Executive Functions and Second Language Literacy in Saudi Secondary Students: Examining the Reciprocal Relationship

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Aala Karim Maayah
Universiti Sains Malaysia, Malaysia

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Abstract: This study examines the possible reciprocal relationship between executive functions (EFs)—inhibitory control, working memory, and semantic and phonemic fluency—and English literacy proficiency among Arabic–English bilingual secondary students in Saudi Arabia. Using a quantitative design, data were collected from 212 male students in one international school. Cognitive abilities were assessed through the Stroop test, lexical fluency tasks, and backward digit recall, while English proficiency in reading and writing was measured using TOEFL scores. Descriptive statistics and Pearson chi-square tests indicated significant associations ($p < .05$), indicating that higher performance in inhibitory control, semantic and phonological processing, and working memory capacity is associated with stronger literacy skills. These findings align with theoretical accounts emphasizing the role of executive control in language and literacy development. The results also suggest that enhancing EF components may support improved L2 literacy outcomes. The study contributes to bilingualism and cognitive-development research by providing evidence from an underrepresented context and offering pedagogical implications for English instruction in multilingual educational settings.

Keywords: bilingualism, cognitive training, executive functions, language proficiency, Saudi Arabia

1. Introduction

Language proficiency is a complex construct resulting from continuous interaction between language-specific and general cognitive processes. A large body of research reports strong relationships between executive function (EF) components and language skills, particularly in reading and writing. In bilingual adolescents, inhibitory control, verbal working memory, and lexical fluency strongly predict L2 reading comprehension and writing performance (Kieffer, Vukovic and Berry 2021; Weaver and Kieffer 2022). In this realm, inhibitory control plays a role in comprehension and expression by allowing one to ignore irrelevant context (Diamond 2013). At the same time, verbal working memory supports complex sentence processing, vocabulary growth, and text-level integration, which are key for academic literacy (Alloway, Gathercole and Pickering 2006; Cain and Oakhill 2006). Lexical fluency, in terms of semantic and phonemic retrieval, improves language production and writing quality. It also supports the use of adaptive reading strategies and the revision process during writing.

However, recent scholarship underscores a bidirectional relationship between executive functions (EFs) and bilingual language proficiency, indicating that EFs not only play a role in successful L2 learning but are also improved by it. From longitudinal and neurocognitive research, the regular use of L2 is a continuous process of improvement in inhibitory control, as learners must repeatedly suppress intrusions from their dominant language, creating repeated opportunities to exercise and refine domain-general inhibition (Bialystok and Poarch 2018). In the meantime, verbal working memory improves as bilinguals monitor linguistic input, which they must sort out, juggle competing representations, and update selections in real time during comprehension and production (Shokrkon and Nicoladis 2021). Neuroimaging findings show that frequent switching between languages improves the efficiency of the anterior cingulate and the prefrontal cortex—areas that play a role in conflict resolution and working memory—showing that these changes are experience-based rather than fixed cognitive traits.

Collectively, bilingual language use is a form of cognitive training that demands coordinating two language systems and progressively strengthens core EF components, thereby creating a dynamic cycle in which EFs support L2 development and L2 engagement, in turn, enhancing EFs. These studies present a picture of a reciprocal development cycle: improved EF skills also enhance L2 processing, and as L2 proficiency increases, cognitive demands increase, thereby refining EF performance. This point of view is also consistent with theories such as Cummins' Threshold and Interdependence Hypotheses, which report a bidirectional relationship between bilingual proficiency and cognitive development.

1.2 Statement of the problem

Although there is substantial evidence on executive functions (EFs) in relation to language and literacy development, research on secondary school students, particularly in the Saudi context, remains limited. Most of the current research was conducted in Western educational settings (Bialystok 2011; Kapa and Colombo 2013; Kieffer 2021), leaving a very narrow picture of how EF literacy (reading and writing) impacts cognitive abilities among Arabic–English bilingual teens in Saudi secondary schools. Moreover, while international research has explored the reciprocal nature of the EF–language relationship, it remains unclear whether prolonged engagement in English as a second language contributes to measurable gains in specific EF components such as inhibitory control, working memory, or lexical retrieval, or whether enhanced EFs subsequently support stronger literacy outcomes (Grundy, Anderson and Bialystok 2017).

This study examines the bidirectional relationship between executive function components (inhibitory control, working memory, semantic fluency, and phonemic fluency) and English literacy skills among secondary Arabic–English bilingual students in Saudi Arabia. In this context, the study aims to determine how executive function skills predict English literacy proficiency in second-language reading and writing. The study investigates whether EF skills predict reading and writing proficiency, and whether higher English literacy proficiency is associated

with stronger EF performance, thereby testing the possibility of a reciprocal developmental pattern supported in recent bilingual cognitive research. Therefore, the study strives to answer the following questions:

1. To what extent do executive-function components (inhibitory control, working memory, semantic fluency, and phonemic fluency) predict English literacy proficiency (reading and writing) among Arabic–English bilingual adolescents?
2. To what extent does English literacy proficiency (reading and writing) predict performance on executive-function tasks among Arabic–English bilingual adolescents?
3. Is there empirical evidence of a reciprocal relationship between executive-function performance and English literacy proficiency in this population?

1.3 Significance of the study

This study is significant in the field of education in Saudi Arabia and in other multilingual settings, as it aims to bridge a gap in cognitive linguistic research on the relationship between executive functions and English literacy in Arabic–English bilingual teens. Due to a methodological gap, the previous literature has mainly examined young children or university students from the West (Bialystok 2011; Kapa and Colombo 2013), thereby leaving out the unique sociocultural, linguistic, and curricular environments of Arabic-English bilinguals in the Middle East (Alrabai 2016). Also, given that English is important for academic success and a key component of educational reform in Saudi Arabia, it is crucial to understand how executive functions relate to language proficiency (Al-Seghayer 2014).

Since, many empirical studies have shown that EF components, particularly working memory and inhibitory control, directly influence reading comprehension, vocabulary growth, and written expression (Cain and Oakhill 2006; Swanson and O'Connor 2009) can potentially enhance literacy skills including reading and writing, insights from the present study could guide the development of targeted interventions, such as EF-enhanced reading programs, working memory supports within writing instruction, and vocabulary teaching methods that foster cognitive flexibility. These applications align with contemporary models of literacy that emphasize cognitive control and integrative text processing (Kendeou and van den Broek 2009; Perfetti and Stafura 2014).

Moreover, this study makes important theoretical contributions by examining the potentially reciprocal relationship between cognitive control and language proficiency in adolescent bilinguals. Recent scholarship suggests that bilingual experience may not only rely on EF but also actively shape it, resulting in a dynamic feedback loop between cognitive control and language development (Grundy et al. 2017). Findings from this research can extend influential frameworks such as the Adaptive Control Hypothesis and Cummins' Interdependence and Threshold Hypotheses (Cummins 1979, 2000) by providing empirical data from a non-Western, understudied population.

