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Bilingual Brains, Monolingual Worlds: A Comparative Study of Cognitive and Linguistic Capabilities

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Abstract—**This research study examines brain efficacy between Arabic-monolingual and English-Arabic bilingual university students by evaluating their vocabulary acquisition, learning capacity, thinking ability, and critical thinking skills. The study also explores the impact of academic semester progression on cognitive performance in both groups. A mixed-methods approach was employed. The study included 222 randomly selected students from various semesters. Data were collected via structured questionnaires, classroom activities, and performance-based assessments. The statistical analyses encompassed descriptive statistics, Chi-square tests, and t-tests. Cronbach's alpha was employed to validate the reliability of the questionnaire responses. Findings indicated that bilingual students outperformed their monolingual counterparts in cognitive flexibility, adaptability, and critical thinking skills. They also demonstrated greater capabilities in vocabulary acquisition and abstract problem-solving. In contrast, monolingual students demonstrated proficiency in activities that necessitated repetition and organization, yet they had difficulties with abstract reasoning. Semester progression improved cognitive performance in both groups, with bilingual students exhibiting a steeper trajectory of improvement. The study provides a distinctive analysis of cognitive differences between monolingual and bilingual students, highlighting the influence of bilingualism on enhancing learning and critical thinking skills. It also highlights the positive impact of academic progression on cognitive developments. The results endorse the cognitive benefits of bilingualism, particularly in activities that require mental flexibility and abstract thinking.**

Index Terms—**bilingualism, critical thinking, cognitive capabilities, academic progression, brain efficacy**

I. Introduction

Language plays a pivotal role in shaping human cognition, serving as both a framework for intellectual development and a tool for communication among learners. It serves not just as a medium for communication but also provides a gateway to shaping thought, learning, and cognitive development (Rabiah, 2018).

Proficiency in two languages is known as bilingualism. It has gained recognition for its potential cognitive benefits, particularly in improving executive skills such as memory, critical thinking, and problem-solving (Adesope et al., 2010; Bialystok, 2011). On the other hand, monolingualism, which employs a single language, offers linguistic depth and immersion that can enhance vocabulary specialization and focused learning (Ellis, 2008). Despite these differences, the comparative cognitive and linguistic outcomes of bilingual and monolingual students remain a subject of academic debate. Migration, globalization, and multilingual education have contributed to the rise of bilingualism worldwide, highlighting the need to comprehend its educational implications. Research indicates that bilingual students frequently perform better on tasks that demand linguistic comprehension and cognitive flexibility (Costa et al., 2008; Gathercole & Thomas, 2009). This dual perspective systematically underscores the comparison of different groups to elucidate their advantages. Despite growing interest in bilingualism, limited research has thoroughly investigated its impact on critical thinking, learning capabilities, and vocabulary acquisition, particularly among university students (Alias, 2018; Sharafi-Nejad et al., 2016).

Previous research has primarily focused on younger people or overlooked the interplay between language and cognitive abilities in higher education (De Groot, 2011). Addressing this gap, the current study compares and contrasts monolingual and bilingual Arab university students in terms of their brain efficacy across critical domains like learning capability, vocabulary, thinking capacity, and critical thinking skills. This study employs a dual-method approach, integrating class activity comprehension exercises and a structured questionnaire to assess competencies in both monolingual and bilingual students. By exploring these differences, this research examines the impact of language diversity on cognitive development and educational outcomes. The findings of this study have the potential to inform the timing of learning, critical thinking, and vocabulary of monolingual and bilingual students. It also illustrates how the intelligence of monolingual and bilingual learning experiences alters the brain efficacy of Arab university students at

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different academic levels. By exploring these variations, the research aims to elucidate the linguistic and cognitive dynamics underlying learning processes and provide valuable insights for educators and decision-makers. Ultimately, understanding these differences may help educators formulate more effective lesson plans and promote equitable learning conditions in bilingual and multilingual classrooms.

