall speeds in both languages, with a notably longer response time in English than in Indonesian. On average, SLI students required over three seconds more to respond to comprehension questions in English, a difference that was statistically significant. This suggests that despite balanced bilingual fluency, English's greater orthographic opacity and syntactic demands may impose additional cognitive load on SLI students, who are already known to have limitations in working memory capacity. Similarly, typically developing (Non-SLI) students also showed a significant delay in recall speed when processing English texts compared to Indonesian, although the time difference was smaller than in the SLI group. This consistent pattern across both groups reinforces the notion that language transparency and syntactic structure influence the ease with which bilingual children retrieve and organize information to answer comprehension questions. This suggest that even in balanced bilinguals, information retrieval may differ depending on the linguistic structure, and SLI students are more vulnerable to such variation due to impaired processing efficiency (Espi-Sanchis & Cockcroft, 2022; Monnier et al., 2022).

Importantly, the study revealed a significant negative correlation between recall speed and comprehension accuracy. In both SLI and Non-SLI groups, students who took longer to respond tended to answer less accurately, regardless of the language. This relationship supports the interpretation that recall speed is not merely a reflection of deeper cognitive engagement, but rather a marker of working memory limitations or processing difficulty (Brunfaut et al., 2021; Weaver & Kieffer, 2022). The consistent pattern across Indonesian and English suggests that longer recall times signal greater cognitive effort or retrieval difficulty, which compromises comprehension performance.

Theoretically, this study supports a content-driven perspective of syntactic complexity, whereby reading comprehension problems are linked to the requirement to hold and process several content units simultaneously in working memory, rather than to morphosyntactic parsing difficulties. These findings align with Srisang and Everatt (2021), who demonstrated that reading comprehension is predicted not merely by vocabulary exposure but by structural processing (e.g., grammar) and higher-order inference skills, depending on learners' proficiency levels. Practically, these results highlight the need of focused reading therapies meant especially for bilingual SLI students, stressing on content structure and working memory

assistance instead of general language exposure. Chunking techniques, visual scaffolds, pre-reading materials previews could help to lower working memory demands during reading in school environments. Teachers should also educate pupils how to mentally segment and digest material sequentially and how to divide big phrases into simpler meaning components. Crucially, these interventions should be conducted in both languages, underlining that, rather than only in one dominant language, comprehension tactics should address content processing skills across languages.

CONCLUSION

This study explored how bilingual Indonesian-English elementary students, with and without SLI, comprehend sentences with varying syntactic complexity. Findings revealed that SLI status was the most consistent predictor of poor performance across all reading measures—accuracy, speed, recall, and fixation—regardless of language. Sentence length had the strongest negative effect, followed by the number of elements and modifiers, indicating that higher content density particularly hindered SLI students' processing. In contrast, syllable length showed no significant impact, suggesting phonological demands were not the primary challenge. While English was read slightly more slowly, both groups performed similarly across languages, implying that comprehension deficits stem from general cognitive-linguistic difficulties rather than from second-language factors. This challenges the assumption that bilingual SLI readers would be disproportionately impaired in their non-dominant language. The study focused on single-clause sentences and used only forward eye-tracking, excluding regressions and function word analysis, which limits the scope of processing insights. The participants' balanced bilingualism also restricts applicability to more diverse bilingual populations. Future research should examine regressive eye movements and multi-clause sentence processing to better understand how SLI readers repair comprehension. It should also compare simultaneous and sequential bilinguals and include function words and morphosyntactic complexity to clarify whether grammatical strain contributes to comprehension breakdowns. Finally, investigating the effectiveness of interventions such as content chunking and working memory strategies may offer targeted support to enhance comprehension for bilingual children with SLI.

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