Since language learning and cognitive development are deeply interconnected, the implications of this study extend well beyond the Saudi context, offering valuable insights for multilingual education curricula across the Gulf, North Africa, and South Asia (Abu-Rabia and Sanitsky 2010). By highlighting the importance of executive functions and literacy development in adolescent bilinguals, this research supports the creation of more effective, inclusive, and contextually relevant educational practices.

2. Review of related literature

Research across cognitive science and psycholinguistics indicates that executive functions (EF)—particularly working memory and inhibitory control—are crucial to vocabulary development, sentence comprehension, and language proficiency (Baddeley 2012; Diamond 2013). Extensive evidence indicates that EF supports the management of linguistic information, the suppression of competing representations, and the coordination of cognitive processes required for effective language use (Miyake et al. 2000; Novick, Trueswell and Thompson-Schill 2005). Studies involving monolingual and bilingual learners alike demonstrate that stronger EF abilities are associated with enhanced lexical access, syntactic processing, and literacy outcomes (Bialystok 2011; Gathercole and Alloway 2008).

This literature review establishes the theoretical and empirical foundations for the relationship between executive functions (EFs) and second-language (L2) literacy development among bilingual learners. It begins by outlining the core components of EFs—working memory, inhibitory control, and cognitive flexibility—and summarizing evidence linking these domains to reading and writing outcomes. The section then reviews bilingual cognitive theories, including cross-linguistic transfer and the interdependence between L1 and L2 proficiency, in order to situate the study within research on Arabic–English bilingualism. Finally, the review highlights gaps in previous scholarship, particularly the limited evidence from adolescent populations in the Gulf context, thereby motivating the current study.

2.1 Executive function and language

Language and executive functioning (EF) are intricate, multidimensional skill sets that develop rapidly during the first five years of a child's life (Gleason and Ratner 2009). A considerable body of recent research has established a significant correlation between the development of EF and language skills in early childhood (Gooch et al. 2016). The mechanisms underlying executive functions promote productive skills because both speakers and listeners must be effectively aware of their thoughts and behaviors in alignment with their objectives.

For example, speakers draw on executive functioning to select appropriate vocabulary from among multiple options to articulate the concepts they intend to convey (Badre et al. 2005). In receptive skills, EF is crucial for coordinating multiple linguistic processes, enabling individuals to comprehend ideas conveyed by others accurately (Novick, Trueswell and Thompson-Schill 2005). Additionally,

bilingual individuals are likely to employ EF to select relevant languages for particular interlocutors and facilitate transitions between languages (Ye and Zhou 2009).

Listeners, for instance, must engage in word decoding, understand syntax, retain vocabulary in memory, consider contextual elements, and often possess an advanced receptive vocabulary to process instructions effectively—underscoring the importance of EF in language processing. The significance of EF in language skills development has motivated scholars to investigate the positive correlation between EF and various language skills, including vocabulary knowledge, literacy development, sentence reading proficiency, reading comprehension, vocabulary acquisition, and syntactic understanding (Butterfuss and Kendeou 2018; Dempster and Cooney 1982; Gathercole and Pickering 2000).

Recent studies further support this link. For instance, Weaver and Kieffer (2022) highlighted the role of executive functions in reading comprehension and fluency among Spanish–English bilingual adolescents, while Kovyazina et al. (2021) demonstrated that stronger executive functions are associated with richer vocabulary and verbal fluency in mono- and bilingual children. Moreover, they showed that executive-function components, particularly working memory and inhibition, significantly predict reading comprehension in bilingual children.

Additionally, Baddeley et al. (1998) emphasized that verbal working memory, particularly phonological working memory, is critical for advancing language comprehension. Phonological working memory is essential for the short-term retention of verbal information while simultaneously engaging in other cognitive tasks, such as understanding spoken messages or decoding written words.

2.2 The impact of inhibitory and working memory on language skills

Like the current study, many scholars emphasize the importance of working memory (WM) as an executive function. Diamond (2013) highlights that WM is fundamental to mastering spoken or written language because produced utterances are not physically presented, and listeners must relate them to what they hear. Therefore, the WM component of EF plays an essential role in acquiring and developing skills that help children focus on multiple streams of information, monitor errors, make decisions, and connect prior reading to current reading in written language.

Regarding listening skills, Mirman and Britt (2014) found that EF skills are intrinsically linked to language processing. They emphasized that specific dimensions of EF are crucial for semantic control, which involves accessing and dynamically manipulating meaningful information. They concluded that this capacity enables individuals to focus on relevant details of a concept while disregarding irrelevant ones. During listening, various lexical entries may be activated; thus, enhancing the activation of the correct entry while inhibiting alternative entries is imperative for accurate word identification. Effective language users must access lexical representations and appropriately balance activation and inhibition.

Haman and Fronczyk (2012) used the Picture Vocabulary Test–Comprehension to examine how WM predicts passive vocabulary development in 3-year-olds. Their longitudinal studies included an evaluation of children's joint attention—the ability to coordinate attention with a social partner—at 18 months. Previous research indicates that abilities developed through joint attention, such as symbolic and representational skills, are significant predictors of later EF development (Miller and Marcovitch 2015; Van Hecke et al. 2012). Furthermore, WM and vocabulary were assessed at 24 months. Their data showed that WM predicted language development, contingent upon earlier competencies in joint attention (Białecka-Pikul, Borkowska and Tomaszewski 2016). These findings reinforce the crucial role of WM in early language development.

Beyond memory skills, scholars have demonstrated that inhibitory control is also a significant contributor to language development (Gandolfi and Viterbori 2020; Yuile and Sabbagh 2021). Hanno and Surrain (2019) suggest that individuals with better inhibitory control can more effectively navigate language's variable rules and implement appropriate vocabulary, syntactic structures, and conventions based on specific contexts.

McClelland et al. (2007) examined inhibitory control using the Head-to-Toes task, alongside vocabulary assessments from the Picture Vocabulary subtest of the Woodcock-Johnson Test, across both fall and spring of prekindergarten. Their results revealed that stronger inhibitory control correlates with better vocabulary and language development. Similarly, Ekerim and Selcuk (2018) conducted a longitudinal study with Turkish preschoolers, finding that inhibitory control skills predict vocabulary growth over one year.

Inhibitory control appears to enable goal-directed behavior by suppressing extraneous thoughts and actions, thereby facilitating learning. Mirman and Britt (2014) also argued that inhibitory control enhances access to stored words by suppressing phonologically similar but semantically distinct words, thus improving vocabulary and syntactic comprehension. Early development of these skills may lead to greater vocabulary knowledge over time.