Recent studies have highlighted the cognitive benefits of bilingualism, particularly its positive impact on executive functions and attentional control. When bilinguals engage in activities that require the simultaneous use of two linguistic systems, it strengthens the brain circuits associated with working memory and cognitive flexibility (Yang, 2017). Moreover, research studies indicate that bilingualism enhances inhibitory control, enabling bilinguals to filter out irrelevant information more effectively than monolinguals (Tao et al., 2021). These cognitive benefits demonstrate the wide-ranging effects of bilingualism on brain processes, spanning several domains, including creativity and problem-solving. Bilingualism in an academic context is linked to enhanced reading comprehension, especially in complicated texts, and increased metalinguistic awareness. Bilingual proficiency makes it easier to recognize and work with linguistic structures. It can also improve learning results in linguistically related disciplines (Chibaka, 2018; Schwartz & Palviainen, 2016). Moreover, bilingual students often demonstrate superior performance that require higher-order thinking, such as critical thinking and problem-solving, due to their advanced cognitive processes (Chaudhary, 2018). These skills provide a robust foundation for academic success, especially in contexts that emphasize intercultural communication. Bilingualism may provide varying academic advantages depending on contextual and individual circumstances. For example, academic performance may be adversely affected by partial bilingualism, where one language is significantly underdeveloped if the linguistic resources are not well-balanced (Privitera & Weekes, 2023). Likewise, societal biases or insufficient educational support may pose challenges for bilingual individuals from underrepresented linguistic communities. Despite these disadvantages, bilingualism offers undeniable cognitive and scholastic advantages when nurtured in conducive settings, equipping individuals with the necessary skills for cross-cultural engagement and lifelong education. This study aims to investigate the learning experiences, cognitive abilities, vocabulary, and brain efficiency of Arabic-monolingual and English-Arabic bilingual Arab university students. To fulfil the aims of this research, the following questions are presented in the current study:

1. How do Arabic-monolingual and English-Arabic bilingual Arab university students differ in terms of brain efficacy as assessed through classroom activities and a questionnaire?
2. Do bilingual students demonstrate superior vocabulary acquisition, learning capability, thinking capacity, critical thinking, and usage compared to monolingual students in classroom activities?
3. Does the level of academic semester influence the brain efficacy, learning capabilities, and critical thinking of monolingual and bilingual students?

II. Literature Review

A. Monolingual and Bilingual Learning and Cognitive Skills

The impact of bilingualism and monolingualism on learning and cognitive skills has been a focal point of research across different fields, including linguistic, education, and psychology. Research indicates that bilingual students frequently exhibit superior cognitive skills in specific domains, such as executive functioning and metalinguistic awareness compared to monolingual students (Silverman et al., 2015; Yayla et al., 2016). Bialystok and Martin (2004) conducted a research study to analyze the learning and cognitive skills of monolingual and bilingual children. Sixty-seven participants participated in this study, comprising 36 English monolinguals and 31 Chinese-English bilinguals. To investigate the differences between monolingual and bilingual learning capabilities, the Peabody Picture Vocabulary Test, Forward Digit Span, and computerized Dimensional Change Card Sort methodologies were employed. Chi-square and ANOVA were used to evaluate the significant difference between monolingual and bilingual participants. The results indicated that bilingual children outperformed monolingual youngsters, exhibiting a considerable disparity. This indicates that multilingualism enhances children's attentional control, especially in activities necessitating inhibition, with negligible effect on representational analysis. This highlights the significance of bilingual experience in shaping distinct learning and cognitive processes. The working memory of bilingual students was more efficient than that of monolingual students. A research study was performed in Canada to compare the cognitive skills and working memory of monolingual versus bilingual children. Fifty-six children were selected for this investigation. Among these, twenty-one were monolingual and twenty-seven were bilingual. Assessments of English receptive vocabulary (PPVT-III) and fluid intelligence (K-BIT) were administered to these youngsters. Results indicated that bilingual children performed well in the working memory test due of practice of switching and monitoring two languages constantly, as compared to monolinguals (Morales et al., 2013). Bilingual children frequently demonstrate superior executive functioning, critical thinking, and flexibility; nevertheless, monolingual kids may possess a more comprehensive vocabulary and greater fluency in one language. Another research study was conducted in Pakistan to examine the cognitive abilities, learning processes, and academic performance of multilingual students. One hundred students and twenty educators participated in this research study. A mixed-methods approach was utilized, integrating quantitative assessments of academic intelligence with qualitative data collected via surveys and interviews. The findings suggest that bilingualism may enhance academic performance and cognitive abilities (Jumani et al., 2024).

B. Vocabulary Acquisition in Monolingual and Bilingual Learners

Critical thinking and vocabulary development are vital for cognitive advancement and language acquisition. Studies on monolingual and bilingual learners have yielded contradictory results on composition and vocabulary size. Research demonstrates that monolingual students generally possess a more extensive receptive vocabulary, while bilingual individuals may display a wider conceptual vocabulary across languages (Bialystok et al., 2010). A study conducted by Li and Hennebry-Leung (2024) revealed that bilingual subtitles in educational videos improve vocabulary recognition and recall among Chinese university students, suggesting that exposure to both languages facilitates vocabulary acquisition. Alqahtani (2015) emphasized the significance of vocabulary depth and breadth for second-language learners, stating that comprehension and expression are facilitated by a strong vocabulary. Nematollahi et al. (2017) showed that focused vocabulary training improves memory and cultivates students' critical thinking skills. It also underscored the efficacy of direct and social strategies for decision-making, which are the least utilized. DeAnda et al. (2018) undertook a study to investigate if the relationship is unique to the language under assessment or pertains to general linguistic or cognitive processes. This study involved English monolingual and English-Spanish bilingual children aged sixteen to twenty-two months. A word recognition speed technique was employed to assess the impact of Bilingualism versus Monolingualism. Results revealed that cross-language correlations in bilinguals indicate that the primary language facilitates processing in the non-dominant language. This result is consistent with cognitive efficiency theories, positing that word processing depends on language experience and overarching learning attributes. Altman et al. (2017) elucidated the generation of verbs and nouns as well as their comprehension in Hebrew. The study involved 53 individuals, comprising Hebrew monolinguals and Russian–Hebrew bilinguals. The results illustrate the quantitative disparities in comprehension and production, with bilinguals exhibiting notable effects. Qualitative differences in errors: Monolinguals' errors stem from rule knowledge, while bilinguals' errors indicate inadequacies in Hebrew (L2) competency. Further research is necessary to examine these dynamics and provide effective teaching practices that accommodate the diverse linguistic backgrounds of university students.

C. Investigating Brain Efficacy Across Monolingual and Bilingual Students

Cognitive neuroscience has primarily focused on investigating brain efficacy in monolingual versus bilingual students, specifically examining the impact of bilingualism on neural efficiency and cognitive functions. Recent research underscores the importance of university students clarifying the effects of bilingualism on cognitive efficiency. Bilingual students often exhibit enhanced executive functions, including superior inhibition, task switching, and attention management (Yurtsever et al., 2023). MacWhinney et al. (2024), Prior and van Hell (2021), and Wiseheart et al. (2016) executed research in which monolingual and bilingual college students engaged in concurrent distinct activities. The results indicate that bilingual students greatly surpassed their monolingual peers, exhibiting enhanced cognitive flexibility and multitasking skills. A recent neuroimaging study has shown that bilingualism affects the brain networks involved in executive function. Anderson et al. (2021) employed fMRI technology to examine the brain regions activated during tasks necessitating response inhibition and interference suppression. In contrast to monolinguals, the results indicate that bilinguals activate distinct brain regions during interference suppression tasks, suggesting that bilingualism may lead to unique neural adaptations that enhance cognitive control. Buchweitz and Prat (2013) contended that the multilingual brain develops adaptive control mechanisms to navigate two languages, resulting in enhanced neuronal processing in the prefrontal cortex. The investigation of bilingual brain efficiency in language tasks was conducted utilizing fMRI. Research indicates that bilingual individuals process information more efficiently than monolinguals, as evidenced by reduced brain activity during similar tasks (Pliatsikas, 2019; Roberts et al., 2018).

A recent study by Gracia-Tabuenca et al. (2024) investigated the brain's functional organization in bilingual learners during second language acquisition. A total of 151 monolingual and bilingual students engaged in this investigation. The fMRI technology was employed to assess brain efficacy in monolingual and bilingual students. The results indicated that whole-brain network evaluations demonstrate increased global efficiency in bilinguals, signifying improved functional integration. The early second-language acquisition enhances cerebral efficiency, highlighting its enduring impact on the functional organization. It concludes that the timing of bilingual schooling modifies the brain's functional architecture at both global and local levels.

Bilingualism provides numerous cognitive and neurological advantages, including enhanced executive functions and both structural and functional brain modifications. Prior research underscores the significance of bilingual education and the cognitive benefits that bilingualism can provide. This study focuses on the brain efficacy of Arabic-monolingual and English-Arabic bilingual Arab university students during classroom activities. This research elucidates the influence of bilingualism on linguistic potential, cognitive abilities, and academic performance.