Ibbotson and Kearvell-White (2015) demonstrated that inhibitory control, as assessed by the Stroop test, predicts grammatical abilities in 5-year-olds, suggesting that successful responses require inhibiting irrelevant stimuli. Mazuka et al. (2009) proposed that inhibitory control may help children persevere with sentence comprehension, particularly when they fixate on incorrect interpretations and struggle to revise them, thereby impeding understanding of the speaker's intent.

Šimleša, Cepanec and Ljubešić (2017) examined the relationships among WM, inhibitory control (assessed via tasks such as the Dimensional Change Card Sort, Digit Span, and CANTAB), and language comprehension (measured using the Reynell Developmental Language Scales) in preschoolers. Their findings indicated that both verbal WM and inhibitory control significantly influence language comprehension, which involves integrating semantic and morphosyntactic knowledge. Since comprehension is context-dependent, inhibitory control is crucial for focusing on new contexts while suppressing prior ones. They also emphasized WM's active role in understanding complex or lengthy utterances,

especially when sentences are incomplete or semantically and structurally complex.

In summary, substantial evidence suggests that executive functions (EF)—particularly working memory, inhibitory control, and cognitive flexibility—are fundamental to language development, starting in toddlerhood and persisting into adulthood. These components are instrumental in acquiring and refining grammar, vocabulary, language comprehension, semantic control, and efficient access to linguistic information (Butterfuss and Kendeou 2018).

3. Method

The methodology of the current study outlines the procedures used to examine the reciprocal relationship between English proficiency and cognitive task performance among secondary school boys in Saudi Arabia. The study employs quantitative methods, including well-established assessment tools and statistical analyses, to provide nuanced insights into the cognitive and linguistic development of Arabic-English bilingual learners.

3.1 The corpus

The study's corpus consists of 212 male students, aged between 14 and 17, enrolled in one international school in Saudi Arabia. Due to the strict gender segregation in Saudi Arabia's educational system, researchers recruit participants from both genders (Hamdan 2005; Alsubaie and Jones 2017); thus, the generalizability of the current study is limited to males. Moreover, participants were drawn from a single international school that follows an international curriculum and are of a high socioeconomic status. This differs from public schools, which have more diverse socioeconomic backgrounds and distinct instructional settings.

Despite these contextual constraints, strict inclusion criteria were implemented to ensure internal consistency within the corpus. All participants should have been enrolled in the international curriculum since early childhood; Arabic is their first language and English their second. This high degree of homogeneity among subjects in terms of academic background, language experience, and teaching methods used yields highly reliable statistics when examining the relationship between cognitive skills and level of bilingual proficiency.

3.2 Data collection

Data collection involved the implementation of several instruments and procedures to ensure reliability and validity. Thus, cognitive abilities included lexical retrieval, working memory, and inhibitory control, each measured using well-validated tools. Lexical retrieval was assessed using phonemic and semantic fluency tasks in which students generated words that either began with a target sound or belonged to a specified semantic category. These are presented as indicators of controlled lexical access and semantic network efficiency (Troyer et al. 1997; Henry and Crawford 2004). For working memory, participants completed the backward digit span task in which they recall sequences of digits in reverse order. This task is a well-established measure of verbal working memory

manipulation and executive updating (Alloway et al. 2006; Conway, Kane and Engle (2005). Inhibitory control was measured using the Stroop task, where the participants responded to incongruent color-word stimuli. Therefore, it is a valid indicator of their ability to suppress automatic responses and handle cognitive interference (Stroop 1935; MacLeod 1991).

Meanwhile, English reading and writing proficiency was evaluated based on students' TOEFL (Test of English as a Foreign Language) scores. To verify the instruments' reliability, a pilot test was conducted with 25 students prior to data collection. That pilot yielded a Cronbach's Alpha of about 0.8, which is very good and indicates high internal consistency and reliability.

3.3 Data analysis

In the present study, the collected data were analyzed using descriptive statistics to provide an overview of participants' cognitive and language skills. The primary inferential analysis used the Pearson Chi-Square Test of Independence to examine the reciprocal possible relationship between students' cognitive ability and their English language proficiency in reading and writing. Cross-tabulations and effect sizes were used to examine the degree and strength of this relationship. This in-depth analysis aims to determine whether higher cognitive ability is significantly associated with improved English reading and writing proficiency, and whether the data support a reciprocal relationship. All statistical procedures were carried out using SPSS Version 26.0 (Bryman 2016), which also facilitated data entry and the running of complex tests, thereby ensuring a very rigorous and replicable analysis.

4. Results and discussion

The results are presented in alignment with the revised research questions to provide a clear, logical, and structured presentation of findings. Each subsection corresponds directly to one research question, followed by relevant tables, figures, and interpretive commentary.

The results presented in the table and stacked bar charts show the role of cognitive skills in reading proficiency, confirming that reading development involves complex interactions across many cognitive domains. The notable association between inhibitory control and reading skill ($\chi^2 = 21.73$, $p < .001$) underscores the fundamental role of executive control processes (Miyake et al 2000; Diamond 2013). Thus, the inhibitory control skill allows the suppression of unnecessary information and maintains concentration during decoding and comprehension. Inhibitory control deficiency is associated with lower reading performance and attention difficulties during literacy tasks.

Table 1. The effect of cognitive skills on reading skill (ER)

Reading Skill (ER)	Stroop proficiency			Pearson Chi-Square
	Low (%)	Medium (%)	High (%)	
Weak Performance	40	56	4	21.73*
Good Performance	17.1	69.9	13	
Excellent Performance	9.4	59.4	31	
Reading Skill (ER)	Semantic Fluency			26.21*
	Low (%)	Medium (%)	High (%)	
Weak Performance	88	12	0.00	
Good Performance	85.4	14.6	0.00	
Excellent Performance	53.1	46.9	0.00	
Reading Skill (ER)	Phonemic Fluency			29.88*
	Low (%)	Medium (%)	High (%)	
Weak Performance	100	0.00	0.00	
Good Performance	72.4	27.6	0.00	
Excellent Performance	46.9	48.4	4.7	
Reading Skill (ER)	Backward Digit Recall			11.70*
	Low (%)	Medium (%)	High (%)	
Weak Performance	88	12	0.00	
Good Performance	74	25.2	0.8	
Excellent Performance	56.3	43.8	0.00	

In a similar vein, a robust relationship between semantic fluency and reading ability ($\chi^2 = 26.21$, $p < .001$) highlights the vital role of semantic network structure in literacy development. Semantic fluency tasks require quick recall of items within a conceptual group; in fact, they provide valid and reliable measures of semantic memory organization, lexical access, and conceptual integration (Gernsbacher 1990). This aligns with Perfetti (2007) and Perfetti and Stafura (2014), who posit that high-quality lexical representations support precise and interconnected processing for better word recognition and skilled comprehension. The table reveals that greater semantic fluency is associated with higher reading proficiency, supporting the idea that well-organized semantic networks facilitate text integration and vocabulary-based comprehension.

Phonemic fluency proves the vital role that phonological processes play in reading ability ($\chi^2 = 29.88$, $p < .001$). The data in Table 1 support Bradley and Bryant's (1983) Phonics Deficit Hypothesis, which states that deficits in phonemic

awareness constrain decoding efficiency. In the same vein, the table shows that all weak readers were in the low-phonemic-fluency group (100%), indicating a clear association between poor phonological processing and limited reading performance.

Nevertheless, high-performing participants showed stronger phonemic fluency (48.4% medium; 4.7% high), which supports that phonological retrieval marked improvements in decoding and in literacy (Torgesen et al 2001).

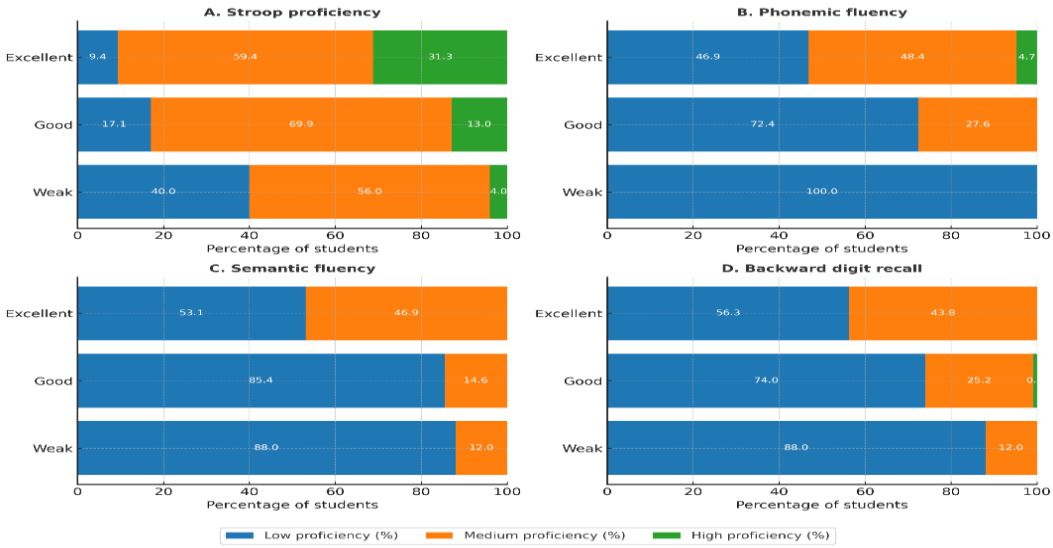

Figure 1. The effect of cognitive skills on reading skill (ER)

Working memory, as measured by our backward digit recall task, also reported a significant association with reading skill ($\chi^2 = 11.70$, $p = .02$). Table 1 shows that low proficiency readers were overwhelmingly in the low working memory group (88%), which in turn plays into the crucial role of verbal working memory in literacy tasks. Higher reading proficiency was associated with better working memory performance (56.3% high and 43.8% medium). These findings align with neurocognitive research indicating that working memory processes – supported by areas such as the dorsolateral prefrontal cortex and the temporoparietal systems – underpin syntactic processing, inference, and integration during reading (Pugh et al 2001).

The table and stacked bar charts show that improvement in executive control, semantic processing, phonological retrieval, and working memory capacity can lead to measurable gains in reading proficiency. However, defects in any of these cognitive abilities lead to poor literacy performance, whereas moderate to high levels of these cognitive skills support stronger reading development. These results demonstrate multiple roles for executive function, semantic networks, phonological awareness, and working memory in reading performance (Torgesen et al 2001).

They also illustrate the significant role of foundational cognitive skills—Stroop inhibitory control, semantic fluency, phonemic fluency, and working memory—in the development and execution of writing skills (EW). These statistical associations reinforce the view that writing is a cognitively demanding activity that depends on executive control, lexical–semantic organization, phonological retrieval, and working-memory capacity.

Table 2. The effect of cognitive skills on writing skills

Writing Skill (EW)	Stroop proficiency			Pearson Chi-Square
	Low (%)	Medium (%)	High (%)	
Weak Performance	28.6	71.4	0.00	17.28*
Good Performance	20.7	64.9	14.4	
Excellent Performance	8.2	63	28.8	
	Semantic Fluency			
Writing Skill (EW)	Low (%)	Medium (%)	High (%)	
Weak Performance	100	0.00	0.00	16.91*
Good Performance	79.3	20.7	0.00	
Excellent Performance	61.6	38.4	0.00	
	Phonemic Fluency			
Writing Skill (EW)	Low (%)	Medium (%)	High (%)	
Weak Performance	92.9	7.1	0.00	19.19*
Good Performance	71.2	28.8	0.00	
Excellent Performance	53.4	42.5	4.1	
	Backward Digit Recall			
Writing Skill (EW)	Low (%)	Medium (%)	High (%)	
Weak Performance	92.9	7.10	0.00	12.71*
Good Performance	72.1	27	0.9	
Excellent Performance	58.9	41.1	0.00	

The data reveal a strong correlation between Stroop performance and writing ability ($\chi^2 = 17.28$, $p < .001$), demonstrating the role of inhibitory control in writing efficiency because writing requires suppression of irrelevant info, maintenance of attentional focus, and the shift between planning, drafting, and revising phrases (Fletcher and Lyon 2011). The data show that 28.6 percent of weak participants fall into the low Stroop category. In this context, Blair and Razza (2007) emphasize that inhibitory control improves coherence,

structure, and revision – the key elements of good writing.

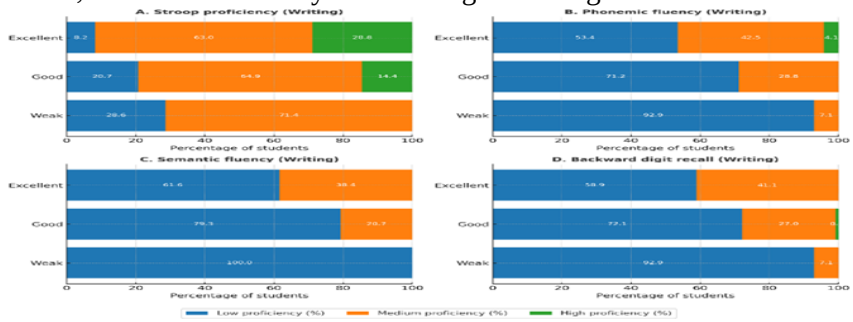

Figure 2. The effect of cognitive skills on writing skills**.**

Semantic fluency reveals a significant association with writing proficiency (χ^2 = 16.91, $p < .001$). For instance, all weak writers have low semantic fluency, as a result of restricted lexical–semantic networks. On the other hand, good writers showed 79.3 percent in the low range and 20.7 percent in the medium range, while excellent writers exhibited 61.6 percent in the low range and none in the medium range, resulting in a 38.4 percent drop in the medium range. The results agree with Perfetti and Stafura (2014), who posit that richer, interconnected semantic representations support idea generation, lexical diversity, and coherent composition.