III. METHODOLOGY

This study employed a mixed-method approach to evaluate the learning, thinking, vocabulary and brain efficacy of monolingual and bilingual Arab university students across different semesters. Quantitative data were collected through the use of comprehension-based activity. An online comprehension-based test for class activities was conducted within a specific timeframe. Following the class-based activity, qualitative data were obtained from participants utilizing both closed- and open-ended questionnaires.

A. Participants

This research study encompassed a total of 222 ESL university students in Saudi Arabia. These students were enrolled in different semesters within the English department. The sample consisted of 55.55% females and 44.45% males. Additionally, all students were selected using a random sampling technique without considering their prior language proficiency. Many of them reported to know additional languages. The students were adults aged between 18 and 25.

B. Instruments

(a). Comprehension-Based Class Activity

A comprehension-based class activity was randomly conducted among 222 participants via the online platform Quizizz (https://quizizz.com/admin), with an emphasis on time management. This class-based activity was divided into four categories: category one, learning capability; category two, thinking capacity; category three, vocabulary; and category four, critical thinking. The outcomes of this activity were evaluated automatically by the Quizizz platform.

(b). Questionnaires Related to Demographic Information, Linguistic Profile and Class Activity Assessment

Following the class activity, the participants completed questionnaires. The questionnaire used in this study consisted on two sections. The first section includes demographic and language-related information, while the second section pertains to the assessment of class activities. It can be further subdivided into sixteen closed-ended questions and seven open-ended questions. The closed-ended questions were classified into four categories: academic year, English language proficiency, monolingual or bilingual status, and overall assessment of class activity and perceptions related to this activity. The demographic data includes fundamental information such as name, gender, age, and primary language.

C. Data Collection

The class activity and questionnaire were conducted in English to collect data. The questionnaire and comprehension-based task were conducted in two distinct ways. The instructor responsible for the relevant classes was initially asked to assist the students in understanding the fundamental concepts of the questionnaire and comprehension-focused class activities. Teachers effectively delivered instructions and elucidations to the students in a clear and consistent Arabic language, due to their experience and familiarity with the students. Secondly, the questionnaire and classroom activity were revised to enhance student comprehension and engagement.

D. Data Analysis

Statistical analysis was conducted with SPSS and GraphPad Prism. A chi-square test was used to examine the disparity between monolingual and bilingual students. Cronbach's alpha was employed to assess the reliability of the questionnaires. The questionnaires employed a Likert scale to gauge the perceptions of Arabic monolinguals and English-Arabic bilinguals about comprehension-based activities. A T-test was conducted to assess the p-value between monolingual and bilingual students throughout various semesters. GraphPad Prism was utilized to create graphs for a clear representation of data.

IV. RESULTS

A. Monolingual and Bilingual Students

Out of 222 participants, 128 exhibited active responses in both activities. Ninety-four other students failed to comprehend the class activity and made no progress in any attempts. The active responses of 128 students were assessed. Random students completed the class-based comprehension activity and questionnaire. Based on class-based activities and questionnaire responses, monolingual and bilingual students were segregated. Approximately 78 students were bilingual, while 50 students were monolingual, as determined by a comprehension-based activity and a questionnaire. GraphPad Prism was employed to create the pie chart depicted below in Figure 1.

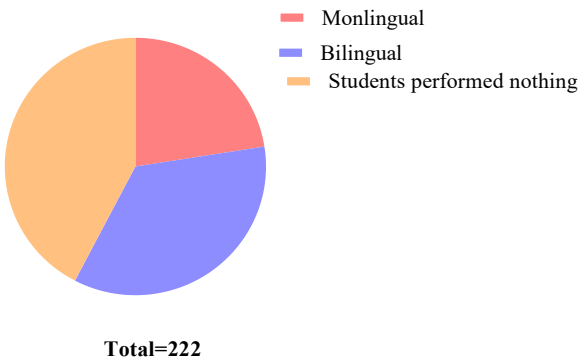

Figure 1. Responses and Questionnaires From Monolingual and Bilingual Students' Activities

Figure 1 illustrates the total number of monolingual and bilingual students who participated in the activity. The researcher differentiated between monolingual and bilingual students based on their performance in activities and questionnaire. This study employed ordinal and nominal variables; hence, a chi-square test was conducted to assess the significance between monolingual and bilingual students. A P-value less than 0.05 is deemed significant. Table 1 presents the notable differences between monolingual and bilingual students.