Phonemic fluency also shows a strong relationship with writing proficiency (χ^2 = 19.19, $p < 0.001$). Weak writers overwhelmingly demonstrated low phonemic fluency 92.9 percent, consistent with the role of phonological processing in spelling, word retrieval, and sentence flow (Bradley and Bryant 1983). Good writers performed at (71.2%) low and (28.8%) medium, whereas excellent writers showed (53.4%) low, (42.5%) medium, and 4.1 percent high phonemic fluency. These findings underscore the importance of phonological awareness in producing accurate and fluent written text.

Working memory, measured by backward digit recall, was also significantly associated with writing proficiency (χ^2 = 12.71, $p = 0.02$). Weak writers showed severe deficits (92.9% low), while good writers exhibited (72.1%) low, (27.0%) medium, and (0.9%) high. Excellent writers demonstrated markedly stronger working-memory capacity, with 58.9 percent in the medium range and 41.1 percent in the upper-medium range, and none in the low category. This aligns with research emphasizing that working memory enables the planning, integration, and revision processes required for coherent writing (Daneman and Carpenter 1980; Alloway and Alloway 2010).

The results indicate that severe deficits across semantic, phonological, and working-memory domains are concentrated among weak writers, consistent with prior findings that these deficits constitute significant barriers to writing development (Melby-Lervåg and Hulme 2013; Snowling and Hulme 2011). However, moderate proficiency in these areas—such as medium semantic fluency, 38.4 percent of excellent writers and medium working memory 58.9 percent —is associated with meaningful gains. Research shows that targeted interventions focused on semantic mapping, phonemic awareness, and strengthening working memory can produce measurable improvements in writing performance (Karbach and Unger 2014).

The data in Table 3 show that Reading Proficiency (ER) is strongly associated with most cognitive skills, including Stroop inhibitory control, semantic fluency, phonemic fluency, and working memory. All chi-square values are below the 0.05 threshold, indicating that cognitive performance levels differ systematically.

Table 3. The effect of reading skill (ER) on cognitive skills

Proficiency Stroop	Reading Skill (ER)			Pearson Chi-Square
	Low (%)	Medium (%)	High (%)	
Weak Performance	27	56.8	16.2	21.72*
Good Performance	10.1	62.3	27.5	
Excellent Performance	2.7	43.2	54.1	
Semantic Fluency	Reading Skill (ER)			26.2*
	Low (%)	Medium (%)	High (%)	
Weak Performance	13.7	62.2	28	
Good Performance	5.9	35.3	58.8	
Excellent Performance	0.00	0.00	0.00	
Phonemic Fluency	Reading Skill (ER)			29.88*
	Low (%)	Medium (%)	High (%)	
Weak Performance	17.4	61.8	20.8	
Good Performance	0.00	52.3	47.7	
Excellent Performance	0.00	0.00	100	
Backward Digit Recall	Reading Skill (ER)			17.71*
	Low (%)	Medium (%)	High (%)	
Weak Performance	14.8	61.1	24.2	
Good Performance	4.8	50	45.2	
Excellent Performance	0.00	100	0.00	

Stroop performance represents a significant correlation with reading ability ($\chi^2 = 21.72$, $p < 0.001$). The stacked bar shows that weak readers scored low on the Stroop test (27%) and that only a small proportion achieved high scores (2.7%). Readers who achieved moderate results achieved better results than weak readers. For instance, 62 percent achieved good Stroop performance, and 43 percent achieved high Stroop performance. This percentage has increased among proficient readers: 54.1 percent of them achieved excellent Stroop performance. What comes through transparently is that as inhibition control increases, there is support for better suppression of irrelevant information, sustained attention, and more coherent comprehension during reading (Miyake et al 2000; Diamond 2013).

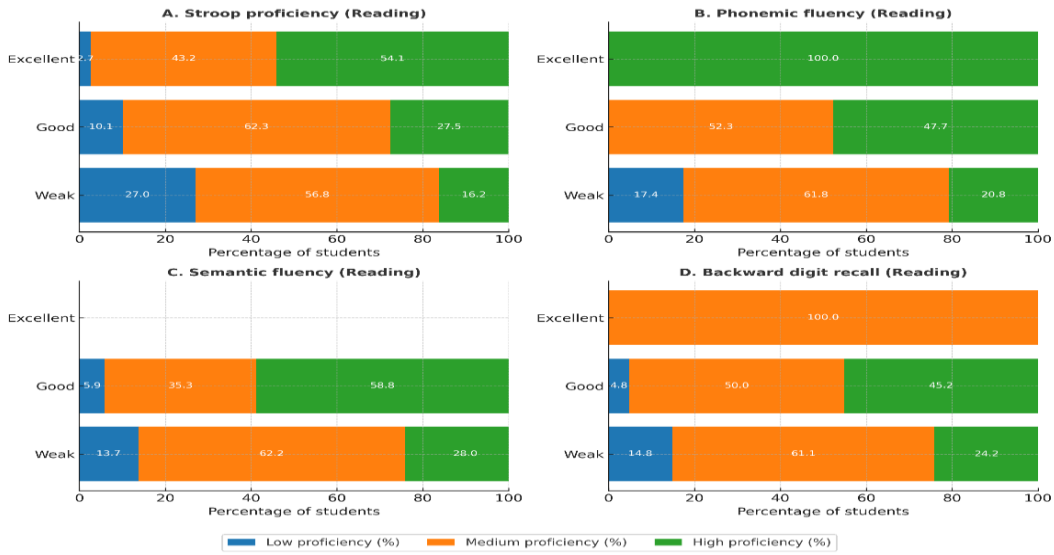

Figure 3. The effect of reading skill (ER) on cognitive skills.

A significant correlation was also revealed between semantic fluency and reading skill ($\chi^2 = 26.20$, $p < .001$). In Table 3, weak readers scored (13.7%) low, (62.2%) medium, and 28.0 percent high in semantic fluency. Nevertheless, good readers perform substantially better, with only (5.9%) low, (35.3%) medium, and 58.8 percent high. The progression from weak to good readers is consistent, as stronger semantic networks are associated with higher reading proficiency. The result reveals that the semantic–phonological integration is better for the meaning extraction and comprehension (Perfetti 2007; Perfetti and Stafura 2014).

Phonemic fluency exhibited the strongest association with reading proficiency ($\chi^2 = 29.88$, $p < 0.001$). Weak readers were distributed as 17.4 percent low, 61.8 percent medium, and 20.8 percent high. In contrast, good readers showed no individuals in the low category (0.0%), with 52.3 percent performing at the medium level and 47.7 percent at the high level. Notably, all excellent readers (100.0%) performed exclusively in the high phonemic fluency category, with 0.0%) (in the low or medium categories. This pattern strongly reinforces the central role of phonological retrieval and processing in reading fluency, decoding accuracy, and rapid word recognition (Wagner et al 1993). High phonemic fluency appears to be a hallmark of advanced reading skill, reducing cognitive load and allowing readers to allocate more resources to comprehension (Kirkham et al. 2003).

Working memory, assessed via backward digit recall, was also significantly associated with reading proficiency ($\chi^2 = 17.71$, $p = 0.02$). Weak readers performed at 14.8 percent low, 61.1 percent medium, and 24.2 percent high. Good readers showed improved distributions: 4.8 percent low, 50.0 percent medium, and 45.2 percent high. Interestingly, excellent readers performed exclusively in the medium category (100.0%), with (0.0%) in the low and (0.0%) in the high categories. This suggests that while adequate working memory is necessary for managing text

integration, inference-making, and comprehension processes Swanson and Sachse-Lee 2000; Klingberg et al 2005), extremely high working-memory scores were not characteristic of the excellent reading group in this dataset. However, strong medium-range working-memory capacity appears sufficient to support advanced reading performance.

Table 3 provides clear empirical evidence that stronger cognitive performance, particularly in inhibitory control, semantic fluency, phonemic fluency, and working memory, is associated with greater reading proficiency. The progressive increase in high-level cognitive performance from weak to good to excellent readers, which in turn supports the theoretical framework that puts forth the interactive roles of executive functions, semantic organization, and phonological processing in literacy development.

Table 4. The effect of writing skill (EW) on cognitive Skills

Proficiency Stroop	Writing Skill (EW)			Pearson Chi-Square
	Low (%)	Medium (%)	High (%)	
Weak Performance	21.6	62.2	16.2	17.27*
Good Performance	14.5	52.2	33.3	
Excellent Performance	0.00	43.	56.8	
Semantic Fluency	Writing Skill (EW)			18.05*
	Low (%)	Medium (%)	High (%)	
Weak Performance	17.4	54.7	28	
Good Performance	0.00	45.1	54.9	
Excellent Performance	0.00	0.00	0.00	
Phonemic Fluency	Writing Skill (EW)			19.20*
	Low (%)	Medium (%)	High (%)	
Weak Performance	18.1	54.9	27.1	
Good Performance	3.1	49.2	47.7	
Excellent Performance	0.00	0.00	100	
Backward Digit Recall	Writing Skill (EW)			12.69*
	Low (%)	Medium (%)	High (%)	
Weak Performance	17.4	53.7	28.9	
Good Performance	3.2	48.4	48.4	
Excellent Performance	0.00	100	0.00	

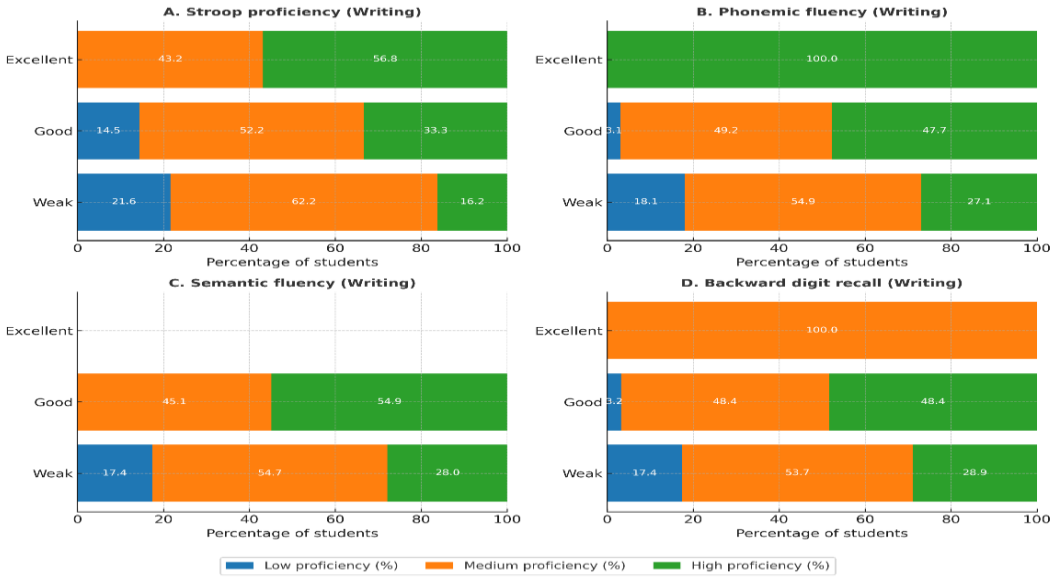

Figure 4. The effect of writing skill (EW) on cognitive skills.

The Stroop task result underscores the importance of inhibitory control and cognitive flexibility in terms of writing proficiency ($\chi^2 = 17.27$, $p < .05$). According to the distribution in the table, 21.6 percent of weak writers demonstrated low Stroop performance, 62.2 percent performed at a medium level, and only 16.2 percent achieved high proficiency. Good writers showed a more advantageous profile, where 14.5 percent in the low category, 52.2 percent in the medium category, and 33.3 percent in the high category. In the excellent category, none of the participants in the writing task were classified as low. However, 43.2 percent were in the medium Stroop performance category, and 56.8 percent were in the high Stroop performance category. The results align with Diamond 2013 and Miyake et al 2000, who found that executive control supports planning, organization, sustained attention, and effective revision, all elements of proficient writing.

Phonemic fluency displayed a similarly strong and statistically significant relationship with writing proficiency ($\chi^2 = 19.20$, $p < 0.05$). Weak writers showed 18.1 percent low, 54.9 percent medium, and 27.1 percent high phonemic fluency. The stacked bar illustrates that good writers had improved phonological-retrieval efficiency, with 3.1 percent in the low category, 49.2 percent in the medium category, and 47.7 percent in the high category. In sharp contrast, excellent writers had the highest phonemic fluency, at (100.0%) in the high category and 0 percent in the low and medium categories. This progression highlights the great importance of phonological retrieval and segmentation in producing accurate spelling, fluent sentence structure, and cohesive text. Therefore, strong phonemic fluency is a mark of highly proficient writers, which, in turn, enables better lexical access and smoother written expression.