TABLE 1
MONOLINGUAL AND BILINGUAL PARTICIPANTS

Active Students			**Chi-square test**		
Total active participants	Monolingual	Bilingual	X^2	df	P-value
128	50	78	6.125	1.00	0.01

B. Participant's Demographics and Educational Background

The study involved 128 active university students, including 50 monolingual Arabic speakers and 78 bilingual Arabic-English speakers. Participants were selected from different academic semesters to ensure a diverse range of demographics and educational backgrounds. The monolingual group consisted of 38% males and 62% females, while the bilingual group comprised 49% males and 51 % females. The participants' ages ranged from 18 to 25 years, with a mean age of 21 years for the monolingual group and 20 years for the bilingual group. Among monolingual participants, 54% were in semesters 1-3, 18% were in semesters 4-6, and 28% were in semesters 6 and beyond. In contrast, 69% of bilingual participants were in the 1-3 semester category, 20% were in the 4-6 semester category, and 11% were in the 6+ semester category. The monolingual group reported Arabic as their sole language, with minimal exposure to English. At the same time, bilingual demonstrated strong proficiency in both Arabic and English, largely due to formal second-language education. This information is illustrated in Table 1, together with their significance values. A Value <0.05 is deemed significant. Table 2 delineates the demographic and educational profiles of monolingual and bilingual participants.

TABLE 2
DEMOGRAPHIC AND EDUCATIONAL PROFILE OF PARTICIPANTS

Category	**Sub category**	**Monolingual (%)**	**Bilingual (%)**	***P-value***
Gender	Male	38	49	0.35
	Female	62	51	0.31
Age	18-20	46	60	< 0.05
	20-23	44	32	0.07
	24+	10	08	0.52
Academic semester	1-3	54	69	< 0.05
	4-6	18	20	1.44
	6+	28	11	0.04
Primary language	Arabic	82	54	0.002
	English	07	16	< 0.05
	Both	11	30	< 0.05
English language proficiency	Beginner to Intermediate	72	32	0.01
	Advanced	21	47	0.05
	Proficient	07	21	< 0.05

Cronbach's Alpha was employed to evaluate the internal consistency of the Likert scale items in the questionnaire. The data indicated the consistency levels of the questionnaire items; in most social scientific research, a score of 0.70 or above is typically regarded as acceptable. SPSS was used to calculate Cronbach's Alpha values for this study. The

questionnaire enquired about students' perceptions of comprehension-based activities. Table 3 presents the results of questions 8 to 10, which relate to students' overall perception of class activity category 1 (Learning capability), focusing on difficulty, understanding, and time management questions. In response to the initial question, "Did you comprehend the paragraph?" the consensus among both monolingual and bilingual students surpasses 50%, with 97.3% of bilingual students and 56% of monolingual students indicating agreement. Analysis revealed that a substantial proportion of monolingual students found the statement in question 8 to be "difficult" or "very difficult". In contrast, bilingual students demonstrated greater understanding, with 77.1% categorizing it as easy and only 5.2% as neutral. Notably, none of the monolingual students deemed the understanding facile.

Table 3 presents Cronbach's Alpha values for monolingual and bilingual students, which are 0.94 and 0.93, respectively, indicating the high dependability of responses from both groups. The Cronbach's Alpha coefficients for the four groups of monolingual students were 0.93, 0.81, 0.94, and 0.92 respectively. Those for the four categories of bilingual students were 0.82, 0.742, 0.88, and 0.87, respectively. The statistics indicate that the items utilized in the current questionnaire are consistent.

TABLE 3
CRONBACH'S ALPHA VALUES FOR THE MONOLINGUAL AND BILINGUAL STUDENTS

Cronbach Alpha Values	Students' perception regarding category1 (Learning capability)	Students' perception regarding category2 (Thinking capability)	Students' perception regarding category3 (Vocabulary)	Students' perception regarding category4 (Critical thinking)
Monolingual	0.93	0.81	0.94	0.92
Bilingual	0.82	0.742	0.88	0.87

C. Brain Efficacy in Monolingual and Bilingual Students

In this study, brain efficacy was characterized by the effectiveness and efficiency with which bilingual and monolingual students received information, retained information, and carried out cognitive activities. Data was collected from classroom activities and open-ended questions incorporated in the questionnaire. Reaction times were measured as the duration required for students to respond to a stimulus by answering a question during classroom activities. The percentage of correct responses during classroom tasks was also utilized to ascertain brain efficacy among students. The performance of students was assessed under tasks with differing difficulty levels and multitasking settings, with the duration and quality of focus during timed activities being monitored. Descriptive statistics and t-tests were employed to ascertain significant differences. Figure 2 illustrates a bar graph analyzing the cognitive efficacy of monolingual and bilingual students, demonstrating significant differences.

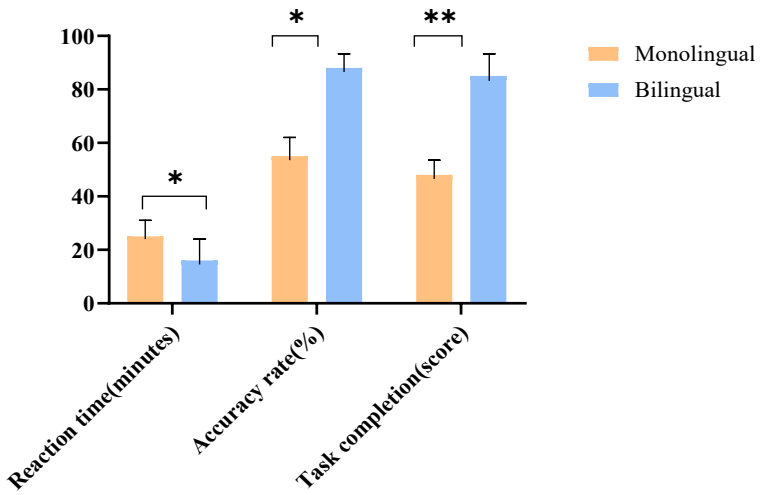

Figure 2. Analyzing the Brain Efficacy of Monolingual and Bilingual Students' Performance
Bar Graph (* show significance, ** shows highly significant result)

Results indicate that bilingual students exhibit a higher accuracy rate compared to monolingual students in classroom activities. Bilingual students understand the English language and accomplish tasks within a constrained timeframe more effectively than monolingual students. This illustrates the higher cognitive efficiency of bilingual students relative to monolingual students.

D. Cognitive Task Performance, Memory Retention and Attention Span Among Students

The relationship between memory retention, cognitive task performance, and attention span in monolingual and bilingual students elucidates the impact of working memory capacity on learning and performance. Table 4 presents criteria to assess the cognitive efficacy and efficiency of monolingual and bilingual students.

TABLE 4
MEMORY RETENTION, TASK PERFORMANCE, AND ATTENTION SPAN IN MONOLINGUAL AND BILINGUAL STUDENTS

Metric	Monolingual	Bilingual	P-value	Interpretation
Task performance (Score)	48±6.93	85±8.84	< 0.05	Bilinguals performed well
Memory retention (%)	46.17±6.83	79.18±5.77	< 0.05	Bilinguals have stronger memory
Attention span (min)	10±7.18	18±7.61	< 0.05	Bilinguals maintain attention longer
Number of attempts	3.34± 5.801	1.43±7.95	< 0.05	Bilingual students performed activity in first attempt

Table 5 illustrates that bilingual students had exceptional performance in comprehension-based activities. Bilingual individuals exhibit enhanced memory capabilities since they completed the task within the constrained time frame. Additionally, Bilingual students exhibited heightened focus while engaging in the activity and completed the task ahead of time. Conversely, monolingual students had diminished attention spans and required extended durations to complete tasks. Bilingual students completed the activity on their initial attempt, but monolingual students required multiple attempts.

E. Learning Capability, Vocabulary Acquisition, Thinking Capacity and Critical Thinking Skills Among Monolingual and Bilingual Students

A comparison of the learning capability, cognitive capacity, vocabulary, and critical thinking skills of monolingual and bilingual students was conducted using a bar graph presented below:

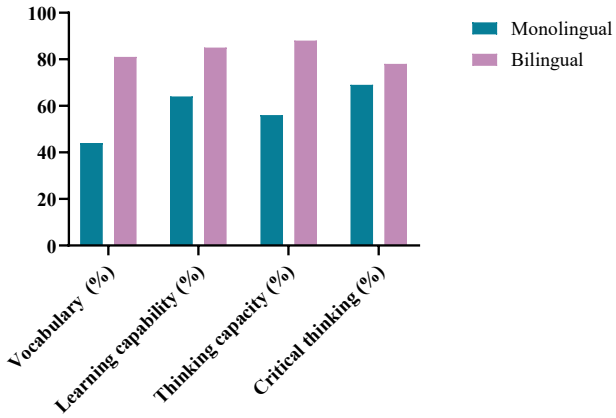

Figure 3. The Learning Vocabulary Acquisition, Learning Capability, Thinking Capacity and Critical Thinking Skills of Monolingual and Bilingual Students