Participants who achieved good writing performance showed a more balanced distribution, with only 3.2 percent in the low category and equal numbers in the medium and high categories at 48.4 percent each. In contrast, excellent writers exhibited a concentrated pattern, with 100.0 percent at the medium level and none at the low or high levels. The distinctive distribution reveals that while top-tier writing performance does not require a high working-memory span, a consistently adequate medium-level working memory is sufficient to support organizing ideas, maintaining coherence, integrating information, and revising text effectively (Alloway and Alloway 2010; Swanson and Sachse-Lee 2020). However, writers with poor working memory may face obstacles in meeting these cognitive demands. However, those with good memory capacity can manage linguistic information, especially during composition.

The current findings align with those of Perfetti and Stafura (2014), who highlight the interaction among executive control, semantic processing, and working memory in the development of literacy. Meanwhile, Miyake et al (2000) emphasize the multi-component structure of executive functions, which play a role in complex cognitive tasks such as writing. The current study reports that a group of cognitive elements coordinates to support writing proficiency. Evidence-based interventions targeting inhibitory control, phonological processing, and working memory enhancement have been shown to improve academic performance (Jolles et al 2017; Diamond and Ling, 2016), with meaningful implications for instructional design and cognitive-skills development in learning writing skills.

5. Discussion

The present study examined how core executive-function components interact with English literacy skills among Arabic–English bilingual adolescents. The discussion below interprets the findings in light of the research questions and relevant theoretical frameworks, highlighting both the predictive contributions of inhibitory control, working memory, and verbal fluency, as well as the role of literacy performance in shaping cognitive outcomes. Taken together, the results reveal a dynamic pattern of mutual influence between cognitive control and bilingual literacy development, offering new insights into how these processes co-develop in instructed language contexts.

5.1 Executive functions as predictors of English literacy (RQ1)

The present study examined the extent to which executive function (EF) components—specifically, inhibitory control, working memory, semantic fluency, and phonemic fluency—predict English literacy outcomes among Arabic–English bilingual adolescents in Saudi Arabia. Consistent with growing evidence that bilingual literacy is supported by domain-general cognitive mechanisms (Diamond 2013; Miyake et al 2000), the findings reveal that students with stronger inhibitory control, greater working-memory capacity, and more efficient lexical fluency achieved higher levels of English reading and writing proficiency. These results reinforce the position that second-language (L2) literacy development is not solely dependent on linguistic exposure but is deeply intertwined with cognitive systems

responsible for attention, memory, and lexical access (Perfetti and Stafura 2014).

The pattern of results is highly compatible with established bilingual cognitive models. Bialystok's (2009, 2011) theoretical framework highlights that bilingual language management recruits and strengthens executive processes—particularly inhibition and attentional control—given the constant demands of switching, suppressing, and selecting between languages. This aligns with our finding that participants with stronger EF skills performed better in English literacy tasks. The results also align with Cummins' (1976, 2000) Threshold Hypothesis, which posits that cognitive advantages associated with bilingualism emerge once a certain level of proficiency is attained in both languages. Accordingly, learners with higher English proficiency in this study demonstrated superior EF performance, reflecting findings that balanced bilinguals outperform less proficient peers on complex EF tasks (Carlson and Meltzoff 2008).

The strong link between semantic fluency and literacy supports the Lexical Quality Hypothesis (Perfetti 2007), which argues that well-specified lexical representations enable deeper comprehension and more coherent writing. Learners with richer, more readily accessed semantic networks demonstrated higher literacy competence, echoing research showing that vocabulary depth and retrieval speed are crucial for L2 comprehension (Jeon and Yamashita 2014). Similarly, the association between phonemic fluency and literacy aligns with the Phonological Deficit Hypothesis (Hulme and Snowling 2011), which posits that efficient phonological processing underlies decoding accuracy and written expression. These results mirror findings that phonological skills continue to influence reading and writing well beyond the early literacy years (Verhoeven and Perfetti, 2021).

Working memory also played a central predictive role. This supports cognitive models showing that reading comprehension and writing impose significant demands on temporary information storage and manipulation (Daneman and Carpenter 1980; Swanson and O'Connor 2009). Students with greater working-memory resources were better able to maintain and integrate textual information, make inferences, and plan coherent compositions—processes fundamental to L2 literacy (Butterfuss and Kendeou 2018). For bilingual learners, these cognitive burdens are amplified by the need to retrieve lexicon and process syntax simultaneously (Kormos 2014), which clarifies why working memory was so strongly associated with literacy proficiency in the current study.

Taken together, the EF-literacy link observed here is consistent with contemporary research emphasizing that bilingual academic performance depends not only on linguistic knowledge but also on the quality of cognitive control processes. These findings underscore the central role of executive functions as foundational predictors of English literacy achievement among bilingual adolescents in the Saudi educational context.

5.2 English literacy as a predictor of executive functions (RQ2)

In addition to executive functions predicting literacy performance, this study's findings demonstrate a reverse association: English literacy proficiency also significantly predicted performance on EF tasks. Students with stronger reading and writing skills demonstrated higher levels of inhibitory control, working memory capacity, and lexical fluency. This pattern aligns with emerging theoretical arguments that literacy engagement itself is a cognitively demanding activity that can strengthen domain-general control mechanisms. Research shows that comprehension of complex texts requires sustained attentional allocation, ongoing monitoring of understanding, inference generation, and integration of discourse information—all of which rely on executive processes (Cain and Oakhill 2006). Thus, learners who engage more deeply with challenging literacy tasks are likely to develop stronger EF skills through repeated exposure.

The findings are consistent with the view that reading and writing serve as "cognitive training grounds" for the development of EF. Writing, in particular, is a recursive process that requires planning, organizing, evaluating, and revising ideas—steps that place high demands on working memory, inhibitory control, and cognitive flexibility (Friedman and Miyake 2017). Bilingual writing amplifies this cognitive load, as learners must coordinate lexical access, syntactic decision-making, and the management of cross-linguistic interference. Studies with bilingual adolescents corroborate these patterns, showing that writing-intensive instruction yields measurable gains in EF performance (Kieffer and Christodoulou 2020). These trends are echoed in research from the Arab region, where engagement in English literacy activities has been found to strengthen EF capacities among bilingual Arabic–English learners (Abdelgafar and Moawad 2015). Taken together, the results indicate that literacy proficiency is not merely an outcome of EF but also a contributor to EF development.