Figure 3 illustrates the differences between monolingual and bilingual learning, vocabulary acquisition, and cognitive abilities. Arabic monolingual students struggled to comprehend the activity, resulting in suboptimal performance. In contrast, Arabic-English bilingual students demonstrate effective task effectively comprehension and exhibit exceptional performance.

F. Impact of Bilingualism on Brain Efficacy, Learning Capabilities and Critical Thinking Across Different Semesters

Data collected across different academic semesters demonstrates the influence of bilingualism on learning, cognition, vocabulary, and cognitive capacity. A T-test was conducted to compare the two groups, as shown in Table 5.

TABLE 5
IMPACT OF BILINGUALISM ACROSS DIFFERENT SEMESTERS

Semester group	Metric	Monolingual (Mean ± SD)	Bilingual (Mean ± SD)	t-value	P-value
1-2	Brain efficacy (%)	66.5 ± 8.4	74.2 ± 7.9	2.15	0.035
	Learning capabilities (score)	62.3 ± 9.1	68.7 ± 8.5	2.45	0.020
	Vocabulary (%)	33± 6.1	55± 9.1	3.31	0.04
	Critical thinking(score)	55.4 ± 7.2	61.8 ± 7.4	2.10	0.038
4-6	Brain efficacy (%)	72.6 ± 7.8	78.1 ± 8.3	2.60	0.015
	Learning capabilities (score)	65.9 ± 8.6	73.4 ± 9.2	3.12	0.005
	Vocabulary (%)	52± 5.3	77±8.1	1.31	0.001
	Critical thinking(score)	60.2 ± 6.9	66.5 ± 7.1	2.75	0.008
6+	Brain efficacy (%)	76.3 ± 3.5	80.4 ± 2.9	1.60	0.120
	Learning capabilities (score)	69.8 ± 3.0	75.0 ± 2.1	1.89	0.065
	Vocabulary (%)	55± 4.8	83± 1.2	1.77	0.02
	Critical thinking(score)	64.5 ± 2.7	70.1 ± 3.5	2.01	0.048

The findings indicate that both monolingual and bilingual students in their sixth semester outperformed their peers in vocabulary. The findings demonstrate that advanced bilingual students in the department exhibited an extraordinary vocabulary. Senior students also attain high marks on subjects related to learning and cognition. This study illustrates that senior bilingual students possess higher brain efficiency and cognitive abilities compared to junior bilingual students.

V. Discussion

This research study aimed to investigate the cognitive differences between Arabic Monolingual and English-Arabic bilingual university students in terms of brain efficiency, language acquisition, learning capacities, cognitive capacity, and critical thinking skills. The results of this study reveal that bilingual students outperformed monolingual students in activities necessitating significant cognitive engagement. This is consistent with the current literature, which asserts that bilingualism enhances cognitive efficiency due to the continual mental challenges of navigating two languages (Anderson et al., 2021; Guzmán-Vélez & Tranel, 2015; Korenar et al., 2023; Mackenzie, 2024). Moreover, bilingual students demonstrated outstanding results in memory recall, problem-solving skills, and attentional management during classroom activities. These findings align with the concept of cognitive reserve and the development of executive function, suggesting that bilingual individuals develop increased brain efficiency over time (Guzmán-Vélez & Tranel, 2015). However, monolingual students seemed to encounter difficulties with activities requiring quick cognitive flexibility, especially those involving unexpected content. This may be ascribed to a more limited cognitive framework, as monolinguals do not participate in the same degree of mental switching as bilinguals. It is noteworthy that monolingual students exhibited competence in tasks requiring structured repetition, indicating that their learning strategies may depend more on concentrated processing than on adaptable cognitive frameworks (Barac & Bialystok, 2012; Kaushanskaya & Marian, 2009).