5.3 Evidence for a reciprocal relationship between EF and literacy (RQ3)

When both predictive directions are considered together, the findings provide compelling evidence for a reciprocal relationship between executive functions and English literacy proficiency. Rather than functioning as isolated constructs, EF and literacy appear to mutually reinforce each other through dynamic, ongoing cognitive–linguistic interactions. This interpretation is strongly supported by Cummins' (1976, 2000) Interdependence and Threshold Hypotheses, which argue that bilingual proficiency and cognitive development evolve through mutually supportive mechanisms. According to these frameworks, growth in academic literacy strengthens higher-order cognition, while enhanced cognitive resources promote deeper engagement with literacy tasks. The positive associations observed in this study closely mirror this theoretical prediction.

Recent empirical work also supports a reciprocal developmental model. Longitudinal studies show that EF abilities and literacy outcomes influence one another over time in multilingual children and adolescents (Weaver and Kieffer 2022; Relyea, Cho and Zagata 2023). Neurocognitive and behavioral evidence suggests that literacy practice enhances attentional control and updating processes, while improved

EF enables learners to navigate complex reading passages, integrate textual meaning, and regulate writing processes more efficiently. Furthermore, bilingual environments—such as Saudi international schools—may intensify this reciprocity, as students regularly alternate between Arabic, English, and often a home dialect. This linguistic complexity increases reliance on both EF and literacy skills, generating a feedback loop in which gains in one domain foster gains in the other (Morales et al 2013). The internal coherence of the present findings, therefore, provides robust support for the existence of a reciprocal, mutually reinforcing relationship between EF and English literacy.

Taken together, the findings demonstrate a coherent pattern in which executive-function components—particularly inhibitory control, verbal working memory, and lexical fluency—cluster systematically with L2 literacy proficiency. Rather than interpreting each cognitive measure in isolation, the results suggest that successful reading and writing in a second language depend on an integrated set of regulatory processes that support attention to text, suppression of irrelevant linguistic cues, and rapid retrieval of semantic and phonological information. These results are consistent with frameworks such as the Lexical Quality Hypothesis, which emphasizes precise lexical representations as the foundation of fluent comprehension, and the Phonological Deficit hypothesis, which highlights the role of phonological access in decoding and writing. Notably, the pattern observed across all EF components suggests that bilingual literacy draws on a constellation of cognitive processes that jointly scaffold text comprehension and written expression, particularly in contexts in which learners must navigate two linguistically distant languages, such as Arabic and English.

To synthesize these findings and illustrate the bidirectional associations identified in this study, Figure 4 presents a conceptual model capturing the reciprocal relationship between executive functions and English literacy outcomes. The model integrates the predictive pathways supported by RQ1 and RQ2 and visually highlights the mutual reinforcement outlined in RQ3.

Executive-function components—namely inhibitory control, working memory, semantic fluency, and phonemic fluency—are shown as direct contributors to the Executive Functions construct, which in turn predicts English literacy performance. Conversely, reading and writing proficiency indicators converge on the English Literacy construct, which also exerts a feedback influence on executive-function development. This visual representation clarifies how cognitive and literacy processes operate in tandem, supporting a dynamic, interactive system rather than a unidirectional hierarchy. It therefore offers a coherent framework that aligns the empirical evidence with contemporary models of bilingual cognitive–linguistic development.

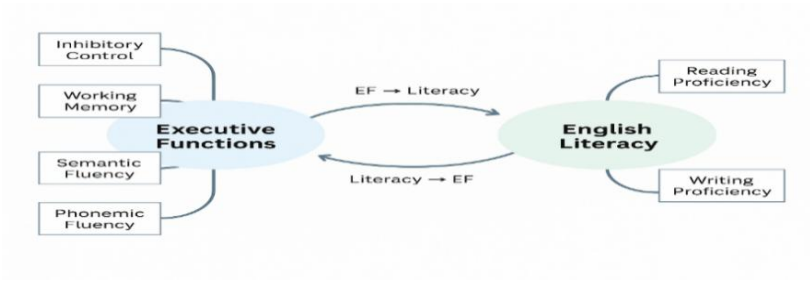

Figure 5. Structural model illustrating bidirectional links between executive functions and English literacy

The figure depicts the structural links between core executive-function components (inhibitory control, working memory, semantic fluency, and phonemic fluency) and English literacy outcomes (reading and writing proficiency). Curved arrows represent reciprocal pathways, highlighting how cognitive control processes support literacy development, while sustained engagement with literacy tasks reinforces executive function in Arabic–English bilingual adolescents.

6. Conclusion

This study demonstrated that executive functions—specifically inhibitory control, working memory, and semantic and phonemic fluency—are strong predictors of English reading and writing proficiency among Arabic–English bilingual adolescents in Saudi Arabia. The results confirm that L2 literacy development is not solely dependent on linguistic exposure, but is profoundly shaped by cognitive systems responsible for attention regulation, temporary information storage, and efficient lexical access. This study presents a framework that integrates cognitive and linguistic theories, demonstrating that executive control processes play a fundamental role in bilingual learners' performance on complex English texts. These results have large-scale implications for how education, including language instruction programs that focus on executive functions, will, in turn, improve literacy outcomes and academic performance among bilingual students in multilingual school settings.

6.1 Mechanisms of the reciprocal relationship

While the cross-sectional nature of this study does not permit causal inference, the patterns observed are consistent with theoretical accounts proposing that executive functions and L2 literacy may reinforce one another over time. On one hand, students with stronger inhibitory control, working memory, and lexical retrieval skills may find it easier to manage the cognitive demands of reading and writing in English. On the other hand, engagement with complex literacy tasks—such as extended reading, inferencing, and revising written work—may repeatedly demand these same executive processes, potentially strengthening them through sustained use. Thus, although longitudinal evidence is needed to confirm the direction of causality, the present findings align with models suggesting a mutually supportive relationship between cognitive control and bilingual literacy development.

6.2 Limitations

Despite the study's contribution, several limitations should be acknowledged. First, the study outcomes are exclusive to male students from one international school, limiting the generalizability of the findings due to the structural gender segregation in Saudi schools, which played a role in the lack of female participation. Thus, future research should include female cohorts across multiple schools to achieve broader representativeness. Second, participants came from comparatively high socioeconomic backgrounds and had received sustained English exposure through an internationally accredited curriculum. Therefore, the results may not extend to public schools' Arabic-medium programs or to lower-SES groups, which may have different language input and cognitive experience. Third, the study employed a cross-sectional design, which does not permit causal inferences regarding the developmental direction of the relationship between EFs and L2 literacy. Thus, we will need a longitudinal approach. Only behavioral measures were implemented in this study. Therefore, future studies should include neurocognitive or neuroimaging methods to examine the neural basis of the relationship between executive control and bilingual literacy.

Aala Karim Maayah- (Corresponding Author)
Universiti Sains Malaysia, Penang, Malaysia
ORCID Number: 0009-0006-6468-5872
Email: aalamaayah@student.usm.my / alaamaiha@yahoo.com
Mobile Number: 00966500965626

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