Bilingual students demonstrated higher performance in vocabulary acquisition and critical thinking tasks. This is likely due to their heightened metalinguistic awareness, which allowed them to identify linguistic patterns and adapt their usage accordingly (Nagy, 2007). The results indicate that multilingual students performed exceptionally well in activities necessitating the application of information to real-world scenarios, demonstrating their superior critical thinking abilities (Leikin, 2013; Marian & Shook, 2012). Monolingual students made considerable progress in vocabulary learning but struggled with tasks that required complex analytical reasoning.

This may arise from a more linear approach to problem-solving, contrasting with the adaptive cognition typically associated with bilingualism (Hommel et al., 2011). The findings of this study are consistent with prior research (Albert et al., 2002; Bialystok, 2007; Kharkhurin, 2008). The bilingual advantage in cognitive abilities and critical thinking substantiates theories, such as the Multilingual Advantage Hypothesis, which suggests that bilingual individuals cultivate enhanced cognitive skills through regular participation in tasks requiring mental flexibility and inhibitory control (Greve et al., 2024; Koch et al., 2023).

The research indicated that the academic semester substantially affected the cognitive performance of both monolingual and bilingual students, with higher semesters demonstrating improved brain efficiency, learning ability, and critical thinking skills. Nonetheless, the effect was more significant among bilingual students. This suggests that as students' progress academically, the cumulative impact of bilingualism on cognitive ability becomes more evident. Bilingual students demonstrated notable improvements in critical thinking and learning efficiency in subsequent semesters, presumably due to their ability to integrate knowledge from diverse linguistic and cultural frameworks. These findings are consistent with Cognitive Load Theory, which asserts that students in advanced semesters develop superior strategies for handling complex material (Plass et al., 2010; Sweller, 2011). Conversely, monolingual students exhibited a more limited improvement across the semesters. Although they had enhanced academic exposure, their progress in critical thinking and learning ability appeared to stagnate relative to that of bilingual students. This may underscore the need for customized interventions to assist monolingual students develop cognitive flexibility and analytical thinking skills.

This research highlights the cognitive benefits of bilingualism, especially in educational contexts. Educators should integrate pedagogical practices that capitalize on the advantages of multilingual students, including collaborative discussions and problem-based learning. Additionally, monolingual students may gain from specific interventions that enhance metalinguistic awareness and critical thinking skills. Moreover, the significance of academic advancement in improving cognitive performance underscores the need for curriculum designs that increasingly assess students' cognitive capacities. Integrating activities that necessitate both organized learning and cognitive adaptability may facilitate the convergence of monolingual and bilingual students. This study offers interesting insights; nonetheless, it is crucial to acknowledge its limitations, including the reliance on self-reported data for specific metrics and the absence of neuroimaging data to assess brain efficacy directly. Future research may investigate these findings through longitudinal designs and sophisticated technologies, such as functional MRI, to further substantiate the influence of bilingualism and academic advancement on cognitive capacities. Furthermore, broadening the study to encompass students from diverse linguistic and cultural backgrounds could yield a more comprehensive understanding of the interplay between bilingualism and various educational systems.

VI. Conclusion

This study offers valuable insights into the cognitive and academic differences between monolingual and bilingual university students. The findings underscore the cognitive benefits that bilingual students possess in terms of brain efficiency, learning flexibility, and critical thinking, while recognizing the challenges encountered by monolingual students in more complex and dynamic cognitive tasks. Bilingual students frequently exhibited enhanced performance in vocabulary acquisition, problem-solving, and critical thinking indicating the cognitive flexibility cultivated through the management of two languages. This substantiates the argument that bilingualism improves executive functions and cultivates a robust cognitive framework. Monolingual students, although proficient in tasks that necessitate concentrated attention and systematic learning, exhibit deficiencies in activities that require quick adaptability and abstract reasoning. Furthermore, the advancement of the academic semester had a significant influence on cognitive development in both groups, with bilingual students demonstrating more substantial cumulative enhancements over time. This accentuates the relationship between bilingualism and academic exposure in enhancing critical thinking and learning capacities, highlighting the need for creating rigorous curricula to facilitate student development. The study highlights the importance of bilingual education in developing advanced cognitive abilities while also identifying areas where monolingual students may benefit from specific interventions. These findings emphasize the growing recognition of bilingualism as a cognitive advantage and emphasize the need to foster inclusive and dynamic educational settings to maximize the potential of all learners. Further investigation is recommended to examine these findings within broader language and cultural frameworks, as well as to assess the long-term effects of bilingualism on academic and cognitive development.

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